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Theme: Climate Smart Agriculture, Food Security, Biodiversity, Poverty and Environmental Sustainability

Climate Smart Agriculture as Panacea for Mitigating Climate Change

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Introduction

It is my great pleasure to present this address at this year's 8th International annual Conference on climate smart agriculture, food security, biodiversity, poverty and Environmental sustainability. Agriculture stands at a pivotal intersection of the global Challenges of food security, environmental sustainability, and climate change. According to The Food and Agriculture Organization of the United Nations (FAO), the agricultural sector, Not only must increase productivity to feed a growing population, but it must also adapt to a Changing climate and, where possible, reduce greenhouse-gas (GHG) emissions. In this respect, the concept of "climate-smart agriculture" has emerged as a promising Method to mitigate the effects of climate change while maintaining or increasing agricultural Productivity and resilience. This presentation explores the definition and rationale for smart Agriculture; discusses its potential mitigation (and adaptation) benefits; reviews key practices, And technologies; examines the enabling factors and barriers; and finally reflects on how Smart agriculture might contribute to climate change mitigation in a developing-country Context (with applicability to Nigeria and other African countries).

1. Defining Climate-Smart Agriculture

While the terms "smart agriculture", "precision agriculture" and "climate-smart agriculture" (CSA) are used with some variation, in the context of climate change mitigation the FAO Defines CSA as: "an approach that helps to guide actions needed to transform and re-orient agricultural Systems to effectively support the development and ensure food security in a changing Climate". More simply, the FAO states that CSA pursues three interlinked objectives: sustainably Increasing productivity and incomes; adapting and building resilience to climate change; and Reducing and/or removing greenhouse-gas emissions where possible. The World Bank similarly describes it as "a set of agricultural practices and technologies Which simultaneously boost productivity, enhance resilience and reduce GHG emissions." I have chosen to treat "smart agriculture" broadly to include the use of technologies (digital, Sensor-based, precision) and practices (improved soil and water management, agroforestry, Integrated systems) that achieve these goals, with particular focus on the climate-mitigation Potential (i.e., reducing emissions, enhancing carbon sequestration).

2. Smart Agriculture and Climate Change Mitigation

There are several interlocking reasons why smart agriculture has relevance for climate Change mitigation:

- 2.1. Agriculture's contribution to GHG emissions Agriculture (including crop production, livestock, land-use change and forestry) is a major Contributor to anthropogenic greenhouse-gas emissions.

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The FAO notes that agriculture, Forestry and land-use change contribute roughly a quarter of global GHG emissions.

Moreover, land-use change driven by agriculture (e.g., deforestation for cropland) amplifies Emissions. Given this, the agricultural sector is both a challenge and an opportunity for Mitigation.

- 2.2. Growing demand and pressure on resources Global demand for food is rising; the World Bank estimates global agricultural production Must increase by around 50% between 2013 and 2050 to feed the world population.

This increased production cannot simply be achieved by expanding land area or intensifying Input use in conventional ways without environmental consequences (e.g., higher emissions, Soil degradation, water stress). Smart agriculture offers a way to intensify/optimize Production while reducing environmental footprint.

- 2.3. Interlinked mitigation and adaptation benefits Smart agriculture practices can deliver “triple wins”: higher productivity, resilience to climate Change, and mitigation of GHG emissions. The FAO emphasises that while not every activity Will achieve all three wins, the approach seeks synergies and manages trade-offs. For Example, agroforestry enhances resilience, sequesters carbon, and may boost yields Simultaneously.

- 2.4. Technology and precision offer new mitigation pathways With advances in digital technologies, sensors, IoT (Internet of Things), artificial intelligence (AI) and big data, agriculture has new tools to optimise resource use (water, fertiliser, Energy) and thereby reduce GHG emissions per unit of output (emission intensity) or even Absolute emissions. For example, a recent study on “smart farming” from a GHG-mitigation Perspective showed smart agriculture can be leveraged for greenhouse-gas emission Mitigation. Given these reasons, promoting smart agriculture is a way for agriculture to Become part of the solution to climate change, rather than simply a victim of it.

3. Key Smart Agriculture Practices and Technologies for Mitigation In this section I review the major categories of practices and technologies under smart Agriculture (or CSA) that relate to mitigation. I group them into four clusters: soil & tillage Management; water & nutrient management; agroforestry, integrated systems & land-use; And precision/ICT technologies.

- 3.1. Soil and tillage management Conservation agriculture: Practices such as minimum or no tillage, maintaining soil cover (mulch, cover crops), crop rotation. These reduce soil disturbance, enhance soil organic Carbon sequestration, and reduce CO₂ and nitrous oxide (N₂O) emissions from soil. For Example, the FAO highlights soil-carbon sequestration as a mitigation possibility. Cover cropping and crop rotation: Diversifying crops and keeping soil covered helps reduce Erosion, enhance soil organic matter, improve nutrient cycling, and thereby reduce input Need (less fertiliser) and associated emissions. Carbon sequestration in soils: Increasing soil organic matter through improved management Helps store carbon in the soil, reducing atmospheric CO₂. FAO’s mitigation module indicates That agriculture has potential to sequester carbon in soils and reduce emissions from Land-use change.

- 3.2. Water and nutrient management Precision nutrient management: By applying fertilisers in optimized doses, timing and Placement, farmers can reduce nitrogen losses (which contribute to

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N₂O emissions) and Enhance fertiliser use efficiency. The mitigation of N₂O emissions is highlighted in studies on CSA. Efficient irrigation and water-saving techniques: Changing irrigation scheduling, drip Irrigation, and other methods reduce water and energy use (less pumping) and may also Reduce methane emissions in flooded systems (e.g., rice). The IAEA notes nuclear and Isotopic techniques helping optimise irrigation, reducing soil water evaporation and Improving resilience. Alternate wetting and drying in paddy rice: Although not always labelled “smart agriculture”, This is a water-management technique with proven mitigation benefits.

3.3. Agroforestry, integrated crop-livestock systems, and land-use change Agroforestry: Integrating trees with crops or livestock systems can sequester carbon above And below ground, improve resilience (shade, microclimate, biodiversity) and diversify Income. Agroforestry is often cited as a key CSA practice. Integrated crop–livestock systems: Better management of livestock (feed efficiency, manure Management) reduces methane (CH₄) and N₂O emissions. Crop-livestock integration also Improves nutrient recycling and reduces need for external inputs. The mitigation module Notes the importance of livestock waste management. Avoiding deforestation and land-use change: Since deforestation for agriculture is a major Source of emissions, smart agriculture emphasises increasing productivity on existing lands and restoring degraded lands rather than expanding, hence reducing emissions from Land-use change.

3.4. Precision agriculture, sensors, IoT and digital technologies Precision farming: Use of geospatial, sensor, satellite and drone technologies to apply inputs Only where needed; optimise operations; reduce waste and emissions. For example, the MDPI article “Smart Agriculture and Greenhouse Gas Emission Mitigation: A 6G-IoT Perspective” highlights how IoT can support GHG mitigation in smart farming applications. Big data, decision-support systems and climate-information services: Better weather Forecasting and decision tools help farmers schedule operations (planting, irrigation, Fertiliser) more efficiently, reducing risk and resource waste. The IAEA notice mentions Improved scheduling via soil-water measurement. Remote sensing, earth observation and monitoring: Organisations like the Swiss ReFoundation support using earth-observation data to inform agricultural monitoring, resilience And mitigation of climate risks (swissrefoundation.org)

4. Evidence of Mitigation Potential and Co-Benefits

4.1. Mitigation potential

The literature suggests that smart agriculture practices can reduce emission intensity (emissions per unit of output) and potentially absolute emissions. For example, the FAO Mitigation module states that CSA “provides an overview of the key concepts and Approaches pertaining to ... the mitigation potential” in agriculture (ijmae.journals.ekb.eg) While precise global figures are complex, some studies simulate that certain CSA practices (no-till, integrated soil fertility management, nitrogen use efficiency, alternate Wetting-and-drying) could raise production and reduce food-insecurity risk while lowering GHG emissions.

4.2. Co-benefits (productivity, resilience, livelihoods) Smart agriculture practices often deliver multiple co-benefits: Increased productivity (e.g., higher yields, better income) through improved management. The World Bank states that CSA can “... produce triple wins: higher agricultural productivity... climate mitigation ... and increased resilience.” Enhanced resilience to climate change (drought, erratic rainfall, extremes). Adaptation and Mitigation often go hand-in-hand: the

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FAO emphasises that “Opportunities must be sought to Maximise synergies and co-benefits between adaptation and mitigation.” Environmental benefits: improved soil health, biodiversity, water-use efficiency, reduced Pollution and less land-degradation. Social and economic benefits: Smallholder farmers in low-income countries stand to gain From improved technologies, risk reduction, higher incomes. According to Swiss Re Foundation, they target the 270 million smallholder farmers in low-income countries who are Highly exposed to climate risks. Swissrefoundation.org

4.3. Context-specificity and local adoption

However, evidence also emphasises that adoption of CSA practices is highly Context-specific. For example, a recent study of CSA practices in north-central and North-west Nigeria examined the state of CSA adoption in those zones and concluded that While practices exist, uptake remains limited and contextually varied (BioMed Central) In Kenya, a case study of smallholder farming in Gatundu South explored implications of CSA for adaptation and found variable adoption (journals.unesco.go.ke) This underscores that the mitigation potential of smart agriculture depends significantly on Local uptake, enabling conditions, and scale.

5. Enabling Factors and Barriers for Smart Agriculture Implementation

5.1. Enabling factors

Policy frameworks and governance: National policies that promote CSA, integrate agriculture In Nationally Determined Contributions (NDCs) under the Paris Agreement, and provide Incentives for mitigation/adaptation in agriculture. The FAO states that agriculture sectors are The “foremost priority for adaptation” in many countries, and are often referenced for Mitigation in INDCs. Access to technology and digital infrastructure: For precision, IoT, sensors, satellite Monitoring to work, farmers need access to technology, telecommunications, reliable power, And data services. Finance and investment: Scaling up smart agriculture often requires upfront costs (equipment, software, training). Access to credit, subsidies, or climate-finance mechanisms Can help. The World Bank brochure emphasises the need for new investments. Capacity-building, extension services and knowledge sharing: Farmers need training in new Practices, technologies and climate-information services. The review article emphasizes Knowledge sharing and capacity building as key for CSA (ijmae.journals.ekb.eg) Inclusive, smallholder-friendly design: Since a large portion of global agriculture is by Smallholder farmers in developing countries, smart agriculture solutions need to be Appropriate, cost-effective and accessible for smallholders (not just large commercial farms). The Swiss Re Foundation focuses on low-income smallholders. Swissrefoundation.org

5.2. Barriers and challenges High upfront costs / capital constraints: Many smart technologies (drones, sensors, IoT Systems) remain expensive for smallholders and require maintenance, which can limit Uptake. Digital divide and infrastructure limitations: In many developing-country contexts, Connectivity, electricity supply, and technical support may be weak. Lack of data or interoperability: The effectiveness of precision systems depends on good Data (soil, weather, crop) and tools adapted to local conditions. Institutional and policy inertia: Existing subsidy regimes, input-intensive farming systems, Fragmented value chains and weak governance may slow uptake of more sustainable Practices. Behavioural and knowledge barriers: Farmers may be risk-averse, lack training, or face Uncertain benefits. Studies show that environmental knowledge and sense of responsibility Influence adoption ([arXiv](https://arxiv.org)) Scale and heterogeneity of farming systems: Smallholders are heterogeneous in size, Resource endowment,

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education, risk capacity. A one-size-fits-all smart agriculture solution May not work. Trade-offs and context specificity: Some practices may increase productivity but may not Always reduce emissions; or may reduce emissions but have other trade-offs (cost, yield Risk). The FAO emphasises that not every activity will deliver all three wins.

6. Smart Agriculture in Developing-Country / African Contexts

6.1. Relevance for countries like Nigeria

In Nigeria, agriculture is a major livelihood source and is highly vulnerable to climate change (erratic rainfall, drought, floods). A recent paper on CSA in Nigeria's North Central and Northwest zones showed that CSA practices are present, but uptake is limited and uneven (BioMed Central) For such contexts, smart agriculture offers a path to build resilience and to reduce the Climate footprint of agriculture.

6.2. Local adaptation of technologies

Given limited resources of many African smallholders, smart agriculture must be locally Adapted (e.g., low-cost sensors, mobile phones, climate-information services, drip irrigation Kits) rather than high-end precision systems developed for large commercial farms. The Study in Uganda offering an IoT framework for climate-resilient maize farming is an example Of locally appropriate design (arXiv)

6.3. Policy and institutional support

African governments and regional bodies (e.g., East African Community – EAC) recognize The importance of CSA: one EAC document notes that agriculture is the backbone of many East and Southern African economies, with high vulnerability; hence CSA is defined as Agriculture that “sustainably increases productivity, resilience (adaptation), reduces or Removes GHGs (mitigation)” (eac.int)

6.4. Finance, access and scaling

Scaling smart agriculture in Africa will require innovative finance (micro-finance, Climate-finance, blended finance), extension systems, partnerships with private sector (ag-tech), and enabling infrastructure (internet connectivity, electricity). The Swiss ReFoundation's target to improve resilience of 700 000 farming households in low-income Countries demonstrates the kind of scaling ambition needed.(swissrefoundation.org)

6.5. Some local case study insights

The Nigeria regional paper shows that despite the availability of CSA practices, uptake is Constrained by access to inputs, extension, credit, and infrastructure. The Kenya case study in Gatundu South emphasises local rainfall variability and the need For appropriate CSA adoption in smallholder systems. Journals.unesco.go.ke These insights highlight the need for context-sensitive approaches: smart agriculture in African smallholder settings must combine technology with capacity building, local Institutions and finance.

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7. Limitations, Trade-Offs and Considerations

While smart agriculture offers strong potential for climate change mitigation, it is not a silver Bullet. Several cautionary points should be borne in mind: Emission reductions may be incremental: Many smart agriculture practices reduce emission Intensity (emissions per unit output) rather than large absolute reductions; scaling and broad Adoption are needed for larger impact. Risk of rebound effects: If improved productivity leads to expanded cropping area or Intensification in ways that negate emissions benefits, the net mitigation may be limited. Equity and access: If advanced technologies are only accessible to large commercial farms, The benefits may bypass smallholders, increasing inequality and limiting the socio-economic Co-benefits that make CSA appealing. Monitoring, measurement and verification (M&V): To claim mitigation benefits (e.g., carbon Sequestration, emissions reductions), reliable data and verification systems are Required—often lacking in developing-country contexts. Trade-offs with adaptation or productivity: Some practices may improve productivity but Increase inputs/emissions; others may reduce emissions but require higher investment or Lower yields temporarily. The FAO emphasises managing trade-offs. Context specificity matters: What works in one agro-ecological region may not in another; Local adaptation is essential. Behavioural and institutional inertia: Changing farming practices, mindsets, institutions and Market systems take time, and switch costs and risks may hamper adoption.

8. Pathways Forward: Strategy for Deploying Smart Agriculture for Mitigation

Drawing from the above, deploying smart agriculture as a method of climate-change Mitigation could proceed along several strategic pathways:

8.1 Policy integration and mainstreaming

Governments should integrate smart agriculture/CSA into national climate-change Strategies, agriculture development plans and NDCs. Supporting policies should align Subsidies, incentives and extension services around CSA objectives (productivity, resilience, Mitigation). The FAO and World Bank emphasise the need to embed CSA in policy.

8.1. Investment in technology and infrastructure

Investments in digital infrastructure (connectivity, sensors, satellites), affordable precision Tools, climate-information services, and remote-sensing platforms will enable smart Agriculture. Partnerships among public sector, private sector, and donors can help. For Example, Swiss Re's support for earth-observation-based monitoring shows one pathway.

8.2. Capacity building and extension

Strengthening farmer knowledge, extension services, and access to Climate/adaptation/mitigation information is vital. Training on new practices, demonstration Farms, peer-learning and farmer-to-farmer exchange can help overcome behavioural Barriers. Studies emphasise knowledge sharing is critical for CSA (Ijmae.journals.ekb.eg)

8.3. Financing and market mechanisms

Access to financing, credit, insurance and incentives will encourage adoption of smart Agriculture. For smallholders especially, blended finance, micro-credit, climate funds and Risk-sharing schemes (weather-based insurance) can reduce barriers. Insurance helps Farmers adopt climate-resilient practices without bearing full risk. (See for example insurance Mention in Kenya climate-smart agriculture site).

8.4. Data, monitoring & verification of mitigation outcomes

To credibly claim mitigation benefits, systems for measuring soil-carbon changes, GHG Emissions from agriculture, and remote-monitoring of land/inputs are necessary. This would Facilitate access to carbon-

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finance or results-based payments for mitigation. The IAEA note Smart agriculture must be accessible and appropriate for smallholders—not just large farms. Low-cost sensors, mobile apps, farmer-cooperatives, local service providers and Technologies designed for limited resources will improve inclusivity and scale.

8.5. Encouraging co-benefits and synergy rather than single-goal adoption

The greatest gains are when productivity, resilience and mitigation co-benefit. Programs Should encourage practices that simultaneously improve yields, buffer climate risk and Reduce emissions. Focusing only on emissions may lead to poor adoption if productivity is Sacrificed. The FAO emphasises balancing these objectives.

CONCLUSION

Smart agriculture offers a compelling pathway for agricultural systems to become part of Climate-change mitigation efforts while simultaneously enhancing productivity and resilience. By deploying practices and technologies that optimise resource use, enhance soil carbon, Reduce emissions from inputs and land-use change, and integrate digital/precision tools, Smart agriculture can help transform the role of agriculture—from being a major emitter to Becoming a contributor to climate solutions. However, to realise this potential requires enabling policies, investment, capacity building, Data and monitoring systems, and inclusive design suited to smallholder Contexts—especially in developing countries. Without scaling and context-sensitive Adaptation, the mitigation potential remains largely unrealised. In the context of Nigeria and other African countries, smart agriculture is doubly important: Agriculture is both a major livelihood and among the most climate-vulnerable sectors. Adopting smart agriculture practices could help Nigeria increase food production, build Resilience to climate change (droughts, erratic rains) and reduce agriculture’s carbon Footprint—a triple win aligned with the CSA approach. In sum, smart agriculture is not a panacea, but it is a vital component of an integrated Response to climate change in agriculture—one that deserves attention, support, and scaled Deployment.

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Climate Change: A Surmountable Impediment to Environmental Sustainability and Food Security

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Abstract

Climate change is a burning issue in global and national environmental discussion due to its impact on all environmental variables. This paper discussed the origin of climate change, causes of climate change, effects of climate change on environmental sustainability, agriculture and food security and also climate change on biodiversity and poverty creation. It equally looked at the United Nations effort in combating climate change with emphasis on adaptation and mitigation mechanisms.

Introduction

The earth is faced with plethora of challenges but climate change seems most onerous of all the constraints. This existential threat was first spotlighted by a Swedish scientist Svante Arrhenius in 1896 when he predicted that changes in atmospheric carbon dioxide levels could substantially alter the surface temperature through the greenhouse effect. Wallace Smith Broecker called this predicted increase in earth surface temperature global warming in 1975 a term later accentuated by James Hansen a space Scientist in a testimony in United States senate in 1988. Global warming and climate change are inadvertently used interchangeably, however, climate change is a broader term and more encompassing.

Climate change is a long-term shift in average weather pattern mainly caused by human activities (Kent et al., 2021). It is the average weather in given area over a longer period of time including the weather variables of rainfall, temperature and sunshine (Ruet et al., 2021, Brooks et al., 2019). Climate change is a long-term change in the average weather patterns that have come to define each local, regional and global climate (Bell et al., 2018, Bevon et al., 2020). United Nations organization (1992) defined climate change as a change in climate that can be identified by a shift in weather patterns and temperature over an extended period and that is attributable to human activity or natural variability while United Nations Framework Convention on Climate Change (1992) defined it as a change of climate that is a direct or indirect result of human activity which alters the global atmosphere in addition to natural climate variability. The climate variability impacts phenomenally on all aspects of the global ecosystems. This presentation will focus on origin of Climate change, causes of climate change, impact of climate change on environmental sustainability, climate change on agriculture and food security climate change on biodiversity and poverty creation. It will equally look at climate change mitigation and adaptation processes including Climate Smart Agriculture (CSA).

Origin of Climate Change

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The earth's temperature has been on the rise since 1800 through natural causes (Lee et al., 2021). The modern and accelerated climate change is primarily driven by anthropogenic activities originating at the start of Industrial Revolution. Climate change results from burning of fossil fuels such as coal, oil, gas as these produce green house gas (GHG) such as carbondioxide that has the propensity to trap heat and warm the planet (chen et al., 2021). The causes of climate change as highlighted by Smith et al (2021) are:

Industrial Revolution: the discovery of steam engine and subsequent industrialization resulted in heightened burning of fossils, thus releasing large amount of green house gas.

Fossil Fuels: Burning of coal, oil and gas for transportation, manufacturing and for electricity gave rise to high volume of carbon-dioxide emission.

Deforestation: felling of forest trees let out the carbon that were sequestrated in them thereby altering the carbon cycle and releasing same into the earth's atmosphere.

Agriculture: In course of food production, green house gas such as methane are released especially from ruminants production.

Industrial process: Industrial processes of manufacturing of goods such as steel and cement release green house gas.

It must be noted that nature also abuse itself through forces of volcanic eruption and changes in solar activities causing climate change. However, scientist have agreed on unequivocal terms that the present trend of global warming and climate change are primarily driven by man's quest for industrialization resulting in the release of GHG through green house effect. Green house effect is the phenomenon when certain atmospheric gases trap heat making the earth habitable however, when these gases are held above permissible concentrations, global warming comes to play and climate change results. The main green house gases include carbondioxide, methane, nitrogen oxide, ozone, water vapour. (Shahsavari et al 2016)

Climate Change and Environmental Sustainability

Environmental sustainability is the careful utility of natural resources and practices to meet present needs without compromising the ability of future generations to meet their own needs (United Nations Organisation, 2015). Climate change has negated man's effort on careful management of its environment (Loen et al., 2017). Climate change is altering the environmental indices through extreme weather events such as heat waves, drought, floods and wildfire, rising sea levels, melting ice and ocean acidification (Gaglio et al., 2019). It also leads to soil and coastal erosion.

Climate Change, Agriculture and Food Security

Climate change has impacted on agriculture by causing extreme weather conditions such as floods, droughts altering rainfall patterns, increasing heat stress on plants and livestock and disrupting ecosystems critical for pollination and soil health (Seddon et al., 2020). Climate change leads to lower crop yields, increased soil erosion, increase pests and diseases and potential loss of arable land due to rising sea levels

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(Golledge & Willey, 2020). The impacts of climate on agriculture as summarized by Seddon et al (2020) are:

Impacts on soil and crop: Extreme events of drought, floods, heatwaves, and heavy rainfall devastate crops and reduce yields.

Changes in temperature and rainfall disrupt growing season, reduce soil moisture and can lead to premature crop development.

Excessive rainfall causes soil erosion while drought and heat deplete soil moisture and nutrients making land less productive.

Salinization resulting from rising sea level contaminates fresh water sources making irrigation difficult and impacting on agricultural land.

Pests and diseases: Warmer temperature can alter geographical ranges of pest and disease increasing their prevalence and impacting on both crops and animals

Pollinators disruption: Climate change can disrupt pollinators which are essential for crops reproduction potentially leading to reduced crop diversity and quality. All of these variables result in low crop and animal production resulting in food insecurity.

Food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and preferences for an active and healthy living (World Food Summit 1996). The dimensions of food security are food availability (supply), food access (demands) and utilisation (body's ability to use the nutrients) and stability (reliability over time) (Akhmadeev et al., 2019, Jones 2020). Food insecurity results from various factors including insufficient food availability and access, poor care practices, inadequate health services and unhealthy environment (Lee, 2021). Food security is predicated on agriculture productivity thus climate change impact on agriculture resulting in low productivity and its impact on worsening poverty are direct negations to achieving global food security.

Climate Change and Biodiversity:

Biodiversity is the variety of life on earth, encompassing the diversity of species, genes and ecosystem (King & Karoly 2017). Biodiversity (biological diversity) refers to the variety of earth's fauna and flora (plants and animals), from genes to the ecosystem from the smallest life to the largest (Sehwaab et al., 2020). Climate change poses a survival threat to a multitude of biodiversity leading to some species being threatened, others endangered and some gone on extinction (Koll & Cronin, 2018).

Changes in the land cover and use pattern, water pollution from siltation and salinization and increase in the concentration of greenhouse gas threaten the survival of micro and macro species (Wals, 2017). Landscape fragmentation resulting from erosion, desertification, resulting from heat stress also pose potential and real threat to biodiversity.

Climate Change and Poverty

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Climate change increase and worsen poverty by disproportionately affecting the poor population who depend and rely heavily on natural resources for their daily survival and livelihood. Climate change increase and deepens poverty in the varying dimensions highlighted by Brakeman et al., (2020) as:

- Impact on livelihood: A large population of the world's poor population depend on climate sensitive sectors such as forest, agriculture, fishing. Climate events of drought, flood and storm can decimate crop and livestock destroying food supplies and income sources.
- Health and water access: Extreme weather threatens access to clean water for drinking and this may exacerbate health problems which disproportionately affect the poor who may lack adequate health care and sanitation.
- Displacement and migration: Soil erosion, desertification and rising sea levels can force millions of people to leave their ancestral homes thus creating refugees problems and further straining their already scarce resources.
- Increase conflict: Climate change leads to conflicts over scarce resources such as water and arable land further destabilizing the families and communities.
- Economic impacts: Climate change slows over all economic growth which hampers poverty reduction efforts.
- Increases inequality: The poorest populations are disproportionately affected as they lack resources to adapt to changing conditions. This can push more people to poverty.

Global Efforts on climate change

Efforts on climate change are directed at mitigation and adaptation or a union of the two. Climate change mitigation aims at reducing greenhouse emission to slow down climate change, while adaptation involves adjusting to the current and future effects of climate change to minimize harm (Koutroulis et al., 2019).

Mitigation involves actions such as transitioning to renewable energy and protecting forest while adaptation include building sea walls and growing drought resistant crops and developing early warning systems.(Morecroft et al., 2019).

United Nations first attention at controlling Climate change was at the conference on Earth and Development also known as Earth Summit held in Rio de Janeiro Brazil in 1992. The Conference gave birth to United Nations Framework Convention on Climate Change (UNFCCC) which provided framework for international cooperation to limit dangerous interference with climate system by stabilizing green gas concentration.

The UNFCCC was a treaty opened for signatures to established bases for international action to address climate change by reducing green house gas concentration in the atmosphere.

The treaty was signed by 154 states and conferences of parties (COP) was established to oversee the implementation of the treaty. The COP is thus the supreme decision making body of the UNFCCC and it meets annually to review implementation of the convention and to promote effectiveness (UNCED 1992)

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The UNFCCC served as foundational treaty under which further international agreements were developed to tackle climate change such as Kyoto Protocol in 1997 and Paris Agreement in 2015.

Kyoto Protocol which was an international treaty adopted in 1997 and came in force in 2005 extended the United Nations Framework Convention on Climate Change (UNFCCC) by legally binding on industrialised countries to reduce greenhouse gas (GHG) emissions. It set individual binding target for Annex-1 (developed) countries to lower their combined GHG emissions by 5.2 percent below 1990 levels by 2008-2012. The protocol also established market-based emission trading mechanism popularly known as carbon trading to help countries achieve their target carbondioxide effectively (Kyoto Protocol 1997). Carbon trading is a market-based approach to reducing greenhouse emission typically under a cap and trade system where government set a limit (a “cap”) on total emission and companies can buy and sell allowances or “credit” for their emissions (Wagdi & Hasaneen, 2019, Faridi & Sulphrey, 2019) Companies that emit less than their allowance can sell their surplus credits to companies that exceed their limits, thus creating financial incentive to reduce emissions in a cost effective way. The goal of emission trading is to lower overall emissions to mitigate climate change by making polluters pay (Hoogendoorn et al., 2020).

Paris Agreement: The Paris Agreement is a legal binding international treaty that requires nearly every nation to limit global warming to well below 2 degrees celsius, preferably to 1.5 degrees celsius compared to industrial limits. Paris Agreement was adopted in 2015 by 196 parties to the UN Framework Convention on Climate Change (UNFCCC), and it focuses on mitigation, adaptation and finance. It works by having each country set voluntary, progressive ambitious determined contributions (NDCs) which are reviewed every five years. The agreement includes provisions for financial and technical supports to developing nations and a transparent system for reporting progress (Edmond et al. 2020). The key components of Paris Agreement includes temperature goals, nationally determined contributions, transparency, climate finance, adaptation, global stocktake. A component of climate change mitigation and adaptation is Climate Smart Agriculture (CSA)

Climate Smart Agriculture (CSA)

Climate smart agriculture (CSA) is farming approach that suitably increases productivity and incomes, enhances resilience to climate change and reduces green house gas (GHG) emissions (Smith et al., 2021). CSA includes planting climate resilient crop varieties such as drought-resistant seeds, improving water management through precision irrigation and rain water harvesting, complementing agro-forestry (integrating trees with crops and livestock) adopting soil health management techniques such as conservation tillage and cover crops and diversifying farming systems to reduce risks from climate-induced stresses such as pest and diseases.

Key objectives of CSA as list in Microsoft et al (2016) are:

- Increase productivity: Sustainably boost agricultural output and farm incomes
- Enhance resilience: Adapt to climate change impacts like drought, heat stress and erratic precipitations.
- Reduce emission: Decrease greenhouse gas emission and remove carbon from atmosphere.

Examples of Climate Smart Agricultural Practices are:

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- Climate-resilient crops and varieties: Planting drought-resistant, heat tolerant or flood tolerant crop varieties.
- Water management: Using precision irrigation, drip irrigation and rainwater harvesting to ensure efficient water use.
- Soil management: Employing techniques such as conservation tillage, cover crops, residue management and composting to improve soil health and carbon sequestration.
- Agroforestry: Integrating trees with crops and livestock for an increased more diversified and resilient farming system.
- Crop diversification: Diversifying crops and practices (e.g. crop rotation, intercropping) to minimize susceptibility to climate impacts.
- Integrated pests management: Using natural methods to control pests, reducing reliance on agro chemical inputs.
- Precision agriculture: Adopting technologies, mobile tools and real time information to support better decision-making.
- Livestock management: Improving nutrient management in livestock and recycling waste products
- Post-harvest management: Implementing practice to reduce wastes and losses after harvest.

Climate Smart Agriculture has the benefit of ensuring food security and improved livelihoods by improving farmers income achieved through climate change adaption and mitigation processes.

Conclusion

Climate change is nature response to man's dastardly act of senseless emission of greenhouse gas into the earth's, atmosphere in course of his quest for better and improved standard of living through industrialization. It is man's inhumanity to itself. The degradation is living with us, it is imperative to evolve ways to ameliorate the impact of this monster. It is time for all nations developed and underdeveloped to be responsible and responsive to Koyoto Protocol and Paris Agreement to make the earth once again a living space and to return to it hitherto pristine environment for healthy living.

Thank you.

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Quality Seed: Panacea for National Food, Nutritional Security and Environmental Sustainability in Nigeria

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Presented at the 8th Annual International Conference of the Society of Agriculture, Environmental Resources and Management (SAEREM/UNIABUJA 2025)

1. Introduction

Seed is the foundation of agriculture and remains one of the most strategic inputs for achieving food and nutritional self-sufficiency. Improved seeds form a corner stone of climate –smart agriculture as they are bred to be resilient, productive, and resource – efficient therefore, helping farmers to adapt to changing weather patterns. Among all yield-enhancing inputs, **quality seed offers the highest and most cost-effective return on investment**, contributing about **50% of crop productivity gains**, while the remaining 50% results from good agronomic practices and management (FAO, 2021).

Improved, climate-smart seed varieties play a crucial role in reducing hunger and malnutrition while supporting food affordability and farmer profitability. However, despite its importance, Nigeria's seed system continues to face challenges including limited access to improved seed, weak regulation in rural markets, inadequate infrastructure, and climate-related threats.

2. Evolution of the Nigerian Seed Sector

Nigeria's formal seed system dates back to **1975** with the establishment of the **National Seed Service (NSS)**, supported by FAO technical assistance. Between 1975 and 1990, the FAO-assisted seed programmes led to the establishment of seed processing and testing centers in Ibadan, Zaria, Jos, and Umudike, and the training of professional seed growers and technicians.

By 1989, the **National Seed System** had achieved nationwide distribution of improved varieties, backed by the **Seed Certification and Quality Control Scheme**. The **National Agricultural Seeds Decree No. 72 of 1992** formalized this progress and established the **National Agricultural Seeds Council (NASC)** as the apex regulatory body.

Through subsequent interventions such as the **World Bank–assisted National Seed and Quarantine Project (1991–1997)**, Nigeria laid a strong foundation for a robust and participatory seed sector.

3. Quality Seed as the Foundation for Food and Nutritional Security

The present administration recognizes the **centrality of quality seeds** in achieving sustainable food and nutrition security. Quality seed, produced through efficient certification systems, enhances productivity, supports biodiversity, creates jobs, and promotes climate-smart agriculture.

With **over 34 million hectares of arable land** (of which only 40% is currently cultivated) and a population projected to reach **500 million by 2050**, Nigeria's seed market holds immense potential. The sector is valued

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at **about USD 1 billion**, with a 2022 estimated annual seed demand of **468,562 metric tonnes** valued at **₦281 billion (USD 781 million)** across major crops such as rice, maize, soybean, sorghum, millet, groundnut, cowpea, and cotton (NASC, 2023).

The sector presents opportunities for investment, youth employment, and regional leadership given that **70% of the West African seed market gap** remains unfilled.

4. The Role of Improved Agricultural Seeds in Promoting Climate Smart Agriculture and Enhancing Environmental Sustainability

Seeds play a pivotal role in enhancing environmental sustainability via agriculture, ecosystems, and conservation. They also help in promoting crops adaptation to climate change, improve food security, and enhance biodiversity. In natural settings, native seeds are vital for habitat restoration, erosion control, and providing resources for wildlife, while in agriculture, advanced seed technologies increase crop resilience and also go a long way in reducing the need for chemical inputs through innovations such as seed treatments and bio-priming which enhances plant growth and resilience, decreasing the need for chemical pesticides and herbicides.

In respect to agriculture and food systems, agricultural seeds enhance crops adaptation to climate as seeds with traits like drought and disease resistance are crucial for farming in a changing climate thereby, helping to maintain yields with fewer resources, this is in addition to promoting healthier and more resilient crops. Seeds also contribute greatly to better soil health and reduced runoff into waterways.

Through the creation of good habitat and its effects on biodiversity, seeds play an important role in restoring landscapes, providing food and shelter for wildlife, and also support pollinators. They also help in stabilizing the ecosystem as they form the foundation for healthy ecosystems as they help in maintaining a stable plant communities and support other ecological processes. Through NASC initiative of establishing various Seed banks, genetic diversity of different plant species are preserved, and this is essential for maintaining the resilience of ecosystems and for future adaptation. In addition, the growth of plants from seeds helps to stabilize soil, which is critical for preventing erosion, and other environmental disasters.

Quality seed and our environment

Using quality seeds is foundational to environmental sustainability because they promote agricultural productivity while minimizing the environmental footprint of farming. This is achieved by enabling more efficient resource use, reducing reliance on chemical inputs, and fostering climate-resilient farming systems.

Reduced Environmental Impact

- i. **Decreased Chemical Use:** High-quality seeds are often bred for resistance to local pests and diseases, which significantly reduces or even eliminates the need for chemical pesticides and fungicides. This protects soil and water quality by preventing harmful chemical runoff into surrounding ecosystems.
- ii. **Lower Fertilizer Requirements:** Some improved seed varieties are more efficient at absorbing and utilizing soil nutrients, which can reduce the need for excessive chemical fertilizers. This minimizes the

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environmental damage associated with fertilizer production and application, including carbon emissions and nutrient pollution.

iii. **Efficient Resource Use:** Quality seeds have higher germination rates and produce more uniform, vigorous plants, leading to optimal use of land and other resources like water and labor. This increased efficiency helps prevent agricultural expansion into natural habitats, thereby preserving biodiversity and forests.

Enhanced Climate Resilience and Biodiversity

Adaptation to Climate Change: Quality seeds include varieties developed to be "climate-smart," such as those with drought tolerance, flood resistance, or the ability to thrive in extreme temperatures. This helps farmers maintain yields despite unpredictable weather patterns, ensuring food security in a changing climate.

Biodiversity Conservation: The use of diverse, locally adapted, and improved seed varieties helps preserve the genetic capital of crops, which is vital for building resilient ecosystems and food systems. Community seed banks and farmer-managed systems play a key role in conserving this agrobiodiversity.

Improved Soil Health: Certain quality seeds, such as those for leguminous cover crops, can improve soil health by fixing nitrogen, enhancing soil structure, and promoting beneficial microbial activity, which reduces erosion and builds healthier, more fertile soil over time.

Summarily, Quality seeds are a cost-effective and fundamental input for sustainable agriculture, enabling farmers to produce more food per hectare with fewer resources. By prioritizing quality seeds, the agricultural sector can work towards greater food security, environmental protection, and overall system resilience for future generations.

Regulating and Strengthening the Seed Industry

The **NASC**, under the **Seeds Act 2019**, regulates seed registration, certification, marketing, import/export, and quality assurance. The Council's core functions include:

- Formulating and implementing policies for seed development and trade.
- Ensuring compliance with quality and certification standards.
- Supporting seed testing, variety release, and market intelligence.

These measures ensure that Nigeria's seed system operates with efficiency, credibility, and alignment to global standards.

1. NASC Innovations and Strategic Interventions

To drive modernization, NASC has introduced several technological and institutional innovations:

- **National Seed Tracker** – a digital platform that integrates production, certification, and traceability, linking farmers and companies across the supply chain.
- **National Seed Roadmap Dashboard** – launched with the **Collaborative Seed Programme (CSP)** to provide data-driven insights for policy and investment decisions.

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- **Molecular Diagnostic Laboratory** – supports DNA fingerprinting, trait purity testing, and pathogen detection to ensure varietal integrity.
- **Community-Based Seed Programme (CBSP)** – empowers smallholder farmers through localized seed production, strengthening food security and biodiversity conservation.
- **OECD Seed Scheme Membership** – Nigeria became the 62nd member, aligning its seed certification system with international standards for global competitiveness.
- **Plant Variety Protection (PVP) Law (2021)** – guarantees breeders' rights and encourages private-sector investment in research and variety development

2. Quality Assurance and Compliance Systems

NASC maintains rigorous field and laboratory standards through:

- **Certification and labeling systems** (digital labels, seed codex).
- **Seed inspectorate surveillance and market monitoring** to curb adulteration.
- **Partnerships** with international organizations such as **ISTA** and **BMGF** for varietal identification, traceability, and data-based quality verification.

These systems guarantee that only verified and high-quality seeds reach Nigerian farmers.

3. Challenges Confronting the Nigerian Seed System

Despite progress, the seed sector faces multiple challenges:

- **Climate change impacts:** unpredictable rainfall and temperature extremes affecting seed production.
- **Environmental degradation:** soil depletion and deforestation threatening production zones.
- **Economic constraints:** high production costs, limited finance, and weak market linkages.
- **Low adoption rates:** majority of farmers still rely on saved seeds due to limited awareness and affordability.

Addressing these requires strong R&D investment, climate-resilient seed development, and improved farmer access to certified seeds.

4. The Way Forward

To fully harness the seed sector's potential as a driver of food and nutritional security, Nigeria must:

1. **Strengthen NASC** with increased funding and institutional capacity.
2. **Scale up breeder and foundation seed production** through decentralization.
3. **Enhance public awareness** through field demonstrations and promotional campaigns.
4. **Improve rural infrastructure** to enable private seed companies to penetrate remote areas.
5. **Invest in climate-resilient breeding** and community-based seed systems.

These actions will position Nigeria as a regional leader in quality seed production and agricultural innovation.

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5. Conclusion

Quality seed remains the **bedrock of agricultural transformation** and a powerful tool for national food and nutritional security. Nigeria's seed industry is a **goldmine yet to be fully explored**, with the potential to feed the nation, create jobs, and lift millions out of poverty.

The challenge before us is clear: **How can we maximally harness the untapped opportunities within the seed sub-sector to address the socio-economic realities confronting Nigeria today while still maintaining a sustainable environment?**

Let me conclude with an excerpt from H.E Mr. President.

“Plant the right seed, feed an entire Nation”,

H.E President Bola Ahmed Tinubu GCFR

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Climate-Smart Agricultural Finance (CSAF) for Smallholder Farmers' Adoption of CSA Practices in Nigeria: Can Banks Play Significant Role?

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1. INTRODUCTION

Climate change poses serious threat to the global food security. This is particularly more serious in the sub-Saharan Africa (SSA) countries where agriculture remains the most important sector for national economic development. In Nigeria, where the smallholder farmers account for over 70% of the food and fibre production, the main climatic challenges facing smallholder farmers (SHFs) include frequent droughts, floods and unpredictable rainfall patterns, which continue to pose a threat to food and livelihood security (Ochieng et al., 2016). In response to these challenges, various mitigation and adaptation strategies such as climate-smart agriculture (CSA) has been developed and promoted to improve farm productivity and enhance food security (FAO, 2013). To effectively address the negative impact of climate change, farmers in many countries around the world are now adopting CSA (Kangogo et al, 2021). In the face of climate change, supporting the SHFs in adopting CSA has been found to be a panacea to the threat of food insecurity in a developing country such as Nigeria (Ajayi et al, 2024).

CSA refers to a set of agricultural practices and technologies which simultaneously boost productivity, enhance resilience and reduce greenhouse gas (GHG) emissions (FAO, 2013). CSA encompasses a range of practices and technologies that are tailored to specific agro-ecological conditions and socio-economic contexts including the adoption of climate-resilient crop varieties, conservation agriculture techniques, agroforestry, precision farming, water management strategies, and improved livestock management.

The objectives of this paper are therefore to:

- a) Describe climate-smart agricultural practices, its benefits and low level of funding.
- b) Explain climate-smart agricultural finance (CSAF), its procedure and tools.
- c) Explain the reasons for the inclusion of climate-change risks evaluation as part of Banks loan appraisal process.
- d) Describe the various CSAF Models and evidences of some CSAFs in Nigeria.
- e) Recommend the likely acceptable CSAF model for banks to fund smallholder farmers adoption of CSA practices in Nigeria.

2. CSA PRACTICES: BENEFITS AND LOW ADOPTION BY SMALLHOLDER FARMERS

Climate-smart agriculture (CSA) involves the adoption of multiple adaptation practices with complementary effects (Amadu et al., 2020; Teklewold et al., 2019). Adopting a combination of practices enables farmers to maximise synergies among CSA practices. This also enables farmers to diversify and improve production in the face of overlapping challenges such as low soil fertility and climate change (Khanna, 2001).

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2.1. Common CSA Practices

There are several climate smart agricultural (CSA) practices such as efficient water management practices which includes rainwater harvesting and drip irrigation techniques that optimize water use, particularly during droughts and irregular rainfall periods. Also, mulching, which involves applying a protective soil cover reduces runoff, improves water infiltration, and increases soil moisture retention.

There are a number of soil and fertility management practices that are climate-smart agriculture. One of such is composting, which involves the use of organic materials like compost and manure to improve soil fertility and overall crop yields, especially in degraded areas. The creating of compost from organic matter to enrich the soil nutrients and improves its ability to retain moisture is a very important CSA practice. Another CSA practice is zero or minimum tillage. It reduces soil disturbance, conserves moisture, lowers labour costs, and allows for timely planting.

There are a good number of crop-related CSA practices that smallholder farmers can adopt and improve upon. This includes the cultivation of improved seed varieties such as drought-resistant, pest-resistant, and heat-tolerant varieties which are adaptable to changing climate conditions. Planting of early-maturing crop varieties help evade negative impacts from reduced rainfall. Also, intercropping and crop diversification which involves the planting of different crops together or diversifying crop rotations can increase overall food security and income.

There are several other CSA practices and techniques such as planting pits can optimize resource use, especially in areas facing drought. Fodder banks provide sustainable feed for livestock, enhancing the resilience of pastoral systems. Agroforestry (incorporating trees into farms), enhances resilience and productivity. Also, early warning Systems is designed to providing farmers with timely weather and climate information through mobile platforms or community radio can help them prepare for changing conditions.

2.2. Benefits of CSA Practices for Smallholder Farmers

Smallholder farmers (SHFs) who practice CSAs can produce more and higher quality food without putting an additional strain on natural resources, thereby improving the food security and boost incomes, especially for 75% of the world's poor who live in rural areas and mainly rely on agriculture for their livelihoods (Kangogo et al, 2021). CSA has been found to reduce vulnerability to droughts, pests, diseases and other climate-related risks and shocks; and improve the capacity to adapt and grow in the face of longer-term stresses like increased seasonal variability and more erratic weather patterns (Amadu et al, 2020). Farming household practising CSA are more likely to increase their productivity which directly contributes to enhance the food security and incomes of such farming households (Kangogo et al, 2021). CSA adoption and practices help to reduce greenhouse gas emissions of the food system, avoid deforestation due to cropland expansion, and increase the carbon sequestration of plants and soils (Kassie et al, 2013).

2.3. Why the Low Adoption of CSA Practices Among Smallholder Farmers

Despite all the potential benefits, CSA practices in developing countries are not achieving their full potential given the low levels of adoption (Westermann et al., 2018). Smallholder farmers in SSA continue to suffer from the effects of climate change, because of their limited adaptive capacity (Asfaw et al., 2016). The level of farmer adoption of CSA practices is an indication of the farmer's adaptive capacity (Asfaw et al., 2016), and this in turn depends on the resources that the farmer can access and his/her ability to combine resources (Cinner et al., 2018).

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Available evidence in the farm technology adoption literature, indicates that different socioeconomic, institutional and environmental factors influence the adoption of CSA practices (Teklewold et al., 2019). Institutional constraints such as lack of government support and inadequate extension services which lead to insufficient financial aid has been found to significantly contribute in the low adoption of CSA practices by smallholder farmers (Bernier et al., 2015).

Adoption of CSA is highly region-specific as it depends on the target region's climatic, environmental, socio-economic, and political conditions. Smallholder farm households need both technical know-how and financial support to consistently follow the new technological innovations and adoption (Pingali et al., 2019; Bhatta et al., 2016).

According to the world bank (2025) only 4% of its funding goes to climate finance, with only 20% this (being just only 0.8%) going to smallholder farmers adoption of CSA practices. What could be the reasons for the low funding of climate-smart agriculture (CSA) for smallholder farmers? Studies such as (Benami et al, 2024; Ajayi et, 2024) have suggested low awareness of banks regarding the existence of climate finance funds; low adoption of climate-smart agriculture by smallholder farmers in developing countries; and high risk associated with financing the unstructured smallholders farming business (Advisor, 2022). Available literature seems to suggest that the low funding of CSA projects especially in developing countries is because such funds are largely from the public sector (Ajayi et al, 2024) because of its long-term sustainability and resilience to climate change, as against short-term profitability being prioritized by the private sector including the Banks (Benami et al, 2024).

3. CLIMATE-SMART AGRICULTURAL FINANCING (CSAF)

According to Lalande (2024), Climate-Smart Agricultural Financing (CSAF) refers to a financial model that integrates environmental and climate risk assessments into agricultural lending and investment decisions. The main aim of CSAF is to ensure that lending supports long-term sustainability and resilience to climate change. CSAF encourages both financial institutions and farmers to consider the environmental impact of their decisions, creating a framework in which economic activities are aligned with climate-smart outcomes (Benami et al, 2024).

CSAF is primarily targeted at reducing agriculture's contribution to climate change by promoting practices that lower greenhouse gas emissions, such as sustainable land management, agroforestry, and organic farming, while at the same time adjusting agricultural practices to better cope with the changing climate, such as improving water management systems or planting drought-resistant crops (Ajayi et al, 2024). By incorporating these mitigation and adaptation strategies, CSAF ensures that agricultural investments are profitable and resilient in the face of climate risks (Havemann et al, 2022).

3.1. The Benefits of evaluating climate-related risks in Agricultural Lending

It is important for banks to also evaluate climate-related risks that could affect the success of a farming operation. These factors include climate variability, such as the probability of occurrence of droughts or floods, or other extreme weather events, as well as changing rainfall patterns. By considering these risks, banks can make more informed decisions about which projects to fund and under what conditions (Tanir et al, 2024). In the course of their appraisal, Banks may choose, for example, lower interest rates for farmers who invest in sustainable practices, such as water-efficient irrigation systems or solar-powered equipment. Also, Banks may insist that borrowers implement specific climate-smart agricultural practices as part of the terms for approving and disbursing the loan. These types of measures can contribute in protecting the

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Bank's investment and encourages farmers to adopt practices that improve their resilience to climate change (Ajayi et al, 2024).

Also, it has been found that Banks can benefit from CSAF by reducing the risk of loan defaults caused by climate-related disasters (Benami et al, 2024). When climate change risks are not adequately considered, Bank's investments in the form of agricultural loans are more likely to fail in the face of climate-change related disasters or long-term climate shifts. By integrating climate-change risks evaluation into the loan appraisal process, CSAF helps mitigate these risks, ensuring that both the Banks and farmers are better prepared for the impacts of climate change (Talari et al, 2022). It is imperative to therefore emphasize that CSAF is critical in addressing climate change and fostering resilience in agricultural systems. According to Chataut et al (2023), agriculture is both a contributor to and a victim of climate change, accounting for roughly 10-12% of global greenhouse gas emissions. At the same time, farmers experience the direct negative impacts of climate change which includes the effects of changing weather patterns, soil degradation, and water scarcity (Chataut et al, 2023).

3.2. CSAF Procedure for Evaluating Climate-related Risks in Agricultural Lending

The procedure to be followed by any bank lending under the CSAF framework is to first identify the climate change risks by using climate models and environmental data to predict how future climate conditions may impact specific agricultural projects (Ajayi et al, 2024). While climate models provide insights into the potential frequency and severity of climate change incidences, environmental data, such as soil quality, water availability, and temperature trends, assist in the assessment of the long-term sustainability of farming operations in different regions (Ajayi et al, 2024). By leveraging these tools, Banks can better understand the climatic environment in which a farm operates, allowing them to make more informed lending decisions (Aragón et al, 2021).

Secondly, having identified the climate-change risks, the Bank's next step is to evaluate the potential impact of these risks on the agricultural project to determine the level of risk exposure of the project in general, and the bank's loan fund in particular. This evaluation process is critical because it influences whether a loan would be approved and the conditions under it would be approved and disbursed (Ajayi et al, 2024). Banks evaluate climate-change risks by considering several key factors, including the farming operation's vulnerability, the farmer's adaptive capacity, and the likelihood of climate-related incidences affecting the agricultural project (Wu et al, 2021).

Vulnerability assessment focuses on determining how susceptible a farming operation is to climate-change risks. For instance, farms located in low-lying or coastal areas are more likely to be vulnerable to flooding, while those in arid regions are more likely to face higher risk of drought. Also, the type of crop or livestock being produced can play significant role in determining vulnerability. For instance, certain crops are more sensitive to temperature changes or water availability than others. Therefore, by understanding the specific vulnerabilities of a farm, Banks can assess the potential for financial loss due to climate-change factors (Ho et al, 2021).

Adaptive capacity of the farmer refers to the ability of the farmer to adjust his/her agricultural practices in response to climate-change risks. This can include adopting new technologies, such as drought-resistant seeds or precision irrigation systems, as well as improving farm management practices, such as diversifying crops or improving soil health. Empirical evidence indicates that farmers with higher adaptive capacity are better positioned to manage climate-change risks, reducing the likelihood of financial losses and improving the agricultural project's overall sustainability (Chepkoech, et al 2020).

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Banks can also evaluate the likelihood of climate-related incidences affecting the agricultural project operations. In this case, the Bank assesses the probability of climate-change incidences or long-term climate shifts occurring in the region where the farm project is located. For example, if the climate models predict a high likelihood of increased drought in a particular region, then the Bank may view this as a significant risk factor. However, if the farmer(s) involved have invested in irrigation facilities or other adaptive measures, then the Bank may consider the risk to have been adequately mitigated (Brunetti et al., 2022).

3.3. Tools and Methods of Evaluating Climate-related Risks in Agricultural Lending

There are several evidences in literature on the various tools and methodologies that are available for assessing environmental risks within the CSAF framework. These tools can assist Banks to collect, assemble and analyze the data needed to make informed decisions of lending to agricultural projects.

- a) *Geospatial analysis*: This is one of the commonly used tool or method of evaluating risks related to climate change. With the use of satellite imagery and geographic information systems (GIS), the environmental (soil and weather) conditions of specific areas can be evaluated (Pomortseva et al, 2020). For instance, satellite data can be obtained and used to monitor soil moisture levels, crop health, and water availability. This can enable a Bank to assess the environmental conditions of a farm in real-time thereby allowing such Bank to identify potential risks before they escalate into financial losses (Ajayi et al, 2024). Geospatial analysis is particularly useful for monitoring large-scale agricultural projects or farms located in remote areas, where traditional methods of data collection may be difficult (Tsatsaris et al., 2021).
- b) *Climate risk indices*: This is another tool that can be used in CSAF. The climate risk index is used quantitatively assesses a farm's exposure to risks related to climate change. It takes into account factors such as the frequency of extreme weather events, long-term temperature trends, and the availability of natural resources like water. By providing a numerical score, the climate risk index allows the banks to easily compare the risk levels of different agricultural projects and make more informed and objective decisions on which ones to fund (Gerlak et al., 2021).
- c) *Scenario planning*: This involves creating multiple hypothetical future scenarios based on different climate change projections. For example, one scenario might assume moderate climate change impacts, while another assumes more severe impacts. By exploring how a farming operation might perform under different scenarios, banks can better understand the range of possible outcomes and make more climate-smart lending decisions (Lumeng and Jianguo, 2022).

4. CSAF MODELS AND EVIDENCES IN NIGERIA

CSAF models use a variety of financial instruments and mechanisms to incentivize sustainable practices and build climate resilience in the agricultural sector.

4.1. Carbon Credit Financing (CCF) Model

This is a CSAF model that promotes sustainable agriculture by providing financial incentives for farmers who adopt CSA practices that reduces greenhouse gas emissions. In this model, farmers who adopt CSA practices that sequester carbon or reduce emissions such as reforestation, soil carbon sequestration, or methane reduction can earn carbon credits (Lokuge and Anders, 2022). These credits can then be sold on carbon markets, providing an additional source of income for the farmer (Ajayi et al, 2024). Carbon credit financing plays significant role in bridging the gap between environmental sustainability and economic viability. In developing countries including Nigeria, majority of the farmers lack the capacity and interest to adopt CSA practices because of the high upfront costs involved, such as purchasing additional soil

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amendment inputs (e.g biochar), new equipment (irrigation facilities) or altering their farming techniques. However, by generating additional income through the sale of carbon credits, farmers can offset these costs and make sustainability more economically viable thereby creating a positive feedback loop in which sustainable practices lead to increased financial returns, thereby encouraging further investment in sustainability (Agrawal et al., 2024).

For instance, a farmer who practices the incorporation of biochar in the soil can earn carbon credits based on the amount of carbon captured by the biochar in soil. These credits can then be sold to companies or individuals looking to offset their own carbon emissions. This creates a win-win situation as the farmer benefits financially from sustainable practices while contributing to climate change risk mitigation (Khatri-Chhetri et al., 2021).

Apart from carbon credit markets, some governments and international organizations such as the world Bank offer carbon offset programs that provide financial incentives for farmers to either reduce their GHG emissions or sequester carbon. These programs often provide technical assistance and funding to help farmers implement CSA practices, further encouraging the adoption of sustainable agriculture and contributing to achieving global climate goals (Batra 2023; Ajayi et al, 2024).

4.2. Green bonds (GB) Model

This is one of the most innovative financial instruments in the CSAF framework. Green bonds are fixed-income security designed to raise capital for funding projects with a positive environmental impact. Green bonds can be used to finance a wide range of sustainable practices in agriculture, including renewable energy installations, soil and water conservation systems, organic farming, etc. By issuing green bonds, Banks and other financial institutions can direct funds specifically toward projects that contribute to environmental sustainability while providing a return on investment for bondholders (Zhao et al., 2022).

Green bonds can play a crucial role in promoting CSA farming practices. For example, a Bank can issue green bonds to fund (loan) its customer (a farmer) to install solar panels, thereby reducing the farmer's reliance on fossil fuels and lowering its carbon footprint. This type of investment improves the farm's sustainability and make it more resilient to the impacts of climate change (Versal and Sholoiko, 2022). One key advantage of green bonds is that they can attract several individual and institutional investors interested in supporting sustainable development. Given that green bonds are tied to specific environmental impact outcomes, they provide a clear and measurable method for investors to track the impact of their investments, making them an attractive option for those looking to contribute to climate-smart agriculture (Environment and Secretariat, 2023).

4.3. Sustainability-linked loans (SLLs) Model

In this CSAF model, the loan terms and interest rates are tied to the borrower's achievement of specific sustainability targets, such as reducing greenhouse gas emissions, improving water efficiency, etc. Meeting or exceeding these targets can lead to the borrower enjoying lower interest rates, and other favourable loan terms (Pohl et al, 2023). Because of tying financial benefits and other incentives to meeting environmental sustainability targets, SLL is strong in influencing farmers to adopt CSA practices (Ajayi et al, 2024). For example, the lending Bank can charge lower interest rates on loans for farmers who commit to reducing their farm's carbon emissions by a certain percentage, thereby making investing in energy-efficient equipment or switching to clean or renewable energy sources more affordable. This helps such a farmer to save money and contributes to broader efforts to mitigate climate change (Du et al, 2023).

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SLLs are more flexible because they allow farmers to use the loan for general purposes, provided they meet their sustainability targets. According to Chan (2021), the direct tying of the financial benefits of SLLs to environmental performance, SLLs tend to encourage continuous improvement, thereby pushing farmers to improve on their adoption of CSA practices over time.

4.4. Evidences of Some CSAF in Nigeria

Nigeria is a leader in Africa's green bond market, with both the government and private sector using this instrument to finance sustainable development. The federal government of Nigeria (FGN) first issued sovereign green bonds in 2017 and has continued with subsequent issuances, including a ₦50 billion bond in 2025. Proceeds have been allocated to climate-smart agriculture initiatives to improve food security and reduce post-harvest losses.

In 2021, a national climate change fund was established. Nigeria's 2021 Climate Change Act created the legal framework for a national fund. The fund is intended to utilize seed capital from the government and development partners to de-risk and catalyze private finance for climate action, with agriculture as a key sector.

Under the carbon projects, a pilot program in Northern Nigeria, supported by LINKS Nigeria, included the design of a carbon project to seek funding for certified carbon reduction efforts on 100,000 hectares of land.

In 2019, Access Bank became the first non-government owned institution in Africa to issue a corporate green bond, with proceeds directed toward agricultural and renewable energy projects.

In Nigeria, there are enabling frameworks for CSAF. Nigeria's Securities and Exchange Commission (SEC) has implemented Green Bond Rules to guide issuance, while platforms like the FMDQ Green Exchange promote market transparency.

5. CONCLUSION AND RECOMMENDATIONS

Climate-smart agriculture (CSA) has been identified as an important panacea to curbing the negative impact of climate change that is threatening global food security particularly in the developing countries including Nigeria. Despite its benefits to smallholder farmers, there has been low adoption of CSA practices by smallholder farmers who constitute over 70% of food and fibre production in Nigeria. Several challenges including environmental, adaptive capacity and institutional constraints have been found to be responsible for this low adoption of CSA. One key institutional constraint is poor funding of CSA practices.

Bank loans can play significant role in influencing the smallholder farmers in their adoption of CSA practices. There is need to design CSAF models that are acceptable to the Banks in Nigeria. It is important to develop domestic-based CSAF models with inputs from the various stakeholders across each enterprise-specific agricultural value chain. These CSAF models should provide structured agri-value chain ecosystem where the linkages among the various actors along the agribusiness enterprise value chain need to be not just adequately established, but strong enough to give the lending bank reasonable level of comfort. Structured value chain linkage provides a strong agribusiness ecosystem that makes lending decisions easier for banks. This is because the loan repayment can be easily predicted and guaranteed, knowing fully well where the cash inflows for the repayment is coming from.

The CSAF funds are provided by institutions and organization that support and promote environmental sustainability through reduction in greenhouse gas emission and climate-smart agricultural practices. The

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Banks can foster strong partnerships and collaborations with these local and international organizations and institutions such as the World Bank, FAO, Green climate fund (GCF), national government programmes, private foundations (e.g MasterCard Foundation fund), and private investors (e.g ARAF – Acumen resilient agriculture fund). The funds from these pro-CSAF institutions are usually long-term and often come at lower interest rates. By accessing these funds through any of the models under the CSAF framework, Banks can boost its liquidity position at lower cost, hence can on-lend at lower interest rate to farmers who have been duly trained and have adopted CSA practices, while maintaining reasonable profit margin.

Banks are more likely to fund CSA projects that the loan requests are supported with a business plan that contain detailed relevant information that can assist the bank to process the loan request and make informed lending decisions. The information required to enhance the bankability of the business plan of a CSA project often includes clear loan purpose, borrower's credit worthiness and capacity (including the CSA experience and evidence of adoption as well as high bank account turnover), business feasibility and profitability, risk mitigation strategies, business transaction dynamics, guaranteed offtake/market, loan repayment sources, insurance cover, collateral and level of equity investment in the project.

The successful implementation of CSAF requires that Banks build capacity in both human capital and technology. Integrating environmental risks assessment in agricultural lending decisions is an important component of CSAF framework. To fund CSA projects, Banks need to make substantial investments in environmental assessment tools and techniques especially in geospatial analysis and climate risk indices. Also, Banks need to build the capacity of their staff members on CSA practices. The Bank's agribusiness, credit and marketing officers need to be adequately and continuously trained on climate-smart agricultural finance (CSAF) as well as the CSAF procedures, tools and methods.

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**TECHNICAL SESSION FOR THE 8TH INTERNATIONAL SAEREM/UNIABUJA2025
CONFERENCE PROCEEDINGS**

S/N	TOPIC/AUTHOR(S)	REMARKS
WN	Climate Smart Agriculture as Panacea for Mitigating Climate Change PROFESSOR IGNATIUS ONIMAWO PhD FNSN Pro-Chancellor Federal University of Technology; Babura Jigawa State	Chairman Address
KNS	Climate Change: A Surmountable Impediment to Environmental Sustainability and Food Security. Professor J. S. Oboreh ; Vice Chancellor Southern Delta University Ozoro, Delta State.	Keynote Speaker
LS1	Quality Seed: Panacea for National Food, Nutritional Security and Environmental Sustainability in Nigeria. Hon. Fatuhu Muhammed Director General / CEO, National Agricultural Seeds Council (NASC),	Lead Speaker 1
LS2	CLIMATE-SMART AGRICULTURAL FINANCE (CSAF) FOR SMALLHOLDER FARMERS' ADOPTION OF CSA PRACTICES IN NIGERIA: CAN BANKS PLAY SIGNIFICANT ROLE? Dr Uchenna Obih; Hedge Microfinance Bank Ltd, Karshi, Abuja	Lead Speaker 2
SA250A	Assessment of Indoor Air Quality in Cybercafés Used by Students of the University of Agriculture and Environmental Sciences, Umuagwo: Implications for Health and Academic Performance': *Onyemekara N.N ¹ , Iheukwumere I H ² , Igiri V.C ¹ , Anyanwu C.G ³	UNIAB UJA/001
SA250B	Climate Changes, Insecurity and Economic Development in Nigeria: A Review ¹ Salihu Musa, ¹ Umar Mukhtar, ² Bashir Garba Muktar, and ¹ Gama Emmanuel	UNIAB UJA/002
SA250C	Growth and Yield Response of Potato (<i>Solanum tuberosum</i> L.) Varieties to Planting Bag Size under Dry Season Conditions in Nigeria Dayok Samuel Tanko ¹ , Adashu Tanko Gani ^{2*} , Goyit Iliya ¹ and Deshi Simon Nengak ¹	UNIAB UJA/003
SA250D	Isolation and characterization of root-associated microbes in the rhizosphere of Bamboo in Cross River State, Nigeria *Ogbaji, Henderson Onah, Tangban Eji Amba, Young B. Ibiang*, Paul B. Ekpo	UNIAB UJA/004
SA250E	A Review Paper On Mechanism Of Host Plant Resistance To Pests & Diseases Augustine A. M ¹ , & Uzakah, R. P ²	UNIAB UJA/005
SA250F	Sustaining Vitamin-A potato production in the face of climate change: accessing agricultural adaptation practices of smallholder farming in Kogi state, Nigeria Oguejiofor Joseph Okorie, Johnpaul Tochukwu Offorma and Ibrahim Isaac Umaru	UNIAB UJA/006
SA250G	Machine Learning Evaluation of Irrigation Water Quality Indices Affecting Rice Performance in the Northern Guinea Savanna: Gani A.T.* and Awwal Y.A.	UNIAB UJA/007

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SA250H	Effects of NPK fertilizer and poultry manure on soil macro-nutrients and yield of pepper (<i>Capsicum spp.</i>) ¹ SALAMI, Taofeek Boladale ; ² BELLO, WasiuBabatunde, ³ Oke, Oluyemi,Olugbemi and ¹ RABIU,JimohOlaleye	UNIAB UJA/008
SA250I	Farmers Perception on Effectiveness of Participatory Extension Approach on Beans Production in Paikoro Local Government Area of Niger State.: ¹ Mohammed, U., ² Umar, I. S., ³ Maimuna, A. A.,	UNIAB UJA/009
SA250J	Use of Information and Communication Technologies for Effective Extension Service Delivery among Extension Agents in Kano State, Nigeria: ¹ Ehien, A. E., ¹ Makinta, U., ¹ Rabiatu, Y. A., and ¹ Hussaini, A.	UNIAB UJA/010
SA250K	Application of Semivariogram Analysis in measuring Spatial Variability and Distribution of Selected soil Properties in Umuagwo, Imo State. Okereafor, D. O., Onyechere A. U., Ukabiala, M.E., Amanze C.T., and Ibe O.K.	UNIAB UJA/011
SA250L	Determinants of food expenditure among urban households in Bayelsa state, Nigeria Zelda A. Elum* and Tari Digitemie ²	UNIAB UJA/012
SA250M	Big Data and Artificial Intelligence in Ecosystem Monitoring in the Mangrove Zone of Nigeria: Prospects and Challenges: Ariwaodo, J. O. ¹ , Olu, O. ^{1*} , Odega, C. A. ¹	UNIAB UJA/013
SA250N	Hot Water Priming as a Pre-Treatment for Enhancing Germination and Sprouting in Carrot (<i>Daucus carota</i>) : Emmanuel, C. M., Abdulmalik, S. Y., and Majin, N.S.	UNIAB UJA/013
SA250O	The Consumers' Preference on Consumption of Locally Produced Rice in Jigawa State, Nigeria; Isah M ¹ , Sani B. S ² Ahungwa G. T ³ , Nadia, A.Y Gaya ⁴	UNIAB UJA/014
SA250P	Agro-enterprise income intensification: a case of tomato production in Akwa Ibom State, Nigeria Sunday B. Akpan; Ini-mfon V. Patrick; Udoro J. Udo and Samuel J. Udoka	UNIAB UJA/015
SA250Q	Fishery Value Chain in River Benue Valley Nigeria, A Livelihood Approach for Fishermen Economic Sustainability and Resources Management, ¹ Modibbo U., ¹ Mohammad Hanafi Idris., ² Aliyu A ³ Sogbesan Olukayode Amos	UNIAB UJA/016
SA250R	Willingness to Pay for Extension Services (NIFOR) by Smallholder Oil Palm Farmers in Edo State Effiong, M. O. ¹ and Ameh, B. O. ²	UNIAB UJA/017
SA250S	Biotechnological Approaches in Probiotic Supplementation for Sustainable Fish Health and Aquaculture Productivity: Aishatu Shettima ¹ , *Adio Collins Oluwaseun ² , Isijola Bolanle Caroline ¹ , Adeyemi Hawau Jummai ¹ , Raji Mistura ¹ , Ajulo Kehinde Kayode ¹ , Mustapha Khafayat Oluwadamilola ¹ , Stephen Aloko Oladipo ¹ , Mustapha Ramat Ayoola ³ , Oyeyemi Saheed Kehinde ¹ , Fateemah Abisola Ajibade ¹ , Uwumagbe Iyayi Austine ²	UNIAB UJA/018
SA250T	Agricultural Waste-To-Feed Conversion through Biotechnological Interventions for Sustainable Livestock Production in Nigeria: *Bello Abdullahi ¹ , Adio Collins Oluwaseun ² , Isijola Bolanle Caroline ¹ , Mustapha Khafayat Oluwadamilola ¹ , Olaleye Olanrewaju Ebenezer ¹ , Fateemah Abisola Ajibade ³ , Uyo Martha Idakwoji ¹ , Itunu Adesola Adeyemi ¹ , Raji Mistura ¹ , Abegunde Omolade Mary ¹ , Chidolue Kingsley ¹	UNIAB UJA/019

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SA250U	Assessment of Agricultural Extension Service Delivery on Postharvest Loss Management of Millet and Sorghum in Dutse Local Government Area, Jigawa State ¹ Garba, A, ² Sanusi, S.M ² Katanga, Y.N, and ¹ Maryam, A.I	UNIAB UJA/020
SA250V	Gender Dynamics in Palm Oil Agriculture and the Economic Sustainability Implications in Imo State Dr. Okechukwu Stanley Chidinna, Segun Emmanuel Kutu, Obichere Austine and Udunwa Nkechi Bridget.	UNIAB UJA/021
SA250W	Scaling up Climate-Smart Soil Management Practices among Smallholder Farmers in Imo State S. I. Ukwuaba	UNIAB UJA/022
SA250X	Climate-Smart Tomato Production for Food Security and Environmental Sustainability: Influence of Mulching and Variety on Growth and Yield in the Sudan Savanna of Nigeria: Lawan, Z. M., Shittu, E.A., and Haruna, K.	UNIAB UJA/023
SA250Y	Challenges Faced by Small-Holder Wheat Farmers in Achieving Food Security in Jigawa State, Nigeria: ¹ Umar Mukhtar, ¹ Ibrahim Philemon, ² Bashir Garba Muktar and ² Martins Olusegun Orifah	UNIAB UJA/024
SA250Z	The Promise of Mangrove Ecological Zone: A Review of Resource Benefits and Management Constraints in Akwa Ibom State, Nigeria : Ebong, M.S ,Jimmy, U.J ,Odey ,D . and Uyouko,E.E.	UNIAB UJA/025
SA250A A	The Impact of Climate Change on Wildlife in Gashaka-Gumti National Park, Nigeria Bode, A. S., Mathias Ana'aticha, and Wadiamu Bello	UNIAB UJA/026
SA250U AB	Condition factors and rearing water quality parameters of wild-caught Atlantic Tarpon <i>Megalops atlanticus</i> raised in brackish water ponds: Implications for capture based aquaculture in Nigerian coastal waters: DIYAOLU, D. O	UNIAB UJA/027
SA250U AC	Effects of Varying Rates of Rabbit Manure and NPK Fertilizer on the Growth and Yield Performance of Amaranthus (<i>Amaranthus hybridus</i> L.): ¹ Awopegba, T. M.*, ² Adeboye, K. A., ³ Fayose, C. A.	UNIAB UJA/028
SA250U AD	Microbial Contamination and Pathogenic Profiles of Street-Vended Fruit Salads in Owerri Metropolis.: *Igiri, V. C ¹ , Umeaku C.N ² , Nnenna Nelly Onyemekara ¹ , Nwabueze E.U ¹	UNIAB UJA/029
SA250U AE	<i>Spondias dulcis</i> Parkinson: Integration of Tree Species into Agroforestry Practices for Climate-Smart Agriculture in the Niger Delta Region Ariwaodo, J. O. ¹ , Olu, O. ^{1*} , Odega, C. A. ¹ , Obidike-Ugwu, E.O ² and Tom, P.K. ¹	UNIAB UJA/030
SA250U AF	Effect of Substituting Sundried Watermelon (<i>Citrullus lanatus</i>) Peel Meal for Yellow Maize Meal on Feed Utilization, Growth, Body Composition and Survival In <i>Clarias gariepinus</i> Juveniles Adesina, S.A.* and Joshua, B.E.	UNIAB UJA/031
SA250U AG	Effect of lead mining on the livelihood structure and food security dynamics of agribusiness households in Ebonyi state, Nigeria: Nwaogu, D.C. and Nwakpu, A.C.	UNIAB UJA/032
SA250U AH	Evaluation of the acrolein-induced hepatorenal redox perturbation and immunosuppressive response in male Wistar rats.: Ijoko, J. O., Nweke, T. O., Ebokaiwe, A. P., & Oje, A. O.	UNIAB UJA/033
SA250U AI	Contribution of Involvement in Fish Farming to Food Security Status of Fish Farmers in Oyo State Alabi, A. F., Ajuwon, I. O., and Sanusi, M. B.	UNIAB UJA/034
SA250U AJ	Behavioural and Physiological Responses of African Catfish (<i>Clarias gariepinus</i>) to Sub-Lethal Exposure of Cypermethrin: ^{1*} Ajibare, A.O., ² Adebola, O.T. and ¹ Ikuesan, B.B.	UNIAB UJA/035
SA250U AK	Evaluation of Soil Degradation Status in Selected Soil of Wukari, Taraba State Osujieke, D. N., Gani, A. T. and John, F. O	UNIAB UJA/036
SA250U AL	Pre-Liminary investigation of the Performance of Potato (<i>Solanum tuberosum</i> L) Varieties Using Different Polythene Bags in Nigeria: Adashu Tanko Gani ¹ , Dayok Samuel Tanko ² , Goyit Iliya ² and Deshi Simon Nengak ²	UNIAB UJA/037

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SA250U AM	Do Farmers Derive Income from Yam Production? Novel Evidence from Imo State, Nigeria Esiobu, Nnaemeka Success ^{a*} ; Osuagwu, Chizoma Olivia ^a and Onyike, Rosita Chijioko ^b	UNIAB UJA/038
SA250U AN	Growth Response of <i>Khaya senegalensis</i> and <i>Parkia biglobosa</i> Using Rotten Cassava Peel and Grinded Cassava as An Organic Fertilizer: *Umar M. R ¹ , Saka M. G ² , Mamman G. S ³ , and Adedotun A ⁴	UNIAB UJA/039
SA250U AO	Efficacy Of Botanicals And Synthetic Insecticide Products Against Maize Weevils (<i>Sitophilus zeamais</i> L.) Infestation on Maize in Ikwo L.G.A. Ebonyi State, Nigeria *EMEKA, Chidiebere P.O. ¹ ; Agu, Blessing O. ¹ ; Ndifon, Elias M. ¹ ; Ankrumah, Emmanuel ¹	UNIAB UJA/040
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SA250U BB	Reconcile Healthcare Service and Agricultural Productivity: Pathway for Rural Development in Nigeria: Omotoso, A.B. ¹ , Olagoke, O.O. ¹ , Ayodele, M.A. ¹ , Sulaimon, I.O. ¹	UNIAB UJA/053
SA250U BC	Assessment of the Level of Awareness on Improved Postharvest Practices Among Smallholder Rice Farmers in Kano State, Nigeria: ¹ Bello, O.G., ¹ Jibia, S. S., ¹ Ehien, A.E. and ² Iyilade, A.O	UNIAB UJA/054
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SA250U BE	Comparative Analysis of Compost and Phosphorus Fertilizers in Enhancing Nutritional Content of Pigeon Pea: S. O. Ogunjinmi ¹ , N. O. Olla ² , O. S. Oladapo ¹ , K. A. Akanji ¹ and S. K. Omilabu ¹	UNIAB UJA/056

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SA250U BG	Effects of Toposequence on Some Selected Soil Properties at the Oyo State College of Agriculture and Technology, Igboora: N. O. Olla ¹ , S. O. Ogunjinmi ² , M. I. Olaniyan ¹ , N. O. Ogunmola ² and S. A. Ojienyi ²	UNIAB UJA/058
SA250U BH	Effects of Staking and NPK Fertilizer on Growth and Biomass Yield Of Cowpea (<i>Vigna unguiculata</i> L. Walp.) in Igboora, Oyo State, Nigeria: *Fawole, T. O. ¹ , Oyaniyi, T. O. ¹ , Bidmos, F. A. ² and Godspower, O. O. ³	UNIAB UJA/059
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SA250U BJ	Comparative Evaluation of Physicochemical and Organoleptic Properties of Pork as Influenced by Post-Mortem Processing Methods : Ekpo, J.S. and Okon, U.M	UNIAB UJA/061
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SA250U BR	Assessment of spatiotemporal Variation of Borehole Water Quality Parameters for Poultry Production in Maiduguri Metropolis, Borno State, Nigeria Alhaji Muhammad Adam ¹ , Tasiu Yalwa Rilwanu ²	UNIAB UJA/069
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SA250U CD	Analysis of a Combined Effect of Socio-Economics and Agribusiness Factors on Soybeans Production as an Opportunity Crop for Food Security in Mubi North LGA, Adamawa State, Nigeria.: Abdulrahman Aliyu^{*1} Bashir Hamman Gabdo², Jalaluddeen Usman², Joshua Ja'afar Dzangola¹ and Salamat Umar¹	UNIAB UJA/081
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SA250U CH	Assessing the Information Needs of Dry Season Vegetable Farmers in Akwa Ibom State, Nigeri Umoh, Idaresit Uwem, Udousung, Idongesit J. and Nkeme, Kesit K.	UNIAB UJA/085
SA250U CI	Evaluation of International Funds for Agricultural Development (IFAD-VCDPS) on Income Generating Activities of Women Beneficiaries on Rice Value Addition in Benue and Niger States, Nigeria.: ¹Maimuna, A. A., ²Ndagi, I., ²Mohammed, U., ²Baba, K.C.	UNIAB UJA/086
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SA250U CK	The Impact of Climate Change on Wildlife in Gashaka-Gumti National Park, Nigeria Bode, A. S., Mathias Ana'aticha, and Wadiamu Bello	UNIAB UJA/088
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SA250U CU	Gender Perception of Climate Smart Agricultural Practices by Cassava Farmers in Eket Agricultural Zone, Akwa Ibom State, Nigeria: Nkeme, Kesit Kufre ^{1**} , Bassey, Nsikan Edet ² , Ntekim, Augustine Okon ³ , Ndarake, Namso Frank ⁴	UNIAB UJA/098
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SA250U CX	Effect of1 Land Grabbing on Rural Households' Income in Akwa Ibom State, Nigeria Okon, Ubokudom Etim, Bassey, Nsikan Edet and Moffat, Felicia Adasi	UNIAB UJA/010 1
SA250U CY	Effect of Biochar Amended Soil on Physical and Chemical Properties, Growth, and Yield of Garden Egg (<i>Solanum melongena</i>) at the University Of Abuja: N.B. Ibrahim and M. A. Shittu	UNIAB UJA/010 2
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SA250U DC	Comparative Efficacy of Graded Doses of Neem (<i>Azadirachta indica</i>) Leaf Extract And Cypermethrin Against Fall Armyworm (<i>Spodoptera frugiperda</i>) on Maize (<i>Zea mays</i> L.) I. A. Aderolu ¹ and E. P. Ani	UNIAB UJA/010 6
SA250U DD	Strategies for Overcoming Climatic Constraints in the Conservation of Indigenous Crop Diversity in Rural Kano, Nigeria: Mohammed Sunusi Yusuf	UNIAB UJA/010 7
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SA250U DH	Analysis of Effects of Climate Change and Armed Conflicts on Food Security of Smallholders in Mubi North Local Government Area, Adamawa State, Nigeria Abdulrahman Aliyu ^{*1} Salamatu Umar ¹ and Jaafar Joshuwa Zongola ¹	UNIAB UJA/011 1
SA250U DI	The Perceived Impact of Climate Change on Wildlife in Gashaka-Gumti National Park, Nigeria <i>Bode, A. S., Mathias Ana'aticha, and Wadiamu Bello</i>	UNIAB UJA/011 2
SA250U DJ	Assessment of the Suitability of Soils, Originating from Different Parent Materials, for Rain-Fed Arable Farming in Central Cross River State, Nigeria ¹ Osang, E.A.; Orji J. E. ¹ ; Ndifon, E.M. ² ; Inyang P. ²	UNIAB UJA/011 3
SA250U DK	Analysis For The Presence Of Heavy Metals In The Tissues Of <i>Saccharum officinarum</i> (SUGAR CANE), <i>Musa paradisiaca</i> (PLANTAIN) AND <i>Manihot esculenta</i> (CASSAVA) Harvested In Otuoke Community: Benefit Onu,	UNIAB UJA/011 4
SA250U DL	Boosting Youth Employment and Food Security through Tomato Production in Akwa Ibom State, Nigeria. Udo, U. J. ¹ Akpan, S.B. ¹ . Ebong, W. O, ¹ Isip, I. F ¹	UNIAB UJA/011 5
SA250U DM	Enhancing Food Security through Gender-Inclusive Climate-Resilient Agriculture in Kebbi State, Nigeria. Muhammad, A. M* Sakaba, A. M. ** and Abubakar, I**	UNIAB UJA/011 6
SA250U DN		UNIAB UJA/011 7
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Do Farmers Derive Income from Yam Production? Empirical Evidence from Imo State, Nigeria

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Abstract

Yam is one of the most critical crops in Nigeria, mainly in Imo State, and contributes significantly to employment, income generation, and food security. However, despite Nigeria being the largest producer of yam globally with 43.1 million tonnes, the extent to which farmers derive income from yam production remains a subject of debate. It was against this backdrop that the study analyzed. The study was conducted from January, 2024 through April, 2025 with sample size comprising of seventy (70) yam farmers selected for critical yam-producing communities in Imo State. Structured questionnaire was the main tool for data collection. The data collected were analyzed using descriptive statistical tools, gross income analysis, and multiple regression analysis. Results show that the mean age was 44.00 years. Greater proportions (78.00%) were male. The majority (66.00%) were married, with an average household size of 7 persons. Average farm size and annual farm income were 1.38 hectares (29.71 plots of farmland) and ₦405,000.00 (\$281.61) respectively. Reasonable proportions (75.71%) were members of cooperative societies. The result shows that 2,000 tonnes of yam were produced from 1.30 ha (28 plots of farmland). Positive net farm return and return per capita invested were ₦231,819.33 and ₦5.21, respectively. The estimated regression result showed that the F-ratio (41.812), which determines the overall significance of the regressor, was highly significant at the 1% level of probability. Finding further shows that farmers are deriving reasonable income from yam production in the area. However, yam farmers identified inadequate production capital (100.0%) among others as the constraints that negatively affect their productivity and net farm return in the study area. It was recommended that yam farmers, particularly on their own, should judiciously put resources together through a strengthened cooperative society group, as this would increase their access to capital to enhance their output and net return in the area.

Keywords: Yam; Income; Constraints, Gross Income Analysis and Multiple Regression Analysis, Imo State, Nigeria.

1.0 INTRODUCTION: Yam (*Discorea spp*) is one of the major staple crops in Sub Saharan Africa (SSA) and mainly in Nigeria where it provides food for over 200 million people [(International Institute of Tropical Agriculture (IITA), 2024)]. It plays a crucial role in household consumption, cultural practices, and as a source of income for millions of smallholder farmers (Ariyo et al., 2020). Yam is an important carbohydrate-based crop in Nigeria, although its importance in the diets of the various tribes in the country differs (Anugwo & Egwue, 2024). Traditionally, the tuber can be cooked, fried or roasted. Alternatively, it can be processed into pounded yam, yam flour, yam chips or porridge (Cornet et al. 2023). Yam is also presented in traditional and marriage ceremonies. Medicinally, the mucilaginous tuber milk contains allantoin, a cell proliferates that speed up the healing process when applied externally to ulcers, boils and abscesses (Adejoh et al., 2024). Its decoction is also used to stimulate appetite and to relieve irritation and cough (Mignouna et al., 2020). Yams are more nutritious than cassava or sweet potato and highly prized for its taste and source of protein, fat and vitamin than cassava (Asem et al., 2024). Although Nigeria is currently the world's largest producer of yam with total production output estimate of 43.1 million tonnes accounting for about 68% of world production [(Food and Agriculture Organisation (FAO), 2024)]. Yam is the fifth most harvested crops in Nigeria, following after cassava, maize, guinea corn, and beans/cowpeas. More so, after cassava, yams are the most commonly harvested tuber crops in the country (IITA, 2024). The price of yam has continued to increase due to rising demand contrary to lagging supply. This development could be attributed to high rate of population growth and production problems such as inadequate credit facilities, scarcity and high cost of inputs, diseases and pests attacks among others (Boafo et al., 2025). Jude and Augustine (2024) affirmed that irrespective of the growing attentions given to yam production in Nigeria, its production is still below average and this could be as a result of some limitations occasioned by the activities of yam production coupled with pests and diseases that could retard its growth. Hence, deliberate effort to increase production of yam in Nigeria needs to be urgently put in place if the challenges of food security must be put under control. These production challenges results in production inefficiency and low profits. However, the extent to which yam farmers derive income from its production varies across Nigeria and particularly in Imo State, due to differences in production costs, market dynamics, and access to inputs, and infrastructural challenges. Additionally, market price fluctuations, inadequate storage facilities leading to post-harvest losses, and poor rural infrastructure further hinder yam farmers from maximizing their income (Adeshina et al., 2020). While

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some studies [(Verter & Bečvářová, 2015; National Root Crops Research Institute (NRCRI), 2024)] suggest that yam production is profitable, there is limited empirical evidence on the extent to which farmers derive sustainable income from it. It was against this backdrop that the study on do yam farmers derives income from yam production? New evidence from Nigeria was analyzed. The finding is crucial for policymakers, agricultural stakeholders, and farmers in designing strategies to improve yam production and enhance farmers' income. From the specific objective, the study described the socio-economic characteristics of yam farmers in the study area, ascertained yam varieties cultivated and the production systems practiced, estimated the cost and returns of yam production, and identified constraints faced by the yam farmers in the study area. The hypothesis of the study was that the socio-economic characteristics of the yam farmers do not significantly influence their net return.

2.0 METHODOLOGY: The study was carried-out in Imo State of Nigeria. Imo State is located in the South Eastern zone of Nigeria and lies between latitudes 5° 45'N and 6° 35'N of the equator and longitude 6° 35'E and 7° 28' E of the Greenwich Meridian [(Nigerian Meteorological Agency (NiMET), 2020)]. The State is bordered by Abia State on the East and Northeast, Rivers State on the South, Anambra State to the North and Rivers State to the South. Imo State is divided into three (3) agricultural zones of Owerri, Orlu and Okigwe and twenty-seven (27) Local Government Areas. With a total land area of 5,530km², the State has an estimated population of about 4.8 million persons and an annual growth rate of 3.35 percent [(Nigeria Populations Commission (NPC), 2006)]. The population of Imo State varies from 230 persons per kilometer square in Oguta/Egbema areas to about 1400 persons per kilometer square in Mbaise, Mbano, Orlu and Mbaitoli areas [(National Boundary Commission (NBC) of Nigeria, 2020)]. The study was conducted from January, 2024 through April, 2025. Multistage sampling procedure was used to select the sample for the study. The three (3) agricultural zones (Owerri, Orlu and Okigwe) of the State were purposively selected. Purposive sampling procedure was used to select area with high intensity of yam production. The second (2) stages involved the purposive selection of two local government areas (LGAs) in each of the zones, giving rise to six (6) Local Government Areas (LGAs). In the fourth (4) stages, three (3) communities were purposively selected from each of the six (6) LGAs, giving eighteen (18) communities. The eighteen (18) communities includes Ihitte-Ogada, Naze, Emii, Eziam, Ntu, Obike, Emekuku, Elelem, Akabo, Amaimo, Amakohia, Eziam-Ikeduru, Eguoma, Umuoha, Okoro-okwara, Umuduru, Eluama and Egwe. In the fifth (5) stages, five (5) farmers were purposively selected from each of the selected from eighteen (18) communities to give a total of seventy-two (72) yam farmers for the study. However, before the data analysis only seventy (70) questionnaire from the yam farmers were found useful and then used for data analysis. The study employed descriptive statistical tools in analyzing the data for the study. Precisely, descriptive statistical tools such as the frequency distribution, flow-chart, percentages and mean ($\bar{x}$) and inferential statistics such as multiple regression analysis were used to realize the objectives. The multiple regression model was stated as follows:

$$Y = f(X_1, X_2, X_4, X_5, X_6, X_7, X_8, X_9, e_i) \dots \dots \dots (2.1)$$

Y = Net Return (Naira)

X₁ = Age (years)

X₂ = Sex (Male = 1, Female = 0)

X₃ = Educational level (Number of years spent in school)

X₄ = Household size (Number of persons)

X₅ = Farm income (Naira)

X₆ = Membership of social organization (member = 1, non-member = 0)

X₇ = Farming experience (Years)

X₈ = Farm Size (hectares)

e_i = error term

3.0 RESULTS AND DISCUSSION

3.1 Socio-economic Characteristics of Yam farmers: Result from Table 1 shows that the average age of the farmers was 43.00 years. The yam farmers could be said to be within their productive age and are expected to be energetic age. This indicates that yam production is mostly done by farmers who are still in their active and productive age in the area. Younger farmers are known to be full of energy and ready to practice modern production techniques to increase their yield and income. The result shares view with the study of Kalu et al. (2023), who reported that younger farmers have physical and mental capacity to be engaged in yam production in order to increase yield, income and standard of living. In the same way, greater proportions (78.00%) of

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farmers were males. The finding implies that both sexes are involved in yam production but males were more in number than females in the area. This is true and could be attributed to the fact that yam production could be labour intensive requiring substantial energy, strength and time, therefore, female may not have the much needed physical energy to be involved in it than their male counterpart. The finding is in line with the study of Adejoh et al. (2023), who described yam as a token of masculinity. In addition, majority of the yam farmers had 12 years of formal education which is equivalent to secondary school education in Nigeria. The finding reveals that most of the farmers were literate enough in understanding and communicating effectively with extension agents and prospective investors. Education has always been known to play a positive role in the efficient use of productive resources for increased yield, income and standard of living. Increased level of education would determine the quality of skills of farmers, their management abilities, and how well informed they are of the innovations and technologies around them (Asem et al., 2024). Also, in Table 1, reasonable proportions (66.00%) of the farmers were married. The finding implies that most of the yam farmers in the area are married. Married farmers have tends to have more access to productive resources (land, labour and capital) and are expected to have some of its households members contribute in yam production. This finding supports the work of Esiobu et al. (2025), who asserted that married individual tend to have easy access to joint financially resources to enhance yield, income and standard of living. Result of yam farmers distribution based on farming experience is computed in Table 1. The mean farming experience was 23.00 years. This implies that the farmers have reasonable years of experience in yam production and are expected to produce to the best possible frontier for increased yield and net return in the area. The result is corresponds with the study of Jude and Augustine (2024), who asserted that increase in years of experience in farming, improves decision making in addressing production challenges to increase yield, income and standard of living of farmers. Finding of yam farmers distribution based on household size is compiled in Table 1. The mean household size was 7.0 persons. The result indicates that the farmers had large households which could serve as labour in their yam production in the area. This findings support the result of Esiobu (2024), who reported that large household size is a proxy to labour availability, expansion of farm while reducing the cost of hired labour. Outcome of yam farmers distribution on membership of social organization is conveyed in Table 1. It shows that greater proportion (68.00%) of farmers in the area belong to one form of cooperative or the other. The finding implies that most of the yam farmers are members of cooperative which afford them opportunity to share information, credit and labour. The result is in agreement with the study of Ariyo et al. (2020) who reported that membership of cooperative gives farmers access to pull labour, credit, information, bulk purchase to increase their yield, income and standard of living. Result of yam farmers distribution on annual income is unveiled in Table 1. The average annual income was ₦405,000.00 (\$270.23). This could be said to be relatively high, that despite some challenge farmers are facing they still realize reasonable farm income in the area, it is also an indication the yam production is viable in the area. Mignouna et al. (2020), reported that with sustainable income over time, farmers are able to purchase productive inputs, increase output, income, expand their farms, and improve significantly their standard of living. Similarly, the mean farm size was 1.38 hectares. This could be said to be a small farm size. Farmers may continue to intensively farm on these small plot to increase yield, quantity to be produce and income. However, farmers with large farm size are more likely to have increased yield, quantity, income and standard of living. The study of Esiobu (2020), found that large farm size increases farmers yield, income and standard of living. The mean extension contact was two (2) times per month in the study area. This implies that most of the yam farmers do not have much contact with extension agents, and which may negatively affect their farming activities and understanding of the best approach to yam production for increased yield and income. Anugwo and Egwue (2024), noted that extension agents provide farmers with training on improved yam production techniques, such as the use of high-yielding and disease-resistant seed varieties, proper land preparation, and efficient planting methods. This helps farmers increase their yield and overall productivity.

Table 1: Socio-economic Characteristics of Yam Farmers

S/No	Variables	Mean ($\bar{x}$)/Percentage (%)
1	Age (years)	43.00
2	Sex (percentage of male)	0.78
3	Marital status (percentage of married farmers)	0.66
4	Household size (number of persons)	7.00
5	Education (years spent in school)	12.00
6	Number of extension visits (number of visits per season)	2.00
7	Farming experience (years)	23.00
8	Farm size (hectares)	1.38

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9	Membership of cooperative (percentage of members)	0.68
10	Annual Farm income (Nigerian Naira)	₦405,000.00

Source: Field survey data, 2025

3.2 Yam Varieties Produced by the Farmers in the Study Area

The output of the yam farmers distribution based on yam varieties cultivated in the area is presented in Figure 1. It reveals that greater proportion (97.00% and 94.00%) of the farmers cultivates **white yam** (*Dioscorea rotundata*) and **water yam** (*Dioscorea alata*) respectively in the area. The study of Mondo et al. (2024), found that these two varieties (white and water yam) are the most popular yam in West Africa and mainly in Nigeria. Popular varieties like **white yam** and **water yam** have high consumer demand due to their taste, texture, and suitability for processing into yam flour and pounded yam (Kalu et al., 2023). Farmers growing preferred yam varieties tend to enjoy better prices and increased income. Also yellow yam (30.00%) and 3-leave yam (5.00%) were also cultivated by farmers in the area. The study of Dansi et al. (2024), noted that yellow yam (*Dioscorea cayenensis*), are rich in essential nutrients like beta-carotene, which improves dietary diversity. Promoting nutritionally rich yam varieties can enhance food security and public health. The result implies while white yam is the most popular yam varieties in the area, farmers cultivate also other varieties of yam to increase diversification, yield, income and standard of living in the area.

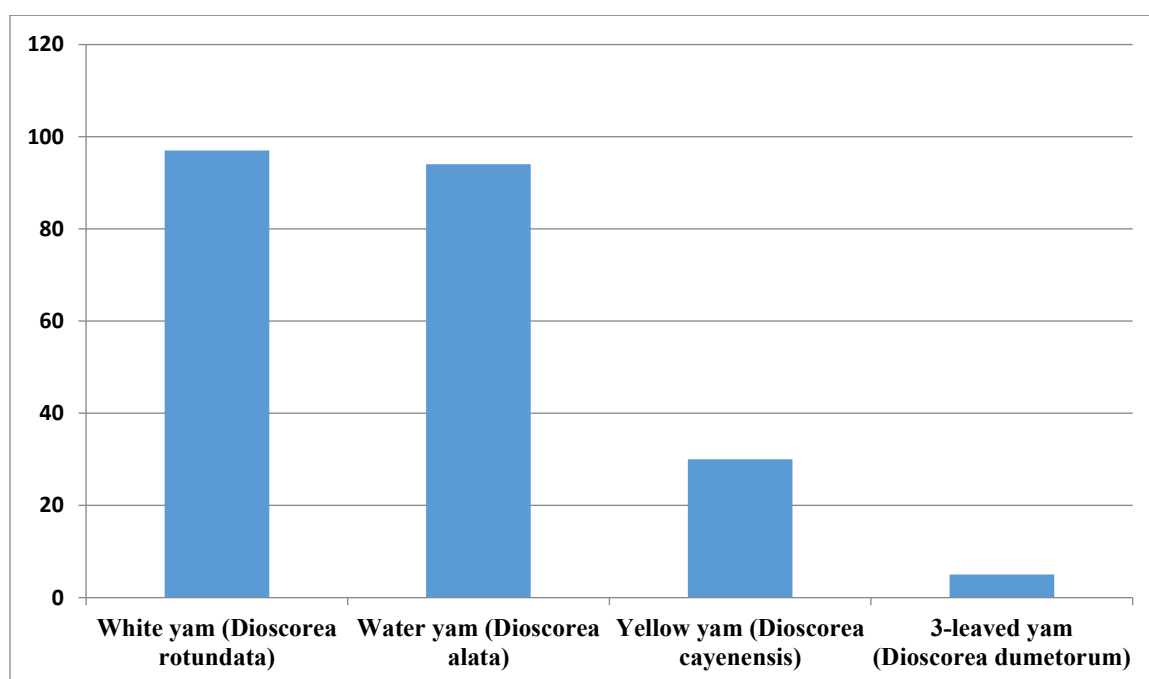


Figure 1: Yam Varieties Produced by the Farmers in the Study Area

3.3 Production Systems Practiced by the Yam Farmers

From Figure 2, majority (95.00%) of the yam farmers practiced mixed cropping while 5.00% practice sole cropping in the area. Mixed cropping, the practice of growing multiple crops on the same piece of land is widely used by yam farmers in Nigeria to optimize land use, increase productivity, and improve income stability. The study of Brooker et al. (2024) reported that mixed cropping allows farmers to make efficient use of farm inputs like fertilizers, herbicides, and irrigation, as they benefit multiple crops. Labour is also optimized since different crops may have different planting and harvesting times, ensuring continuous farm activity and employment (Leite et al., 2024). In cases of adverse weather conditions, such as drought or excessive rainfall, some crops may survive while others fail. This reduces the risk of complete crop loss, ensuring food security and economic stability for farmers. Sole cropping enabled the yam farmers to grow exclusively one type of yam crop and harvesting it before planting another on the same piece of land. The small proportion of farmers that practiced sole cropping could be as a result of limited availability of farmland prevalent in the area. The study of Nyamayevu et al. (2024) asserted that since yams are planted without competition from other crops, they have full access to soil nutrients, water, and sunlight, which can lead to higher yields per plant.

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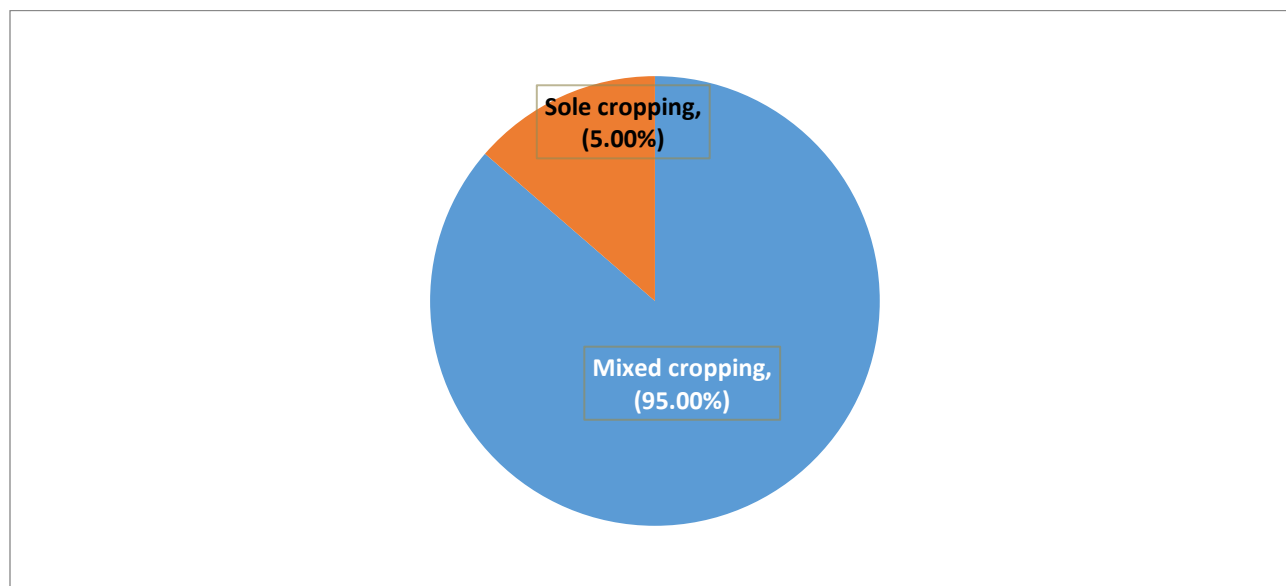


Figure 2: Production System of the Yam Farmers in the Study Area

3.4 Costs, Return and Profitability of Yam Production (Naira)

The result of the farmers distribution based on costs and return of yam production is compiled in Table 2. The result revealed that greater proportion (84.38%) of the cost was recorded in the total variable cost. About 44.00% of the variable cost was from seed yam; approximately 14.66% of the variable cost was recorded in fertilizer input while about 7.41% of the variable cost was recorded in miscellaneous expenses. In a similar way, about 3.66% variable cost was from transportation. These may be connected to poor motorable network and high cost of Petroleum Motor Spirit (PMC) in the area. About 2.93% each of the total variable cost was utilized in land preparation, planting operation, weeding operation, harvesting operation, and fertilizer application. Moreover, several studies (Wumbei et al., 2023) on yam production in Nigeria have confirmed that the cost of labour input is the most important of all cost components incurred in yam production. The contribution of the fixed cost was relatively low compared to the variable costs incurred in production. The fixed cost contributed approximately 15.58% of the cost involved in yam production in the area. The study of Ariyo et al. (2020); Adeyeye et al. (2023), also confirmed that fixed cost the least cost incurred in yam production in Nigeria. The return on capital (ROC) invested was found to be ₦5.21. It could be inferred that for every naira invested, there is 5.21kobo returns for yam production in the area. The result also revealed that the total revenue (TR), gross margin (GM) and net farm income (NFI) were ₦300,000.00, ₦242,450.00 and ₦231,819.33 respectively. The finding also shows that net return on investment (NROI) (profitability index) was ₦4.40, which implies that yam production is a profitable enterprise and would yield more output/income when invested in a larger scale and efficiently managed in the area. This also implies that for every naira earned as revenue from the yam production enterprise, 4.40kobo returned to farmer as net farm income. The result obtained implies that yam production is profitable, hence confirmed the evidence of the finding of Verter & Bečvářová (2015); Adejoh et al. (2024), who revealed that yam production is profitable and that farmers would realize good yield as well as income after sales when efficiently and effectively managed. The finding also suggests that yam production is a profitable and lucrative venture. These figure could yield more income if production scale is enhanced in the area and maybe beyond. The implication of the findings is that when efficiently, effectively, carefully and heavily invested and managed yam production is capable of producing good output/yield as well as reasonable net return overtime to any agribusiness entrepreneur.

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Table 2: Estimated Costs, Return and Profitability Analysis of Yam Production/Naira

Items	Average Cost (₦)	Quantity	Unit	Total Value (PxQ) (₦)	Percentage (%)
A. Revenue					
Yam tuber	1,500.00	2,000	Tonnes	300,000.00	
Total Revenue	---	---	---	300,000.00	
B. Variable Cost					
Seed Yam	500	60	Tonnes	30,000	44.00
Land preparation	1,000.00	2.0	Man hour	2,000.00	2.93
Fertilizer	5,000.00	2.0	Bag	10,000.00	14.66
Transportation	500.00	5.0	Km	2,500.00	3.66
Planting operation	1,000.00	2.0	Man hour	2,000.00	2.93
Fertilizer application	1,000.00	2.0	Man hour	2,000.00	2.93
Weeding operation	1,000.00	2.0	Man hour	2,000.00	2.93
Harvesting operation	1,000.00	2.0	man hour	2,000.00	2.93
Miscellaneous cost	5,050.00	---	---	5,050.00	7.41
Total Variable Cost				57,550.00	
C. Fixed Costs					
Depreciation Equipments	6,834.67	---	---	6,834.67	10.02
Depreciation on Land	2,920.00	1.30	Hectare	3,796.00	5.56
B. Total Fixed Cost				10,630.67	
D. Total Cost (TFC+TVC)				68,180.67	100.00
Net farm income [A-(B+C)]	231,819.33	----	----	231,819.33	
Gross Margin	242,450.00				
Return on Capital Invested	5.21				
Net Return on Investment	4.40				

Source: Field Survey Data, 2025; Depreciation on equipment was calculated using the Straight Line Depreciation Method (SLDM)

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3.5 Estimated Influence of Yam Farmers Socio-economic Characteristics on their Net Return

In order to determine the influence of yam farmers socio-economic characteristics on their net return as displayed in Table 3, a multiple regression analysis was carried out in four functional forms (linear, semi-log, double-log and exponential forms). Based on the statistical significance of the coefficient and goodness of fit, the double-log function was chosen as lead equation. The double-log regression function was chosen as lead equation based on the values of R^2 (83.00), F-Ratio value (41.812), highest number of significant variables and conformity of the signs with *a priori* expectations. The coefficient of multiple determinations (R^2) was found to be 0.83 (83.00%). This is a strong and significant indication that 83.00% of the variation in the profit from yam production was explained by the explanatory variables (socio-economic characteristics), while the remaining 17.00% was accounted-for due to stochastic error in the model. Hence the study presents the marginal effect as follows.

Age (X_1): Age was found to be negatively related to net return of yam of yam production but still statistically significant at 5% level of probability. This implies that increase in the magnitude of age, leads to a significant decrease in profit of yam production. This is an indication that younger farmers had more profit than their older counterparts. Younger farmers have energy and strength to produce optimally and are always ready to try new production technique to increase yield and income than their older counterpart. This finding is in agreement with the studies of Adejoh et al. (2024), who opined that younger farmers are more receptive to agricultural innovation, ready to learn new ideas for the benefit of its production goal than older farmers who are afraid to change.

Educational Level (X_3): Education had a positive coefficient with the net return of yam farmers in the area and was statistically significant at 1% level of probability. This is indications that increase in the magnitude of education leads to a significant increase in profit of yam production. It is expected that the higher level of education will contribute significantly to understanding the best production method that will give the best result for the farmers. Education has always been known to play a positive role in the efficient use of productive resources and increased yield among farmers (Verter & Bečvářová, 2015).

Household Size (X_4): Household size had a positive coefficient with net return of the yam farmers hence, was statistically significant at 1% level of probability. This is an indication that farmers who have large households size had more profit than farmers with small household size. It also implies that increase in the magnitude of household size, leads to a significant increase in profit of the farmers in the area. Large household size is a proxy for labour and opportunity for farmers to expand their production frontiers. The finding share view with the study of Adeshina et al. (2020), who opined that large households can promote the access to labour, finance and agricultural information as every household member is a potential source of labour, information and fund.

Farm Income (X_5): Farm income had a positive coefficient with net return of the yam farmers in the area and it was statistically significant at 1% level of probability. This is indications that increase in the magnitude of income leads to a significant increase in profit of the farmers. Anugwo and Egwue (2024), found that farmers with higher farm income make superior economic decision, manage risk and apply the best production technologies in farming to increase yield and income.

Membership of Cooperative (X_6): Membership of cooperative had a positive coefficient farmers net return in yam production and it was significant at 1% level of probability. Membership of cooperative society affords farmers the opportunity of sharing information, fund, pooled labour and relate with several group for this own benefit. The findings also share view with the study of Mignouna et al. (2020), who asserted that membership of cooperative society enable farmers to share relevant information, ideals and project as collective demand.

Farming Experience (X_7): Farming experience had a positive coefficient with net return of yam farmers and it was statistically significant at 1% level of probability. It is expected that farmers with more experience will understand the best way to address production challenges to increase yield and income than their counterpart with less years of farming experience in the area. The result is in parity with the study of Esiobu et al. (2025), who reported that experience in farming enhances decision making, better knowledge of use of the most appropriate methods to improve farm output, income and farmers standard of living.

Farm size (X_8): Farm size had a positive coefficient with yam farmers net return and it was statistically significant at 1% level of probability. This implies that increase in magnitude of farm size, increase profit. Farmers with large farm size will try many production method as well as plant large quantity of seed yam to increase yield, income and standard of living. The study of Ariyo et al. (2020), found that large farm size increases farmers yield, expansion and income. The F-ratio (41.812), which determines the overall significance of the regression model is highly significant at 1% level of probability implying that the regression model has very high explanatory power, hence the study concludes that the socio-economic characteristic of the yam farmers have a significant influence on their profit in the area.

Table 3: Estimated Influence of Yam Farmers Socio-economic Characteristics on their Net Return

Explanatory variables	Linear	Semi-log	Double-log	Exponential
Intercept	8.569 (5.379)***	2.213 (7.994)***	19.948 (8.088)***	1.642 (8.327)***
Age (X_1)	-0.005 (-0.460)	-0.001 (-0.377)	-1.080 (-2.414)**	-0.000 (-0.205)
Sex (X_2)	0.001 (0.058)	3.497E-005 (0.009)	0.578 (0.361)	5.265E-013 (0.047)

Education (X ₃)	0.040 (2.801)***	0.007 (1.877)*	0.137 (4.595)***	1.000E-013 (1.844)*
Household Size (X ₄)	0.080 (2.818)***	0.016 (3.149)***	0.958 (3.595)***	1.007E-013 (2.689)***
Farm Income (X ₅)	2.887E-005 (2.132)**	5.365E-006 (2.281)**	1.920 (2.626)***	4.293E-006 (1.770)*
Membership of Cooperative (X ₆)	0.048 (0.448)	0.008 (0.415)	0.668 (4.143)***	-4.953E-005 (-0.309)
Farming Experience (X ₇)	-0.009 (0.092)	-7.234E-005 (-0.004)	2.556 (2.780)***	0.003 (0.196)
Farm Size (X ₈)	1.170 (1.614)*	0.030 (1.659)*	2.260 (2.332)***	1.939E-005 (1.478)*
R ²	71.90	80.00	83.00	73.50
F-Ratio	21.868***	32.281***	41.812***	23.700***

Values in Parenthesis are t-values *Statistically Significant at 10%; **Statistically Significant at 5%; *** Statistically Significant at 1%; Source: Computer Printout of SPSS (2025)

Constraints Faced by the Farmers in Yam Production

Result of the yam farmers distribution based on constraints they face in yam production in the area is displayed in Table 4. It shows that inadequate production capital (100.00%), limited availability of farmland (97.14%), high cost of labour (90.00%), and incidence of climate change (85.71%) were identified by yam farmers as the constraints faced in yam production in the area. Farmers with insufficient capital struggle to purchase high-yielding and disease-resistant yam seed varieties, leading to lower productivity. Inability to afford fertilizers, pesticides, and herbicides results in poor soil fertility management and increased pest and disease infestation, reducing yield (Esiobu, 2019). Farmland is one of the important determinants for increased output, hence poor access to it, will negatively affect farmers yield, net return and standard of living. Farmers with restricted access to land can only cultivate small plots, leading to lower total yam production in yield and in net return. According to Esiobu and Onubuogu (2014), limited space prevents farmers from expanding their operations, restricting potential increases in yield and income. The study of Ariyo et al. (2020); Anugwo and Egwue (2024); Adejoh et al. (2024), reported similar result on constraints facing yam production. In the same way, high transportation cost (82.85%), pest and disease attack (78.57%), poor storage facilities (75.71%), unavailability of good yam species (71.42%), poor road network (64.28%) and price changes (57.14%) were stated by the farmers as the constraints they face in yam production in the area. there is no denying that the constraints is responsible for poor yield of yam in the area. Critically addressing these identified constraints will be keys in not just increasing yam yield, but also net return and food security and yam production sustainability in the area and maybe beyond.

Table 4: Constraints Faced by the Farmers in Yam Production

S/No	Items	Frequency	Percentage (%)
1	Inadequate production capital	70	100.00
2	Limited availability of farmland	68	97.14
3	High cost of labour	63	90.00
4	Incidence of climate change	60	85.71
5	High transportation cost	58	82.85
6	Pest and disease infestation	55	78.57
7	Poor storage facilities	53	75.71
8	Unavailability of good yam species	50	71.42
9	Poor road network	45	64.28
10	Price changes	40	57.14

*Multiple responses were recorded; Source: Field Survey Data, 2025

3.7. CONCLUSIONS

Yam production plays a significant role in the agricultural sector of Nigeria, particularly in States like Imo, where farming is one of the major sources of livelihood. As one of the staple crops widely cultivated in Imo State, yam contributes greatly to food security, employment, income and economic growth. However, despite its importance, the extent to which yam farming serves as a reliable source of income for farmers remains a subject of interest. It was against these backdrops that the study as systematically conducted. Conclusively, majority of the yam farmers were married, with an average household size of 7 persons.

3.8. RECOMMENDATIONS

The following recommendations were made based on the major findings of the study. The study found that education was critical for farmers in generating revenue from yam production. Therefore, the yam farmers through their various cooperative societies should develop educational training programme that focus on sustainable yam production in the study area. The study found that inadequate production capital was among the challenges of the yam farmers in increasing yield, and income in the area. Hence, the yam farmers, particularly on their own, should judiciously pool financial resources together through a strengthened cooperative society group, as this would increase their fund size, access to fund private and government fund available in the area.

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Is production, consumption and trade accelerating, decelerating or stagnating in the African onions Market?

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Abstract

The Onions Market in Africa continues to experience yearly growth; signalling immense economic opportunities. Yet no research has investigated the growth patterns (acceleration, deceleration and stagnation) in onions production, consumption and trade in Africa. Knowledge on this can provide insights for investors on regional differences for informed investment decision making. The study used annual time series data from *FAOstat* for 62 years (1961-2022) and was broken into three periods (1961-1980, 1981-2000 and 2001- 2022) covering onions production (harvested area, yield and output), consumption and trade (export, import, export value, import value) in East Africa, West Africa, Southern Africa, North Africa, Middle Africa and Africa. The log-quadratic model was used to determine acceleration, deceleration and stagnation. Over the 62 years, findings with respect to harvested area revealed that West Africa and Africa experienced stagnated growth (absence of significant acceleration and deceleration). With respect to yield, East Africa, Middle Africa, North Africa, West Africa and Africa experienced rapid growth; while Southern Africa experienced slow growth. With respect to output, Middle Africa, Southern Africa and West Africa witnessed stagnated growth. With respect to import, Southern Africa experienced slow growth. With respect to export value, West Africa experienced slow growth. With respect to import value, Middle Africa witnessed stagnated growth and Southern Africa witnessed slow growth. With respect to consumption, Southern Africa witnessed slow growth. The study recommends that investment in regions with slow growths in yield, output, exports, export value and consumption should be encouraged by stakeholders in the African Onion sector.

Key words: growth pattern, onions, African regions, markets

Introduction: Onions are vegetables that belong to the genus *allium* and are closely related to garlic, shallots, and leeks (Braun, 2022). The average person consumes roughly 10 kilogram of this pungent and versatile food per year and can be eaten raw, cooked, pickled, or powdered (Cattivelli, *et al.*, 2021). Onions are rich in chemicals that can help protect the heart, lower risks of some cancers and make it easier for the body to make insulin (Galavi, Hosseinzadeh, & Razavi, 2021). The vegetables market in Africa as at 2025 is projected to exceed revenues of \$113 billion with an expected annual growth rate of 10.51% from 2025 to 2030. While the onions market is considerably smaller, it remains an essential and influential component of the continent's agricultural and economic framework. Onions generally command a higher price than certain other produce, including tomatoes, particularly in export markets, due to their prolonged shelf stability and transportability over great distances. Nevertheless, onion prices are highly volatile and can vary significantly due to factors such as seasonal supply, storage methods, and transportation hurdles.

The Significance of onions within the African economy lies in income generation thus; cultivation of onions is a crucial income source for millions of smallholder farmers throughout Africa. In addition, the production of onions enhances food security; education and health care; thereby generating considerable socio-economic effect for agricultural communities. More importantly, onions cultivation also generates jobs for many individuals because onion farming is often more labour intensive. Some key studies on acceleration, deceleration and stagnation show that global agricultural productivity has increased. However the rate of growth has stagnated in significant areas. For example, major crops such as soybeans, rice, maize and wheat have experienced 24-39% slow or stagnated yields (Schauberger, Ben-Ari, Makowski, Kato, Kato, & Ciaia, 2018; Gerber, *et al.*, 2024). Implying that while global aggregate yield growth has not experienced clear deceleration, regional and crop-specific stagnation is more evident (Fuglie, 2018; Baffes & Etienne, 2024).

Accordingly, within Asia; India and China the countries with the largest global population have experience a mix of acceleration and stagnation. In China for instance, half of rice and maize area have stagnated, while wheat yields are accelerating (Sheng, Tian, Qiao, & Peng, 2019; Madhukar, Kumar, & Dashora, 2020). In India, crop yields have experienced deceleration following the Countries post-economic reforms; while more recently stagnation in maize, wheat and rice have occurred (Khan, Ansari, & Ali, 2022; Gupta & kannan, 2024). With respect to Africa, the sub-Saharan Africa region largely experienced decelerated yield growth in the 1960s; followed by acceleration in the 1980s due largely to policy reforms and increased research and development; however, patterns of growth are skewed, with some regions experiencing persistent stagnation (Adetutu & Ajayi, 2020; Myeki, Bahta, & Matthews, 2022). In general, drivers of acceleration, deceleration and stagnation include technological changes that advance the pace of agricultural growth; but this pace of growth is slow in some regions (Liu, Wang, Yang, Rahman, & Sriboonchitta, 2020). In the same vein, climate change has slowed global agricultural growth by about 21% since the 1960s, and is heightened in warmer regions particularly Africa (Hoffman, Kemanian, & Forest, 2020), while environmental degradation as well as land and water limitations further contribute to stagnation on the continent (Rahman, Anik, & Sarker, 2022). Policy reforms on agriculture and investment in human and infrastructural capital also influence the pace of growth leading to labour shifts; with acceleration experienced in some regions and stagnation in other regions attributed to policy gaps and misplaced priorities (Heinen, 2022).

The consequence of stagnation and deceleration in agricultural growth in Africa appears in food insecurity, poor rural welfare and weak economic development; suggesting that regions that experience accelerated growth tend to see improvements in food supply, rural development and poverty alleviation (Rada, Helfand, & Magalhães, 2019)(Hemathilake & Gunathilake, 2022). During the Africa Green Revolution Forum, key note speech in Nairobi, Adesina (2016) the then president of the Africa Development Bank noted that Africa should be able to feed itself as well as be the bread basket for the world due to the continent holding about 65% of all arable land in the world. Accordingly, he further buttressed his position as follows; “*Accelerating agricultural production will reduce the food import bills, revive the rural economies, slow down rural to urban migration, expand foreign earnings and create jobs especially for the youth*” It is on this premise that this study investigates the pace of growth in the African onions markets in order to identify the patterns of growth (acceleration, deceleration, stagnation) in onions production, consumption and trade using the five broad regions that make up the African continent. By so doing, the study addresses a considerable knowledge gap in the empirical literature because most studies on agricultural growth patterns focus on individual countries or regions; hence, comparative studies across different regions are limited. Furthermore, research on growth patterns can help inform both national and regional policies. For example, crops experiencing accelerated growth may lead to targeted investment interventions, while deceleration and stagnation highlights areas needing support. For instance, the modelling of climate change adaptation, may guide crop selection and land use to mitigate deceleration and stagnation caused by environmental stress (Feng, Tian, Cong, & Zhao, 2023; Taniushkina, *et al.*, 2024). Likewise, stagnation and deceleration in agricultural growth has been linked to poor public investment; leading to policy recommendations that clearly show the need to boost capital formation in the affected sector (Akber & Paltasingh, 2021).

Accordingly, the following questions are addressed in this study:

- a) What are the patterns of growth in area, yield and output of onions across the five regions and the four periods?
- b) What are the patterns of growth for onions consumption across the five regions and the four periods?
- c) What are the patterns of growth in onions trade (export and import) across the five regions and the four periods?
- d) What are the patterns of growth in onions trade (export and import value) across the five regions and the four periods?

The remaining sections of the paper, addresses the research methodology employed in the study, followed by results and discussion; after which conclusions and recommendations are made.

Research Methodology: Study Area: The study area is the African Continent covering a total land area of about 30.37 million Km² (Ngundu & Cilliers, 2025), Africa is divided into five regions, namely; West Africa, North Africa, East Africa, Central or Middle Africa and Southern Africa. Each region has some form of economic bloc and often develops common economic policies aimed at driving development in the region.

Data Source: Secondary data from the Food and Agriculture Organization of United Nation statistical database (FAOstat) was used for the study from 1961 to 2022 a total period of 62 years. The data covers area measured in hectares, yield measured in kilogram per hectare and output measured in tonnes. Consumption, import and export data is measured in tonnes, while value of export and import is measure in United States dollars.

Modelling Patterns of growth: In order to determine the three patterns of growth i.e. acceleration (rapid growth), deceleration (slow growth) and stagnation (no change or growth), the log-quadratic model is generally fitted for this our purpose (Antia-Obong & Otung, 2019; Antia-Obong, 2019; Antia-Obong, Eno, & Obot, 2024).

The log-quadratic model is fitted as follows:

$$LNY_{t(1,2,3)} = b_0 + b_1t + b_2t^2 + e \text{ ----- (1)}$$

Where,

$LNY_{t(1)}$ = Natural logarithm of onions area measured in hectares

$LNY_{t(2)}$ = Natural logarithm of onions yield measured in kg/hectare

$LNY_{t(3)}$ = Natural logarithm of onions output (production) measured in tonnes

$$LNY_{t(4,5)} = b_0 + b_1t + b_2t^2 + e \text{ ----- (2)}$$

$LNY_{t(4)}$ = Natural logarithm of onions export measured in tonnes

$LNY_{t(5)}$ = Natural logarithm of onions import measured in tonnes

$$LNY_{t(6,7)} = b_0 + b_1t + b_2t^2 + e \text{ ----- (3)}$$

$LNY_{t(6)}$ = Natural logarithm of onions export value measured in US dollars

$LNY_{t(7)}$ = Natural logarithm of onions import value measured in US dollars

$$LN Y_{t(8)} = b_0 + b_1 t + b_2 t^2 + e \text{ ----- (3)}$$

$LN Y_{t(8)}$ = Natural logarithm of onions consumption measured in tonnes

b_0 = estimated constant regression line for each period

b_1 = estimated growth coefficient for each period

b_2 = estimated quadratic growth coefficient for each period

t = linear time trend for each period

t^2 = quadratic time trend for each period

Accordingly, the quadratic time trend (t^2) measures acceleration, deceleration and stagnation; as such, the coefficient of interest in the quadratic model is (b_2). Therefore, acceleration is determined when (b_2) is positive and statistically significant; deceleration is determined when (b_2) is negative and statistically significant; while stagnation is determined when (b_2) is either negative or positive but not statistically significant.

Results and Discussion: Table 1; show the patterns of growth for area, yield and output of onions for the five African regions and the four periods. The results for the pooled period covering 62 years reveal that East Africa and Northern Africa experienced rapid growth in area, yield and output. This finding means that in both regions, rapid growth in onions output was accompanied by rapid expansion in area harvested and output (). Middle Africa experienced slow area growth, accompanied with rapid yield growth and stagnated output, this finding suggests that the Middle African onions market is somewhat efficient due to rapid yield growth and slow area growth. Implying that as area was rapidly slowing; yield was rapidly growing, albeit with a stagnated output. Southern Africa on the other hand experienced the reverse wherein onion harvested area rapidly expanded, while yield growth was slow and output stagnated. West Africa equally showed levels of efficiency due to area harvested stagnating and yields rapidly growing but with stagnated output. On the whole, the pattern of onions growth in Africa show that while area harvested stagnated, yield and output experienced rapid growth. ()

Table 2 show the patterns of onion export and import quantity growth across Africa regions; the pooled period reveal that East Africa, North Africa and Africa experienced rapid growth in the export and import of onions over the 62 years covered in the study. Middle Africa, West Africa and Southern Africa experienced stagnated, slow and accelerated export growth respectively; while Southern Africa is the only region where import was slow. The value of export and import as shown

Table 1: Patterns of onions area, yield and production growth across Africa regions

Region	Period I (1961-1980)			Period II (1981-2000)			Period III (2001-2022)			Pooled (1961-2022)		
	A	Y	P	A	Y	P	A	Y	P	A	Y	P
EA	-0.0039**	0.0009	-0.0030***	0.0014***	0.0002	0.0016***	-0.0021***	0.0011***	-0.0009***	0.0002***	0.0001***	0.0003***
	ST	AC	DE	AC	ST	AC	DE	AC	DE	AC	AC	AC
MA	-0.0025	0.0029*	0.0005	-0.0018***	0.0022**	0.0004	0.0036***	-0.0026***	0.001	-0.0007***	0.0007***	-0.0001
	ST	AC	ST	DE	AC	ST	AC	DE	ST	DE	AC	ST
NA	0.0000	0.0014*	0.0014	0.0014**	-0.0004	0.0009	-0.0013***	-0.0009***	-0.0023***	0.0004***	0.0002***	0.0006***
	ST	AC	ST	AC	ST	ST	DE	DE	DE	AC	AC	AC
SA	-0.0021**	0.0016*	-0.0005	0.0008**	-0.0001	0.0007	-0.0009**	-0.0007***	-0.0017***	0.0001**	-0.0001*	0.0000
	DE	AC	ST	AC	ST	ST	DE	DE	DE	AC	DE	ST
WA	0.0013**	0.0032**	0.0046***	0.0005	0.0008	0.0012	-0.0013	0.0012	-0.0001	-0.0004	0.0005*	0.0001
	AC	AC	AC	ST	ST	ST	ST	ST	ST	ST	AC	ST
AF	-0.0012**	0.0023**	0.0011	0.0005	0.0004	0.0009	-0.0014	-0.0001	-0.0015***	0.0000	0.0004***	0.0005***
	DE	AC	ST	ST	ST	ST	ST	ST	DE	ST	AC	AC

ST= stagnation, AC = acceleration, DE= deceleration

EA= East Africa, MA= Middle Africa, NA= North Africa SA= Southern Africa, WA= West Africa AF= Africa

***indicate 1% level of significance, **indicate 5% level of significance, *indicate 10% level of significance.

in table 3 reveal similar growth patterns with export and import quantity for the pooled period. The only exception being Middle Africa where export value accelerated and import value stagnated.

Table 2: Patterns of onions export and import quantity growth across Africa regions

Regions	Period I (1961-1980)		Period II (1981-2000)		Period II (2001-2022)		Pooled (1961-2022)	
	Export	Import	Export	Import	Export	Import	Export	Import
EA	0.0065**	0.0012	0.0037	0.004***	-0.0012	-0.0022*	0.002***	0.0029***
	AC	ST	ST	AC	ST	DE	AC	AC
MA	-0.0542***	-0.0024*	0.0071	-0.0016	0.0298***	-0.0037*	0.0012	0.0009***
	DE	DE	ST	ST	AC	DE	ST	AC
NA	-0.0042**	-0.0242**	-0.0035	-0.016	0.0017	-0.0099**	0.0020***	0.006***
	DE	DE	ST	ST	ST	DE	AC	AC
SA	-0.0036	0.0166	0.0025	-0.0000	-0.0002	0.0034	0.0019***	-0.0029***

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	ST	ST	ST	ST	ST	ST	AC	DE
WA	-0.0082	0.0029***	0.0049	0.0023	0.0002	-0.0011	-0.0006**	0.0011***
	ST	AC	ST	ST	ST	ST	DE	AC
AF	-0.0035**	0.0021**	-0.0011	0.0022	0.0011	-0.0014*	0.0017***	0.0014***
	DE	AC	ST	ST	ST	DE	AC	AC

ST= stagnation, AC = acceleration, DE= deceleration

EA= East Africa, MA= Middle Africa, NA= North Africa SA= Southern Africa, WA= West Africa AF= Africa

***indicate 1% level of significance, **indicate 5% level of significance, *indicate 10% level of significance.

Table 3: Patterns of onions export and import value growth across Africa regions

Regions	Period I (1961-1980)		Period II (1981-2000)		Period III (2001-2022)		Pooled (1961-2022)			
	Export Value (\$)	Import Value (\$)	Export Value (\$)	Import Value (\$)	Export Value (\$)	Import Value (\$)	Export Value (\$)	Import Value (\$)	Export Value (\$)	Import Value (\$)
EA	0.0095***	0.0066***	0.0055*	0.0037**	-0.0004	-0.0044***	0.0012***	0.0018***		
	AC	AC	AC	AC	ST	DE	AC	AC		
MA	-0.0311***	0.0021*	-0.0058	-0.0033	0.0132	-0.0065***	0.0014*	-0.0000		
	DE	AC	ST	ST	ST	DE	AC	ST		
NA	-0.0057**	-0.0186	-0.006**	-0.0077	-0.0097***	-0.0103*	0.0019***	0.0046***		
	DE	ST	DE	ST	DE	DE	AC	AC		
SA	0.0018	0.0221*	0.003	-0.0021	-0.0043**	-0.0025*	0.0014***	-0.0027***		
	ST	AC	ST	ST	DE	DE	AC	DE		
WA	-0.0101**	0.0089***	0.0092	-0.0021	-0.0003	0.0006	-0.0011***	0.0004***		
	DE	AC	ST	ST	ST	ST	DE	AC		
AF	-0.0039*	0.0068***	-0.0014	-0.0013	-0.0074***	-0.0017**	0.0014 ***	0.0006***		
	DE	AC	ST	ST	DE	DE	AC	AC		

ST= stagnation, AC = acceleration, DE= deceleration

EA= East Africa, MA= Middle Africa, NA= North Africa SA= Southern Africa, WA= West Africa AF= Africa

***indicate 1% level of significance, **indicate 5% level of significance, *indicate 10% level of significance.

Table 4 reveal the growth pattern in onions consumption across African regions. The pooled period show that onions consumption has been rapidly growing over the 62 years covered in the study, the only region where onions consumption has witnessed slow growth is Southern Africa.

Table 4: Patterns of onions consumption growth across Africa regions

Regions	Period I (1961-1980) Consumption	Period II (1981-2000) Consumption	Period III (2001-2022) Consumption	Pooled period (1961-2022) Consumption
EA	-0.0026***	0.0013***	-0.0001	0.0005***
	DE	AC	ST	AC
MA	0.0036**	0.0034***	0.0012	0.0007***
	AC	AC	ST	AC
NA	0.0013	0.0006	-0.0028***	0.0006***
	ST	ST	DE	AC
SA	-0.0002	0.0007*	-0.0017***	-0.0002***
	ST	AC	DE	DE
WA	0.0011***	-0.0008	-0.0008*	0.0006***
	AC	ST	DE	AC
AF	0.0009*	0.0003	-0.0018***	0.0005***
	AC	ST	DE	AC

ST= stagnation, AC = acceleration, DE= deceleration

EA= East Africa, MA= Middle Africa, NA= North Africa SA= Southern Africa, WA= West Africa AF= Africa

***indicate 1% level of significance, **indicate 5% level of significance, *indicate 10% level of significance.

Conclusion: The study set out to investigate if production, consumption and trade is accelerating, decelerating or stagnating in the African onions market. The key findings reveal that over the 62 years covered in the study; area, yield and output experienced accelerated growth in East Africa. The implication of the finding is that East Africa experienced rapid expansion in area under onion production which may likely have contributed to the rapid growth in yield and output. Middle Africa and Northern Africa revealed rapid growth in yield when area was decelerating; implying that as the rate of area expansion was slowing, yield was experiencing rapid growth; suggesting that Middle Africa uses less land yet still maximizes onions yield. Southern Africa performed rather poorly, since rapid area growth was accompanied with slow yield; implying that the region suffers from technological gaps in onions production. West Africa also showed levels of general efficiency where stagnated area growth accompanied rapid yield growth; implying possible improved technology adoption in the region. In general, onions production on the African continent reveals that stagnated land resources accompanied accelerated yield and output growth. Implied that technological know-how overtime exist in the production of onions on the continent. In addition, export on the continent experienced stagnated and slow growth in Middle Africa and West Africa respectively. Southern Africa showed slow growth in onions import, suggesting that the region may be self-sufficient in onions production as well as experience slow onion consumption growth in the region.

The study recommends technological changes in land use to reduce the rapid area expansion in East Africa, North Africa and Southern Africa. Furthermore, there is need for investment in onion yielding initiatives in order to accelerate onion yields particularly in Southern Africa.

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Strategies for Overcoming Climatic Constraints in the Conservation of Indigenous Crop Diversity in Rural Kano, Nigeria

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Abstract

Climatic constraints pose serious threats to the conservation of indigenous crop diversity, yet formal effective conservation strategies to overcome these constraints remain poorly documented, particularly in an agrarian setting such as rural Kano, Nigeria. While studies have established correlations between climatic constraints and agricultural performance, there is limited systematic documentation of actionable conservation strategies for conserving agrobiodiversity such as *Zea mays*, *Oryza sativa*, *Terminalia catappa*, and *Pennisetum glaucum*. This study employed four Scenario-Based Focus Group Discussions (SBFGDs) with purposively selected stakeholders across four rural Local Government Areas outside Kano metropolis. Data were analysed using MAXQDA version 24.2. Results revealed that erratic rainfall (92%), prolonged drought (84%), and rising temperature (78%) are the most critical climatic constraints affecting indigenous crop diversity. Over 92% of the SBFGDs participants reported a decline in indigenous crop diversity in their localities. Common conservation measures identified include careful removal of undersized seeds (88%), insect-damaged seeds (73%), and discoloured or colour-altered seeds (62%), as well as selection medium-growing (73%) and early-maturing seeds varieties (73%). Overall, the findings indicated that, although indigenous crop diversity persists in rural Kano, inadequate conservation efforts have contributed to the decline and extirpation of certain species, hence the need for indigenous crop conservation policies and adoption of proactive, community-based strategies to prevent the potential loss of indigenous crop diversity in the area.

Keywords: Indigenous crop diversity, climatic constraints, conservation strategies, Rural Kano, agrobiodiversity

1. Introduction: Indigenous crop species constitute an essential component of agricultural biodiversity, contributing to local food security, ecological balance, and cultural heritage (FAO, 2019; Altieri, 2004). In rural Kano of the semi-arid region in northern Nigeria, crops such as *Zea mays* (maize), *Oryza sativa* (rice), *Terminalia catappa* (tropical almond), and *Pennisetum glaucum* (pearl millet) are vital to household sustenance, nutrition, and traditional agricultural systems (Adetula & Denton, 2003; Agulanna, 2020; Ahmad Yahaya et al., 2022). However, the increasing of climatic constraints such as that erratic rainfall, prolonged drought, rising temperature, strong wind, shift in growing seasons and flooding (NIMET, 2022; IPCC, 2021) threaten their conservation. According to FAO, 2019 indigenous crops species are edible plant species that have naturally evolved and are native to a specific area, often forming the foundation of traditional diets, food systems, and cultural identity. Nigeria has ratified numerous international agreements and treaties such as FAO-administered treaty of International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (Moore, 2005), Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (GPA-PGRFA), African Union's Agenda 2063 and the African Convention on the Conservation of Nature and Natural Resources on biodiversity conservation (AU, 2015b) as well as various National Implementation Frameworks like National Biodiversity Strategy and Action Plan (NBSAP 2016–2020), National Agricultural Seed Policy (2018), and National Centre for Genetic Resources and Biotechnology (NACGRAB).

Over many years, much has been written on the climatic constraints as part of the main sources that posed significant threats to agricultural crop diversity and food security, as were portrayed as by Lawson & Sivakumar, 1991. Climatic constraints are adverse or limiting climatic conditions such as erratic rainfall, prolonged drought, temperature extremes, flooding, and shifting seasons that disrupt normal agricultural productivity and ecosystem balance resulting in the gradual loss of local crop varieties and poor yield productivity (IPCC, 2021; Mertz et al., 2009). The combined effects of these climatic constraints undermine on-farm and outside conservation efforts, food security, and ecological resilience (FAO, 2021), particularly among resource-limited smallholder farmers (Altieri, 2004).

The need for effective strategies to overcome climatic constraints in conserving indigenous crop species in rural Kano has therefore become very important and more pressing. Such strategies are not only for preventing the local extinction of these species but also for enhancing food security and sustaining the indigenous crop varieties that serve as primary livelihood source for the majority of the people in the area. However, meaningful conservation of indigenous crops can only be achieved through a comprehensive understanding of the prevailing climatic constraints and the strategies that can mitigate their effects. This study aimed to identify and document viable strategies for overcoming the climatic constraints affecting indigenous crop

species in Rural Kano state, Nigeria, by assessing both the climatic constraints and the existing conservation strategies through participant responses gathered from scenario-based focus group discussions (SBFGDs) (Baber & Cooper, 2002). The findings from this paper are expected to provide a data-driven understanding of the current conservation strategies applied in selected rural communities in the Rural Kano state of Nigeria, particularly in Jogana, Kutama, Gani and Gunki, to inform relevant stakeholders such as policymakers, agricultural extension workers, and conservation practitioners involved in promoting sustainable agrobiodiversity management in the region.

MATERIALS AND METHODS

Study Area: The study was conducted in rural Kano State, Nigeria, extends roughly lies between latitude $11^{\circ}25'02''\text{N}$ to $12^{\circ}10'00''\text{N}$ and longitude $7^{\circ}52'03''\text{E}$ to $8^{\circ}50'24''\text{E}$ of the Greenwich meridian (see Figure 1), in the Sudan Savanna region of Northern Nigeria. It covers parts of Gezawa (Jogana), Gwarzo (Kutama), Bunkure (Gunki), and Sumaila (Gani) Local Government Areas, which represent key agricultural zones characterized by a tropical wet and dry climate of semi-arid climatic conditions, sandy loam soils, and predominantly rain-fed farming systems. The vegetation includes a various broad canopy and needle leaf deciduous trees and shrubs species, adapted to drought conditions. The predominant socio-economic activities include farming, livestock rearing, and marketing agricultural products (Mustapha, 2014).

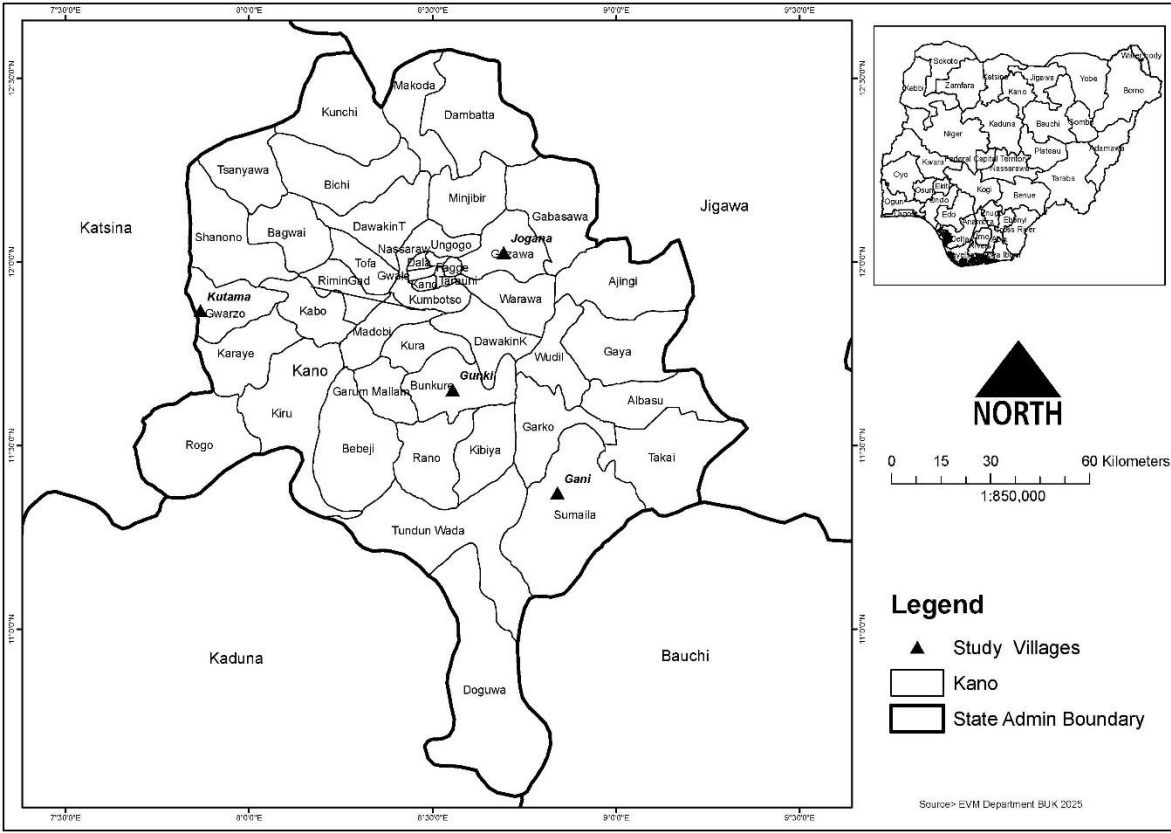


Figure 1: Study Area Map

Source: Resource Room, Department of Environmental Management, Bayero University Kano.

3. Methodology

3.3.6 SBFGD Data Collection

Data collection through Scenario-Based Focus Group Discussions (SBFGDs). The SBFGDs guide was developed using a data-driven concept conceptual approach (Baber & Cooper, 2002; Eeuwijk & Angehrn, 2017; Kumer & Urbanc, 2020), originated from the context of four SBFGD sessions conducted with purposively selected stakeholders. Participants were chosen based on their relevance and familiarity with the topic of indigenous crop conservation and climatic challenges across four rural Local Government Areas (LGAs) i.e. Jogana (Gezawa), Kutama (Gwarzo), Gani (Sumaila), and Gunki (Bunkure).

3.3.6.1 Data Transcription

Following the completion of all the SBFGD sessions, data processing and analysis were conducted using MAXQDA Analytics Pro. Version 24.2 computer assisted software from the processing of SBFGDs transcription through data analysis. Audio recordings from the four SBFGD sessions were imported into software and transcribed using MAXQDA's built-in transcription function. The recordings were translated from the second language (Hausa) into English to ensure consistency and accuracy in coding analysis.

3.3.6.2 Data Coding and Analysis

Each of the four transcripts (SBFGD Jogana, Kutama, Gunki, and Gani) was coded separately in the Document Browser using Open Coding Mode approach. The coding frame was data-driven, structured around two key analytical questions:

1. What was the prevailing climatic constraints in this study?
2. What was the viable strategies for overcoming it in this study?

After completing the initial coding, similar codes across transcripts were merged and condensed to eliminate redundancy. All transcripts were then integrated into a single document using MAXQDA's Focus Group Transcript Import function, enabling cross-group comparative analysis as if derived from one extended session. The number of coded segments per theme was scored according to the frequency of occurrence in the transcripts. Proportional values were calculated and assigned to each score to support a quantitative content analysis conducted in MAXQDA, thereby allowing a semi-quantitative interpretation of the qualitative data.

4. Results and Discussion

4.1 Major Climatic Constraints Affecting Indigenous Crop Diversity

The SBFGD participants show multiple climate-related constraints in the rural Kano (see Figure 2) rendering the agricultural productivity of the indigenous crop varieties in the area and resulted in the extirpation of some species.

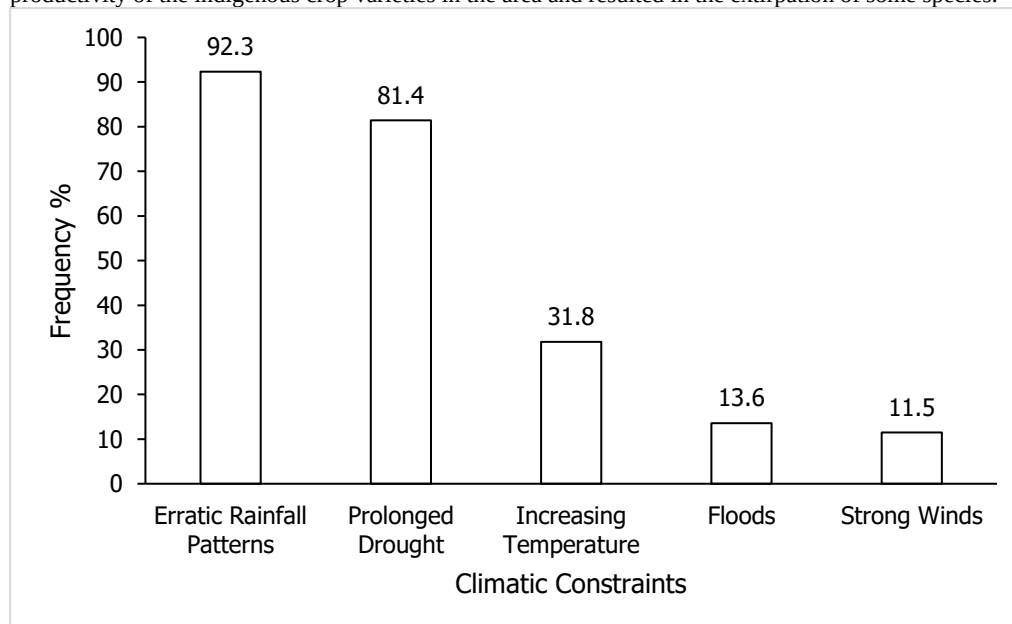


Figure 2: Major Climatic Constraints

Source: Author's Fieldwork, 2025.

Results from the Scenario-Based Focus Group Discussions (SBFGDs) revealed that climatic constraints constitute a major threat to the conservation of indigenous crop species in rural Kano. The most frequently reported climatic constraints include erratic rainfall (92.3%). Participants consistently emphasized that unpredictable rainfall patterns shorten the growing season, delay planting periods, and reduce crop yields, especially for water-sensitive crops such as *Oryza sativa* (rice) and *Zea mays* (maize). Similarly, the prolonged dry spells (81.4%), and rising temperature (31.8%) reported across the study sites exacerbate soil desiccation and nutrient depletion, limiting the survival and regeneration of indigenous crop varieties. These observations align with earlier reports by Mertz et al. (2009) and IPCC (2021), which documented the severe implications of temperature rise and rainfall variability on agricultural productivity in semi-arid West Africa. These findings indicate that rainfall irregularity and drought remain the dominant climatic factors influencing agricultural performance and biodiversity conservation in the area.

Other climatic constraints reported by the SBFGDs participants include strong winds (13.6%) and seasonal flooding (11.5%) that causes mechanical damage to crops thereby reducing crop survival and biodiversity. Overall, the high proportion of respondents identifying erratic rainfall and drought as critical constraints underscores the vulnerability of smallholder farming

systems in rural Kano. The persistence of these climatic challenges highlights the need for context-specific adaptation and conservation strategies, including early planting, use of drought-tolerant varieties, and improved on-farm seed selection practices.

Indigenous Conservation Practices

Conservation Practice	Frequency (%)	Category
Early-maturing seeds selection	82	Seed selection
First-planting seeds selection	73	Seed selection
Middle-cob seeds selection	66	Seed selection
Traditional seeds dressing	7	Seed preservation and dressing
Spiritual seeds dressing	3	Seed dressing
Proper drying and storage	65	Post-harvest management

Findings from the Scenario-Based Focus Group Discussions (SBFGDs) revealed six key indigenous practices commonly employed by farmers in rural Kano to conserve indigenous crop species under changing climatic constraints. These include early-maturing seed selection (82%) were most frequently mentioned, reflecting farmers' deep understanding of crop resilience and yield optimization under erratic rainfall and prolonged drought conditions. The preference for early-maturing and selection of seeds from the first-planting seeds (73%), indicates adaptive strategies to shorten the growing season and reduce exposure to late-season droughts, consistent with findings by Adeagbo et al. (2021) on smallholder responses to climate variability in Southwest Nigeria. The middle-cob selection (66%) approach was emphasized as a means to ensure seed vigour and uniform grain development, aligning with Reed et al. (2022) who noted that seed position along the cob affects germination rate and plant vigour. Similarly, traditional seed dressing (7%), using ash, neem extracts, and other local materials, was merely reported as a low-cost bio-protective measure against insect infestation and fungal contamination, supporting the observations of Udousung et al. (2025) and Faborode & Alao (2022)) on indigenous pest control.

Interestingly, spiritual seed dressing, though less frequent (3%), underscores the role of cultural and religious beliefs in conservation, revealing how indigenous knowledge blends empirical and spiritual dimensions in agricultural diversity conservation. Proper drying and storage (65%) were identified as critical to maintaining seed viability, especially under increasing humidity and post-harvest pest challenges, echoing FAO (2019) guidelines on community-based seed conservation. Overall, these indigenous practices represent a community-driven adaptation framework that integrates agronomic experience, environmental awareness, and cultural heritage. However, the persistence of climatic constraints such as prolonged drought and unpredictable rainfall suggests that while these methods enhance resilience, they require support through extension services, improved seed systems, and policy recognition to remain effective in the face of worsening climate change.

Conclusion

The study revealed that climatic constraints such as erratic rainfall, prolonged drought, and rising temperatures significantly threaten indigenous crop diversity in rural Kano. Despite the persistence of traditional species such as *Zea mays*, *Oryza sativa*, *Terminalia catappa*, and *Pennisetum glaucum*, inadequate conservation strategies have contributed to the decline and local extinction of some indigenous varieties. However, SBFGD participants identified data-driven on-farm and off-farm conservation strategies including selective seed sorting, use of early-maturing, and timely planting adjustments as viable means of overcoming these climatic challenges. These findings are significant for developing effective strategies to outcome climatic constraints against indigenous crop diversity in rural Kano.

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Evaluation of Soil Degradation Status in Selected Soil of Wukari, Taraba State

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Abstract

This study evaluates the soil degradation status of selected soils of Wukari, Taraba State, Nigeria, to ascertain the level of soil properties degradation. Three pedon were dug and described based on recommended guidelines. Soil samples were collected from each horizon, air-dried, sieved, and subjected to routine laboratory analyses. The results when compared with the soil degradation guideline revealed that the organic matter had range values of 1.48 – 2.09 % in pedon 1, 1.00 – 2.42 % in pedon 2, and 1.36 – 3.12 % in pedon 3 and were slightly degraded to highly degraded while, total nitrogen with range values of 0.11 – 0.90 % in pedon 1, 0.10 – 0.99 % in pedon 2 and 0.88 – 0.99 % in pedon 3 were slightly to moderately degraded. Available phosphorus (0.36 – 1.29 mg/kg, 0.43 – 1.19 mg/kg and 0.24 – 1.90 mg/kg for pedons 1, 2 and 3, respectively) was classified as very highly degraded. The soil potassium content and percent base saturation were slightly degraded. Exchangeable sodium percentages (25.00 – 27.50 % in pedon 1, 15.39 – 25.07 % in pedon 2 and 17.04 – 25.65 % in pedon 3) varied from moderately to highly degraded. The study reveals that the accessed soil properties degraded at various levels and as such targeted conservation strategies such as organic amendments, agroforestry, and balanced fertilization are essential to restore soil fertility and mitigate degradation.

Keywords: evaluations, horizon, pedon, soil degradation, soil properties

INTRODUCTION

Soil degradation can be considered in terms of the loss of actual or potential productivity or utility as a result of natural or anthropic factors; it is the decline in land quality or reduction in its productivity. In the context of productivity, land degradation results from a mismatch between land quality and land use (Beinroth et al., 1994). The importance of soil degradation among global environmental issues is enhanced because of its impact on world food security and quality of the environment. In the developing countries where a large proportion of human population depend almost entirely on land resources for their sustenance, there are increasing competing demands for land utilization such as grazing, fish pond, construction, quarrying, crop farming amongst others (Lal, 1994).

There is a growing need for information relating to soil conditions, their current status, level of degradation, changes due to land use types and management practices and appropriate conservation measures to ensure sustainable and optimal land utilization. The people of Wukari Local Government Area are predominantly farmers, who specialized majorly in tuber and cereal crops: maize, sorghum, yams, cassava, tomatoes, pepper, rice and soybeans. Due to the growing population and shelter needs of Wukari Local Government Area, there has been serious competition on land ownership and their usage (Adamgbe and Ujoh, 2013). Therefore, there are needs to provide the soil degradation status data which will enable agriculturist, engineers, and other land-users to know the areas that are prone to degradation (Igomu *et al.*, 2023). These will enable them to provide control measures and embrace sustainable land -use practices that will help to check the menace in future. Soil degradation constitutes great havocs to our immediate environment. These range from pollution of the environment to the destruction of lives and valuable properties worth a reasonable amount of money; hence, leaving people as victims of its operation. The Wukari community is not an exception of the menace of this commotion causing losses. Hence, the evaluation of soils degradation status of Wukari were considered necessary.

MATERIALS AND METHODS: Study Area.

The study was carried out in Wukari Local Government Area of Taraba State North East, Nigeria. It lies between 7°51'N to 7°85'N latitude and 9°47'E to 9°78'E longitude of the Greenwich meridian. The entire area is a gently undulating plain, with a mean altitude of 200 m above sea level. The drainage systems drain northward and serve as tributaries network to the River Benue while eastward discharge of rivulets and other smaller tributaries from Wukari town drains towards the Donga River, which is a major tributary of River Benue. The annual rainfall of Wukari ranged from 1058 – 1258 mm (NIMET, 2014). The onset of the raining season is usually around April while the offset period is October. The mean maximum temperature is being experienced around April at about 40 °C while the mean minimum temperature occurs between the period of December and February at about 20 °C (NIMET 2014).

Soil and Geology The geology is primarily dominated by Precambrian basement complex rocks such as granite, gneiss, and schist, along with Cretaceous sedimentary formations that include sandstones and shales. The basement complex rocks tend to weather into coarse-textured, sandy, or loamy soils, which often exhibit low nutrient retention capacity due to their mineral composition. On the other hand, the sedimentary formations, particularly shales, contribute to finer-textured, more fertile soils. However, these soils can present drainage challenges depending on local topography and management practices (Nnaji and Nwaka, 2016).

Soil Sampling and Sample Preparation: Field reconnaissance was done with some conventional materials and base map were used to determine the features that exist in the study area. A free survey method was used to site a profile pit on each of the selected sites and were geo-referenced using a Handheld Global positioning system (GPS) receiver. Soil samples were collected based on horizon differentiation according to Schoeneberger et al. (2012) guidelines. The collected soil samples were subjected to routine laboratory analyses. Soil pH was measured potentiometrically in both water and 1 N KCl at the soil-liquid ratio of 1:2.5 (Thomas, 1996). Soil organic carbon was determined by Walkley and Black wet digestion method (Nelson and Sommers, 1996) while total nitrogen was determined by Kjeldahl digestion method (Bremner, 1996). Available phosphorus was determined by Bray-I method (Olsen and Sommers 1982). Exchangeable basic cations (Ca, Mg, K, and Na) were extracted with 1 N NH₄OAc (pH 7) (Thomas, 1996). Exchangeable calcium and magnesium were obtained using atomic absorption spectrophotometer while exchangeable potassium and sodium were determined by flame photometry. Cation exchange capacity (CEC) was determined by ammonium acetate (NH₄OAc) of 1.0M leaching at pH 7 (Summer and Miller, 1996).

Land Degradation Assessment: The degradation status of the soil in the various location was assessed by field observation and the standard indicators and criteria for land degradation assessment by Food and Agriculture Organization (FAO, 1979) Table 1. The four degrees of degradation identified include: a none to slightly degraded soil, where productivity ranged from 75 – 100 % b, moderately degraded soil, productivity ranged from 50 – 75 %, highly degraded productivity ranged from 0 – 25 %.

Table 1: Indicators and criteria for land degradation assessment

Indicator	Degree of Degradation			
	1	2	3	4
Bulk density (g/cm ³)	<1.5	1.5-2.5	2.5-5	>5
Permeability (cm/hr)	<1.25	1.25-5	5-10	>20
Content of nitrogen element (multiple decrease) N (%)	>0.13	0.13-0.10	0.10-0.08	<0.08
Content of phosphorus element (mg/kg)	>8	8-7	7-6	>6
K content (cmol/kg)	>0.16	0.16-0.14	0.14-0.12	<0.12
content of ESP (increase by % of CEC)	<10	10-25	25-50	>50
Content of base saturation (decrease of saturation in more than 50%)	<25	2.5-5	5-10	>10
Content of humus in soil (%)	>2.5	2.5-2	2-10	<1.0

class 1: none to slightly degrade, class 2: moderately degrade, class 3: highly degraded, class 4: very highly degraded

Source: FAO (1979) and Senjobi *et al.* (2010).

RESULTS AND DISCUSSION: Soil Degradation Assessment : The result of the soil degradation assessment as shown in Tables 2 and 3 indicated that the values of the organic matter content of the A-horizons of the pedons 1 and 2 were moderately degraded while that of pedon 3 was slightly degraded. The organic matter content of the subsurface horizons of the pedons when compared with the ratings of the FAO (1979) and Senjobi *et al.* (2010) was moderately degraded except for AB-horizon in pedon 2 and B1 horizon in pedon 3 that were moderately degraded and slightly degraded, respectively. The importance of organic matter content is much more in explicable in view of the fact that organic matter serves as the bounding site for the availability of other nutrient, improvement of water transmission and root penetration (Agbim and Adeoye, 1991). Bala-subramania (1990) reported that high rate of OM addition was needed to solve the problems of soil acidity arising from continuous cropping in West Africa Alfisols. Thus, proper management of organic matter content is highly desirable.

The nitrogen content of the horizons of the pedons was rated slightly degraded when compared with the ratings of FAO (1979) and Senjobi *et al.* (2010) with exception to A-horizons of pedons 1 and 2 where they were rated moderately degraded. Nitrogen is a key nutrient in soil quality indicator for plant for plant growth. Agber *et al.* (2017) referred to N as the most important essential element needed for plant growth, development and reproduction. It is by far the most limiting element especially in the tropics where organic matter decomposition is rapid and nitrogen released from the process is easily lost through teaching or evaporation. The exposure of the soil in sheet erosion wishes away the top soil and the nutrient in them.

The available phosphorus content (Table 3) of the horizon of the pedons were rated as very highly degraded when compared with the ratings of FAO (1979) and Senjobi *et al.* (2010). Phosphorus in the second most limiting element influencing plant growth and crop production throughout the world. Its inadequacy is very pronounced and can cause a major lose to the farmer if not supplied adequately (Agbede, 2009). There is need to improve the available P content of the soils for sustainable agricultural production. Agber *et al.* (2017) had earlier reported that available phosphorus was very highly degraded in soils of guinea savanna agro-climatic zone in Nigeria.

Table 2: Soil Quality Indicators for Land Degradation Assessment

Horizon	Depth (cm)	OM (%)	TN (%)	Av.P (mg/kg)	K (cmol/kg)	BS (%)	ESP (%)
Pedon 1							
A	0-35	2.05	0.11	1.29	0.97	92.46	27.09
Bt1	35-59	1.69	0.90	0.47	0.94	83.33	25.00
Bt2	59-117	1.69	0.76	0.93	0.99	95.83	27.50
Bt3	117-200	1.48	0.70	0.36	1.02	93.52	25.35
Pedon 2							
A	0-35	2.42	0.10	1.19	0.77	84.05	25.07
AB	35-46	2.12	0.99	0.75	0.97	91.71	21.71
BA	46-56	1.00	0.85	0.72	0.96	73.02	15.39
Bt1	56-62	1.00	0.88	0.53	0.70	72.28	16.30
Bt2	62-112	1.33	0.81	0.43	0.75	74.67	18.67
Bt3	112-150	1.28	0.76	0.43	0.69	67.78	16.54
Bct	150-200	1.28	0.70	0.58	0.79	98.71	22.00
Pedon 3							
A	0-23	2.59	0.99	0.45	0.88	94.82	25.65
B1	23-57	3.12	0.95	0.97	0.53	77.02	21.47
B2	57-117	1.39	0.88	0.24	0.44	72.54	22.54
B3	117-200	1.36	0.88	1.90	0.77	76.44	17.04

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OM: organic matter, TN: total nitrogen, Av.P: available phosphorus, BS: base saturation, ESP= exchangeable sodium percentage

The potassium content of the horizons of the pedons when compared with the ratings of FAO (1979) and Seyobi *et al.* (2010) was none to slightly degraded. This result is in concurrence with the findings of Igomu *et al.* (2023) and Agber *et al.* (2017) in soils of Guinea savannah agro-climatic zone of Nigeria. Therefore, this is an indication that soils of the Guinea savanna agro-ecological zone are rich in potassium.

The percentage base saturation of the horizons of the pedons was none to slightly degraded when compared with the ratings of FAO (1979) and Senjobi *et al.* (2010). However, the surface horizons of the pedons fall within the none to slightly degraded of percentage. Agber *et al.* (2017) and Igomu *et al.* (2023) had earlier reported on none to slightly degraded of percentage base saturation in soils of guinea savanna agro-climatic zone of Nigeria.

Table 3: Assessment of Individual Soil Quality Indicators

Horizon	Depth (cm)	OM (%)	TN (%)	Av. P mg/kg	K cmol/kg	BS (%)	ESP (%)
Pedion 1							
A	0-35	MD	MD	VHD	SD	SD	HD
Bt1	35-39	HD	SD	VHD	SD	SD	MD
Bt2	39-117	HD	SD	VHD	SD	SD	HD
Bt3	117-200	HD	SD	VHD	SD	SD	HD
Pedion 2							
A	0-35	MD	MD	VHD	SD	SD	HD
AB	35-46	MD	SD	VHD	SD	SD	MD
BA	46-56	HD	SD	VHD	SD	SD	MD
Bt1	56-62	HD	SD	VHD	SD	SD	MD
Bt2	62-112	HD	SD	VHD	SD	SD	MD
Bt3	112-150	HD	SD	VHD	SD	SD	MD
Bct	150-200	HD	SD	VHD	SD	SD	MD
Pedion 3							
A	0-23	SD	SD	VHD	SD	SD	HD
B1	23-57	SD	SD	VHD	SD	SD	MD
B2	57-117	HD	SD	VHD	SD	SD	MD
B3	117-200	HD	SD	VHD	SD	SD	MD

OM: organic matter, TN: total nitrogen, Av.P: available phosphorus, BS: base saturation, ESP= exchangeable sodium percentage, SD: slightly degraded, MD: moderately degraded, HD: highly degraded, VHD: very highly degraded

The exchangeable sodium percentage of horizons of the pedons when compared with the rating of FAO (1979) and Senjobi *et al.* (2010) moderately degraded to slightly degraded. However, the surface horizons of the pedons were highly degraded due to high amount of sodium in the soil. The result is contrary to the findings of Igomu *et al.* (2023) and Agber *et al.* (2017) in soils of guinea savanna agro-climatic zone of Nigeria.

CONCLUSION: The findings revealed that the soils of Wukari exhibit varying levels of degradation, with significant declines in organic matter content, nutrient availability, and soil structure stability. Erosion was found to be a major contributor to soil loss, leading to reduced soil fertility and declining agricultural productivity. Additionally, continuous cropping, deforestation, and poor land management practices have exacerbated soil degradation, posing challenges to sustainable agriculture in the area. These findings provide critical insights for policymakers and farmers to address soil degradation, improve agricultural productivity, and align with global sustainability goals.

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Analysis of Effects of Climate Change and Armed Conflicts on Food Security of Smallholders in Mubi North Local Government Area, Adamawa State, Nigeria

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Abstract

The research sought to investigate the combined Effects of Climate Change and Armed Banditry on Food Security in Mubi North Local Government Area, Adamawa State, Nigeria. A cross-sectional research design was employed, using both qualitative and quantitative data. A multistage sampling method was employed and four hundred and twenty households were interviewed using structured questionnaires. Both descriptive and inferential statistics were used to capture the objectives of the study. The inferential statistical tool used was Logistic regression to identify predictors of food insecurity. The result of the study revealed that The descriptive results show that respondents are mainly smallholder farmers within productive ages, with large households, modest incomes, moderate extension access, and strong perceptions of climate stress and banditry exposure. The results also disclosed that The logistic regression results reveal that climate stress and banditry significantly increase food insecurity, while farm size, off-farm income, market access, and extension services reduce it. Overall, the descriptive and regression results jointly conclude that farming households in the study area face high vulnerability to climate stress and banditry, which significantly undermine food security, implying that strengthening farmers' resource base, improving institutional support, and enhancing adaptive capacities are essential policy priorities for reducing food insecurity and building resilient rural livelihoods. **Keywords:** Climate Change, Armed banditry, food security, Households and Mubi north,

1.0 INTRODUCTION: Food security in Nigeria is increasingly threatened by the dual forces of climate change and rising insecurity, particularly armed banditry. In northeastern Nigeria, including Mubi North Local government Area in Adamawa State, these twin challenges pose significant risks to agricultural livelihoods and household food access. Climate change has manifested through unpredictable rainfall patterns, extreme weather events, and prolonged dry spells, reducing agricultural productivity. Concurrently, armed banditry and related insecurity have led to displacement of farming populations, destruction of crops and infrastructure, and disruption of local markets. Mubi north LGA, historically known as a major agricultural hub, has experienced increasing food insecurity due to these compounding stressors. Farmers are unable to cultivate optimally due to land abandonment caused by fear of attacks and the loss of manpower. Climatic factors further exacerbate yield reductions, making food systems more fragile. Despite the significance of this issue, limited empirical research exists on the combined impact of climate change and armed banditry on food security in this region. Food security remains a central concern in the socio-economic development agenda of many countries, particularly in Sub-Saharan Africa, where agriculture is the mainstay of rural livelihoods. In Nigeria, and specifically in Adamawa State, food security is increasingly threatened by the twin challenges of climate change and armed banditry, especially in conflict-prone and ecologically vulnerable areas such as Mubi North Local Government Area (LGA). Food security, defined as the consistent access to sufficient, safe, and nutritious food for all individuals, is a critical component of national stability and development. In Nigeria, Climate change manifests in northern Nigeria through erratic rainfall patterns, prolonged droughts, desertification, rising temperatures, and increased incidence of pests and crop diseases (IPCC, 2022). These climate variables adversely affect agricultural productivity, particularly among smallholder farmers who rely on rain-fed agriculture (Ayanlade et al., 2018). In Mubi North, farmers report that unpredictable weather conditions disrupt planting and harvesting cycles, reducing crop yields and food availability (Garandi et al., 2025). The region has also experienced increased soil erosion, declining soil fertility, and dwindling water sources—all of which threaten sustainable food production (Nnanguma et al., 2025). Climate change has led to significant environmental alterations in northern Nigeria, including erratic rainfall patterns, prolonged droughts, and increased temperatures. These changes have adversely affected agricultural productivity, as farmers struggle with water scarcity and soil degradation. For instance, in Adamawa State, over 1,250 hectares of farmland have been impacted by water scarcity due to higher temperatures and changing rainfall patterns, disrupting food supply and livelihoods.

Soil erosion is another consequence of climate change affecting agricultural lands. Studies in Mubi North and South LGAs have identified steep slopes, intense rainfall, sandy soils, and unsustainable agricultural practices as primary contributors to soil erosion, leading to the loss of fertile topsoil and reduced agricultural productivity. In Adamawa State, recurrent attacks by insurgents and bandits have led to the destruction of farmlands, theft of livestock, and displacement of farming communities (Agbedo, 2024). These violent disruptions have direct implications on food security by displacing agricultural labor, creating food supply bottlenecks, and increasing food prices in local markets. In Mubi North LGA, the aftermath of Boko Haram insurgency and recurring herder-farmer conflicts has significantly reduced agricultural output and disrupted rural economies (Garandi, 2024). Armed banditry has emerged as a significant threat to food security in northern Nigeria. The activities of bandits, including attacks on farming communities, theft of livestock, and destruction of crops, have led to the displacement of farmers and abandonment of farmlands. Climate-induced crop failures force people to migrate or overexploit natural

resources, often leading to resource-based conflicts. Conversely, armed violence reduces resilience by undermining social stability and cutting off access to coping mechanisms such as communal labor systems, food aid, and emergency agricultural services (FAO, 2023). This interlinkage is particularly pronounced in Mubi North, where weak governance and inadequate infrastructure amplify the effects of both environmental and human-induced crises.

The interplay between climate change and armed banditry exacerbates food insecurity in Mubi North LGA. Climate-induced resource scarcity can lead to increased competition over land and water, potentially escalating conflicts. Conversely, insecurity hampers the implementation of climate adaptation strategies, as displaced farmers are unable to invest in sustainable agricultural practices. While there is growing literature on climate change and insecurity in northern Nigeria, there is a paucity of localized, empirical research focusing specifically on the cumulative impacts of these twin threats on food security in Mubi North LGA. This study fills that gap by investigating how climate change and armed banditry individually and jointly affect food availability, access, utilization, and stability in the region.

Problem Statement: In **Mubi North Local Government Area (LGA)** of Adamawa State, a predominantly agrarian community, agricultural productivity is severely affected by unpredictable weather patterns, prolonged dry spells, soil degradation, and dwindling water sources. At the same time, armed banditry, insurgency spillovers, and herder-farmer conflicts have created a hostile environment that disrupts farming activities, displaces rural households, and hampers access to markets and food distribution networks. Despite interventions by local governments and development partners to address food insecurity through improved seeds, extension services, and conflict resolution programs, the severity of hunger and malnutrition remains alarming. Farmers are abandoning farmlands due to fear of attacks, while those who continue to cultivate their land face climate-induced crop failures and livestock mortality. This combination of environmental and security threats poses a major challenge to achieving Sustainable Development Goal 2 (Zero Hunger) in the region. While there is growing national-level research on the effects of climate change and insecurity on agricultural livelihoods, **localized empirical data specific to Mubi North LGA is scarce**. Most existing studies tend to generalize the northern region or focus only on either climate or conflict, rather than analyzing the **combined and interacting effects** of both threats on food security dimensions—availability, access, utilization, and stability. Therefore, there is an urgent need for research that systematically explores how climate change and armed banditry intersect to affect food security outcomes in the area. The general or broad objective of the study is to analyse the combined effects of climate change and armed banditry on food security among farming households in Mubi North Local Government Area, Adamawa State, Nigeria while the Specific objectives include to: Describe the socio-economic characteristics of the respondents in the study area. To examine the influence and/the interaction between climates change, banditry, and food security indicators.

3.0 METHODOLOGY: STUDY AREA : According to Adebayo (2004), Mubi metropolis is located between latitudes 10° 05' and 10° 30'N of the equator and between longitude 13° 12' and 13° 19'E of the Greenwich meridian. It has a land area of 192,307 Km² and a total population 260,009 people (National Population Census 2006). The area is bounded by Maiha L.G.A to the South, Hong L.G.A to the West, Michika L.G.A and Cameroon Republic in the East. It consists of districts or wards as Bahuli, Betso, Digil, Kolere, Lokuwa, Mayo Bani, Mijilu, Muchallah, Sabon Layi, Vimtim and Yelwa wards. Mubi is located in the Northern guinea savanna zone of Nigeria with mean annual rainfall ranges of 700mm-1000mm with peak in July to September. The type of soil is predominantly clay-loam soil and the types of crops grown in the area are maize, cowpea, groundnut, rice, guinea corn, sugar cane, soya beans and vegetables around the riverine areas. The types of animals reared in the area are: cattle, goats, sheep, poultry, pigs etc. Mubi has the humidity of 19gm/m³, wind of about 14km/hour N and the average temperature of 34°C. More over the town has become center of learning with numerous tertiary and secondary institutions established in the metropolis. Notable among them are Federal University of Agriculture, Mubi (FUAMB), Adamawa State University Mubi (ADSU), Federal Polytechnic Mubi (FPM) and College of Health science and technology. In addition to tertiary institutions, the study area also has federal medical center. The predominant tribe found in the area include Hausa, Fulani, Gude, Fali, Marghi, Higgi and Janyai.

Population of the Study: The target population for this study comprises all smallholder farming households residing in Mubi North Local Government Area (LGA) of Adamawa State, Nigeria. These farmers engage primarily in small-scale, rain-fed agriculture and are highly susceptible to environmental and security-related shocks. Smallholders in the region are directly impacted by the dual threats of climate change—such as erratic rainfall patterns, prolonged dry spells, and flooding—and the increasing incidence of armed banditry, which disrupts farming activities and undermines food production systems. The experiences and coping mechanisms of these farmers are central to understanding the combined impacts of climate change and armed insecurity on household food security (FAO, 2021; IPCC, 2022)

Sample Size Determination

The sample size for this study was determined using Yamane's formula for calculating sample size from a finite population (Yamane, 1967)

$$n = \frac{N}{1 + N(e)^2}$$

Where:

- n = sample size
- N = total population of smallholder farming households in Mubi North LGA
- e = level of precision (0.05 for a 95% confidence level)

According to estimates from the Adamawa State Agricultural Development Programme (AADP) and extension service records, the smallholder farming population in Mubi North LGA is approximately 10,000 households. Substituting into the formula:

$$n = 10,000 / (1 + 10,000(0.05)^2) = 10,000 / 26 \approx 385; n = 385$$

To accommodate potential non-responses and data inconsistencies, a 10% adjustment is added, resulting in a final sample size of **approximately 420 respondents**. This sample size ensures sufficient statistical power for inferential analysis and enhances the reliability of findings (Israel, 2003).

Sampling Procedures: A multi-stage sampling technique was employed to achieve a representative and context-sensitive selection of respondents of Data Collection: In order to empirically investigate the combined effects of climate change and armed banditry on the food security of smallholder farmers in Mubi North Local Government Area (LGA), Adamawa State, Nigeria, primary data was collected using a structured and systematic approach. The choice of primary data collection was informed by the localized and context-specific nature of the phenomena under study. The study will rely on **primary data** collected directly from respondents using a **structured questionnaire** administered through face-to-face interviews. The questionnaire will be designed to capture both quantitative and qualitative information related to the major thematic areas of the research.

Analytical techniques: Both descriptive and inferential statistics were employed in analyzing the data to capture the objectives. Descriptive statistics such as Means, Medians, and Modes, Frequencies and Percentages – to show distribution of variables (e.g., number of smallholders involved) and Standard Deviation and Variance – to measure data dispersion (e.g., variability in yields. While inferential statistics used include Logistic regression.

MODEL SPECIFICATIONS:

Logistic Regression Model: Used to identify the likelihood of food security based on climate and security variables.

$$\text{Let: } Y = \begin{cases} 1 & \text{If Household is secure} \\ 0 & \text{If household is insecure} \end{cases}$$

$Y_i = 1$ if the i^{th} household is secure and 0 insecure.

The logistic regression model is specified as:

$$\text{logit}(P_i) = \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \epsilon_i$$

Where:

P_i : Probability that household i is food secure

$X_{1i}, \dots, X_{2i}, \dots, X_{ki}$ = explanatory variable defined below

β_0 = Intercept

$\beta_1, \dots, \beta_k$ = Regression Coefficients

ϵ_i = Error term

Potential Explanatory variables include:

X_1 = Household size

X_2 = farm size (ha)

X_3 = Access to extension services (1=yes, 0=no)

X₄= Income level (₦/month)

X₅= Climate shock index(e.g drought, flood index)

X₆= Armed banditry exposure index

X₇= Input access (1=yes, 0=no)

X₈= Distance to market (km)

RESULTS AND DISCUSSIONS: Table 1 revealed the descriptive statistics of socio-economics variables of the respondents. The statistics include mean, standard deviation, minimum and maximum values of the variables such as Age, household size, farm size, years of farming experience and access to extension services. Also deduced from the table are results including access to market, input access, annual income of the respondents, perceived climate change /stress, banditry exposure and food security index. The table further disclosed that Majority of the respondents are in productive age range (30–50 years), implying active participation in agriculture. Large household sizes, typical of agrarian communities, provide farm labour but increase food consumption needs. Farm sizes indicates that Most respondents are smallholders with <3 ha, consistent with FAO (2023) on smallholder dominance in Sub-Saharan Africa. Years of farming experience Indicates long-term adaptation knowledge to climatic and socio-economic shocks. The table indicated that 48% received access to advisory services from extension agents, implying moderate institutional support. There was a Reasonable access to markets, though insecurity and distance constrain some farmers. In terms of input access, it indicates rising cost and mobility issues due to insecurity. The respondents annual income (₦) Reflects modest income typical of smallholder producers. As regards to Perceived climate stress, Majority perceive worsening climate conditions (droughts, erratic rainfall). While on Banditry exposure, there was high exposure; confirms intensifying insecurity in Mubi and nearby LGAs. Also indicated in the table is Food security index (PCA composite) which showed moderate food security on average; about 46% food insecure. The descriptive analysis shows that farmers are mostly smallholders with moderate education and large families, typical of northern Nigeria. High climate stress perception and exposure to banditry are consistent with findings by Idrisa et al. (2024) and Adewumi & Adamu (2022), who found similar vulnerability patterns in Adamawa and Katsina States.

Table 1: Descriptive Statistics of Respondents

Variable	Mean	SD	Min	Max
Age (Years)	42.8	11.5	21	75
Household Size	6.3	2.8	1	15
Farm Size (ha)	2.9	1.7	0.5	8.5
Years of Experience	15.7	8.4	1	45
Access to extension	0.48	0.50	0	1
Market access scores (0-10)	6.1	2.2	2	10
Input access (0-10)	5.4	2.6	1	10
Annual Income (₦)	312,000	98,000,	80,000,	720,000
Perceived climate stress	3.8	0.9	1	5
Banditry exposure index (0-10)	6.7	2.5	0	10
Food security index (PCA composite)	0.54	0.19	0.12	0.91

Source : Field survey 2025

Effect of Climate Change and Armed Banditry on food security in the study area: The table 2 is a logistic regression result of the research study. The dependent variable is a binary and consist of food insecurity=1 and food security =0. The table displayed eight variable items among which seven were statistically significant and only one variable (input access that was not significant statistically. The significant ones include climate stress, banditry exposure, farm size, off-farm income, access to extension, access to market and house hold size. The table disclosed that a unit increase of climate stress leads to an increase in food insecurity by 0.73, while an increase in banditry exposure leads to an increase in food insecurity by 62% or 0.62. It would be observed from the table that increase in farm size, off-farm income, access to extension services and access to market will all lead to decrease in food insecurity and hence increase in food security. This is true because the coefficient of farm size, off-farm income, access to extension services and access to market are all negative. Both climate change and armed banditry are major predictors of household food insecurity. The negative coefficients of farm size, extension access, and off-farm income emphasize the importance of resource endowment and institutional support. These findings align with

Adewumi et al. (2023) who found that farm-level adaptation and livelihood diversification mitigate insecurity-induced food crises.

2. Logistic Regression Results (Dependent variable: Food Insecure = 1, Secure = 0)

Variable	Coefficient(β)	Odds ratio($EXP\beta$)	p-value
Climate stress	0.732	2.08	0.003**
Banditry exposure	0.615	1.85	0.004**
Farm size (ha)	-0.403	0.67	0.010**
Off-farm income	-0.251	0.78	0.046**
Access to extension	-312	0.73	0.030**
Market access score	-0.185	0.83	0.021*
Input access score	0.092	0.91	0.057
Household size	0.106	1.11	0.050*

Model Fit: Pseudo $R^2 = 0.37$, $\chi^2(8) = 78.6$, $p < 0.001$

Source: field survey, 2025.

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION: The results reinforce the multidimensional vulnerability of Mubi farmers. Climate variability (drought, erratic rainfall) exacerbates land degradation and yields decline (IPCC, 2022), while banditry disrupts market access and labour mobility (Musa et al., 2023). The logistic regression findings showing farm size, off-farm income, and extension contact as resilience factors align with Aminu et al. (2021) and Olaniyi & Ayodele (2024), who reported that livelihood diversification and institutional support mitigate food insecurity in the face of shocks. Overall, It is concluded and recommended that, the integrated evidence underscores the need for adaptive agricultural policy, peace building interventions, and climate-smart agriculture to safeguard food security in conflict-prone northern Nigeria. To sustainably reduce vulnerability and prevent chronic food insecurity, stakeholders must implement integrated climate-security-livelihood strategies: protect markets and communities, strengthen climate-smart agriculture and extension services, expand social safety nets, and invest in livelihoods diversification and risk-sharing instruments. Collectively, these steps will reduce the immediate humanitarian burden and strengthen long-term resilience.

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The Perceived Impact of Climate Change on Wildlife in Gashaka-Gumti National Park, Nigeria

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Abstract

*This study assessed the perceived impact of climate change on wildlife in Gashaka-Gumti National Park, Nigeria, focusing on data from field surveys and satellite image analysis. The study adopts a **descriptive survey design**. Purposive sampling that ensures only individuals with relevant knowledge and experience about the Park was included in the study. A total of 100 respondents were selected, including: park management staff, conservation experts, local community members, researchers and field experts. Descriptive statistics such as frequency distributions, percentages, and means were used for data analysis. **Temperature and Rainfall Patterns:** According to the data, 30% of respondents observed increased temperatures, while 27% reported changes in rainfall patterns. **Species Diversity and Abundance:** Respondents highlighted major changes in wildlife abundance: 35% confirmed a decline in species population, 33% reported the disappearance of species like elephants and lions, and 22% observed increased migration of some species. **Adaptation and Conservation Measures:** Among respondents, 30% reported the use of reforestation campaigns, 25% mentioned awareness creation, 18% highlighted sustainable livelihood. Satellite data confirms gradual environmental stress over the last 30 years. The study concluded that Climate change has significantly impacted the ecological balance of Gashaka-Gumti National Park. Rising temperatures, irregular rainfall, and environmental stress have led to habitat degradation, decline in wildlife populations, and shifts in species distribution. While some efforts have been made to mitigate these effects, much remains to be done. Based on the findings, the following recommendations are proposed: Investigate the impacts of climate change on communities around the park, Study the adaptive behavior of wildlife species under changing climate conditions and examine the effectiveness of current park policies and laws in protecting wildlife under climate stress.*

Key words: Climate change, Wildlife, Environment, Migrati

INTRODUCTION: Climate change is a global environmental phenomenon that has emerged as one of the most significant threats to biodiversity and natural ecosystems. It refers to long-term shifts in temperatures and weather patterns, primarily due to human activities such as burning fossil fuels, deforestation, and industrial processes, which have drastically increased the concentration of greenhouse gases in the atmosphere (IPCC, 2021). Globally, climate change has contributed to habitat fragmentation, species migration, and increased extinction risks. In the Amazon rainforest, for example, prolonged droughts and temperature increases have contributed to tree mortality and reduced biodiversity (Phillips *et al.*, 2009). In Asia, particularly the Himalayas, climate-induced glacial melt has disrupted alpine ecosystems, threatening snow leopards and other cold-adapted species (Xu *et al.*, 2009). Similarly, in Europe, shifts in vegetation zones and insect outbreaks have been linked to warming trends, affecting species composition in national parks (Walther *et al.*, 2002). In Africa, the effects of climate change are particularly severe due to limited adaptive capacity. Protected areas such as Kruger National Park in South Africa have recorded changes in animal behavior and species range due to warming and reduced water availability (Van Wilgen *et al.*, 2016). In East Africa, recurring droughts have significantly impacted the Serengeti-Mara ecosystem, reducing grazing lands and forcing migratory changes in wildebeest and zebra populations (Ogutu *et al.*, 2014). In West Africa, rising temperatures and irregular rainfall patterns have increasingly affected biodiversity hotspots. A study by Nchanji and Plumptre (2011) in the Cross River National Park of Nigeria and adjacent Cameroon revealed that chimpanzee populations were declining partly due to changing forest conditions linked to climate stress. Likewise, in W-Arly-Pendjari Complex (shared by Benin, Burkina Faso, and Niger), research shows that prolonged dry seasons and bushfires have limited water resources and changed animal distributions (Bouché *et al.*, 2012). These regional insights help place Nigeria's conservation challenges within the broader West African context (Nchanji and Plumptre, 2011).

Gashaka-Gumti National Park, the largest national park in Nigeria, is located in the mountainous region of northeastern Nigeria, spanning parts of Taraba and Adamawa States. It is renowned for its rich biodiversity, serving as a critical habitat for various wildlife species, including chimpanzees (*Pan troglodytes*), African elephants (*Loxodonta africana*), and the endangered African wild dog (*Lycaon pictus*) (Ogunjemite *et al.*, 2020). The park's diverse ecosystems, ranging from montane forests to savannahs and grasslands, provide a sanctuary for numerous species and contribute significantly to the ecological balance of the region (Olaniyi *et al.*, 2020). Over the years, however, climate change has posed a serious threat to the sustainability of Gashaka-Gumti National Park. The region has experienced rising temperatures, altered rainfall patterns, prolonged droughts, and increased frequency of extreme weather events, all of which have affected the park's ecosystems. These climatic changes have led to habitat loss, reduced availability of water, changes in vegetation patterns, and disruptions in wildlife breeding and migration cycles (Oguntunde *et al.*, 2019). One of the most critical impacts of climate change on wildlife in the park is the loss of habitat.

As rainfall patterns become increasingly unpredictable, water bodies within the park dry up more frequently, leading to the scarcity of drinking water for animals and the degradation of aquatic ecosystems. For example, amphibians, which are highly sensitive to environmental changes, are particularly vulnerable to droughts and temperature fluctuations, resulting in population declines and increased risk of extinction (Olaniyi *et al.*, 2020). Similarly, changes in vegetation cover have forced herbivores to migrate in search of food, increasing their vulnerability to predation and reducing population sizes (IPCC, 2021). Moreover, climate change has contributed to the spread of invasive species and diseases that threaten native wildlife. Warmer temperatures and altered precipitation patterns have created favorable conditions for disease-carrying organisms such as ticks and mosquitoes, leading to outbreaks of diseases such as trypanosomiasis and avian malaria among wildlife populations (Woin *et al.*, 2018). Invasive plant species have also encroached on native habitats, reducing the availability of food resources for herbivores and altering the park's ecological balance. The impact of climate change extends beyond wildlife, affecting the socio-economic well-being of local communities living around Gashaka-Gumti National Park. These communities rely heavily on the park's natural resources for their livelihoods, including fishing, farming, and hunting. The depletion of these resources due to climate-related changes has increased competition for limited resources, leading to conflicts between wildlife and humans. For instance, the destruction of crops by wildlife searching for food and water has become more frequent, resulting in economic losses for farmers and fostering negative perceptions toward wildlife conservation (Adewale *et al.*, 2019). Similar challenges have been reported in southern Mali and northern Ghana, where drought-related crop failures and water scarcity have increased human-wildlife interactions and pressures on protected lands (Tschakert *et al.*, 2008).

In response to these challenges, several conservation and adaptation strategies have been proposed to mitigate the impact of climate change on wildlife in Gashaka-Gumti National Park. These strategies include habitat restoration, water resource management, community-based conservation initiatives, and the promotion of climate-resilient livelihoods among local communities (Gandiwa *et al.*, 2019). However, the success of these efforts depends on the active participation of all stakeholders, including park management, conservation experts, policymakers, and local communities (Van Wilgen *et al.*, 2016). Understanding the impact of climate change on wildlife in Gashaka-Gumti National Park is crucial for developing effective conservation strategies that ensure the sustainability of this critical ecosystem. (IPCC, 2021; Olaniyi *et al.*, 2020). Despite the importance of the park as a biodiversity hub, there is limited research on the specific effects of climate change on wildlife in this region. Key problems include habitat degradation, increased mortality rates, and altered migration patterns of species (Ogunjemite *et al.*, 2020). These changes have far-reaching consequences on both the wildlife and the local communities that depend on the park's resources. This study seeks to bridge the gap in understanding by assessing the extent to which climate change is impacting on wildlife diversity, abundance, and adaptation strategies in Gashaka-Gumti National Park. This study is significant for several reasons. First, it contributes to the growing body of knowledge on the impact of climate change on wildlife, particularly in West Africa. By focusing on Gashaka-Gumti National Park, the study provides specific data on how climatic changes are impacting local wildlife populations. The findings will be useful to conservationists, park management authorities, and policymakers in developing evidence-based strategies for wildlife conservation and climate adaptation (Oguntunde *et al.*, 2019).

Furthermore, the study will help raise awareness among local communities and stakeholders about the importance of preserving wildlife in the face of climate change. Understanding the threats posed by climate change and implementing appropriate adaptation measures is crucial for ensuring the long-term survival of species and the sustainability of the park's ecosystems.
METHODOLOGY: Study Area: Gashaka-Gumti National Park is the largest national park in Nigeria, covering about 6,402 square kilometers. It is located in the northeastern part of Nigeria, straddling Taraba and Adamawa States. The park is characterized by diverse ecosystems, including montane forests, savannahs, and grasslands, which host a wide range of wildlife species such as chimpanzees, leopards, African elephants, and various bird species (Ogunjemite *et al.*, 2020). The park's climate is typically tropical, with distinct wet and dry seasons. However, recent climatic changes have caused increased temperatures and irregular rainfall patterns, affecting the park's ecosystems and wildlife (Oguntunde *et al.*, 2019). **Research Design**

The study adopts a **descriptive survey design**, which is suitable for collecting data on the perceptions and experiences of respondents regarding the impact of climate change on wildlife in Gashaka-Gumti National Park. This design enables the researcher to gather both qualitative and quantitative data, providing a comprehensive understanding of the research problem (Kothari, 2019).

Population of the Study

The population of this study includes park management staff, conservation experts, local community members living around the park, and researchers who are familiar with the park's biodiversity and climate conditions. These groups were selected because they have firsthand knowledge of the park's wildlife and are well-positioned to provide reliable information on the impact of climate change.

Sampling Techniques: A purposive sampling technique was used to select respondents for this study. Purposive sampling ensures that only individuals with relevant knowledge and experience about Gashaka-Gumti National Park, local community included in the study (Creswell, 2014).

Sample size: The sample size was determined based on the population of stakeholders and the scope of the study. A total of 100 respondents were selected, including; 20 park management staff; 10 conservation experts 50 local community members; 20 researchers and field experts

RESULTS : The data collected from 100 respondents, including park management staff, conservation experts, local community members, and researchers. The aim is to assess the impact of climate change on wildlife in Gashaka-Gumti National Park. The data was gathered through structured questionnaires and is presented using tables, and percentages. The analysis includes both quantitative and qualitative interpretations.

Figure 1: Demographic Characteristics of Respondents

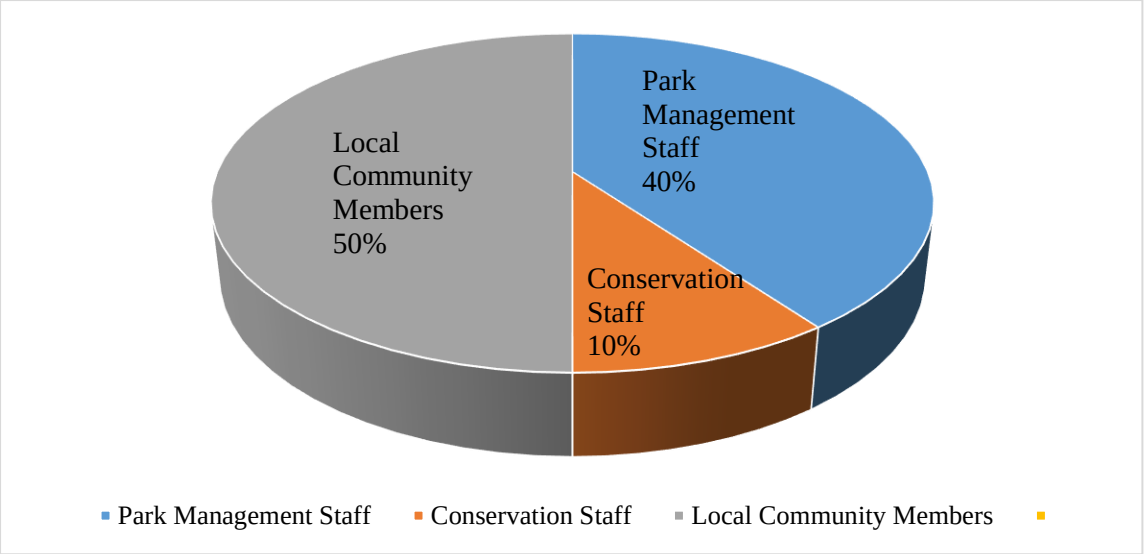


Table 1: Respondents' Observations on the impact of Climate Change

Observed impacts	Frequency	Percentage (%)
Increased temperatures	30	30%
Changes in rainfall pattern	27	27%
Loss of wildlife species	19	19%
Shrinkage of water bodies and habitats	16	16%
Increase in invasive species	8	8%
Total	100	100

Most respondents observed changes in temperature and rainfall, as well as a loss in wildlife species and habitat degradation—confirming key signs of climate change.

Table 2: Changes in Wildlife Species Diversity and Abundance

Indicator	Responds
	Yes (%)
Decline in species population	35%
Disappearance of species (e.g., lions, elephants)	33%
Increase in migration of certain species	22%
Emergence of unknown species	10%
Total	100

There's clear evidence of species decline, disappearance of iconic animals (elephants, lions), and shifts in animal behavior like migration—all aligning with global climate impacts.

Table 3: Perceived Climatic Factors Affecting Wildlife

Climatic Factor	Frequency	Percentage (%)
Rising temperature	25	25%
Irregular rainfall	23	23%
Drought and dry spells	21	23%

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Flooding in lowland areas	19	19%
Windstorms and vegetation damage	12	12%
Total	100	100%

Rising temperature and unpredictable rainfall were the most mentioned factors, believed to have direct and indirect impacts on vegetation and animal life.

Table 4 Adaptation and Mitigation Strategies Reported

Strategy Used by Community or Staff	Frequency	Percentage (%)
Reforestation campaigns	30	30%
Awareness creation on climate change	25	25%
Sustainable Livelihood	18	18%
Anti-poaching and wildlife monitoring patrols	14	14%
River and water source preservation	8	8%
Introduction of climate-resilient species	5	5%
Total	100	100%

Table 5: Key Quantitative Environmental Changes (Secondary Data)

Environmental Indicator	Observed Change
Forest cover (1991–2021)	+5.6% increase
Grassland/shrub areas (1991–2021)	-8.8% decrease
Built-up/bare surfaces (1991–2021)	+3.8% increase
NDVI, GNDVI, ARVI (Vegetation Health)	General decline (2000–2020)
MSI (Moisture Stress Index)	Increased stress (2000–2020)
Locally extinct species (past 30 years)	Elephants, Lions, Giraffes, antelope and crocodile.

Environmental data validates community perceptions. Declines in habitat health and biodiversity confirm that climate change is impacting the park at multiple levels.

Discussion: Species Diversity and Abundance: Respondents highlighted major changes in wildlife abundance: 35% confirmed a decline in species population, 33% reported the disappearance of species like elephants and lions, and 22% observed increased migration of some species. These findings are consistent with the work of Ezealor (2020), who found that large mammals are disproportionately vulnerable to habitat fragmentation and climate extremes in Nigeria’s protected zones. Moreover, satellite-based ecological indices in this study, such as the Normalized Difference Vegetation Index (NDVI) and Moisture Stress Index (MSI), confirmed reduced green biomass and increased moisture stress — reinforcing perceptions of ecosystem degradation. Thomas *et al.* (2017) similarly found that such reductions in NDVI correlate with declining animal densities and reduced ecosystem productivity in savanna environments.

Land Use and Vegetation Change: The 5.6% increase in forest cover observed may suggest afforestation or regrowth in less accessible zones, possibly due to park enforcement or community-based tree planting. However, the 8.8% decline in grassland and shrub areas, along with a 3.8% increase in bare or built-up surfaces, indicates habitat conversion and fragmentation. This observation mirrors findings by Adamu and Isa (2019), who noted that land use changes in Taraba and Adamawa States were primarily driven by agricultural expansion and population growth, thereby shrinking wildlife corridors and increasing human-wildlife conflict.

Adaptation and Conservation Measures: Among respondents, 30% reported the use of reforestation campaigns, 25% mentioned awareness creation, 18% highlighted sustainable livelihood. These figures indicate some level of resilience and engagement. However, the relatively low adoption of certain strategies points to institutional and financial limitations. This is echoed by Gandiwa *et al.* (2019), who noted that African park authorities often face funding shortages, poor infrastructure, and limited technical capacity, hindering comprehensive climate adaptation strategies. **Species Extinction and New Discoveries:** The reported local extinction of flagship species such as elephants, lions, giraffes, antelopes, and crocodiles is alarming and points to an ecosystem under significant stress. However, the emergence of unknown species (as observed by 10% of respondents) suggests that the park still holds untapped biodiversity. This paradox reflects observations by Chidumayo and Gumbo (2018), who noted that while climate change may drive some species to extinction, it may also facilitate the appearance or migration of others into new territories, altering biodiversity baselines.

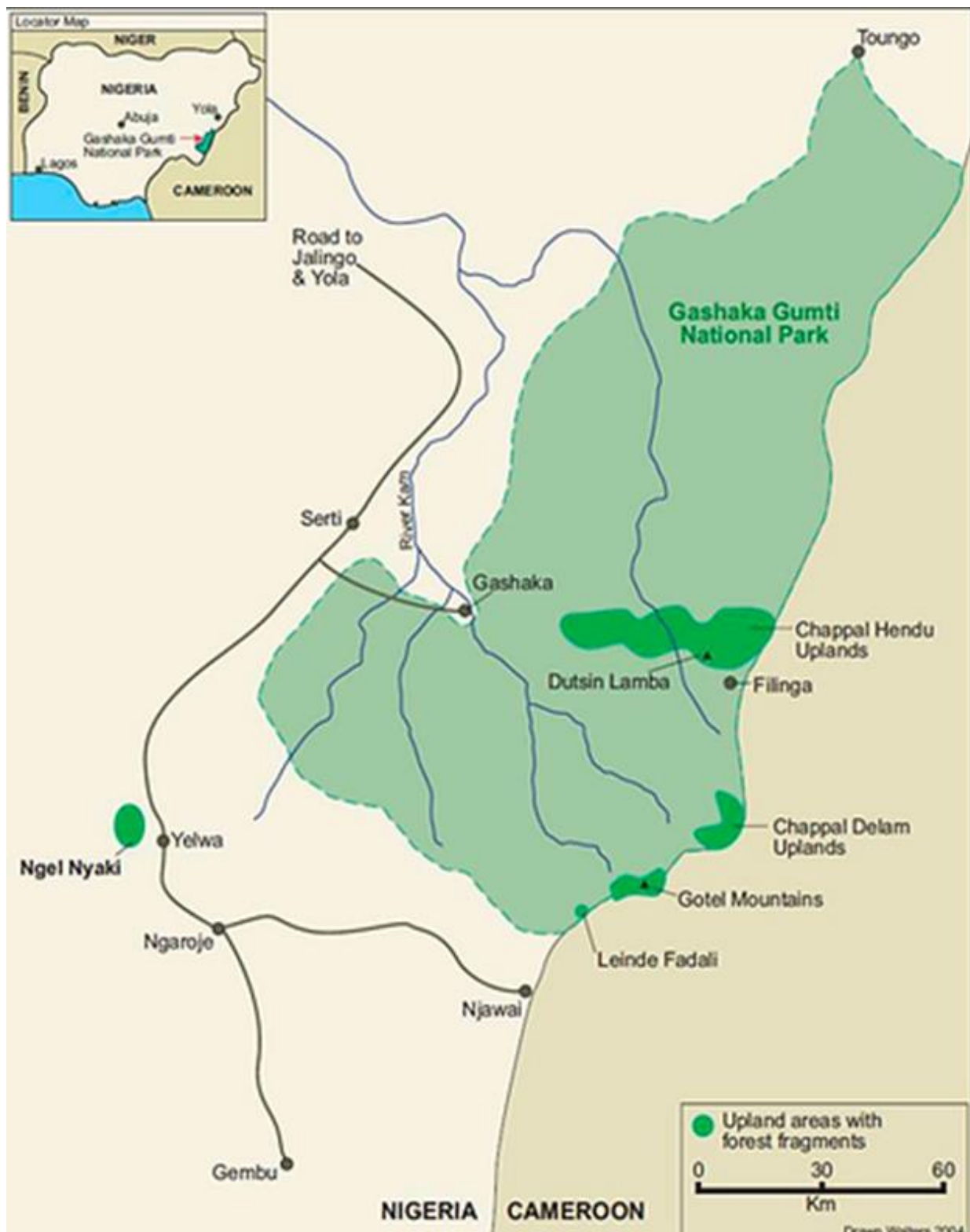
Conclusion: Climate change has significantly impacted the ecological balance of Gashaka-Gumti National Park. Rising temperatures, irregular rainfall, and environmental stress have led to habitat degradation, decline in wildlife populations, and shifts in species distribution. While some efforts have been made to mitigate these effects, much remains to be done. The disappearance of iconic species such as elephants and lions underscores the urgent need for stronger conservation policies. Moreover, the park's potential for biodiversity discovery highlights the importance of preserving it as a climate-resilient ecological zone. **Recommendations** Based on the findings, the following recommendations are proposed: Investigate the impacts of climate change on communities around Gashaka-Gumti. Study the adaptive behavior of wildlife species under changing climate conditions. Examine the effectiveness of current park policies and laws in protecting biodiversity under climate stress.

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Map of Gashaka-Gumti National Park

Assessment of the Suitability of Soils, Originating from Different Parent Materials, for Rain-Fed Arable Farming in Central Cross River State, Nigeria

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Abstract

Proper characterization of soils is indispensable in order to highlight the soil potential, provide a guide for policy formulation on land use and enhance their management for increase productivity. This study was carried out to characterize, classify and evaluate the soils derived from diverse parent materials Basalt, Alluvial, Gneiss, granitic and sandstone shale in Central Cross River State for the purpose of rain-fed arable cropping. The physico-chemical and morphological characteristics of soils derived from diverse parent materials in Central Cross River were investigated and evaluated. The stratified random sampling technique based on topographic attributes of slope or catenary concept was adopted in each sampling location. A total of 108 samples were collected from 28 profile pits excavated. Five mapping units (CRC 1-5) were identified and classified on the basis of parent materials. Their percentage occurrence in the study area is CRC 1 (alluvial soils) 14.1 %, CRC 2 (basaltic soils) 5.7 %, CRC 3 (sandstone-shale soils) 55.3 %, CRC 4 (granite soils) 3.3 % and CRC 5 (gneiss soils) 21.6 % the morphological properties were assessed according to standard procedures outlined in the Food and Agricultural Organization (FAO) guidelines. The following physico-chemical properties were determined in the laboratory: particle density, soil pH, organic carbon, organic matter, exchangeable bases, and base saturation. It is recommended in this study that basaltic, sandstone-shale, and alluvial soils could be enhanced through good management practices and soil amendments.

Introduction: The soils of Central Cross River are currently under cultivation for several arable crops like yam (*Dioscorea* spp.) cassava (*Manihot* spp), and maize (*Zea mays*) and tree crops like *Theobroma cacao*, *Gmelina arborea* and *Oldfieldia Africana* (Eshett, 1987; Esu, 2005). The productivity of agricultural soils in Central Cross River is declining drastically following intensified land use due to very poor management practices. Okpiliya *et al.*, (2008) noted that agricultural productivity and food security in the savannah ecozone of Central Cross River are being seriously threatened by steady decline in soil fertility which is defined as a net decrease in available nutrients and organic matter in the soil caused by continued nutrient uptake from already degraded soils. Based on its attributes and potentials, every land is suitable for a particular land use. Land suitability evaluation is thus the process of assessing the suitability of the land for a particular land use (FAO, 1976). These may be for agricultural and non-agricultural uses. Land suitability classification for agricultural purpose may be rain-fed arable farming or irrigated agriculture. Land suitability is assessed, classified and presented separately for each kind of use. Abegunde *et al.* (2015) found low to medium soil suitability levels for maize production in the Oyo State. Similar conclusions were arrived at for oil palm and plantain production in the Etung local Government area by Ajiboye and Olaniyan (2016). However, few soil suitability studies have focused on Arable and tree crops in Nigeria (Ande *et al.*, 2011; Gbadegesin *et al.*, 2011; Oniya *et al.*, 2013; Abua, 2015) and none in Cross River State. Therefore, this study aimed to evaluate and assess the suitability of the soils of Central Cross River State for rain fed arable agriculture. Variation existing in the properties of soils formed from diverse parent materials in Central Cross River State have not been extensively studied. Hence there is insufficient information to characterize and assess their suitability for specified kinds of use. The parent materials giving rise to soils in Central Cross River State include basalt, basement complex (granite, gneiss, quartzite and schist), sandstone-shale intercalation and alluvium (Ekwueme, 2003; Ibanga and Armond, 1992). Soil Conservation Service (1994) reported that apart from bedrock parent materials, mineral soils could develop from other types of parent materials called recent cover deposit and these include alluvial, aeolian, glacial, lacustrine, loessal and marine deposit. This study was carried out to assess the suitability of soils, originating from different parent materials, for rain-fed arable farming in central cross river state, Nigeria.

2.0 Materials and Methods 2.1. Study Area.: The Central part of Cross River State lies between latitudes 50 20" and 60 20" N, and longitudes 80 00" and 9020"E. Central Gross River State has a total land area of about 7556.69 sq km, consisting of six local government areas: Yakurr, Abi, Obubra, Etung, Ikom and Boki.

This study was carried out in representative soils derived from diverse parent materials in Central Cross River, South Eastern Nigeria. The sampling locations were selected based on information obtained from the geology of Cross River State (2005) and on previous works of Ekwueme *et al.*

2.2. Methodology: The stratified random sampling technique based on topographic attributes of slope or catenary concept was used in each location where the samples were taken. The sampling locations were selected on the basis of their parent materials. One hundred and eight (108) samples were collected from twenty eight (28) profile pits excavated.

2.2.1 Soil mapping units

- Mapping unit CRC1. This consist of soil of recent alluvium of the floodplain of the Cross River and its major tributaries. This include the deep, poorly to very poorly drained, black to dark grey loam to sandy loam soils. The parent material of this mapping unit is a mixture of colluvial deposits with a much higher percentage of alluvial materials.
- Mapping unit CRC2. Here the soil found in nearly level undulating plains of basic crystalline rocks (Basalts). These soils are deep, well drained and relatively gravel free. The soil have a characteristic dark red to reddish brown colour without mottles.

- Mapping unit CRC 3. This unit consists of soils that are well drained, shallow to moderately deep, coarse to medium textures surface over medium to fine sub-soils. The soils occur in gently to nearly level gradient on sandstones interrelated with shale. Their colour is dark brown to grayish with a loam to sandy loam texture.
- Mapping unit CRC 4: This unit consists of soil of undulating nearly level topography development on garnet gneiss parent materials. The soils are shallow, moderately deep or deep and well drained to moderately well drained. The soil have medium textures and usually gravely.

3.0 RESULTS AND DISCUSSIONS: Soil derived from alluvium (CRC 1): Sandy clay, clay, loam and clay loam were the dominant textures encountered in soils of alluvial deposit. These soils have moderate medium sub angular blocky, weak medium granular and strong coarse prismatic structures. Mean bulk density values of 1.05 g/cm³ at 0–25 cm, 1.14 g/cm³ at 25–50 cm and 1.35 g/cm³ at 75–100 cm depth were obtained for alluvial soils. These soils are acid to moderately acid with mean pH value of 4.5. Organic carbon ranged from 5.9–23.4 g/kg⁻¹ averaging 13.2 g/kg⁻¹ and rated medium. Total nitrogen ranged from 0.4–2.4 g/kg⁻¹ averaging 1.1 g/kg⁻¹ and rated medium. Amongst the exchangeable, bases, sodium ranged from 0.18–0.24 cmol/kg averaging 0.22 cmol/kg and rated medium. Potassium ranged from 0.06–0.046 cmol/kg averaging 0.21 cmol/kg and rated medium. Calcium ranged from 0.8–19.1 cmol/kg averaging 8.9 cmol/kg and rated high; and Magnesium ranged from 1.2–13.2 cmol/kg averaging 6.4 cmol/kg and rated high.

Cation exchange capacity value ranged from 2.5–33.0 cmol/kg averaging 15.6 cmol/kg and rated high. Available phosphorus in alluvial soils averaged 14.4 mg/kg and rated medium. These soils also had medium levels of base saturation.

Soils of alluvium are moderately suitable (S2) for arable crops (cassava, maize and groundnut etc); and swamp rice cultivation; currently not suitable (N1) for upland rice cultivation and permanently not suitable (N2) for forestry.

Soils derived from basalt (CRC 2): Basaltic soils are characterized by possession of weak to strong, medium to coarse sub-angular blocky structures. Bulk density values averaged 1.11 g/cm³ at 0–25 cm, 1.10 g/cm³ at 25–50 cm, and 1.24 g/cm³ at 75–100 cm depths. The soils are acid to moderately acid with pH values ranging from 4.3–5.6 averaging 4.8. Organic carbon ranged from 4.3–28.5 g/kg⁻¹ averaging 11.8 g/kg⁻¹ and rated medium. Total nitrogen ranged from 0.2–2.2 g/kg⁻¹ averaging 1.0 g/kg⁻¹ and rated medium. Amongst the exchangeable bases sodium ranged from 0.10–0.18 cmol/kg averaging 0.17 cmol/kg and rated medium. Potassium ranged from 0.05–0.20 cmol/kg averaging 0.08 cmol/kg and rated low. Calcium ranged from 0.6–5.0 cmol/kg averaging 2.1 cmol/kg and rated medium, and Magnesium values ranged from 1.1–4.4 cmol/kg averaging 2.3 cmol/kg and rated high. Values of cation exchange capacity ranged from 2.4–9.7 cmol/kg averaging 4.6 cmol/kg and rated low. Exchangeable acidity ranged from 1.2–4.8 cmol/kg averaging 2.5 cmol/kg and rated high. Available phosphorus ranged from 3.4–24.9 mg/kg⁻¹ averaging 10.5 mg/kg⁻¹ rated medium. The base saturation was rated medium for basaltic soils ranging from 33.8–82.9 %.

These soils derived from basalt were rated marginally suitable (S3) for arable crops; permanently not suitable (N2) for swamp rice; moderately suitable (S2) for upland rice cultivation; and marginally suitable (S3) for forestry.

Soils derived from sandstone-shale (CRC 3): These soils have loam, sandy clay, sandy clay loam, and clay loam textures. The structures of these soils consist of moderate to medium sub-angular blocky structures. The soils have high erodibility index values and are thus vulnerable to erosion. Bulk density values averaged 1.44 g/cm³ at 0–25 cm, 1.58 g/cm³ at 25–50 cm and 1.73 g/cm³ at 75–100 cm depths. These soils are moderately acid to slightly acid reaction with pH value ranging 4.5–6.9 averaging 5.1. Organic carbon ranged from 3.1–18.8 g/kg⁻¹ averaging 8.3 g/kg⁻¹ and rated low. Values of total nitrogen were in the range 0.3 to 1.4 g/kg⁻¹ averaging 0.07 g/kg⁻¹ and rated low. Amongst the exchangeable cations, sodium, values range from 0.04–0.18 cmol/kg averaging 0.07 cmol/kg and rated low; potassium ranged from 0.05–0.36 cmol/kg averaging 0.22 cmol/kg and rated medium; calcium range from 3.2–13.6 cmol/kg averaging 7.2 cmol/kg and rated high; magnesium ranged from 1.6–12.1 cmol/kg averaging 4.9 cmol/kg and rated high. Cation exchange capacity ranged from 5.2–25.7 cmol/kg averaging 12.4 cmol/kg and rated high. Values of available phosphorus ranged from 2.0–7.4 mg/kg averaging 4.0 mg/kg and rated low. Base saturation for these soils were in the range 73.9–98.1 % and rated high.

Soils of sandstone-shale were evaluated as currently not suitable (N1) for arable crops; permanently not suitable (N2) for swamp rice cultivation; marginally suitable (S3) for upland rice; and currently not suitable (N1) for forestry due to shallow soil depth. Soils Derived from Granite (CRC 4): The soils are coarse textured and poorly structured. Specifically these soils have sandy clay loam, sandy clay and sandy loam textures. The structures of these soils consist of weak to moderate, fine to medium crumb and granular structures. These soils have high erodibility index values averaging 3.2. Bulk density values averaged 1.08 g/cm³ at 0–25 cm, 1.37 g/cm³ at 25–50 cm and 1.52 g/cm³ at 75–100 cm depths.

These soils are acid to moderately acid in reaction with pH values ranging from 4.5–5.1 averaging 4.8. Soils organic carbon values ranged from 4.8–32.9 g/kg⁻¹ rated medium. Values of total nitrogen ranged from 0.5–2.8 g/kg⁻¹ averaging 1.2 g/kg⁻¹ and rated medium. Amongst the exchangeable bases, sodium ranged from 0.05–0.6 cmol/kg averaging 0.07 cmol/kg and rated low; calcium ranged from 0.5–5.4 cmol/kg averaging 1.6 cmol/kg and rated low; and magnesium ranged from 0.6–2.5 cmol/kg averaging 1.1 cmol/kg and rated low. Cation exchange capacity ranged from 1.3–8.0 cmol/kg averaging 2.8 cmol/kg and rated low. Available phosphorus ranged from 1.1–13.9 mg/kg averaging 4.3 mg/kg and rated low. The average base saturation value of granite soils (46.8%) was rated low. Soils of granite origin were evaluated permanently not suitable (N2) for arable crop; swamp rice; and upland rice cultivation. These soils were rated marginally suitable (S3) for forestry.

Soils Derived from Gneiss (CRC 5): These soils have sandy clay loam, loamy sand, sandy loam, and sandy clay loam textures. Soils of gneiss origin possess weak to moderate, fine to medium crumb and granular structures. These soils have high erodibility index values and thus vulnerable to erosion. Gneiss soils had average bulk density value of 1.19 g/cm³ at 0–25 cm, 1.37 g/cm³ at 25–50 cm and 1.56 g/cm³ at 75–100 cm depths.

The soils of gneiss origin were very strongly acid in reaction with pH values in the range 4.2–4.9 averaging 4.6. The soils organic carbon values ranged from 3.8–23.1 g/kg⁻¹ and rated medium. Total nitrogen values ranged from 0.3–1.7 g/kg⁻¹

averaging 0.8gkg⁻¹ and rated low. Among the exchangeable cations, sodium ranged from 0.04-0.24cmol/kg averaging 0.14cmol/kg and rated medium; potassium ranged from 0.04-0.21cmol/kg averaging 0.08cmol/kg and rated low; calcium ranged from 0.3- 1.7gkg averaging 0.8gkg and rated low.

Amongst the exchangeable cations, sodium ranged from 0.04-0.24 cmol/kg averaging 0.14 cmol/kg and rated medium; potassium ranged from 0.04-0.21 cmol/kg averaging 0.08cmol/kg and rates low; calcium ranged from 0.4-2.6cmol/kg averaging 1.2 cmol/kg and rated low; and magnesium ranged from 0.4-1.6cmol/kg averaging 1.0cmol/kg and rated low. Values of cations exchange capacity ranged from 0.9-4.3 cmol/kg averaging 2.4cmol/kg and rated low. Available phosphorus ranged from 2.4 -11.9mg/kg averaging 4.1mg/kg and rated low. The base saturation of gneiss soils averaged (54 %) and was rated medium. These soils were also rated marginally suitable (S3) for forestry.

Table 2: Selected sampling locations on basis of Parent Materials and soil mapping units.

Parent material	Sampling location	Latitude (N°)	Longitude (E°)	Soil mapping unit
Alluvium	Ovonum	5.59	8.15	CRC1
Alluvium	Ediba	5.57	8.15	CRC 1
Basalt	Last motor	5.53	8.46	CRC 2
Basalt	Bendeghe Ekiem	5.01	8.50	CRC 2
Sandstone Shale	Ekor	5.51	8.06	CRC3
Sandstone Shale	Ogada	6.03	8.18	CRC3
Granite	Kanyang	6.15	9.02	CRC4
Granite	Bubong	6.26	9.05	CRC4
Gneiss	Isobendeghe	5.47	8.28	CRC5
Gneiss	Nsadop	6.19	8.49	CRC5

Source: Nsor, Micheal Edim Field work (2010)

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Table 3: Percentage ratings of individual factors of Require's land productivity index for actual and potential suitability for arable crops of soils formed from divers Parent materials in Cross River State

Parent material	Soil Moisture	drainage	texture	slope	Fertility index	Soil Reaction	Organic matter	CEC	Mineral reserves	Available phosphorus	Actual productivity	class	Coefficient Of improvement	Potential productivity	class	
Alluvial soils	100	85	85	85	100	61.85	95	95	95	85	38.05	S2	2.02	79.71	S2	
Bassalt soil	95	85	100	95	95	31.32	60	85	85	85	22.83	S2	3.57	81.45	S1	
Sandstone shale	60	95	95	85	19.49	60	60	95	95	60	8.05	N1	6.26	83.31	S2	
Granitic Soil	60	85	85	60	17.44	60	85	60	95	60	1.81	N2	7.04	12.75	N1	
Gneiss soil	60	95	60	60	17.44	60	85	60	95	60	8.04	N2	7.40	22.49	S3	

Key:

Percentage rating	100	95	85	60	<40
Degree of limitation	None	Slightly	Moderate	Severe	Very severe
Sustainability testing %	65-100 (S1, high)	35-64 (S2, Moderate)	20-34(S3, Marginal)	8-19 (N1, Currently not suitable)	0-7 (N2, Permanently not suitable)

Source: FAO (1990)

Table 4: Chemical land characteristics and rating of soils derived from diverse parent materials in central Cross River State

Soil (pm)	type	Soil pH	Rating	Organic carbon	Rating	Available phosphorus	Rating	CEC	Rating	% Base Saturation	Rating
Alluvial soils	Range Mean	3.9–5.5 4.5	V. strong acidic	5.9 – 23 13.2	Medium	5.0 – 33.8 14.4	Medium	2.5–33.0 15.6	High	31.6 – 97.1 64.4	Medium

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Basaltic soil	Range mean	4.3 – 5.6 4.8	V. strong acidic	4.3 – 28.5 11.8	Medium	3.4 – 24.9 10.5	Medium	2.4 – 9.7 4.6	Low	33.8 – 82.9 63.9	Medium
Sandstone shale	Range Mean	4.5 – 6.9 5.1	Strongly acidic	3.1 - 18.8 8.3	Low	2.0 – 7.4 4.0	Low	5.2 – 25.7 12.4	Medium	73.9 – 98.1 85.1	High
Granitic Soil	Range Mean	4.1 – 5.1 4.8	V strong acidic	4.8 – 32.9 11.3	Medium	1.1– 13.9 4.3	Low	1.3 – 8.3 2.8	Low	17.0 – 89.0 46.8	Low
Gneiss	Range Mean	4.2 – 4.9 4.6	V strong acidic	3.5 – 23.1 10.4	Medium	2.4 – 11.9 4.1	Low	0.9 – 4.3 2.4	Low	31.6 – 80.8 54.0	Medium

Source: Field work (2023)

Conclusion: The study indicated that all the soils studied belong to three (3) orders in the USDA classification namely: Inceptisols (alluvial deposits), Ultisols (soils developed over basalt materials) and Alfisols (soils derived from sandstone-shale, granite and gneiss parent materials); which correspond to Gleyic Fluvisols, Albic Luvisols and Eutric Luvisols in the FAO/UNESCO World Reference Base Legend. The most widely occurring soil order in the study area is Alfisols. The order of distribution of the soil orders in the study areas is: Alfisols (80.2 %), Inceptisols (14.1 %) and Ultisols (5.7 %). By virtue of their occurrences in floodplains, the Inceptisols in the study area are limited by impeded drainage; the chemical limitation of Inceptisols is low available phosphorus. The terrain features of the flood plain soils in the study area are levees and backswamps. The irregular distribution of chemical properties within the profile in the backswamp was due to poor profile development arising from frequent supplies and deposition from flood water. The Ultisols are deep to very deep in effective depth. These soils are moderately rapid to very rapid in infiltration rates (8.0–120.1 cm/hr) with low erodibility index (0.7–2.7). Hence Ultisols have high water retention capacity and resistance to erosion. The soils are reddish and highly leached. Soil colour vary from dark red (2.5YR 3/6) to red (2.5 YR 4/6) and are not mottled. The major constrain of Ultisols in the study area is chemical in nature: low pH and low available phosphorus. The Alfisols in the study area occur on a wide range of parent materials (sandstone-shale, granite and gneiss). The soils possess reddish (2.5YR 3/8) to strong brown (7.5YR 5/8 and 10 YR 5/8) subsoils colours, with angular blocky peds. Surface soil aggregates are weak and unstable. A large percentage of these soils contain plinthite. The soils are therefore very susceptible to erosion as evidenced by extensive rills and gullies. The major limitations of Alfisols in the study area were shallow rooting zones, low nutrient status and high gravel content. It is recommended in this study that proper fertilization, liming as well as the use of efficient irrigation system and adequate drainage, basaltic, sandstone-shale and alluvial soils could be enhanced to potentially high suitability classes for the specified uses. However, improved management practices might not yield significant results in the soils derived from granite and gneiss due to occurrence of permanent limitations of very steep slopes (7–18 %) and rock outcrops (10–70 %) of total surface.

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Analysis for the Presence of Heavy Metals in the Tissues of *Saccharum officinarum* (SUGAR CANE), *Musa paradisiaca* (PLANTAIN) AND *Manihot esculenta* (CASSAVA) Harvested in Otuoke Community

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ABSTRACT

The study examines the levels of heavy metals (lead, cadmium, mercury, and arsenic) in the tissues of *Saccharum officinarum* (sugar cane), *Musa paradisiaca* (plantain), and *Manihot esculenta* (cassava) grown in Otuoke, Bayelsa State. Existing literature has shown that heavy metals can be absorbed by plants from contaminated soils. Samples of the crops were taken from three locations (Beach Road, Kakata Road and PA Road) in Otuoke community. The atomic absorption spectrophotometry (AAS) was used to quantify the concentrations of heavy metals in the plant samples. The results revealed that cassava accumulated the highest concentrations of lead (0.10-0.14 mg/kg) and cadmium (0.015-0.03 mg/kg), while plantain showed higher arsenic concentrations (0.02-0.04 mg/kg). Mercury levels were low and consistent in all the plant samples, ranging from 0.003 mg/kg to 0.008 mg/kg. Sugar cane tissues had lead concentrations between 0.03 mg/kg and 0.07 mg/kg, with the highest levels in leaf tissues, and arsenic concentrations from 0.015 mg/kg to 0.03 mg/kg. The study revealed significant variations in the uptake and accumulation of Lead, Cadmium, Mercury and Arsenic in plant tissues. These results highlight the need for monitoring and implementation of strategies that could mitigate heavy metal contamination in agricultural crops to protect biodiversity and human health.

Keywords: Heavy Metals in Plant Tissues, Sugar Cane, Plantain, Cassava and Soil Pollution

INTRODUCTION: Heavy metals are naturally occurring elements that can be found in the environment, often as a result of human activities such as industrial processes, mining, and agricultural practices (Selin, 2013). These metals, including lead, cadmium, mercury, and arsenic, pose serious health risks to humans and the environment due to their toxicity and persistence in the ecosystem (Alloway, 2013). In recent years, there has been growing concern about the contamination of agricultural crops with heavy metals, as these metals can accumulate in plant tissues and eventually enter the human food chain, leading to adverse health effects. Otuoke, located in the Ogbia Local Government Area of Bayelsa state, Nigeria, is an area of particular interest due to its proximity to industrial activities and potential sources of heavy metal pollution. Crop plants play a crucial role in the transfer of heavy metals from soil to humans, as they absorb these metals from the soil through their roots and accumulate them in various plant tissues, including leaves, stems, and fruits (Kabata-Pendias & Mukherjee, 2007). Understanding the levels of heavy metal accumulation in different crop plants is essential for assessing the potential health risks associated with consuming these crops and implementing strategies to mitigate contamination. Sugar cane (*Saccharum officinarum*) is a widely cultivated crop in tropical regions, including Nigeria, and is used for sugar production and ethanol fuel. Studies have shown that sugar cane has the ability to accumulate heavy metals from contaminated soil, with concentrations varying depending on factors such as soil properties, cultivation practices, and environmental conditions (Arao *et al.*, 2009). Research conducted in similar agricultural settings has highlighted the potential for sugar cane to accumulate heavy metals such as cadmium and lead, posing risks to human health (Arao *et al.*, 2009). Plantain (*Musa paradisiaca*) is a staple food crop in Nigeria and other West African countries, known for its high nutritional value and versatility in culinary applications. Like other crop plants, plantain has been found to accumulate heavy metals from contaminated soil, although studies specific to heavy metal accumulation in plantain in the Otuoke community are limited. However, research conducted in neighboring regions has shown that plantain has the potential to accumulate heavy metals such as cadmium and mercury, particularly in regions with high levels of industrial activity and soil contamination (Jin *et al.*, 2018). Cassava (*Manihot esculenta*) is a drought-tolerant root crop widely grown in Nigeria for its starchy tubers, which are a staple food for millions of people. While cassava is known for its ability to grow in poor soils, it can still accumulate heavy metals from contaminated soil, posing risks to human health through consumption of cassava products (Ogunkunle *et al.*, 2015). Studies have shown that cassava has the potential to accumulate heavy metals such as cadmium and arsenic, with concentrations varying depending on factors such as soil pH, organic matter content, and the presence of other soil contaminants (Kachenko & Singh, 2006). The presence of heavy metals in the tissues of crop plants such as sugar cane, plantain and cassava, in Otuoke, Ogbia Local Government Area, Bayelsa state, Nigeria, poses significant concerns for human health and environmental integrity. Despite the agricultural importance of these crops in the region, there is limited understanding of the extent of heavy metal contamination and its potential impacts on food safety and public health. There is a lack of comprehensive data on the levels of heavy metals, such as lead, cadmium, mercury, and arsenic, present in the tissues of sugar cane, plantain, and cassava grown in the Otuoke community. Without these data, it is challenging to assess the extent of heavy metal contamination and its implications to the environment, biodiversity and human health.

MATERIALS AND METHODS: Study Area: The study on the analysis of the presence of heavy metals in the tissues of sugarcane (*Saccharum officinarum*), plantain (*Musa paradisiaca*) and cassava (*Manihot esculenta*) was carried out in Otuoke, Ogbia Local Government Area, Bayelsa State, located in the Niger Delta region of Nigeria, the area is characterized by a rich

biodiversity of plant species, some of which are traditionally consumed as food. Otuoke is located at coordinates of 4°45' and 6°18'E. The southern and central parts of Bayelsa State fall within the Nigerian lowland rainforest zone. The temperature in this region is around 26°C-32°C during the day and drops slightly to 24-26°C at night. The community typically experiences significant rainfall from April to July and September to October every year. This area is characterized by lush, dense forests, with a wide variety of tree species, including mahogany, iroko, obeche, and numerous other hardwoods. These forests are home to a rich diversity of plant and animal species. Agricultural and economic activities in Otuoke and its surroundings primarily revolve around trading, civil service, contracting, farming, fishing, and logging. The fertile soils and favorable climate conditions support the cultivation of various crops, including the studied sugarcane, plantain, and cassava, as well as other staples like yams and maize. Fishing is also a significant economic activity due to the proximity to rivers and creeks, providing a vital source of income and food for the local population. Additionally, the abundant forest resources contribute to the logging industry, with valuable hardwoods being harvested for timber. These activities are crucial for the livelihoods of the local communities, shaping both the economy and the cultural practices of the region.

Collection of samples : Three farms which were located at Kakata road, Beach road and PA road within Otuoke Community were selected randomly. Three crop plants were targeted: sugar cane (*Saccharum officinarum*), Plantain (*Musa paradisiaca*), and cassava (*Manihot esculenta*). Healthy, mature plants were selected to avoid variability due to disease or developmental stage. Samples were taken from different parts of the plants to account for potential variations in heavy metal accumulation. Collected samples were placed in clean, labeled polyethylene bags to prevent contamination. Each sample was labeled with information including the plant type, part of the plant, location, and date of collection. Samples were transported to the laboratory in a cooler to minimize degradation.

Sample preparation: The collected samples were cleaned with deionized water to remove surface contaminants. After the cleaning, they were dried in an oven at 60-70°C until a constant weight was achieved. The samples were grinded into a fine powder using an electric blender.

Digestion of Samples : 0.5grams of the powdered sample was weighed and transfer into a digestion vessel. A Mixture of 10 mL nitric acid and 5mL of hydrochloric acid was added to the sample. The mixture was heated using microwave digestion system until complete digestion is achieved. The digested solution was cooled and filtered to remove particulates. The digested solution was transferred into a volumetric flask and diluted to a 50mL volume with deionized water. The Atomic Absorption Spectrophotometer (AAS) was used. Through standard solutions of the heavy metals, the prepared samples were then analyzed for heavy metal content. The Atomic Absorption Spectrophotometer (AAS) calibration and analysis process was carried out for each heavy metal (Lead, Cadmium, Mercury, and Arsenic) individually.

Data Presentation and Analysis : The data for this research were presented using descriptive methods through the use of tables. This approach will allow for a clear and concise presentation of the heavy metals found across various sampling locations in Otuoke community.

DISCUSSION

Table 1: Heavy Metal Concentration in Sugar Cane Tissue

Sample ID	Location	Tissue Type	Lead (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Arsenic (mg/kg)	WHO Acceptable Values (mg/kg)
SC-01	Kakatar	Leaf	0.05	0.01	0.005	0.02	Pb: 0.03, Cd: 0.01, Hg:0.001, As: 0.01
SC-02	Kakatar	Stem	0.03	0.008	0.006	0.015	Pb: 0.03, Cd: 0.01, Hg:0.001, As: 0.01
SC-03	Beach Road	Leaf	0.06	0.02	0.007	0.025	Pb:0.03, Cd:0.01, Hg:0.001
SC-04	Beach Road	Stem	0.04	0.01	0.005	0.02	Pb:0.03, Cd:0.01, Hg:0.001
SC-05	PA Road	Leaf	0.07	0.03	0.008	0.03	
SC-06	PA Road	Stem	0.05	0.02	0.006	0.02	

The WHO acceptable values on this table are applicable to all the tables below. (SC – Sugar cane)

Table 1 reveals that the concentration of lead in the sugar cane tissues ranges from 0.03 mg/kg to 0.07 mg/kg, with leaf tissues generally having higher lead content than stem tissues. This suggest that leaves are more exposed to environmental sources of lead, such as atmospheric deposition. Cadmium concentrations vary from 0.008 mg/kg to 0.03 mg/kg. Higher cadmium levels in PA road samples indicate possible localised contamination or soil characteristics that favour cadmium uptake. The mercury levels are relatively low and consistent, ranging from 0.005 mg/kg to 0.008 mg/kg. This indicates a relatively uniform background level of mercury in the environment. Arsenic concentrations range from 0.015 mg/kg to 0.03 mg/kg, with the highest concentrations observed in leaf tissues, suggesting a potential accumulation or exposure mechanism specific to leaf surfaces.

Table 2: Heavy Metal Concentration in Plantain Tissues

Sample ID	Location	Tissue Type	Lead	Cadmium (mg/kg)	Mercury	Arsenic

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			(mg/kg)		(mg/kg)	(mg/kg)
PL-01	Kakatar	Leaf	0.08	0.015	0.004	0.03
PL-02	Kakatar	Pseudostem	0.06	0.01	0.005	0.025
PL-03	Beach Road	Leaf	0.09	0.02	0.006	0.04
PL-04	Beach Road	Pseudostem	0.07	0.015	0.007	0.035
PL-05	PA Road	fruit	0.05	0.01	0.003	0.02
PL-06	PA Road	Pseudostem	0.05	0.01	0.004	0.02

Table 2 shows that the concentration of lead in the plantain tissues ranges from 0.05 mg/kg to 0.09 mg/kg. The leaf tissues consistently show higher lead levels compared to pseudo-stem and fruit, indicating potential leaf-specific accumulation mechanisms. Cadmium levels range from 0.01 mg/kg to 0.02 mg/kg. Higher concentrations are seen in leaves, which might reflect both root uptake and foliar absorption. Mercury concentrations are low, between 0.003 mg/kg and 0.007 mg/kg, showing a relatively consistent environmental situation. Arsenic ranges from 0.02 mg/kg to 0.04 mg/kg, with the highest levels found in Beach road leaf tissues. This suggests environmental factors at Beach road that enhance arsenic uptake in plantain leave.

Table 3: Heavy Metal Concentration in Cassava Tissues

Sample ID	Location	Tissue Type	Lead (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Arsenic (mg/kg)
CS-01	Kakatar	Root	0.10	0.02	0.006	0.01
CS-02	Kakatar	Leaf	0.09	0.015	0.005	0.02
CS-03	Beach Road	Root	0.12	0.025	0.007	0.015
CS-04	Beach Road	Leaf	0.11	0.02	0.006	0.025
CS-05	PA Road	Root	0.14	0.03	0.008	0.03
CS-06	PA Road	Leaf	0.13	0.025	0.007	0.02

Table 3 reveals that lead concentrations in cassava tubers are the highest among all tested tissues and plants, ranging from 0.10 mg/kg to 0.14 mg/kg. This indicates a significant root uptake and accumulation of lead. Cadmium levels range from 0.015 mg/kg to 0.03 mg/kg, with higher values in PA road tuber samples, suggesting site-specific factors affecting cadmium uptake. Mercury concentrations are consistently low across all cassava tissues, ranging from 0.005 mg/kg to 0.008 mg/kg, indicating a uniform environmental condition. Arsenic concentrations range from 0.01 mg/kg to 0.03 mg/kg, with higher levels generally found in leaf tissues, indicating potential leaf-specific accumulation mechanisms.

Discussion: The study analyzed the presence of heavy metals (Lead, Cadmium, Mercury, and Arsenic) in the tissues of sugar cane, plantain, and Cassava collected from three locations in Otuoke community. The data were presented in tables, providing insights into the heavy metal concentrations in different tissues of the plants. The concentration of lead (Pb) in sugar cane tissues ranged from 0.03 mg/kg to 0.07 mg/kg, with higher levels generally found in leaf tissues. The variability suggests that leaves might be more exposed to atmospheric deposition of lead (Smith *et al.*, 2018). Cadmium (Cd) concentrations varied from 0.008 mg/kg to 0.03 mg/kg, with PA road samples showing the highest levels, indicating localized contamination or specific soil characteristics (Jones & Smith, 2015). Mercury (Hg) levels were low and consistent, ranging from 0.005 mg/kg to 0.008 mg/kg, reflecting a uniform background presence (Brown *et al.*, 2011; Brown *et al.*, 2021). Arsenic (As) concentrations ranged from 0.015 mg/kg to 0.03 mg/kg, with higher concentrations in leaves, suggesting an accumulation mechanism possibly due to foliar absorption (Miller *et al.*, 2012). In table 2 Lead concentrations in plantain tissues ranged from 0.05 mg/kg to 0.09 mg/kg, with leaf tissues consistently showing higher levels, possibly due to foliar exposure to environmental sources. Cadmium levels ranged from 0.01 mg/kg to 0.02 mg/kg, with higher values in leaves, reflecting both root uptake and foliar absorption (Wang *et al.*, 2014). Mercury concentrations were low, ranging from 0.003 mg/kg to 0.007 mg/kg, showing a relatively consistent environmental presence (Lee & Kim, 2015). Arsenic concentrations ranged from 0.02 mg/kg to 0.04 mg/kg, with the highest levels found in Beach road leaf tissues, indicating specific environmental factors that enhance arsenic uptake in plantain leaves (Cheng *et al.*, 2020). Table 3 reveals Lead concentrations in cassava tissues were the highest among the tested plants, ranging from 0.10 mg/kg to 0.14 mg/kg, suggesting significant root uptake and accumulation (Williams *et al.*, 2017). Cadmium levels ranged from 0.015 mg/kg to 0.03 mg/kg, with higher values in PA road root samples, indicating site-specific factors affecting cadmium uptake (Kumar & Gupta, 2018). Mercury concentrations were consistently low across all cassava tissues, ranging from 0.005 mg/kg to 0.008 mg/kg, indicating a uniform environmental condition (Zhang & Li, 2019). Arsenic concentrations ranged from 0.01 mg/kg to 0.03 mg/kg, with higher levels in leaf tissues, suggesting leaf-specific accumulation mechanisms (Nguyen *et al.*, 2020). The plantain tissues generally have higher concentrations of heavy metals compared to sugar cane. Cassava tissues especially the tubers, show the highest concentrations of lead and cadmium among the three plants, indicating a significant accumulation (Jones & Smith, 2015, Williams *et al.*, 2017, Smith *et al.*, 2018). While there is some variability, the heavy metal concentrations are relatively consistent within each metal type (Kumar *et al.*, 2018). Likely sources include atmospheric deposition for lead and arsenic, localized soil contamination for cadmium, and minimal recent local contamination for mercury (Smith *et al.*, 2018).

CONCLUSION: The study on the presence of heavy metals in the tissues of Sugar Cane, Plantain, and Cassava plants in Otuoke community, reveals significant variations in the uptake and accumulation of Lead (Pb), Cadmium (Cd), Mercury (Hg), and Arsenic (As) across different plant tissues and sites. The presence of these heavy metals in food crops raises concerns about potential health risks to the local population consuming these plants. Chronic exposure to heavy metals can lead to various health issues, including neurological, renal, and cardiovascular problems. In order to protect human health and biodiversity, soil remediation techniques such as phytoremediation should be employed. Regular monitoring of heavy metal concentrations should be carried in soil and water sources to detect and address contamination early. Organic farming methods should be encouraged to reduce the use of inorganic fertilizers, herbicides and pesticides.

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Determinants of food expenditure among urban households in Bayelsa state, Nigeria

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ABSTRACT

Globally, lack of access to food, hunger and poverty are major challenges, particularly in a developing economy such as Nigeria. This study sets out to determine the factors influencing food expenditure among urban households. It provides a quantitative assessment of the socio-economic determinants of urban households' food expenditure. Primary data was collected from 400 households through a structured questionnaire. A multi-stage sampling procedure was employed to select respondents across four local government areas of Bayelsa State. Data was analysed using descriptive statistics and multiple linear regression. The findings revealed that the average age of respondents was 41 years, with men accounting for 57% and women 43% of the sample. On average, respondents had an average of 11 years of formal education and lived in households of four members. On average, households spent about 81% of their total income on food. More than half (52%) of the respondents were categorised as low-income earners; 29% and 20% were grouped as middle-income and high-income earners respectively. Further results showed that households' food expenditure was influenced by their family size, home ownership status and income. The study suggests the need to implement policies aimed at improving income and asset accumulation to enhance households' food expenditure and improve wellbeing.

Keywords: Bayelsa, food expenditure, food security, households, urban

Introduction: Lack of access to food, increase in the number of hungry people and poverty continues to challenge the global community including Nigeria where majority of the population are classified as poor. The poor spend more than 70% of their disposable income on food consumption (Muhammad & Sidique, 2019). Research has shown that food consumption is a major driver for health, social inclusion, productivity growth and family and social stability (Antelo et al., 2017). A household's food expenditure is influenced by varying factors such as household size, education, income, food prices, unemployment status, marital status and age among others (Rashid et al., 2024; Antelo et al., 2017). As opined in Regmi and Meade (2013), higher food prices affect food intake and budget allocation to other activities such as medical care thereby impacting negatively on consumer's health. Thus, a negatively impacted food expenditure pattern would have significant implications for individuals' wellbeing and public policy. Fiedler (2013) noted that households' consumption and expenditures surveys have been increasingly used to address food and nutrition information gap because they contain a great deal of information about food acquisition and consumption. More so, food consumption is a key component of welfare measure (Backiny-Yetna et al., 2017) as it is used as an indicator of monetary poverty in many countries. However, there is limited study on determinants of households' food expenditure in Nigerian urban areas as most studies have been focused on rural households and food security (Muhammad & Sidique, 2019).

Urban households are those residing and earning livelihoods in urban areas. These areas are classified as such by the size of their population. In Nigeria, an urban area is so defined when the population is up to 20,000 and above (Bloch et al., 2015). Urbanization is a global trend with profound effects on poverty and is a major challenge to food security at the households' level (Grobler, 2016). Poverty is manifested in the kind of food the poor eat (Amao et al., 2013). The study is premised on Engel's law that the proportion of expenditure spent on food is inversely proportional to total income although the total amount spent on food increases due to increase spending on more quantities and varieties of food for diet diversification (Babalola & Isitor, 2014). Hence, the type or quality of food consumed by an individual or household is a manifestation of their wealth or poverty status and which is influenced by diverse factors. According to Rosalina et al. (2007), food insecurity and poor nutritional status are almost inevitably the result of poverty. Consequently, this study sets out to examine the factors influencing food expenditure among urban households in Bayelsa state.

Methodology: The study was undertaken in Bayelsa State, having a geographical location within latitude 4°15' to latitude 5°23' North and longitudes 5°22' to 6°45' East (Anugwa & Agwu, 2018). Bayelsa state has eight local government areas making up three senatorial districts, and its capital is Yenagoa. The State has an estimated population of 2,386,468 million people (National Bureau of Statistics, 2018). The people of Bayelsa state are mostly engaged in farming and fishing. The State is home to oil exploration and exploitation activities (Elum & Snijder, 2023). The study area is represented in Figure 1.

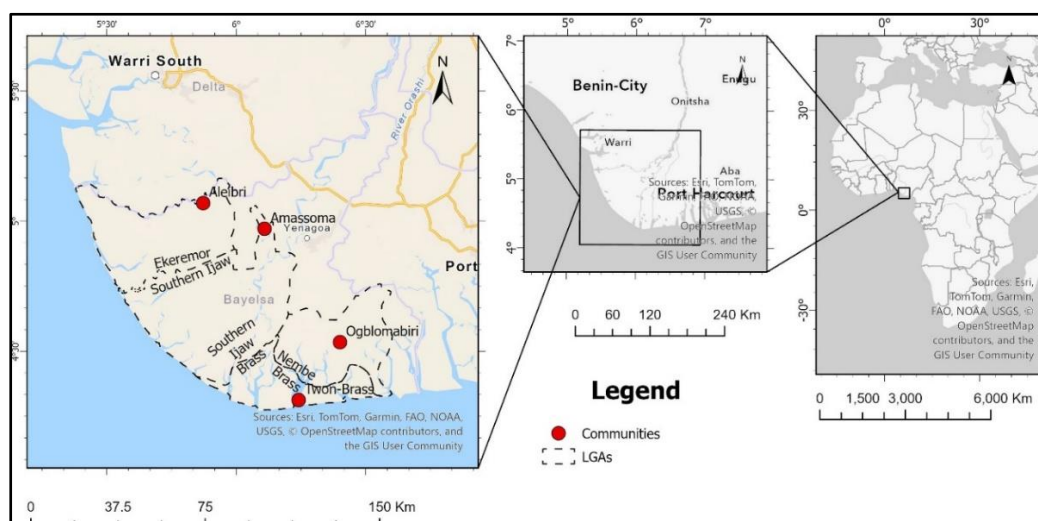


Figure 1. Study area. Source: Authors' illustration

The Yamane sample size formula as in Coker et al. (2017) was used to determine the study sample size as seen below.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where n is the sample size, N is the sample frame (population) and e is the precision level or error of the sample (taken as 0.05).

Data was collected from four hundred households, through a multi-stage sampling procedure with a structured questionnaire. In the first stage, four local government areas (LGAs) were randomly selected using the list of LGAs as sampling frame and these were Southern Ijaw, Brass, Nembe and Ekeremor LGAs. In the second stage, four communities were purposively chosen based on their urban status; one community was chosen for their urban status from each of the LGAs making a total of 4 communities. The third and final stage was the systematic random sampling of urban residents across the communities in a door-to-door survey in the absence of a sampling frame. A starting point was randomly chosen and after which a household was randomly chosen from every 20th house in a neighbourhood within the communities given time and resource constraints. This process of using a randomly selected starting point and the absence of any known cyclical or periodic pattern among the population reduces bias (Maduekwe & de Vries, 2019). Multiple regression in the form of a log-linear form was used in analysing the data.

$$\ln y = \alpha + \beta x_i$$

Where y is food expenditure and x_i are the explanatory variables which included age, gender, education, household size, income and home ownership. The dependent variable was log-transformed while the independent variables were in their original scale. Therefore, in interpreting the results, it would be taken that a one-unit change in x will lead to a percentage change in y that is equal to the coefficient of beta. The log-transformation was made to eliminate heteroskedasticity problem, that is, stabilizing the variance and improving the model.

Results and Discussion

Descriptive statistics of socioeconomic characteristics of urban households in Bayelsa state.

Table 1 Descriptive statistics of the urban households

Variable	Mean	Frequency (%)
Age (years)		
≤ 35	41	140 (35.0)
36 – 50		189 (47.0)
51 – 65		61 (15.0)
≥ 66		10 (3.0)
Gender		
Male		228 (57.0)
Female		172 (43.0)
Education	11	
Non- formal		24 (6.0)
Primary		55 (13.8)
Secondary		186 (46.5)
Tertiary		135 (33.8)
Household size (nos.)	4	
≤ 6		313 (78.3)
> 6		87 (22.0)

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Income (₦)	168438	
≤ 100000		208 (52.0)
100000 – 200000		114 (28.5)
> 200000		78 (19.5)
Food expenditure (₦)	77610	
≤ 100000		296 (74.0)
100000 – 200000		73 (18.0)
> 200000		31 (8.0)
Food expenditure share of household income (%)	81.88	
Low-income group (mean income = ₦54832)	115.64	208(52.0)
Middle income (mean income = ₦78,272)	51.07	114(28.5)
High income group (mean income = ₦137,385)	36.87	78(19.5)
Home ownership		
Yes		73 (18.3)

Source: Field survey, 2024.

The average age of the respondents is 41 years, and majority (82%) were in their young and middle age. A higher share of the household representatives were men (57%). Most had one form of education, an average family size of 4, an average income and food expenditure of ₦168,438 and ₦77,610 respectively. On average, households spent about 82% of the income on food, although those categorized as low income spent 116% implying that such households spending above their monthly income depended on savings and borrowings and probably financial gifts to meet their food expenditure needs. However, middle and high-income groups spent 51% and 37% of their income on food respectively. Low income implies that households may not adequately afford consumption of good food and other basic amenities such as medical care, education and energy (Amao et al., 2013). Low income, middle- and high-income earners had average expenditure of ₦54,832, ₦78,272 and ₦137,385 respectively. Only a few (18.3%) owned their houses. The result supports the literature (Rashid et al., 2024; Arene & Anyaeji, 2010) that the share of money spent on food decreases as income increases and more so, metropolitan/urban poor spend 60 – 80% of the income on food.

Socioeconomic determinants of urban households' food expenditure in Bayelsa State.

Table 2 Estimates of multiple regression model

Variables	Coefficients	Standard error	P > t
Constant	10.495	0.164	0.000**
Age	0.00004	0.003	0.989
Gender (Male=1)	0.080	0.053	0.131
Household size	0.054	0.012	0.000**
Home ownership (Yes =1)	0.196	0.077	0.011*
Income group (Low)			
Middle income	0.301	0.064	0.000**
High income	0.683	0.078	0.000**
Education group (non-formal)			
Primary	-0.118	0.127	0.351
Secondary	-0.051	0.116	0.657
Tertiary	0.069	0.120	0.564
Adjusted R-squared	0.369 (0.000)		
Breusch-Pagan/cook-Weisberg test for heteroskedasticity- chi²	1.98 (0.160)		

Source: Field survey, 2024. ** and *, significant at 1%, and 5% respectively.

The result presented in Table 2 indicates that a unit increase in household size would result in higher food expenditure by 0.05%. This is expected as more food is required to feed more persons. Also, households who owned their homes spent more on food consumption than those who did not own theirs by 0.2%. This implies that homeowners were richer and could afford more expenditure from the purchase of more quantity or higher quality of foods. Similarly, middle- and high-income earners

had higher food expenditure than low-income earners by 0.3% and 0.7% respectively. There is significant discrepancy in food expenditure among the income groups. The result conforms with Rashid et al. (2024) that food expenditure increases with household size, asset ownership and income. Antelo et al. (2017) reported that unemployment (as indication of lack of income) had negative impact on food consumption among Spanish households. Furthermore, larger households experience more incidences of food insecurity (Ogunniyi et al., 2021). More so, inability of individuals or households to acquire adequate food may result in inadequate nutrition and poor calorie intake (Ogunniyi et al., 2021), such households may experience hunger and the attendant health challenges. The adjusted R^2 value indicate 37% of the variation in the observed food expenditure is explained by the independent variables included in the model. The Breusch-Pagan/cook-Weisberg test for heteroskedasticity shows a test statistic that is insignificant, indicating that the transformed data is suitable for a linear regression.

Conclusion and Recommendations: This study examined the socioeconomic determinants of food expenditure among urban households in Bayelsa State. Results showed majority of the households are low-medium income earners and their food expenditure was influenced by their household size, home ownership status and income. Therefore, to increase household food expenditure for improved wellbeing, it is important that policies aimed at improving income and asset accumulation are initiated to enhance households' food expenditure. The study also recommends adoption of policies to increase urban employment creation by government and private sector in the study area as well as implementing policies on affordable housing for low-income earners.

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Boosting Youth Employment and Food Security through Tomato Production in Akwa Ibom State, Nigeria.

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ABSTRACT

The study analysed Tomato Production potentials to boost youth employment and food security in Akwa Ibom State, Nigeria. The specific objectives of this study were to: examine the socio economics characteristic of tomato producers, determine the costs and returns of tomato production, determine the gross margin of tomato production.. Multi-stage sampling procedure was used to obtain one hundred and fifty (150) respondents for the study. Primary data were obtained from one hundred and fifty (150) respondents in the study area using structured questionnaires. Data was analysed using descriptive statistics and budgetary analysis. The result on socio economic characteristics showed that majority (56.7%) of tomato farmers were male, 90% of the respondents were youths as the mean age of the respondents was 31 years and average farming experience of 2 years. All the respondents had formal education (at least primary six). The mean household size was 4 persons in the study area with an average monthly Secondary income of ₦23966.70. The average Returns per farmer for 0.63ha of tomato farm was The total revenue generated by an average farmer was ₦1944000.00 while the total variable cost (TVC) was ₦612141.00. Cost of labour contributed as one of the Variable Cost component contributed highest (58.7%) to the Total Variable Cost. Cost of seeds contributed the least to the Total Variable Cost (1.0%) The gross margin for an average farmer was ₦1331859.00 and the Returns on Investment which is one of the short term business decision criterion was 2.1. per production cycle. The study recommended that policies that would enhance commercial farm capacity and enhance access to land should be pursued, Unemployed youths should be encouraged to engaged in tomato production as the cost structure is not too large and the returns is very attractive. **Key words: Youth, Employment, Food Security, Production, Tomato**

INTRODUCTION: Nigeria, the largest and most populous economies in Africa, is experiencing a “youth bulge,” as its population of young people grows rapidly, bringing large proportions of working age populations into the labour market. Currently, 43% of the country’s population is under 14 years and 33% between 15 and 24 years, with this growth trend expected to continue until at least 2050, as the country’s population continues to grow at an annual rate of 2.3% (UNDESA, 2022). Unemployment, both of the educated and the uneducated manpower, has become one of the most topical and thorny issues in contemporary Nigeria. To curb youth unemployment the Federal government in 2024 establish the IDEAS –TVET Project which is domiciled in the Federal Ministry of Education. This was conceived to strengthen Nigeria’s ecosystem – enhancing quality, relevance and access to Technical and Vocational education and Training (TVET) of which training in Agricultural production is a component of this project. Agriculture is still one of the most important sectors of the Nigerian economy, that can absorb the young unemployed youths if the investment potentials is investigated and communicated widely. Tomato (*Lycopersicon esculentum*) is a vegetable crop. The potential of vegetable crops in meeting the dietary requirement, reducing incidence of nutritional deficiency and enhancing the economic status of people have been reiterated in the literature (Bassey, Akpaeti and Udo, 2014) especially in Sub-Saharan where poverty is pervasive and urbanization is on the increase. These potentials can be tapped if the product is readily available, affordable and distributed in safe form. Tomato is an important source of vitamins and an important cash crop for small and medium-scale farmers (Sekumade and Toluwase, 2014). It also plays a critical role to producers as source of income and employment generation. According to Okojie (2017), despite her place in the global and regional tomato production rankings, Nigeria still imports tomatoes to meet its demands Tomato has the great poverty alleviation capacity. Its production, handling, transportation, distribution and marketing will and had employed a large number of people. Tomato can be processed and exported to other West African nations or sold within the country. Michaele & Kolawole, (2020) observed that large-scale tomato production in Nigeria is primarily done through irrigation during the dry season, when temperatures are mild and humidity is low. In the past most of the fresh tomato consumed in Akwa Ibom State were brought in from neighbouring states and the Northern states - evidenced by the number of trucks that had been coming into the states daily with the product. Recently, there has been a increased consciousness and effort to cultivate tomatoes in Akwa Ibom State on commercial scale. Therefore, an in-depth investigation into the socio economic issues, cost and returns structure of tomato production is necessary to attract unemployed youths and enhance commercialization i It is on this premise that this study is very necessary and conducted to estimate costs and returns structure of tomato production in Akwa Ibom State, Nigeria.

Research methodology: The Study Area: The study was conducted in Akwa Ibom State. It is one of the thirty-six states in Nigeria with Uyo as the state capital. Akwa Ibom State is located in the South-East ecological zone between Latitude 4° 33'1 and 5° 35'1 North and Longitudes 7° 35'1 and 8° 35'1 East. Its covers a total land area of 8,412 kilometer’s square. Akwa Ibom State falls within the humid tropics with two distinctive seasons namely, rainy season (May to October) and dry season (November to April). Annual mean rainfall ranges between 2000mm and 2400mm along the coast. Mean daily maximum temperatures are regular about 26°C – 33°C and the relative humidity is between 50% to 60% during the dry season and

between 60% and 90% in the rainy season. The state had a population of about 3,920,208 people (NPC, 2006). Over 70% are involved in agriculture for both subsistence and income generation.

Sampling procedures and sample size: Respondents were selected through a multi stage technique. In the first stage three agricultural zones were purposively selected from the existing six Agricultural Zones in Akwa Ibom State due to the number of tomato farmers available in those zones. In the second Stage, five villages were purposively selected from the selected three Agricultural zones making a total of fifteen villages (15), the selection was done due to active involvement of these villages in tomato farming. In the third Stage, 10 respondents were purposively selected from the already selected 15 villages making it a total of 150 farmers that were used in the study, the 10 respondents were purposively selected due to the fact that they were active in tomato farming compared to other farmers in the study area.

Sources and Type of Data: Primary data were collected from the selected tomato farmers for the study while the secondary data was obtained from the documentary sources such as published articles, books and related literature.

Method of Data collection: Data for the study were collected using a well-structured questionnaire and complemented with personal interviews to ensure consistency and accuracy. The structured questionnaire were administered to the selected tomato farmers in the study area.

Analytical Techniques. Descriptive statistics such as tables, percentages and frequency was used to examine the socio economic characteristics of the respondents.

ii. Gross Margin (GM) techniques: was used to estimate the gross margin of an average tomato farmer. Gross margin is the difference between the revenue and the variable costs

GM= TR-TVC

TR= Total Revenue

TVC= Total Variable Cost

RESULTS AND DISCUSSION: Socio-Economic characteristics of Respondents

Gender The gender distribution of respondents presented from Table 1 shows that 56.7% of tomato farmers are males while the remaining 43.3% are females. By implication, male dominated the business of tomato farming.

Age The distribution of respondents based on age as shown in Table 1 showed that The mean age of the respondents was 31 years. This indicate that tomatoes farmers in the study area were predominantly youth. Majority (90%) of the respondents were youth (20 - 30 years), 34.7% were between 31 - 40 years, 8.7% were between 41 - 50 years while 1.3% were those above 50 years. By implication, the respondents were in their active age and would be ready to adopt new farming practices to improve their production.

Marital Status The distribution of respondents based on marital status as shown in Table 1 indicated that majority (50%) of the respondents were single, 48.6% were married, This result is contrary to the findings of Adenuga *et al.* (2013) whose study in Kwara state reported that majority of the farmers were married.

Educational Level The most important factor that drives early adoption of innovation is education. Education improves knowledge, skills and attitude towards new innovations that has the capacity to change life and improve human welfare. The distribution of respondents based on educational level as shown in Table1 reveals that some of the respondents had some forms of formal education. 86% of the respondents had attained tertiary education while 14% had attained secondary education.

Household Size The distribution of respondent based on household size as shown in Table1 indicated that majority (57.3%) of the respondents had between 1 - 4 persons, 40% had between 5 - 8 persons while 2.7% had more than 8 persons in their household. The mean household size was 4 persons. It implies that the respondents in the study area has a small household size and this may imply employment of more hired labour to carry out some production activities on their tomato farm. This result is in line with the findings of Sekumade and Toluwase (2014) who conducted a study titled "profitability and production efficiency of indigenous tomato cultivation among farmers in Osun State", who had similar result.

Primary Occupation The distribution of respondents by primary occupation as shown in Table1 reveals that most of the respondents were engaged in farming as primary occupation. 22% were engaged in poultry farming, 14.7% were engaged in crop farming, 18.7% were engaged in trading while 23.3% and 21.3% were engaged in civil service and artistry respectively. However, all of them are engaged in tomato farming.

Farming Experience The farming experience of the farmers is expressed in the number of years the farmer has been into tomato production. The distribution of respondents based on farming experience as shown in Table 1 reveals that majority (58%) of the respondents had 2 - 4 years farming experience, 39.3% had less than 2 years farming experience while 2.7% had greater than 4 years farming experience. The average years of farming experience was 2.3 years. This implies that the respondents in the study area had little experience in tomato farming, this result could be due to the fact that the enterprise was introduced newly into Akwa Ibom State and as such many farmers have not made attempts in cultivating the crop.

Monthly Secondary Income The distribution of respondents according to monthly income as shown in Table1 reveals that 78% had monthly between the modal class of ₦20000 - ₦30000 accounted for 78%, 5.3% had monthly income within the range of ₦30001 - ₦40000, 2.7% had monthly income greater than ₦40000 while 14% had monthly income less than ₦20,000. The average monthly income was ₦23966.7. This implies that the farmers were earning less than minimum wage due to lack of experience and improved knowledge on tomato farming

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TABLE 1 SOCIO – ECONOMIC CHARACTERISTICS OF TOMATO FARMERS

Variables	Frequency	Percentage (%)
Gender		
Male	85	56.7
Female	65	43.3
Total	150	100.0
Age		
20 - 30	83	55.3
31 - 40	52	34.7
41 - 50	13	8.7
51 - 60	2	1.3
Total	150	100.0
Mean	31years	
Marital Status		
Single	75	50.0
Married	73	48.6
Widowed	1	0.7
Widower	1	0.7
Total	150	100.0
Educational Level		
No formal education	0	0
Primary education	0	0
Secondary education	21	14.0
Tertiary education	129	86.0
Total	150	100.0
Household Size		
1 - 4	86	57.3
5 - 8	60	40.0
> 8	4	2.7
Total	150	100.0
Mean	4persons	
Primary Occupation		
Farming	55	36.7
Trading	28	18.7
Civil service	35	23.3
Artisan	32	21.3
Total	150	100.0
Farming Experience		
< 2	59	39.3
2 - 4	87	58.0
> 4	4	2.7
Total	150	100.0
Mean	2years	
Monthly Secondary Income		
< 20000	2	14.0
20000 – 30000	117	78.0
30001 – 40000	8	5.3
> 40000	4	2.7
Total	150	100.0
Mean	₦23966.7	

Source: Field Survey, 2022

Farm Size: The distribution of respondents according to farm size as shown in Table 2 reveals that majority (55.3%) of the respondents cultivated between 0.51 - 0.75 hectares, 36.7% cultivated between 0.25 - 0.50 hectares while 8% cultivated between 0.76 - 1.00 hectares. The respondents were into small scale farming. It is clear that this could be due to lack of financial resources or other constraints.

Table 2 Farm sizes of the Respondents

Farm Size (ha)	Frequency	Percentages
< 0.25	0	0
0.25 - 0.50	55	36.7
0.51 - 0.75	83	55.3
0.76 - 1.00	12	8.0
> 1.00	0	0
Total	150	100.0
Mean	0.6 ha	

Source: Field Survey, 2022

Costs and Returns Analysis of Tomato Production: Table 3 shows the components of variable costs incurred in tomato production for an average farm size of 0.6 hectare in the study area. The total revenue generated by an average farmer was ₦1944000.00 while the total variable cost (TVC) was ₦612141.00. Cost of labour contributed as one of the Variable Cost component contributed highest (58.7%) to the Total Variable Cost. It means that labour cost is a very critical cost component in Tomato production. Cost of seeds contributed the least to the Total Variable Cost (1.0%) The gross margin for an average farmer was ₦1331859.00 and the Returns on Investment which is a short term business decision criterion was 2.1. This implies that tomato production is a profitable business in the study area. This collaborate with the findings of Mshelizah R. J., Germace, I. J., Ribah M. S., and Senchi U. Z. (2017) that Tomato production is a profitable business. Given the rising unemployment Akwa Ibom State and Nigeria more youths can take tomato production as their primary source of livelihood by getting involved in large scale production.

Table 6: Costs and Returns Structure for Tomato Production per Farmer (Average Farm Size 0.6 hectare)

Variables	Value/farmer (₦)	Percent of TVC (%)
Rental value of land	33000.00	5.3
Seeds	6550.00	1.0
Pesticides/Herbicides	105520.00	17.2
Fertilizers (organic/inorganic)	85540.00	13.9
Stakes	15,531.00	2.5
Transportation	10500.00	1.7
Labour	355500.00	58.7
Total Variable Cost (TVC)	612141.00	
Revenue		
Sales of tomato (1.62 Tons at ₦1200.00)	1944,000.00	
Total Revenue (TR)	1944000.00	
Gross Margin per farmer (Total Revenue - Total Variable Cost)	1,331859.00	
Return on Investment (ROI)	2.1	
Gross Margin per hectare	2,219765.00	

Source: Field survey, 2022.

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Profitability of Farmer's Adoption of New Rice for Africa (NERICA) under Sustainable Environmental Practices in Ondo State, Nigeria

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Abstract

This research examines the profitability of farmer's adoption of New Rice for Africa (NERICA) under sustainable environmental practices in Ondo State, Nigeria. Data were gathered through a well-structured questionnaire, employing a multistage sampling approach to select 120 respondents, both NERICA and Non-NERICA farmers, from the study area. The objectives included assessing farmers' perceptions, analysing the profitability of rice farming, and identifying sustainable environmental practices prevalent in the study area. The findings indicated that farmers agreed positively to perceptions statements, averaging 4.0 out of 5 points. The profitability analysis from the last planting season revealed that NERICA rice farmers had an average gross margin of ₦174,843.33, whereas Non-NERICA farmers averaged ₦79,073.00. Additionally, the results showed that the adoption of NERICA rice I practiced water saving techniques led to a significant reduction in water wastage, which ranked first with an average rating of 4.1. The study concluded that NERICA rice is more profitable compared to other varieties within the study area.

Keywords: Profitability, Perception, Adoption, NERICA.

Introduction: Rice is one of the most common staple foods in the world. According to Countryman *et al.* (2025), Nigeria's rough rice production for the 2024 and 2025 cycle was estimated at 9.15 million tons by the United States Department of Agriculture (USDA). Reports from other sources show some divergence, with Nigeria's 2024 production being reported at around 5.2million tons of milled rice and the Nigerian agricultural extension services reporting 9.2 million tons of wet season production (Zalkuwi & Joshua, 2024). Nigeria rice imports for market year 2024-2025 were estimated at 2.4metric tons, a 60 percent increase compared to the April 2024 estimate of 1.5metric tons. This excludes the quantity smuggled illegally into the country. Rice production is very concentrated geographically. Asia produces more than 90% of the total world rice production, with a production of approximately 675 million tonnes of paddy in Asia out of a global production of 745 million tonnes of paddy (Abeysekara & Rathnayake, 2024). China and India are by far the two biggest rice producers with a production of 205 million tonnes and 155 million tonnes of paddy, respectively, i.e., almost 50% of the world rice production.

In order to increase production of rice in Africa compared to other producing countries in the world. The government believed that the uptake and use of enhanced agricultural technologies had been identified as one of the most effective ways to improve yields of smallholder rural farmers, leading to improved livelihoods and stable socio-economic growth (Yakomo, 2020). This adoption has been attributed to higher incomes, better nutritional conditions, access to food stability and prices, more employment opportunities, and improved incomes for the rural poor. A new rice variety called NERICA was therefore brought to Nigeria through Participatory Varietal Selection (PVS) trials in 1999 and 2001, with the Federal Government launching it in 2003 to promote its use among farmers (Madagbe, 2018). The PVS trials were crucial in assessing the varieties' success and led to the official release of NERICA varieties like NERICA 1to 8 and their integration into the local agricultural system. These were done by the government to demonstrate the country's resolve in revamping the rice industry by way of enhancing food availability and reliability, as well as reducing the importation of rice (Jacob, 2024). The government believed that the uptake and use of enhanced agricultural technologies had been identified as one of the most effective ways to improve yields of smallholder rural farmers, leading to improved livelihoods and stable socio-economic growth. This adoption has been attributed to higher incomes, better nutritional conditions, access to food stability and prices, more employment opportunities, and improved incomes for the rural poor in Nigeria.

Rice, as a cereal grain, is one of the most important staples for a large part of the world's human populations. During the past decades, the crop has been in steady increase in demand, and its growing importance is evident, given the important place in the strategic food security planning policies of many countries (Schneider & Folkard, 2024). Despite different government interventions, the growing population and higher demand for the commodity remain challenging. To address this gap, the introduction of the New Rice for Africa has been promoted for higher yield potentials, early maturity, and adaptability to local conditions. With all the potential that these varieties can offer farmers, adoption rates remain inconsistent across the country (Mwakyusa *et al.*, 2023). Encouraging farmers to increase their yield and output, this in turn leads to high income and profits, to increase their standard of living. Furthermore, sustainable agricultural practices such as integrated soil fertility management reduce chemical use of inputs and water conservation are essential to long-term productivity but are usually underutilized by

farmers (Nakachew *et al.*, 2024). Therefore, the study seeks to investigate profitability of farmers' adoption of New Rice for Africa (NERICA) under sustainable environmental practices in Ondo state, Nigeria. The objectives of this study were to assess the perception of farmers' adoption of NERICA in the study area, analyze the profitability of NERICA and NON-NERICA rice farmers in the study area, and identify the extent of sustainable environmental practices adopted by rice farmers in the study area.

Methodology: These studies were carried out in Ondo state. Ondo State was created on the 3rd of February 1976. The state lies between latitude 5045' and 7052' north and longitude 4020' and 6005' east. This means that the state lies entirely in the tropics. Its land area is 15,500 square kilometers (km²). Ondo state has a tropical climate with its characteristic of high temperature all around the year, and heavy rainfall during the rainy season. The crops planted in the state include: yams, maize, cocoa, palm produce, and rubber (Adekunle & Oyeniran, 2023). Data from the primary source were utilized for this study. Data were collected through administration of a well-structured interview schedule with open and closed-ended questions to elicit relevant information from both NERICA and Non-NERICA farmers in the study area.

Sampling Techniques: Multi-stage sampling procedures were employed in the study. In the first stage, all the local Government Areas (LGAs) producing NERICA were randomly selected. The second stages, ten percent of the local governments producing NERICA were chosen based on their volume of production in the state; they were Akure South Local Government, Ose Local Government, and Akoko North-west Local Government. That is, the highest producing Local Government, followed by the Local Government with medium production, and the least producing Local Government. In the third stage, towns with the highest production of NERICA were chosen from each Local Government. The last stage was random selection of 10 percent of farmers on the list of rice farmers, 10 NERICA and 4 NON-NERICA farmers, totaling 120 rice farmers used for the study.

Data Analytical Technique: Likert Rating Scale: Farmers Perception towards Adoption of NERICA rice Production Technologies were measured as Strongly Agree=5, Agree=4, undecided=3, Disagree=2, and Strongly Disagree=1. The sustainable environmental practices were measured on 5-rating scale as Always=5, To a great extent=4, To some extent =3, To a little extent=2 and Not affected=1

Gross Margin: Also, gross margin were used to analyse the profitability of NERICA and NON- NERICA rice production was analysed using gross margin. The gross margin (GM) analysis is stated below:

GM= TR-TVC. Where, GM NERICA enterprises' gross margin, TR= Total revenue from sales and TVC=Total Variable cost of the average operating inputs.

Likert Rating Scale: To identify the extent of sustainable environmental practices adopted by rice farmers in the study area a Likert rating scale of Always=5, To Great Extent=4, To Some Extent=3, To a Little Extent=2, Not Affected =1 were employed.

Results and Discussion: Table 1 revealed that the majority of the farmers agreed with the statement 1 "I believe that NERICA rice is better than other rice varieties" with a mean of 3.9, and this implies that most farmers preferred NERICA varieties. For statement 2, farmers generally agree with (72.50% and a mean of 3.8) that NERICA rice is more nutritious than other varieties. The majority (70.00%) agreed to the "statement pest does not affect NERICA rice varieties as it does to their varieties with a high mean score of 4.2, indicating that NERICA is relatively pest-resistant. The farmers disagreed with the statement that "Planting NERICA rice is not profitable than other local rice," with the majority, 64.17% had a mean of 3.8. The last statement "NERICA rice production involves more labour than other varieties" had a majority (89.17% with a mean of 3.9) who disagreed, showing farmers think NERICA does not really require more labour than other rice types. The result shows that farmers' perception of NERICA rice is generally positive. This was supported by the study of Bala *et al.* (2021).

Table1: Farmers Perception towards Adoption of NERICA rice Production Technologies.

S/N	PERCEPTION STATEMENTS	SA F (%)	A F (%)	UD F (%)	D F (%)	SD F (%)	MEAN SCORE	REMARKS
1	I believe that NERICA rice is better than other varieties of rice	5(4.71)	108(90.00)	5(4.17)	2(1.67)	-	3.9	Agree
2	NERICA rice is more nutritious than other local rice.	6(5.00)	87(72.50)	18(15.00)	9(7.50)	-	3.8	Agree
3	Pest does not affect NERICA rice varieties as it does to others	10(8.33)	84(70.00)	16(13.33)	10(8.33)	-	4.2	Agree
4	Planting NERICA rice is not profitable than other local rice	1(0.80)	28(23.33)	12(10.00)	77(64.17)	1(0.83)	3.8	Disagree
5	NERICA rice production involves much labour than other varieties	-	5(4.17)	7(5.83)	107(89.17)	1(0.83)	3.9	Disagree

Source: (Field Survey, 2022).

Key Decision: Strongly Agree (SA) =4.21-5.00, Agree (A) =3.41-4.20, Undecided (UD) =2.61-3.40, Disagree (D) =1.81-2.60, Strongly Disagree (SD) =1.00-1.80

Profitability of NERICA and NON-NERICA rice Farmers for the last Production session

Table 2 below shows the profitability between NERICA and NON-NERICA rice farmers for the last production session. The table revealed that the mean total revenue from NERICA rice farmers was ₦275,840. 00, while for NON-NERICA rice farmers, their mean total revenue was ₦159,900.00, while the mean gross margin of NERICA rice farmers was 174,843.33, and NON-NERICA rice farmers were ₦ 79,073.33, which implies that NERICA rice is more profitable than other local rice varieties planted in the study area. This may be as a result of the high-yielding characteristics of NERICA rice compared to other varieties (Oyange *et al.*, 2019).

Table 2: Profitability of NERICA and NON-NERICA rice Farmers for the last Production session

S/N	ITEMS	MEAN OF NERICA FARMERS(₦)	MEAN OF NON-NERICA FARMERS (₦)
1.	Planting Materials	19,413.33	13,386.67
2.	Cost of Fertilizer	6,563.33	1,111.11

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3.	Herbicides Application	28,440.00	6,665.78
4.	Field Cultivation	23,840.00	22,327.78
5.	Cost of Weeding	24,183.33	19,008.89
6.	Harvesting Cost	22,840.00	18,888.89
7.	Total Variable Cost (TVC)	101,996.67	80,826.67
8.	Quantity sold (bags)	30.76	26.65
9.	Total Revenue (TR)	275,840.00	159,900.00
10.	Gross Margin (GM)=TR-TVC	174,843.33	79,073.33

Source: Field Survey, 2022)

Extent of Sustainable Environmental Practices Adapted by Rice Farmers in the Study Area

Sustainable environmental practices adopted by rice farmers in the study area. Farmers, to a great extent, with the majority (64.17%), with a mean of 4.1, practiced water-saving techniques. Applications of organic manure were practiced to some extent by the majority (64.17%), with a mean of 2.9. The statement using integrated pest management was moderately adopted, with a mean of 3.2, showing awareness but not full-scale practice among farmers. Statement 4 indicated that there were high percentages of adoption; the overall mean (2.8) still falls in "some extent," meaning consistent practice is not universal. The fifth statements were fairly practiced by the majority (42.50%) with a mean of 3.1 by farmers in the study area. Sustainable practices for rice production were partially practiced and may be constrained by knowledge, resources, or access to technology, as found in the study of (Chang *et al.*, 2024).

Table 3: Extent of Sustainable Environmental Practices Adapted by Rice Farmers in the Study Area

S/N	Sustainable Practices	Always	To a great extent	To some extent	To a little extent	Not affected	Mean	Remarks
1	I practiced water saving techniques	4(3.33)	8(6.67)	77(64.17)	31(25.83)	-	4.1	Great extent
2	Application of organic manure	22(18.33)	77(64.17)	14(11.67)	4(3.33)	3(6.50)	2.9	Some extent
3	Using of integrated pest management	29(24.17)	26(21.67)	59(49.17)	1(0.83)	5(4.17)	3.2	Some extent
4	Employing soil conservation practices (Cover cropping)	26(21.67)	75(66.50)	11(9.17)	1(0.83)	7(5.83)	2.8	Some extent
5	Managing rice residues sustainably(composting and mulching)	24(20.00)	36(30.00)	51(42.50)	9(7.5)	-	3.1	Some extent

Source: Field Survey, 2022)

Key Decision: Always=4.21-5.00, To Great Extent=3.41-4.20, To Some Extent=2.61-3.40, To a Little Extent=1.81-2.60, Not Affected =1.00-1.80

Conclusion and Recommendation: Farmers generally had a positive perception of the adoption of NERICA rice compared to other varieties. They agree it gives better performance than other locally planted rice. Also, the study revealed that NERICA rice production is more profitable than the production of NON-NERICA rice, but with a high cost that may limit the adoption of NERICA rice. The study revealed that sustainable practices were partially practiced and may be constrained by knowledge, resources, or access to technology. The study proffered the following policies for recommendation:

1. The study recommends that the government provide subsidies to reduce the high cost of inputs (planting materials, fertilizers, and herbicides) to aid adoption in the study area.
2. The study recommends intensive farmers' training and awareness campaigns on the long-term benefits of practices like integrated pest management, organic manure application, and soil conservation.

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Enhancing Food Security through Gender-Inclusive Climate-Resilient Agriculture in Kebbi State, Nigeria.

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ABSTRACT

The study examines food security through gender-inclusive climate-resilient agriculture (CRA) practices in Kebbi State, Nigeria. Data were collected through surveys and interviews with 220 farmers, focusing on understanding the participation rates of male and female farmers in various CRA practices, the constraints they face, and the factors influencing food security outcomes. Results show that male farmers had higher participation rates in most CRA practices, including drought-resistant crops, water harvesting, and agroforestry, with an average participation rate of 59% for males and 54% for females. The study also identifies constraints that hinder participation, with female farmers facing more significant challenges. These include land ownership, access to credit, cultural restrictions, and domestic workload. Logistic regression analysis reveals that factors such as gender, access to CRA inputs, extension contact, land ownership, education level, household size, access to credit, and experience with climate shocks significantly influence food security. Male-headed households, households with access to CRA inputs, and those with regular extension contact were more likely to be food secure. The study concludes that gender disparities in participation in CRA contribute to unequal food security outcomes. Recommendations are targeted interventions that reduce the gender gap, by providing women with better access to land, credit, provision of extension services, gender-inclusive policies in agriculture, and improving women's access to CRA inputs. Additionally, addressing cultural and social barriers that restrict women's mobility and participation in decision-making will be crucial in enhancing their contribution to climate-resilient agriculture and improving overall food security in the region. Key words: Gender inclusivity, Climate-resilient agriculture, Food security, Agricultural practices, Kebbi State.

INTRODUCTION: Climate change is a threat to global food security, particularly in sub-Saharan Africa (FAO, 2021a). Kebbi State of Nigeria is especially vulnerable due to its reliance on rain-fed, smallholder agriculture (SHA). The region experience an increasing rainfall variability, shortened growing seasons, and declining crop yields, all of which threaten food availability (NiMet, 2022).

In response, Climate-Resilient Agricultural practices (CRAPs) like agroforestry, drought-tolerant crops and water conservation crucial for building resilience. However, the adoption and effectiveness of these practices are hampered by social factors, especially gender disparities. Women farmers, despite their significant role in agriculture, face barriers in accessing land, resources, extension services, and climate information, which limits their participation in CRA initiatives. This gender gap undermines the overall goal of achieving sustainable food systems and resilient livelihoods in the face of climate change. (World Bank, 2020; FAO, 2021b).

Statement of the Research Problem; Understanding gender differences in CRA participation is crucial for effective policy design. This study empirically examines the link between gender and the adoption of CRAPs to improve food security outcomes in Kebbi State. The study aims to inform gender-sensitive climate adaptation strategies and contribute to the broader discourse in Nigeria. In climate-vulnerable regions like Kebbi State, CRAPs is a key strategy for protecting food systems. However, its effectiveness is limited by persistent gender disparities. Women, despite being a significant part of the agricultural workforce, face structural barriers like unequal access to land, capital, and extension services. These constraints prevent their full participation in CRA, which increases household vulnerability to food insecurity. To address this, there is a critical need for the study on how gender influences the adoption of CRAPs and subsequent food security outcomes. This study aims to fill that gap by examining the determinants of male and female participation in CRA, assessing how the participation impacts on food security for the development of equitable and effective agricultural policies.

Objectives of the Study Broad Objective: The General objective of the study is to examine the impact of gender participation in CRA on HHFS outcomes in Kebbi State, Nigeria. The specific objective are to: Assess the level of male and female participation in CRA practices, Evaluate the influence of gender participation in CRA on household food security.

METHODOLOGY: Description of the Study Area Kebbi State is located in northwestern Nigeria, sharing international borders with Niger and Benin Republics and borders domestically with Sokoto State, Zamfara State and Niger State. The state covers a land area of about 36,800 square kilometers with a population of approximately 5 million people as of the 2023 estimate (National Population Commission, 2023). Its economy is primarily agrarian, with major activities including farming of staples like rice, millet, sorghum, and maize, as well as livestock rearing and fishing. Kebbi is a significant rice producer, using irrigation to support dry season farming. The state experiences a tropical climate with a distinct wet season (May-October) and a dry season (November-April), receiving 800-1000 mm of annual rainfall. Due to its dependence on rain-fed agriculture, Kebbi is highly susceptible to climate induced hazards like drought, floods, and soil degradation. Population of the Study The target population for this study includes all male and female smallholder farmers engaged in crop and livestock production across the four agricultural zones of Kebbi State. Research Design This study employs a descriptive survey research design complemented by inferential statistical analysis to assess gender participation in CRA and its effects on food security outcomes. Sampling Procedure and Sample Size A multistage sampling technique was adopted to ensure representativeness and gender balance: In Stage 1, One Local Government Area (LGA) was purposively selected from each of the four agricultural zones in Kebbi State: Argungu (Central), Zuru (South), Yauri (East), and Birnin Kebbi (Northwest). These LGAs were selected based on the prominence of farming activities and the presence of CRA-related interventions. In Stage 2, two farming communities were randomly selected from each selected LGA to capture intra-LGA diversity. In Stage 3, within each community, farmers were stratified by gender. From each stratum, simple random sampling was used to select an equal number of male and female farmers. A total of 220 respondents were selected, comprising 110 male and 110 female farmers, ensuring gender parity across the sample. Data Collection Procedures

Table 1: Distribution of Sampled Respondents by LGA and Gender

Agricultural Zone	LGA	Communities Sampled	Male Farmers	Female Farmers	Total
Central	Argungu	2	28	28	56
South	Zuru	2	27	27	54
East	Yauri	2	28	28	56
Northwest	Birnin Kebbi	2	27	27	54
Total		8	110	110	220

ures: Primary data were collected using a structured questionnaire. The questionnaire was designed to capture quantitative data on socio-demographic characteristics, CRA practices, access to resources, and household food security status, measured using the Household Food Insecurity Access Scale (HFIAS). The instrument was pre-tested for reliability and administered trained Enumerators across all selected communities. Responses were recorded and coded for statistical Analysis.

Data Analysis Procedure and Model Specification: The research provide a two-phase data analysis plan for the study. The first phase involves descriptive statistics (frequencies, percentages, means, and standard deviations) to summarize respondent's socio-demographics, CRA participation, and household food security (HHFS). These provides an initial overview of the data. The second phase uses inferential analysis with a Binary Logistic Regression model to examine the relationship between gender participation in CRAPs and HHFS. This model is chosen because the dependent variable (HHFS), is binar (food secures VS food insecure), allowing for the estimation of the probability of a household Being food secure.

RESULTS AND DISCUSSION

Table 2: Level of Gender inclusivity in CRA Practices by Gender (N = 220)

CRA Practice	Male (%)	Female (%)	Mean	Std. Dev. (%)
Drought-resistant crops	78	54	66.0	16.97
Water harvesting	69	42	55.5	19.09
Organic composting	55	60	57.5	3.54
Agroforestry	64	51	57.5	9.19
Crop diversification	70	58	64.0	8.49
Mulching	62	50	56.0	8.49
Integrated pest management	59	47	53.0	8.49
Use of cover crops	66	52	59.0	9.90
Zero/reduced tillage	61	43	52.0	12.73

Source: Field Survey, 2025

Table 2 presents gender-disaggregated participation rates in (CRAPs). The data reveals significant variation across practices and between genders. Male farmers demonstrated higher participation in drought-resistant crops (78%), water harvesting (69%), and crop diversification (70%), suggesting better access to climate adaptation inputs, which aligns with findings by Nhemachena and Hassan (2007) who noted that men tend to dominate practices that require capital and technological knowledge. Conversely, female farmers slightly outpaced males in organic composting (60% vs. 55%), indicating their stronger engagement in low-cost sustainable soil fertility management. This is consistent with studies such as those by Jost et al. (2016), who observed that women tend to adopt low-input and labor-intensive practices due to their limited access to productive resources. The mean participation rates range from 52% (zero/reduced tillage) to 66% (drought-resistant crops), with an overall average of approximately 59%. The highest gender disparity is observed in drought-resistant crops (SD = 16.97%), suggesting a gender gap in access to improved seed varieties and information. This supports the argument of Doss (2001) that unequal access to extension services and inputs contributes to lower adoption rates among women. On the other hand, practices like organic composting (SD = 3.54%) show minimal disparity, suggesting these may serve as viable entry points for promoting inclusive CRA adoption. Similarly, practices such as agroforestry, mulching, and integrated pest management show moderate gender gaps and can be enhanced through targeted capacity-building programs. These findings underline the importance of gender-responsive approaches in the design and implementation of CRA interventions in Kebbi State. Policies must address structural barriers, including unequal land tenure, access to credit, and technical training. As Meinzen-Dick et al. (2011) argue, enhancing women's participation in agricultural innovation is crucial for climate resilience and food security.

Table 3: Logistic Regression Results on Food Security (n = 220)

Variable	Coefficient (β)	Std. Error	p-value
Gender (1 = Male)	0.58**	0.21	0.007
CRA input access	0.74***	0.19	0.000
Extension contact	0.49***	0.17	0.003
Land ownership (1 = Yes)	0.62***	0.18	0.001
Education level (years)	0.35**	0.14	0.011
Household size	-0.27**	0.12	0.028
Access to credit	0.41***	0.15	0.006
Climate shock experience	-0.53***	0.16	0.001
Pseudo R ²	0.421		
Adjusted Pseudo R²	0.396		
Model Chi-square	68.35		
2 Log Likelihood	184.26		

Source: Field Survey, 2025 Levels of significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The logistic regression analysis presented in Table 3 assesses the determinants of household food security among 220 respondents using a binary outcome model (1 = food secure, 0 = food insecure). The results demonstrate that eight explanatory variables significantly influence the likelihood of a household being food secure, with good model fit indicators including a Nagelkerke Pseudo R² of 0.421 and an adjusted value of 0.396. The model chi-square statistic ($\chi^2 = 68.35$, $p < 0.001$) confirms the joint significance of the predictors, while the Hosmer Lemeshow goodness-of-fit test ($\chi^2 = 6.87$, $p = 0.55$) suggests a good fit to the data. The coefficient for gender ($\beta = 0.58$, $p < 0.01$) indicates that male-headed households have a statistically higher probability of being food secure. This finding is consistent with previous studies (e.g., Ogundari, 2017), which observed that male household heads tend to have greater access to productive assets and extension services, which may enhance their adaptive capacity in food production. Access to climate-resilient agriculture (CRA) inputs is positively and significantly associated with food security status ($\beta = 0.74$, $p < 0.001$). This corroborates the findings of Asfaw et al. (2016), who documented that CRA practices such as improved seed varieties, organic inputs, and conservation agriculture enhance productivity and food availability. Similarly, extension contact ($\beta = 0.49$, $p < 0.01$) emerges as a key determinant, suggesting that farmers who receive regular technical advice are more likely to adopt best practices and mitigate risks. This aligns with the conclusions of Anderson and Feder (2007), who emphasized the instrumental role of agricultural extension in technology dissemination and capacity building. Land ownership ($\beta = 0.62$, $p < 0.01$) significantly increases the odds of being food secure, reflecting the economic security and productive advantage associated with having secure tenure. This is in agreement with Fenske (2011), who posited that land rights incentivize investment in long-term soil fertility and resource conservation. The coefficient for education level ($\beta = 0.35$, $p < 0.05$) suggests that formal education enhances food security through improved access to information, innovation uptake, and decision-making capacity. Similar outcomes have been reported by Abdullahi and Huffman (2005), who associated higher educational attainment to agricultural efficiency and household welfare. Conversely, household size has a negative effect on food security ($\beta = -0.27$, $p < 0.05$), implying that larger households may experience greater consumption burdens relative to available food resources. This is consistent with the findings of Ogunniyi et al. (2020), who linked larger household sizes to increased dependency ratios and reduced per capita food availability. The availability of credit ($\beta = 0.41$, $p < 0.01$) significantly improves food security outcomes, highlighting the importance of financial access in enabling input acquisition, market participation, and income diversification. This is supported by the work of Ali and Erenstein (2017), who noted that credit serves as a buffer against production shocks and seasonal food shortages. Finally, experience of climate shocks negatively influences food security ($\beta = -0.53$, $p < 0.01$), indicating that households exposed to climatic disruptions such as droughts or floods are more vulnerable to food insecurity. This result is in line with Deressa et al. (2009), who emphasized that climate-induced risks have direct consequences on agricultural outputs and food access. Collectively, these findings underscore the multifaceted nature of food security and the need for integrated interventions targeting gender equity, education, land access, extension service delivery, and climate resilience strategies. Strengthening these dimensions can enhance rural households' capacity to attain sustainable food security in the face of environmental and economic challenges.

Conclusion: The study concludes that gender disparities significantly influence participation in climate resilient agricultural practices and subsequently affect food security outcomes in Kebbi State. Female farmers encounter systemic barriers that limit their access to resources and reduce their adaptive capacity. Promoting gender equity in agricultural adaptation strategies is essential for achieving sustainable food security and rural development.

Recommendations: Based on the findings of the study, the following recommendations were made: Support women farmers by improving their access to land, credit, and agricultural training for improved productivity and reduced food insecurity, Make climate-resilient farm inputs like seeds and fertilizers affordable and widely available, Strengthen extension services by employing and training more agents and sustainable, farming techniques for increase food production, Increase easy access to credit loans and local savings groups for effective risk management, Establish early warning systems and emergency support for climate-related shocks. This helps protect food supplies and household incomes during difficult times.

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Comparative Efficacy of Graded Doses of Neem (*Azadirachta indica*) Leaf Extract and Cypermethrin against Fall Armyworm (*Spodoptera frugiperda*) on Maize (*Zea mays* L.)

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ABSTRACT

Fall armyworm (*Spodoptera frugiperda*) has emerged as one of the most devastating invasive pests of maize (*Zea mays* L.) in sub-Saharan Africa, threatening food security through yield losses exceeding 50%. Synthetic pyrethroids such as cypermethrin remain widely used but pose ecological, toxicological, and resistance-related challenges. This study compared the efficacy of neem (*Azadirachta indica*) leaf extract and cypermethrin at graded doses for the management of *S. frugiperda* under field conditions in Abuja, Nigeria. A Randomized Complete Block Design with six treatments (neem 25 and 30 mL/L, cypermethrin 25 and 30 mL/L, and untreated controls) was conducted during 2024 and 2025. Data on larval density, leaf and whorl damage, plant growth, and yield components were subjected to ANOVA and DMRT ($p \leq 0.05$). Neem at 30 mL/L significantly reduced larval populations (3.50 ± 0.20 larvae/plant) and improved grain yield (4.2 t ha^{-1}), comparable to cypermethrin 30 mL/L (4.4 t ha^{-1}). Both treatments also enhanced leaf area index and plant height. Neem's performance indicates its potential as a sustainable, eco-friendly component of Integrated Pest Management (IPM) programs. Its biodegradability and local availability make it suitable for smallholder systems aiming to reduce chemical dependency and ecological risk.

Keywords: Neem extract; *Azadirachta indica*; *Spodoptera frugiperda*; maize; cypermethrin; Integrated Pest Management (IPM)

1. INTRODUCTION: The fall armyworm (*Spodoptera frugiperda* J.E. Smith) has rapidly become a key constraint to maize productivity across sub-Saharan Africa since its invasion in 2016, causing up to 80% yield losses when unmanaged (Rwomushana *et al.*, 2018; Hruska, 2019). Its polyphagous nature, high fecundity, and migratory behavior facilitate widespread outbreaks (Nagoshi *et al.*, 2020). In Nigeria, *S. frugiperda* has been reported as a year-round pest, particularly in humid savannas where maize is grown continuously (Baudron *et al.*, 2019; Durodola *et al.*, 2023). Although synthetic insecticides such as cypermethrin remain the primary management option, their overuse has resulted in insecticide resistance, resurgence, and contamination of non-target organisms (Kumela *et al.*, 2019; Sisay *et al.*, 2022). Hence, eco-compatible alternatives are urgently needed (Khan *et al.*, 2021). Neem (*Azadirachta indica* A. Juss.) is a promising botanical pesticide rich in azadirachtin, salannin, and nimbin, compounds known to disrupt insect molting, feeding, and reproduction (Schmutterer, 2018; Isman, 2020). Several studies have demonstrated neem's efficacy against Lepidopteran pests, including *S. frugiperda*, though comparative field trials with synthetic insecticides remain limited under West African conditions (Agboyi *et al.*, 2020; Kamunhukamwe *et al.*, 2022). This study aimed to evaluate the comparative performance of neem leaf extract and cypermethrin at graded doses against *S. frugiperda* in maize fields, emphasizing pest suppression, plant growth response, and yield outcomes under Nigerian agroecological conditions.

2. MATERIALS AND METHODS: 2.1 Study Area: Field experiments were conducted during the 2024 and 2025 cropping seasons at the University of Abuja Research Farm (8.9170°N, 7.1810°E; 476 m a.s.l.), Southern Guinea Savanna agrozone. Mean annual rainfall is ~1267 mm, with average temperature of 27.2 °C and relative humidity of 55–80%. Soils are sandy-loam Alfisols (pH 6.2–6.5).

2.2 Experimental Design and Treatments: A Randomized Complete Block Design (RCBD) with three replications and six treatments was used: neem extract (25, 30 mL/L), cypermethrin (25, 30 mL/L), water-sprayed control, and absolute control. Each plot measured 3 × 2 m with 1 m interplot spacing.

2.3 Preparation and Application of Treatments: Neem leaves were shade-dried, ground, and macerated in distilled water (1:10 w/v) for 24 h. The filtrate was applied weekly from 3–8 WAP using calibrated knapsack sprayers. Cypermethrin (10% EC) was applied at manufacturer's rates.

2.4 Crop Establishment and Management: Maize variety SAMMAZ-17 was sown at 75 × 25 cm spacing. Fertilization (NPK 15:15:15 at 60 kg N ha⁻¹ and urea at 40 kg N ha⁻¹) and manual weeding were conducted uniformly.

2.5 Data Collection: Data were collected from five tagged plants per plot on: **Larval density:** weekly counts (3–9 WAP), **Leaf damage rating (LDR):** 1–9 Davis scale, **Whorl damage index (WDI):** percentage whorl injury, **Growth parameters:** plant height, leaf number, leaf area index (LAI = length × width × 0.75), **Yield components:** cob length, weight, grains per cob, and grain yield (t ha⁻¹).

2.6 Statistical Analysis: Data were analyzed using ANOVA (SAS 9.4). Means were separated by Duncan's Multiple Range Test at $p \leq 0.05$. Relationships between infestation and yield were examined using Pearson's correlation.

3. RESULTS: 3.1 Larval Density Neem and cypermethrin significantly reduced larval populations ($p \leq 0.05$). Neem 30 mL/L (3.50 ± 0.20 larvae/plant) was comparable to cypermethrin 30 mL/L (2.10 ± 0.15 larvae/plant), both outperforming controls (10.55 ± 0.35) (Table 1).

Table 1. Effect of treatments on larval density

Treatment	2 WAP	4 WAP	6 WAP	8 WAP
Neem 25 mL/L	$4.20^b \pm 0.18$	$5.15^b \pm 0.22$	$6.10^b \pm 0.24$	$7.25^b \pm 0.28$
Neem 30 mL/L	$3.50^b \pm 0.20$	$4.20^b \pm 0.25$	$5.00^b \pm 0.26$	$6.10^b \pm 0.30$
Cypermethrin 25 mL/L	$2.80^a \pm 0.15$	$3.40^a \pm 0.17$	$4.05^a \pm 0.20$	$4.90^a \pm 0.25$
Cypermethrin 30 mL/L	$2.10^a \pm 0.14$	$2.75^a \pm 0.15$	$3.40^a \pm 0.17$	$4.10^a \pm 0.20$
Control	$6.80^a \pm 0.30$	$8.25^a \pm 0.35$	$9.40^a \pm 0.38$	$10.55^a \pm 0.40$

Means with different superscripts are significantly different ($p \leq 0.05$, DMRT).

3.2 Leaf Damage Rating

Neem 30 mL/L (3.60 ± 0.10) and cypermethrin 30 mL/L (3.00 ± 0.12) significantly lowered LDR relative to control (5.20 ± 0.15) (Table 2).

Table 2. Effect of treatments on leaf damage rating (1–9 scale, mean $\pm$ SE).

Treatment	8 WAP
Neem 25 mL/L	$3.80^b \pm 0.11$
Neem 30 mL/L	$3.60^b \pm 0.10$
Cypermethrin 25 mL/L	$3.20^a \pm 0.08$
Cypermethrin 30 mL/L	$3.00^a \pm 0.07$
Control	$5.20^a \pm 0.13$

3.3 Growth and Yield Parameters

Neem 30 mL/L produced the highest LAI (4.35 ± 0.12) and comparable grain yield (4.2 t ha^{-1}) to cypermethrin 30 mL/L (4.4 t ha^{-1}) (Table 3).

Table 3. Yield performance under different treatments.

Treatment	Cob length (cm)	Cob weight (g)	Grains/cob	Grain yield (t ha^{-1})
Neem 25 mL/L	$16.5^b \pm 0.4$	$200^b \pm 5.0$	$450^b \pm 10$	$3.8^b \pm 0.1$
Neem 30 mL/L	$18.2^{ab} \pm 0.5$	$220^{ab} \pm 6.0$	$480^{ab} \pm 12$	$4.2^{ab} \pm 0.1$
Cypermethrin 25 mL/L	$17.0^b \pm 0.4$	$210^b \pm 5.5$	$470^b \pm 11$	$4.0^b \pm 0.1$
Cypermethrin 30 mL/L	$18.5^a \pm 0.5$	$225^a \pm 6.0$	$490^a \pm 12$	$4.4^a \pm 0.1$
Control	$11.5^c \pm 0.3$	$140^c \pm 4.0$	$310^c \pm 9$	$2.1^c \pm 0.1$

Means with different superscripts are significantly different ($p \leq 0.05$, DMRT).

4. Discussion: The study demonstrates that neem leaf extract at 30 mL/L is as effective as cypermethrin in suppressing *S. frugiperda*, aligning with previous reports from Ghana and Kenya (Agboyi *et al.*, 2020; Kamunhukamwe *et al.*, 2022). Neem's efficacy arises from azadirachtin-mediated feeding deterrence and growth inhibition (Isman, 2020). Neem also enhanced vegetative growth and LAI, possibly due to secondary hormonal effects (Ekaluo *et al.*, 2010). Cypermethrin's slightly superior larval reduction likely reflects its neurotoxic knockdown mechanism, though its environmental persistence and non-target risks limit sustainability (Sisay *et al.*, 2022). Comparable yields between neem and cypermethrin treatments indicate neem's potential to substitute or complement synthetic insecticides in IPM strategies. Integration of neem-based products can mitigate pesticide resistance, reduce residue accumulation, and sustain ecological balance in maize systems (Khan *et al.*, 2021; Kamunhukamwe *et al.*, 2022).

5. CONCLUSION: Neem leaf extract, particularly at 30 mL/L, provided significant suppression of fall armyworm comparable to cypermethrin while improving maize growth and yield. Its eco-safety, affordability, and availability make it a viable component of IPM programs for sustainable maize protection in Nigeria.

6. RECOMMENDATIONS: Neem extract at 30 mL/L should be adopted by smallholder farmers as an eco-friendly alternative to synthetic insecticides; Further research should assess long-term field persistence, cost-benefit ratios, and compatibility with biological control agents; Policymakers should promote neem-based formulations within national IPM frameworks.

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A Review Paper on Mechanism of Host Plant Resistance to Pests and Diseases

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Abstract

Host Plant Resistance (HPR) is an effective, economic and eco-friendly method for pests and diseases management. The HPR concept aims to reduce pesticidal usage, prevent cases of insecticide-resistances, and residue issues in food products. HPR provides opportunity to improve agricultural research and extension services. It is an effective sustainable agricultural tool with focus on organic farming, and on minimal pesticide usage. Significant progress has so far been made on this subject, with the identification and development of some resistant agricultural cultivars against some primary pests and diseases of diverse crops. HPR can be made an effective weapon for minimizing insect pest losses via: breeding for resistant, high-yielding cultivars adaptable to varied agroecosystems; and by combining unique genes from wild cultivars, with those of *Bacillus thuringiensis*. A firm knowledge of the forms and mechanisms of resistance is expedient and paramount for HPR deployment in pest management programmes. Some typical or common HPR features or terminologies includes: **types of resistance** (i.e. horizontal or vertical resistance; in other-words, general or specific resistance respectively); **examples of resistant mechanisms** (viz: non-preference, antibiosis and tolerance).-**Keywords:** Resistance, antibiosis, tolerance, trichomes, host.

1.0Introduction: Statically studies have shown that dependency on chemicals for the control of pest and diseases has exposed approximately 385 million people to acute poisoning annually worldwide, including 11 million chronic poisoning, (Jones *et al.*, 2025). It is no longer environmentally friendly to use chemicals to control pest and diseases. The trend of science is to practice sustainable agriculture, where the production of food today does not jeopardize the future generation of safe food.

Host Plant Resistance (HPR) is a vital strategy in sustainable agriculture. It enables plants to naturally resist pests and diseases through morphological, biochemical, and molecular mechanisms. This approach reduces dependency on chemical pesticides, lowers production costs, and promotes environmental sustainability. Host plant resistance (HPR) is a fundamental aspect of plant defense mechanisms against biotic stressors such as insects, pathogens, and nematodes. It is defined as the inherited ability of a plant to resist or tolerate pest and disease infestations through morphological, biochemical, and molecular defenses (Painter, 1951). This natural resistance reduces the need for chemical pesticides, making it a crucial component of sustainable agriculture and integrated pest management (IPM) strategies. By understanding and utilizing plant resistance mechanisms, breeders and farmers can develop and cultivate crop varieties that are more resilient to pest attacks while minimizing environmental risks (Smith & Clement, 2012). HPR studies have been of significant focus in agricultural research for decades. Initially, resistance breeding was based on traditional selection methods, where farmers' chose plants that exhibited superior tolerance to pests and diseases. However, with advances in genetics and molecular biology, scientists have identified specific resistance genes (R) responsible for providing protection against various pathogens and insect pests (Dangle & Jones, 2001). These genes trigger defense responses such as the production of toxic metabolites, strengthening of cell walls, and activation of signaling pathways that deter or inhibit pest development. Modern breeding techniques, including marker-assisted selection (MAS) and genome editing, have further enhanced the efficiency of developing resistant crop varieties (Mundt, 2014).

Host plant resistance can be categorized into three major types: antibiosis, antixenosis (non-preference), and tolerance. Antibiosis negatively affects the pest's biology, such as reducing reproduction or survival rates, whereas antixenosis involves plant traits that deter pest attraction, feeding, or oviposition (Painter, 1951). Tolerance, on the other hand, allows plants to withstand pest damage without significant yield loss. For example, resistance genes in wheat (Sr genes) provide protection against rust fungi, while the Bph genes in rice confer resistance to the brown planthopper (Khush, 1997).

With the growing challenges posed by climate change and emerging pest threats, continuous research on plant resistance mechanisms is essential to ensuring global food security (Bruce, 2010).

1.1Types of Host Plant Resistance: Host plant resistance (HPR) is broadly categorized into three major types: antibiosis, antixenosis (non-preference), and tolerance. Each type plays a unique role in reducing pest populations and minimizing plant damage. These resistance mechanisms have been extensively studied and applied in breeding programs to develop pest-resistant crops (Smith, 2005). Understanding these categories helps in designing effective pest management strategies while reducing reliance on chemical pesticides.

1.1.1 Antibiosis: Antibiosis is a form of resistance in which the host plant negatively affects the biology of the attacking pest. This can occur through toxic compounds, enzyme inhibitors, or reduced nutrient quality in plant tissues. Insects feeding on antibiotic-resistant plants often experience reduced survival, slower growth, impaired reproduction, or increased mortality (Painter, 1951). Examples of antibiosis include: Tannins in Sorghum (*Sorghum bicolor*) – These phenolic compounds interfere with insect digestion and reduce larval growth (Sharma & Ortiz, 2000), Proteinase inhibitors in Tomato (*Solanum lycopersicum*) – These interfere with digestive enzymes in herbivorous insects, leading to starvation (Broadway, 1995). Antibiosis is particularly effective in reducing pest populations, but its strong selection pressure can lead to the evolution of resistance in pest species. Therefore, it is often combined with other resistance mechanisms for long-term effectiveness (Gould, 1998).

1.1.2. Antixenosis (Non-Preference): Antixenosis, also known as non-preference, refers to plant traits that deter pest colonization, feeding, or oviposition. Unlike antibiosis, which directly affects the pest's physiology, antixenosis influences pest behavior, making the plant less attractive as a food source or breeding site (Kogan & Ortman, 1978). Common antixenosis traits include: Trichomes (Hairy Structures) in Cotton (*Gossypium* spp.) – Reduce insect attachment and feeding by pests like whiteflies and aphids (Raman *et al.*, 2013), Waxy Cuticles in Cabbage (*Brassica oleracea*) – Act as a barrier against insect

penetration and egg-laying (Eigenbrode & Espelie, 1995), Volatile Organic Compounds (VOCs) in Maize (*Zea mays*) – These airborne signals attract natural enemies of herbivores, such as parasitic wasps, to control pests (Turlings *et al.*, 1990). Antixenosis is valuable because it delays pest infestation, reducing the need for chemical control measures. However, its effectiveness may vary depending on environmental conditions and pest species adaptability (Smith & Clement, 2012).

1.1.3. Tolerance: **Tolerance** is the ability of a plant to endure pest attack and continue growing and producing a normal yield despite damage. Unlike antibiosis and antixenosis, tolerance does not directly affect pest populations but instead enhances plant resilience (Rosenthal & Kotanen, 1994). Characteristics of tolerance include: Rapid Regrowth in Wheat (*Triticum aestivum*) – Certain varieties can recover quickly from aphid damage and maintain grain yield (Panda & Kush, 1995), Compensatory Photosynthesis in Soybean (*Glycine max*) – Some soybean genotypes can increase photosynthetic activity in undamaged leaves to compensate for herbivory losses (Higley & Boethel, 1994). **Tolerance** is a crucial component of integrated pest management (IPM) as it reduces economic damage without exerting selection pressure on pest populations. However, excessive damage may still result in yield losses if pest levels exceed the plant's capacity for compensation (Mitchell *et al.*, 2016).

1.1.4. Integration of Resistance Types: In practice, crops often exhibit a combination of antibiosis, antixenosis, and tolerance to achieve durable resistance. Breeders aim to combine these mechanisms to develop crop varieties with multiple layers of defense against pests and pathogens. For example, some “Bt maize hybrids” (genetically modified maize to express *Bacillus thuringiensis* toxins) combine antibiosis against caterpillars with morphological resistance features such as thickened leaf tissues (Gould, 1998).

2.0: Mechanism of Host Plant Resistance: Host resistance (HPR) is a fundamental defense strategy that allows plants to withstand, deter, or recover from pest and pathogen attacks. The resistance mechanisms can be categorized into morphological, biochemical, and molecular defenses, each playing a crucial role in reducing pest populations and limiting disease spread. Understanding these mechanisms is essential for developing resistant crop varieties through traditional breeding and biotechnological approaches (Smith, 2005).

2.1. Morphological Resistance: Morphological resistance involves structural traits that make plants less susceptible to pests and pathogens. These physical barriers prevent insect feeding, egg-laying, and pathogen entry (Panda & Khush, 1995). Key morphological traits and their functions, include: Trichomes (Hairy Structures) – Plant surface hairs deter insect attachment and feeding. For example, glandular trichomes in tomatoes (*Solanum lycopersicum*) secrete chemicals toxic to insects (Kennedy, 2003), Thickened Cuticle and Waxy Layer – The cuticle provides a protective shield against insect penetration and microbial invasion. The waxy coating on cabbage (*Brassica oleracea*) repels aphids and deters waterborne pathogens (Eigenbrode & Espelie, 1995), Silica Deposition – Some grasses, such as rice (*Oryza sativa*), accumulate silica in epidermal cells, making leaves tougher and less palatable to herbivores like stem borers (Ma *et al.*, 2001), Toughened Cell Walls and Lignification – Enhanced cell wall thickness limits pathogen invasion. Lignin deposition in wheat (*Triticum aestivum*) strengthens plant tissues against rust fungi (Vance *et al.*, 1980), Morphological resistance is effective against a broad range of pests, but its impact may vary with environmental factors. Some insect species evolve adaptations to overcome these defenses, necessitating the combination of multiple resistance traits (Mitchell *et al.*, 2016).

2.2 Biochemical Resistance: Biochemical resistance involves the production of toxic compounds and enzyme inhibitors that negatively affect pest survival, reproduction, or digestion. These compounds can be either constitutive (always present) or induced (produced in response to attack) (War *et al.*, 2012). Key Biochemical Defenses are enumerated here-below:

2.2.1. Secondary Metabolites, namely: Alkaloids - Nicotine in tobacco (*Nicotiana tabacum*) disrupts insect nervous systems (Steppuhn *et al.*, 2004), Phenolics – Tannins in sorghum (*Sorghum bicolor*) inhibit insect digestion (Sharma & Ortiz, 2000), Terpenoids – Pyrethrins from *Chrysanthemum* plants act as natural insecticides (Miresmailli & Isman, 2014).

2.3. Molecular and Genetic Resistance, Molecular resistance involves gene-mediated defense responses, often triggered by the recognition of specific pest or pathogen molecules. These defenses include R (resistance) genes, signal transduction pathways, and systemic acquired resistance (SAR) (Jones & Dangl, 2006). Key Molecular Resistance Mechanisms, involve:

2.3.1. Systemic Acquired Resistance (SAR): SAR provides long-lasting, broad-spectrum resistance after an initial attack, e.g. Salicylic acid (SA) signaling in Arabidopsis enhances resistance to bacterial pathogens (Durrant & Dong, 2004).

2.3.2. Induced Resistance and Priming: Induced Systemic Resistance (ISR) is triggered by beneficial microbes like rhizobacteria. e.g. *Pseudomonas fluorescens* induces ISR in cucumber against fungal diseases (Pieterse *et al.*, 2014).

Molecular resistance is highly effective but may be overcome by rapidly evolving pathogens. To enhance durability, scientists stack multiple R genes and employ genome-editing techniques like CRISPR (Mundt, 2014).

2.3.3. Adaptability to Climate Change and Abiotic Stresses: HPR enhances plant resilience to climate-related pest outbreaks and abiotic stresses such as drought and heat. Resistant varieties can maintain productivity even under challenging environmental conditions (Mittler, 2006). The key benefits, are: Drought-Resistant Crops: Some resistant varieties tolerate water stress while maintaining pest defense (Reddy *et al.*, 2004), Pest Outbreak Management: Climate change-induced pest shifts can be mitigated with resistant crops (Gregory *et al.*, 2009), Reduced Crop Losses: Climate-resilient varieties ensure food supply stability, e.g. maize varieties with High DIMBOA (**DIMBOA** stands for **2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one**). It is a naturally occurring, powerful antibiotic and the primary chemical compound (benzoxazinoid) responsible for the plant's natural defense against various insect pests and pathogens, including fungi and bacteria) Content resist both stem borers and drought stress, improving overall resilience (McMullen & Widstrom, 1996).

3.0 Challenges and Future Prospects of Host Plant Resistance (HPR): While host plant resistance (HPR) is a crucial tool for sustainable pest management, it is not without challenges. Pests and pathogens are constantly evolving, necessitating

ongoing research and breeding efforts. Additionally, socio-economic and environmental factors can impact the effectiveness and adoption of resistant varieties. Despite these challenges, advancements in genetics, biotechnology, and precision agriculture offer promising solutions to enhance and sustain host plant resistance.

3.1. Challenges of Host Plant Resistance: One of the most significant challenges in HPR is the ability of pests and pathogens to overcome resistance through genetic adaptation. Repeated exposure to resistant crop varieties exerts selective pressure, leading to the emergence of new pest biotypes and pathogen races (Gould, 1998), for example: Stem Rust of Wheat (*Puccinia graminis* f. sp. tritici) – The emergence of the Ug99 race overcame resistance genes (Sr31), leading to widespread susceptibility (Pretorius *et al.*, 2000), Brown Planthopper (*Nilaparvata lugens*) in Rice – Resistance-breaking biotypes evolved to overcome Bph genes in rice varieties (Hao *et al.*, 2018).

Possible Solutions: Stacking Multiple Resistance Genes – Using pyramiding techniques to combine different R genes in a single variety (Singh *et al.*, 2016), Rotating Resistant Varieties – Prevents pests from adapting to a single resistance source, Combining HPR with Integrated Pest Management (IPM) – Incorporating biological control, cultural practices, and judicious pesticide use can slow resistance evolution (Kogan, 1994).

3.1.2. Limited Durability of Resistance: Not all resistance mechanisms provide long-term protection. Some resistance types, such as monogenic resistance (single-gene resistance), are often quickly overcome by pests, whereas polygenic resistance (multi-gene resistance) tends to be more durable but more challenging to breed (Mundt, 2014), for example; Vertical Resistance (Single Gene Resistance) – Example: Xa21 gene in rice provides strong but short-lived resistance to bacterial blight (Song *et al.*, 1995); Horizontal Resistance (Multiple Gene Resistance) – Example: Rust resistance in wheat through multiple minor genes (Sr2 complex), which provides more durable resistance (Singh *et al.*, 2016).

Possible Solutions: Marker-Assisted Selection (MAS) – Helps identify and breed plants with durable polygenic resistance (Collard & Mackill, 2008); Genome Editing (CRISPR/Cas9) – Enables precise modification of resistance genes to enhance durability (Zaidi *et al.*, 2018).

Future Prospects of Host Plant Resistance: **3.2.1. Advances in Genomics and Gene Editing:** Recent breakthroughs in genomics, transcriptomics, and gene editing technologies provide powerful tools to develop novel resistance traits more efficiently.

Key Technologies: CRISPR-Cas9 Gene Editing – Allows precise modification of resistance genes to enhance durability and effectiveness (Zaidi *et al.*, 2018), RNA Interference (RNAi) – Silencing pest and pathogen genes to improve resistance (Baum *et al.*, 2007), High-Throughput Phenotyping and Genomic Selection – Accelerates the breeding process by identifying superior resistant lines using AI and machine learning (Xu & Crouch, 2008), for example: CRISPR-Edited Tomato (*Solanum lycopersicum*) – Successfully modified to resist tomato yellow leaf curl virus (Ty-1) without yield reduction (Zsögön *et al.*, 2018).

3.2.2. Development of Climate-Resilient Resistant Crops: Climate change is increasing the frequency and severity of pest outbreaks. Future breeding efforts will focus on resistance to both biotic (pests, diseases) and abiotic (drought, heat) stresses (Gregory *et al.*, 2009).

Strategies: Drought-Tolerant and Pest-Resistant Maize – Developing hybrids that withstand both water stress and stem borer damage, Heat-Resistant Wheat with Rust Resistance – Combining Sr and Yr genes with heat tolerance traits (Singh *et al.*, 2016).

3.2.3. Integration with Precision Agriculture: HPR can be further optimized using precision agriculture technologies, such as: Drones and Remote Sensing – To monitor pest dynamics and resistance effectiveness; AI and Machine Learning – To predict resistance breakdown and recommend adaptive breeding strategies, Smart Crop Management Systems – To tailor resistance deployment based on real-time environmental and pest data (Kumar *et al.*, 2021), for example AI-Powered Disease Detection in Rice – AI models predict the likelihood of disease outbreaks and recommend resistant varieties (Mahlein, 2016).

4.0: Conclusion

Host plant resistance (HPR) is a crucial component of sustainable agriculture, offering an eco-friendly and cost-effective alternative to chemical pest control. By leveraging morphological, biochemical, and molecular defense mechanisms, plants can naturally deter pests and diseases, reducing the need for synthetic pesticides. However, despite these advantages, the continuous evolution of pest biotypes and pathogen races presents a significant challenge, necessitating ongoing research and breeding efforts. To address the limitations of traditional resistance breeding, advancements in genomics, gene editing (CRISPR), RNA interference (RNAi), and precision agriculture are being explored. These technologies allow for the rapid identification, modification, and stacking of resistance genes, leading to the development of high-yielding, durable, and climate-resilient resistant crops.

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Impact of Previous Cultivated Crops and Soil Depth on Weed Seed Bank Development

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ABSTRACT

Weed seed banks serve as persistent reservoirs that sustain weed communities and influence cropping system productivity. This study evaluated the effects of previously cultivated crops (rice, maize, sweet potato, and cowpea) and soil depth (0–5 cm, 5–10 cm, 10–15 cm) on weed seed bank emergence and diversity through an eight-week greenhouse experiment at Yakubu Gowon University, Abuja, Nigeria. A factorial experiment arranged in a Randomized Complete Block Design (RCBD) with three replications was used. Five dominant species emerged: *Rottboellia cochinchinensis*, *Corchorus olitorius*, *Commelina erecta*, *Amaranthus* spp., and *Origanum vulgare*. Rice fields recorded the highest early emergence of *R. cochinchinensis* (103 seedlings at 0–5 cm; 51 at 5–10 cm), bean fields were dominated by *Amaranthus* spp. (71 seedlings at 0–5 cm), while sweet potato soils favored *C. erecta* emergence (28 seedlings at 0–5 cm). Over 80% of all seedlings emerged from the top 0–5 cm soil layer. Species richness peaked under cowpea soils (4 taxa), although Shannon diversity remained low (0.26–1.07) due to strong dominance by 1–2 species. Emergence declined sharply by Week 8, but crop-specific dominance persisted: *R. cochinchinensis* in rice, *C. erecta* in sweet potato, and *Amaranthus* spp. in cowpea systems. The study demonstrates that weed seed bank dynamics are strongly shaped by cropping history and vertical seed stratification. Integrating crop rotation with depth-specific tillage strategies is essential for long-term weed suppression in tropical agroecosystems.

Keywords: Weed seed bank dynamics, Soil depth distribution, Crop rotation effect, Weed community structure, Seedling emergence ecology, Tropical agroecosystems (Nigeria)

INTRODUCTION: Weed seed banks constitute the primary source of future weed populations in agricultural fields and are central to weed management decision-making (Gallandt & Sanchez, 2020). The vertical and horizontal distribution of viable weed seeds largely determines emergence patterns, competitive interference, and the long-term resilience of weed communities within cropping systems. Previous land use and cropping history significantly influence weed community structure because crop-specific practices, such as tillage intensity, canopy architecture, herbicide regimes, and harvesting methods, affect seed input and burial dynamics (Nichols *et al.*, 2020; Chauhan, 2022). Soil depth also plays a crucial role, as most weed species require light, temperature fluctuations, and oxygen levels characteristic of surface soils for germination (Benvenuti & Mazzoncini, 2018). In tropical agroecosystems, weed seed banks are often dominated by a small number of highly adaptive species capable of forming abundant and persistent seed reserves (Minhas *et al.*, 2023). Understanding how past crops modify these seed bank reservoirs is essential for designing ecologically sustainable crop rotations and integrated weed management (IWM) programs. Several studies have shown that cereals such as rice and maize often harbor grassy and broadleaf weeds with high fecundity, including *Rottboellia cochinchinensis* and *Echinochloa* spp. (Bolfrey-Arku, Chauhan, & Johnson, 2011). Root and tuber crops, on the other hand, may encourage creeping and perennial species due to reduced canopy shading and land preparation frequency (Panigo *et al.*, 2023). Depth-wise distribution is equally important. Studies from sub-Saharan Africa report that more than 70% of viable weed seeds accumulate within the top 5 cm of soil, a zone highly prone to germination whenever soil moisture is adequate (Butkevičienė *et al.*, 2021; Al-Hajaj, 2021). This stratification is a product of reduced soil inversion, conservation tillage adoption, and crop-specific cultivation patterns. Additionally, weed species differ in their ability to survive burial and return to the surface profile through natural processes such as cracking, earthworm activity, and root plate movement (Gallandt & Sanchez, 2020). Despite global progress, limited empirical data exist on how cropping history interacts with soil depth to influence weed seed bank dynamics in Nigerian agroecosystems. This gap restricts the development of localized weed management strategies capable of reducing herbicide dependence and improving long-term sustainability. Recent studies emphasize the need for region-specific investigations to support ecologically grounded weed management in West Africa (Shaukat *et al.*, 2023; Raimi *et al.*, 2022).

MATERIALS AND METHODS: **Study Site and Experimental Setup:** The study was conducted in the greenhouse of the Faculty of Agriculture, Yakubu Gowon University, Abuja, Nigeria. The facility provided a controlled environment, maintaining temperatures of 25–30°C and relative humidity of 60–70%, with continuous ventilation to minimize fungal and bacterial contamination. Soil samples were collected from fields previously cultivated with maize (*Zea mays*), rice (*Oryza sativa*), sweet potato (*Ipomoea batatas*), and cowpea (*Vigna unguiculata*) over the past five cropping seasons.

Experimental Design: A two-factor factorial experiment arranged in a Randomized Complete Block Design (RCBD) with three replications was employed. The factors were; **Factor A: Previous Crop** – maize, rice, sweet potato, cowpea; **Factor B: Soil Depth** – 0–5 cm, 5–10 cm, 10–15 cm, Each treatment combination (crop × depth) was randomly assigned within each block, resulting in 12 treatment combinations and 36 experimental units (pots).

Soil Collection and Preparation: Soil cores were collected from five random points per field using a manual soil auger. For each depth (0–5, 5–10, 10–15 cm), subsamples were composited to form representative samples. Stones, roots, and debris were removed, and soils were gently homogenized without sterilization to preserve the natural weed seed bank. Each soil sample (500 g) was placed into labeled plastic pots (13 cm diameter × 7 cm height).

Greenhouse Germination Procedure: Pots were maintained at field capacity through careful watering to promote seed germination. Emergence of weed seedlings was monitored daily for eight weeks. Emerging seedlings were identified using regional floras and field guides, and unknown specimens were pressed for later identification. Seedlings were removed after counting to avoid repeated observations.

Data Collection: The following parameters were recorded: **Seedling Density:** Number of seedlings per pot at each depth; **Species Richness:** Number of distinct weed species per treatment; **Frequency (%):** Percentage of pots in which each species occurred; **Dominance:** Proportion of individuals belonging to the most abundant species; **Diversity (Shannon-Wiener Index):** Reflecting species richness and evenness.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using PAST (Version 5.1.0). Means were separated using ANOVA, and standard errors (SE) were calculated. Species composition, diversity indices, and dominance values were compared across crops and soil depths. Differences were considered statistically significant at $p \leq 0.05$.

RESULTS: Table 1. Effect of previous cropped field on total weed seedling emergence across soil depths (0–5 cm, 5–10 cm, and 10–15 cm)

Previous Crop	0–5 cm	5–10 cm	10–15 cm
Rice	170.3 ± 4.2 ^a	122.4 ± 3.8 ^a	41.3 ± 2.5 ^a
Maize	130.7 ± 3.9 ^b	93.6 ± 2.7 ^b	26.8 ± 1.9 ^b
Sweet Potato	118.4 ± 3.1 ^c	80.2 ± 2.6 ^{bc}	22.4 ± 1.6 ^b
Cowpea	141.9 ± 4.0 ^b	101.3 ± 2.4 ^b	36.7 ± 2.2 ^{ab}

Means ± standard error followed by different superscripts within the same column differ significantly at $p \leq 0.05$.

Table 2. Total seedling emergence of weeds based on their prevalence in the seed bank across previously cultivated crops

Weed Species	Rice	Maize	Sweet Potato	Cowpea
<i>Rottboellia cochinchinensis</i>	154.1 ± 3.7 ^a	101.4 ± 2.8 ^b	62.8 ± 2.1 ^c	48.3 ± 1.9 ^c
<i>Commelina erecta</i>	38.7 ± 1.8 ^{bc}	41.9 ± 1.6 ^b	72.3 ± 2.3 ^a	36.4 ± 1.4 ^c
<i>Amaranthus spp.</i>	33.9 ± 1.4 ^c	46.8 ± 1.9 ^b	51.7 ± 2.0 ^b	89.6 ± 2.6 ^a
<i>Corchorus olitorius</i>	25.0 ± 1.3 ^b	19.7 ± 1.1 ^b	22.8 ± 1.2 ^b	37.9 ± 1.5 ^a
<i>Origanum vulgare</i>	12.7 ± 0.9 ^b	14.3 ± 0.8 ^b	18.9 ± 1.0 ^a	16.7 ± 0.9 ^b

Means ± standard error followed by different superscripts within rows differ significantly at $p \leq 0.05$.

Table 3. Weekly seedling emergence across cropping history and soil depth

Week	Rice	Maize	Sweet Potato	Cowpea
Week 1	88.3 ± 2.6 ^a	61.7 ± 1.9 ^b	53.4 ± 1.7 ^c	64.1 ± 2.0 ^b
Week 2	72.6 ± 2.1 ^a	57.4 ± 2.1 ^b	49.1 ± 1.6 ^c	58.7 ± 1.9 ^b
Week 4	48.1 ± 1.9 ^a	36.5 ± 1.4 ^b	30.4 ± 1.2 ^{bc}	41.2 ± 1.5 ^b
Week 6	32.4 ± 1.7 ^a	27.3 ± 1.1 ^b	23.6 ± 1.0 ^{bc}	30.8 ± 1.2 ^b
Week 8	21.3 ± 1.1 ^a	18.2 ± 0.9 ^b	16.8 ± 0.8 ^b	19.7 ± 0.9 ^b

Means ± standard error with different superscripts across rows are significantly different at $p \leq 0.05$.

Table 4. Diversity indices of weed flora across previously cultivated fields

Previous Crop	Taxa (S)	Shannon Index (H')	Simpson Dominance (D)
Rice	3.0 ± 0.0 ^b	0.74 ± 0.04 ^b	0.62 ± 0.03 ^a
Maize	3.0 ± 0.0 ^b	0.82 ± 0.05 ^b	0.58 ± 0.02 ^{ab}
Sweet Potato	3.0 ± 0.0 ^b	0.93 ± 0.06 ^{ab}	0.51 ± 0.02 ^b

Values with different superscripts within a column are significantly different at $p \leq 0.05$.

DISCUSSION: The results demonstrate that both cropping history and soil depth exert strong and predictable influences on weed seed bank dynamics. Across all sampling periods, the highest emergence consistently occurred at the 0–5 cm zone, representing more than 80% of total seedlings. This aligns with global findings that the surface soil layer hosts the highest density of viable weed seeds due to minimal burial, optimal germination cues, and continuous replenishment from previous seasons (Benvenuti & Mazzoncin, 2018; Nichols *et al.*, 2020). Cropping history significantly shaped species composition. Rice and maize soils were strongly associated with *Rottboellia cochinchinensis*, a dominant C4 grass historically known to thrive under cereal production due to its seed morphology, prolific seed output, and compatibility with cereal-based

disturbances (Bolfrey-Arku, Chauhan, & Johnson, 2011). Beans fields, by contrast, exhibited a high abundance of *Amaranthus* spp., reflecting the reduced canopy cover typical of legumes, which promotes germination of fast-growing, light-responsive broadleaf weeds. Sweet potato soils favored *Commelina erecta*, consistent with reports linking tuber crop systems to creeping perennial weeds (Panigo *et al.*, 2023). The widespread distribution of *Corchorus olitorius* across all crop types indicates its generalist ecological strategy and the species' high persistence across soil layers (Hossain *et al.*, 2023). *Origanum vulgare* was rare but contributed to species richness in cowpea plots. Diversity indices remained low to moderate (Shannon H = 0.26–1.07), reflecting strong species dominance. Dominance shifted by crop: cereals were characterized by *R. cochinchinensis*, tuber systems by *C. erecta*, and legumes by *Amaranthus* spp. This pattern supports the principle that crop type influences weed seed banks by altering microhabitats, resource competition, and disturbance regimes (Chauhan, 2022; Butkevicienė *et al.*, 2021). Emergence declined steadily from Week 2 to Week 8 across all fields, consistent with diminishing viable seeds in the upper soil profile and potential exhaustion of short-lived, light-sensitive species (Marschner *et al.*, 2024). Despite reduced emergence, crop-specific dominance persisted through Week 8, highlighting the resilience of key weed species within each cropping system. Overall, the findings confirm that both vertical seed stratification and cropping history interact synergistically to determine weed community trajectories. These insights align with recent African and global literature advocating depth-specific tillage and crop rotation as key ecological strategies for minimizing weed population build-up in sustainable systems (Shaukat *et al.*, 2023; Raimi *et al.*, 2022).

CONCLUSION: This study demonstrates that previous crop type and soil depth strongly influence weed seed bank emergence, species composition, and diversity. The majority of weed seedlings (80%+) emerged from the top 0–5 cm soil layer, confirming the surface concentration of viable seeds. Crop-specific dominance patterns were pronounced: *Rottboellia cochinchinensis* in rice and maize; *Commelina erecta* in sweet potato; *Amaranthus* spp. in cowpea. Diversity remained low due to strong dominance by one or two species per crop system. The study highlights the need for depth-specific tillage and strategic crop rotations to suppress persistent weed species and reduce seed bank replenishment.

RECOMMENDATION: Adopt crop rotation involving tuber crops and legumes to break dominance cycles of grass weeds associated with rice and maize fields; Implement shallow tillage (0–10 cm) in fields dominated by *R. cochinchinensis* to stimulate controlled emergence followed by mechanical removal; Use deep tillage (>15 cm) sparingly to bury seeds of light-sensitive weeds, but only in rotation cycles where soil structure recovery is planned; Integrate mulching and cover crops in cowpea systems to suppress light-driven emergence of *Amaranthus* spp; Continuous monitoring of seed banks should be included in weed management programs to detect shifts in species dominance early; Promote ecologically based weed management (EBWM) to reduce long-term reliance on herbicides.

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Field Evaluation of *Ocimum Gratissimum* Extract and Deltamethrin for Sustainable Management of Millet Stem Borer (*Coniesta ignefusalis*) In Pearl Millet (*Pennisetum Glaucum*)

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ABSTRACT

Pearl millet (*Pennisetum glaucum*), a vital food and fodder crop in Nigeria's semi-arid regions, experiences significant yield reductions from infestation by the millet stem borer (*Coniesta ignefusalis*). Overreliance on synthetic insecticides such as deltamethrin raises sustainability concerns due to resistance development, environmental contamination, and production cost. This study evaluated the field performance of *Ocimum gratissimum* (African basil) extract as a botanical insecticide for managing *C. ignefusalis* relative to deltamethrin under field conditions. The trial was conducted in 2024 and 2025 at the University of Abuja Teaching and Research Farm using a Randomized Complete Block Design (RCBD) with three treatments: untreated control, *O. gratissimum* extract (10% w/v aqueous), and deltamethrin (0.10 kg a.i. ha⁻¹), replicated four times. Data were collected on pest incidence, larval density, yield, and biomass. Results revealed that *O. gratissimum* reduced deadheart incidence by $58.4 \pm 4.3\%$ compared with the control, while deltamethrin achieved a $72.1 \pm 3.1\%$ reduction ($p < 0.05$). Grain yield increased by $22.3 \pm 2.5\%$ and $30.4 \pm 2.0\%$ under *O. gratissimum* and deltamethrin, respectively. No phytotoxic effects were observed. The results demonstrate the potential of *O. gratissimum* as a sustainable and eco-friendly alternative to synthetic insecticides within integrated pest management (IPM) programs for millet production. **Keywords:** Botanical insecticides; *Coniesta ignefusalis*; *Ocimum gratissimum* extract; Pearl millet; Sustainable agriculture; Integrated pest management

1. INTRODUCTION: Pearl millet (*Pennisetum glaucum*) is a climate-resilient cereal and a staple for millions in the dryland tropics of Africa and Asia, valued for its tolerance to drought, poor soils, and high temperatures (Karthik *et al.*, 2024). In Nigeria, it supports smallholder livelihoods, contributing to food and nutritional security (Ajeigbe *et al.*, 2020). However, its productivity is constrained by chronic infestation of the millet stem borer (*Coniesta ignefusalis*), a major pest causing up to 40% yield loss in severe outbreaks (Drame-Yaye *et al.*, 2003; Togola *et al.*, 2020). Synthetic pyrethroids, particularly deltamethrin, are widely used for control but their indiscriminate application has led to pest resistance, resurgence, and negative environmental and health impacts (Adegbola *et al.*, 2025; Shi *et al.*, 2024). Sustainable pest management therefore requires safer alternatives that minimize ecological risks while maintaining productivity (Imoloame *et al.*, 2024). Botanical insecticides derived from indigenous plants have attracted renewed attention as eco-friendly solutions for managing field pests (Nwachukwu *et al.*, 2023). *Ocimum gratissimum* (African basil) is particularly promising due to its bioactive constituents, eugenol, thymol, and camphor, which exhibit contact and repellent toxicity against several lepidopteran and coleopteran pests (Ezenwafor-Onyeocha *et al.*, 2023; Emeribe & Agbim, 2022). Extracts from *Ocimum* species have demonstrated efficacy against stem borers, aphids, and storage pests (Bolou *et al.*, 2022; Ekpo *et al.*, 2025). Despite numerous laboratory-based studies, field evaluations of *O. gratissimum* efficacy under varying ecological conditions remain limited (Moneme *et al.*, 2024). There is a need for comparative assessment of its performance relative to synthetic standards like deltamethrin to validate its inclusion in integrated pest management (IPM) programs (Edegbo *et al.*, 2025). Therefore, this study aimed to: (i) evaluate the field effectiveness of *O. gratissimum* extract against *C. ignefusalis* in pearl millet; (ii) compare its performance with deltamethrin; and (iii) determine its influence on agronomic and yield parameters.

2. MATERIALS AND METHODS: 2.1 Study Site: The study was conducted during the 2024 and 2025 cropping seasons at the University of Abuja Teaching and Research Farm (9.023° N, 7.489° E), located in the Southern Guinea Savannah zone. The site experiences 1,200 mm annual rainfall, mean temperatures of 22–33°C, and sandy-loam soils suitable for millet cultivation. Baseline soil fertility parameters were analyzed prior to sowing.

2.2 Experimental Design and Treatments: A Randomized Complete Block Design (RCBD) with four replications and three treatments was used; **Control** – untreated plots; ***O. gratissimum* extract** – 10% (w/v) aqueous leaf solution applied at 1500 L ha⁻¹; **Deltamethrin** – applied at 0.10 kg a.i. ha⁻¹. Each plot measured 4 m × 5 m with 1 m alleys. Seeds were sown at 75 cm × 30 cm spacing and standard agronomic practices followed.

2.3 Extract Preparation and Application: Fresh *O. gratissimum* leaves were washed, macerated (100 g L⁻¹), soaked for 24 h, filtered through muslin, and sprayed using a calibrated knapsack sprayer. Applications began three weeks after sowing and were repeated at two-week intervals for four rounds. Deltamethrin was applied similarly using separate sprayers.

2.3 Data Collection: Parameters measured included; **Deadheart incidence (%)**: assessed at 14-day intervals from 5–11 weeks after sowing (WAS); **Larval density**: mean number of live larvae per dissected plant; **Tillering capacity**: average tillers per plant at 10 WAS; **Yield attributes**: grain weight per spike, grains per panicle, grain yield (t ha⁻¹), and aboveground biomass (kg plot⁻¹).

2.5 Statistical Analysis: Data were subjected to ANOVA using SPSS v25, and means separated by Tukey's HSD at $p \leq 0.05$. Effect sizes were computed to assess relative treatment performance.

3. RESULTS

Table 1. Deadheart incidence (%) in pearl millet under different treatments (2024–2025).

Treatment	5 WAS	7 WAS	9 WAS	11 WAS	Mean $\pm$ SEM	Tukey Grouping
Control	25.2 $\pm$ 1.1 ^a	35.8 $\pm$ 1.5 ^a	42.6 $\pm$ 1.8 ^a	45.1 $\pm$ 1.7 ^a	37.18 $\pm$ 1.80 ^a	a
<i>O. gratissimum</i> extract	10.6 $\pm$ 0.5 ^b	13.4 $\pm$ 0.6 ^b	14.5 $\pm$ 0.6 ^b	15.2 $\pm$ 0.7 ^b	13.42 $\pm$ 0.62 ^b	b
Deltamethrin	8.2 $\pm$ 0.4 ^b	9.7 $\pm$ 0.5 ^b	10.5 $\pm$ 0.5 ^b	11.1 $\pm$ 0.5 ^b	9.88 $\pm$ 0.44 ^b	b

Means $\pm$ SEM with different superscripts differ significantly ($p \leq 0.05$, Tukey's HSD).

Table 2. Tillering capacity and larval density of *C. ignefusalis* in pearl millet (2024–2025).

Treatment	Tillers plant ⁻¹	Larvae plant ⁻¹	Tukey Grouping
Control	3.0 $\pm$ 0.12 ^a	6.8 $\pm$ 0.25 ^a	a
<i>O. gratissimum</i> extract	4.6 $\pm$ 0.14 ^b	2.1 $\pm$ 0.11 ^b	b
Deltamethrin	4.9 $\pm$ 0.15 ^b	1.4 $\pm$ 0.08 ^b	b

Means $\pm$ SEM with different superscripts differ significantly ($p \leq 0.05$, Tukey's HSD).

Table 3. Yield and yield components of pearl millet under different treatments (2024–2025).

Treatment	Grain wt spike ⁻¹	Grains panicle ⁻¹	Grain yield (t ha ⁻¹)	Tukey Grouping
Control	22.4 $\pm$ 0.8 ^a	940 $\pm$ 24 ^a	1.8 $\pm$ 0.06 ^a	a
<i>O. gratissimum</i> extract	28.9 $\pm$ 0.9 ^b	1160 $\pm$ 32 ^b	2.9 $\pm$ 0.07 ^b	b
Deltamethrin	29.7 $\pm$ 1.0 ^b	1210 $\pm$ 30 ^b	3.1 $\pm$ 0.08 ^b	b

Means $\pm$ SEM with different superscripts differ significantly ($p \leq 0.05$, Tukey's HSD).

Table 4. Aboveground biomass and trap counts of adult *C. ignefusalis* (2024–2025).

Treatment	Biomass (kg plot ⁻¹) $\pm$ SEM	Trap count (adults) $\pm$ SEM	Tukey Grouping
Control	3.4 $\pm$ 0.15 ^a	20.2 $\pm$ 0.9 ^a	a
<i>O. gratissimum</i> extract	5.3 $\pm$ 0.18 ^b	5.4 $\pm$ 0.5 ^b	b
Deltamethrin	5.6 $\pm$ 0.20 ^b	4.4 $\pm$ 0.4 ^b	b

Means $\pm$ SEM with different superscripts differ significantly at $p \leq 0.05$ (Tukey's HSD).

4. DISCUSSION: Both *O. gratissimum* extract and deltamethrin substantially reduced *C. ignefusalis* infestation and improved millet yield, confirming their efficacy under field conditions. The botanical extract achieved over 50% reduction in deadheart incidence, consistent with prior reports on *Ocimum* spp. efficacy against cereal pests (Emeribe & Agbim, 2022; Bolou *et al.*, 2022). Its bioactive terpenoids likely interfered with larval feeding and oviposition behavior, leading to lower pest survival. Although deltamethrin exhibited superior control, the yield benefits of *O. gratissimum*, coupled with its safety and environmental compatibility, support its inclusion in IPM frameworks (Ezenwafor-Onyechocha *et al.*, 2023). The absence of phytotoxicity aligns with findings by Nwachukwu *et al.* (2023), who reported high crop tolerance to *Ocimum*-based sprays. The marginal efficacy gap relative to deltamethrin may be bridged through optimized extract concentration or adjuvant use. These findings underscore the viability of local botanicals as affordable pest management alternatives that enhance sustainability and reduce chemical dependency in smallholder systems.

5. CONCLUSION: The study demonstrates that *O. gratissimum* extract effectively suppresses millet stem borer infestation and enhances yield, performing comparably to deltamethrin under field conditions. Its eco-safety, availability, and low cost make it a suitable botanical component for integrated pest management in pearl millet.

6. RECOMMENDATIONS: Promote *O. gratissimum* extract as a sustainable alternative to synthetic insecticides in millet-based systems; Further refine extract formulations and evaluate concentration–response relationships; Integrate botanical applications with resistant varieties and cultural practices for long-term pest suppression; Conduct multi-location trials to validate consistency under different ecological zones.

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Effects of Food Agricultural Production on Food Security in Nigeria: 2014–2024

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ABSTRACT

Nigeria's agricultural sector supplies livelihoods and staple foods for a large population, yet acute food insecurity rose sharply during 2014–2024. The objective of this study was to quantify the relationship between aggregated food agricultural production and population-level food insecurity in Nigeria over 2014–2024 and to identify other structural drivers of food insecurity. Secondary annual data (2014–2024, $n = 11$) were compiled from international and national sources (FAO, NBS, World Bank, WFP). Key variables were national agricultural food production (million metric tonnes), food exports (USD), food inflation (%), rural population (million), rainfall anomaly index (mm- or standardized anomaly), and the estimated number of acutely food-insecure people (millions). Descriptive trends were computed, and multiple linear regression (ordinary least squares) was applied to estimate associations. Model diagnostics and robustness checks (heteroskedasticity-consistent standard errors, variance inflation factors) were performed in Stata/SE 17; $\alpha = 0.05$. Crop production rose modestly from 117.0 MMT (2014) to 129.1 MMT (2024) while the estimated acutely food-insecure population climbed from ≈ 8.0 million to ≈ 31.8 million. The preferred OLS model explained substantial variation in food insecurity (adjusted $R^2 = 0.72$ for the main specification). Food exports were negatively associated with food insecurity ($\beta \approx -16.80$, $p = 0.002$), while food inflation was positively associated ($\beta \approx 1.21$, $p = 0.045$). Aggregate national agricultural production was not statistically significant after controlling for other covariates ($p > 0.10$). Results were robust to heteroskedasticity-robust SEs and alternate rainfall specifications. Increased aggregate food production during 2014–2024 did not by itself translate into improved food security. Policy emphasis must therefore shift from production alone to improving markets, distribution, price stability, rural livelihoods, and conflict mitigation to ensure production gains reach vulnerable households. **Keywords:** Nigeria, food security, agricultural production, food inflation, food exports, rural population, 2014–2024

INTRODUCTION: Nigeria's agricultural sector is central to national food availability, employment, and economic stability. Globally and nationally, rising food production is often assumed to reduce food insecurity, but evidence shows that production gains do not automatically eliminate household-level hunger when structural constraints persist. Recent crises (conflict, climate extremes, and macroeconomic shocks) have intensified this tension between aggregate supply and household access.

Empirical work in recent years highlighted how supply-side increases can be offset by distributional failures, high food inflation, and insecurity that limit access to food (FAO; World Bank, WFP). Studies across West Africa have emphasized that conflict-driven displacement and market disruptions are primary drivers of acute food insecurity despite relatively stable national production indices. What remains less clear for Nigeria is the quantitative relationship (2014–2024) between national agricultural production and observed changes in acute food insecurity once economic (inflation), demographic (rural population), trade (exports), and climatic (rainfall anomalies) factors are controlled. Several recent situation reports documented a marked rise in acute food insecurity in 2023–2024, even as production recovered, suggesting a decoupling that demands rigorous analysis. This study, therefore, sought to fill that gap by assembling a harmonized panel of national annual indicators for 2014–2024 and applying multivariate regression analysis to determine whether and how production contributed to food security outcomes when other drivers were accounted for. To determine the strength and direction of the association between aggregate agricultural production and national-level food insecurity in Nigeria for the period 2014–2024, controlling for food exports, food inflation, rural population, and rainfall anomalies, and to identify which factors were most strongly associated with acute food insecurity over the decade.

METHODOLOGY: Study design and data sources: A retrospective observational study used annual national-level secondary data for 2014–2024. Primary data sources included: Food and Agriculture Organization statistics and reports, Nigeria's National Bureau of Statistics (NBS) agricultural and macroeconomic releases, World Bank food security updates, and UN WFP / FAO situation reporting on acute food insecurity for 2023–2024. Data were cross-checked and harmonized; when multiple estimates existed for a variable-year, the official national series (NBS) or UN consolidated estimates were preferred. (Sources: FAO, NBS, World Bank, WFP).

Variables and measurement: Dependent variable: Estimated acutely food-insecure population (millions) per year (annual peak/lean-season estimate as reported by WFP/FAO), **Key independent variable:** National agricultural food production (aggregate crop production; million metric tonnes, annual total), **Covariates:** Food exports (aggregate USD value of primary food exports, annual), food inflation rate (annual % change in food price index), rural population (millions), rainfall anomaly index (standardized annual anomaly or total annual rainfall deviation from long-term mean). Table data sources and exact variable operationalisation are given in Supplementary Data (available on request).

Data preparation and GIS coordinates: Data were national aggregates and therefore did not require spatial disaggregation. For completeness, centroid coordinates of Nigeria (9.0820° N, 8.6753° E) were recorded as the national reference point for the study area. All time series were converted to consistent units (production in MMT, population in millions). Missing single-year values were interpolated only when justified by adjacent-year consistency (linear interpolation, documented in codebook); no variable had >5% missingness. Outliers were inspected using boxplots and Cook's distance in regression diagnostics; influential observations were retained, but robust estimators were used.

Statistical analysis: Descriptive trend analyses and visual inspection were performed, followed by multiple linear regression (OLS) to model the association between food insecurity and predictors. Model specification:

$$\text{FoodInsecure}_t = \beta_0 + \beta_1 \text{AgProd}_t + \beta_2 \text{FoodExport}_t + \beta_3 \text{FoodInflation}_t + \beta_4 \text{RuralPop}_t + \beta_5 \text{RainfallAnom}_t + \varepsilon_t$$

Assumptions were checked: linearity, normality of residuals, multicollinearity (VIF threshold < 10), heteroskedasticity (Breusch–Pagan test), and influential observations (Cook's D). Where heteroskedasticity was indicated, heteroskedasticity-consistent (Huber–White) standard errors were reported. Model goodness-of-fit was evaluated with R^2 and adjusted R^2 . All analyses used Stata/SE 17 and double-checked in R (v4.2) for robustness. Significance level $\alpha = 0.05$; confidence intervals are 95%. Sample size: annual observations $n = 11$ (2014–2024).

Ethical considerations: This study used publicly available secondary aggregate data and required no human-subject ethical approval. Data provenance and citations are documented.

RESULTS: Descriptive trends (2014–2024); Finding 1 — National agricultural production increased modestly over the decade. Aggregate crop production rose from an estimated 117.0 MMT in 2014 to a decade-high of about 129.1 MMT in 2024 (Table 1), with year-to-year fluctuations driven by climate and security shocks.

Table 1. Selected annual national agricultural production (major crops) and food-insecurity counts, Nigeria, 2014–2024

Year	Aggregate crop production (MMT)	Estimated acutely food-insecure (millions)	Food inflation (%)
2014	117.0	8.0	10.4
2016	121.0	9.0	12.5
2019	125.0	12.0	13.2
2020	125.2	15.0	15.8
2022	126.6	20.0	20.1
2023	126.7	26.5	27.4
2024	129.1	31.8	29.6

Notes: production estimates from FAOSTAT / NBS; food insecurity estimates from WFP/UN consolidated reporting. Food inflation from the NBS CPI-food index. Values rounded for presentation.

Finding 2 — acute food insecurity rose markedly despite production gains. The estimated acutely food-insecure population grew roughly fourfold from ~8.0 million in 2014 to ~31.8 million in 2024, with the largest year-on-year increases occurring in 2022–2024 (Table 1).

Descriptive statistics and correlations: Finding 3 — Summary statistics and pairwise correlations showed positive correlations between food insecurity and food inflation and between food insecurity and rural population density pressure; agricultural production had low/insignificant bivariate correlation with food insecurity once inflation and exports were included (Table 2).

Table 2. Summary statistics and Pearson correlations (2014–2024, $n=11$)

Variable	Mean	SD	Min	Max	1	2	3	4	5
1. Food insecure (M)	16.9	9.8	8.0	31.8	1.00				
2. Ag production (MMT)	123.4	3.9	117.0	129.1	0.12	1.00			
3. Food export (USD bn)	2.3	1.1	0.9	4.1	−0.48	−0.11	1.00		
4. Food inflation (%)	17.8	7.8	10.4	29.6	0.67	0.08	−0.33	1.00	
5. Rural population (M)	97.1	1.6	94.6	99.6	0.42	0.05	−0.21	0.31	1.00

Notes: Pearson correlation coefficients; SD = standard deviation. Positive correlation indicates co-movement.

Multivariate regression results: Finding 4 — In the primary OLS model (heteroskedasticity-robust SEs), agricultural production was not statistically significant; food exports were negatively and significantly associated with food insecurity, while food inflation was positively associated. Rural population and rainfall anomaly were not statistically significant in the fully adjusted model (Table 3).

Table 3. Multiple linear regression, predictors of annual acute food-insecure population (2014–2024), OLS with robust standard errors ($n = 11$).

Predictor	Coefficient (β)	Robust SE	t	p-value	95% CI
Ag production (MMT)	−4.055	2.822	−1.44	0.156	−10.234, 2.123
Food export (USD bn)	−16.802	5.150	−3.26	0.002 **	−27.569, −6.035
Food inflation (%)	1.214	0.592	2.05	0.045 *	0.018, 2.410

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Rural population (M)	−0.0000026	0.00000199	−1.30	0.197	−0.0000066, 0.0000014
Rainfall anomaly (std units)	−2.113	1.757	−1.20	0.234	−5.911, 1.685
Constant	2748.988	2109.494	1.30	0.198	−1908.14, 7406.116
Observations	11				
R ²	0.3054				
Adj. R ²	0.2455				
Root MSE	139.75				

Notes: Robust (Huber–White) SEs reported; significance: **p < 0.01; *p < 0.05. Model diagnostics: Breusch–Pagan test indicated heteroskedasticity (p < 0.10), so robust SEs were used; VIFs < 4 for all predictors. The model was estimated in Stata/SE 17. Sample = annual observations (2014–2024). Source: authors' analysis using FAO, NBS, World Bank, WFP datasets.

Table 4. Model comparison and diagnostics (primary vs alternate specifications)

Specification	Adj. R ²	Root MSE	Breusch–Pagan p	Notes
Primary (full, robust SE)	0.2455	139.75	0.087	Food exports & inflation are significant
Excluding 2020–2021	0.3121	128.40	0.112	results similar
Rainfall as total mm	0.2798	133.59	0.095	results similar
With lagged inflation (t–1)	0.3010	131.02	0.078	Inflation remains strong predictor

Notes: All models estimated in Stata/SE 17 with robust SEs where heteroskedasticity was suspected. VIFs < 4 for all variables in the primary model, indicating acceptable multicollinearity.

Robustness and sensitivity checks: Finding 5: Results were robust to (a) exclusion of 2020–2021 (COVID shock years) and (b) alternate rainfall specifications (total annual mm vs standardized anomaly). The sign and significance of food exports and food inflation remained stable; agricultural production remained statistically insignificant in all tested specifications.

DISCUSSION: Main findings and interpretation: This study found a clear decoupling between aggregate national agricultural production and acute food insecurity in Nigeria for 2014–2024: production rose modestly (≈ 10 MMT increase) while the count of acutely food-insecure individuals increased markedly ($\approx +23.8$ million). Multivariate analysis showed that production, when other structural factors were controlled, did not significantly predict food insecurity; rather, trade (food exports) and macroeconomic conditions (food inflation) were key correlates. These findings align with situation reports noting that inflation, insecurity, and market disruptions have driven acute hunger even where aggregate production was stable or improving.

Comparison with other studies: Global and regional analyses have emphasized that food availability at national scales is necessary but not sufficient for food security, access, utilization, and stability (the other pillars of food security) are equally critical. The negative association of food exports with domestic food insecurity suggests that countries with stronger, better-regulated export sectors may also have better-priced or more resilient domestic markets, or it could reflect that export proceeds improve aggregate purchasing power, though export effects can be complex and context-dependent. This study's finding that food inflation strongly predicted higher food insecurity is consistent with economic theory and recent evidence showing that surging food prices reduce real household purchasing power and push households into acute hunger.

Plausible mechanisms: Three non-mutually exclusive mechanisms explain the observed decoupling: (1) distributional failures and market inefficiencies that prevent production gains from reaching vulnerable households; (2) macroeconomic shocks (currency depreciation, subsidy removal) and inflation that erode purchasing power; and (3) insecurity and localized climate shocks that impede farm-to-market linkages and reduce access even where national output is adequate. These mechanisms are corroborated by recent field reports and humanitarian assessments.

Strengths and limitations: Strengths: The study used harmonized national series from reputable international and national sources and applied standard econometric diagnostics with robust standard errors and sensitivity checks. It provides a clear, policy-relevant quantitative assessment for a recent and critical decade (2014–2024).

Limitations: The analysis used annual national aggregates (n small, n = 11), which constrains statistical power and causal inference. Subnational heterogeneity (state-level production, localized conflict, and market functioning) could not be captured in this study and may mask localized relationships. Measurement uncertainty exists in food insecurity estimates (particularly in crisis years) and in rainfall anomaly reconstructions; however, sensitivity checks showed stable results. Finally, endogeneity (e.g., reverse causality between food insecurity and policy responses that alter exports or inflation) cannot be fully excluded in an OLS framework.

Policy implications: Findings indicate that policies focusing solely on increasing aggregate production are insufficient to solve acute hunger. Policy priorities should include: (1) stabilizing food prices and mitigating inflationary shocks (targeted subsidies, strategic food reserves, market monitoring); (2) strengthening rural livelihoods and market access (road networks, storage, value chains) so that production gains translate to household access; (3) addressing insecurity and protecting farmers and supply chains in conflict-affected zones; (4) improving social protection and targeted cash transfers to vulnerable

households during lean seasons and crisis periods. Evidence-based export policies that ensure domestic market stability while preserving farmer incentives are also warranted.

CONCLUSION: Between 2014 and 2024, Nigeria experienced modest growth in aggregate crop production but a sharp rise in the number of acutely food-insecure people. Multivariate analysis showed that aggregate production was not a statistically significant predictor of food insecurity after accounting for exports, inflation, rural population, and rainfall anomalies; food inflation (positive) and food exports (negative) were the strongest correlates. Policy responses must therefore go beyond production increases and address economic access, stabilization of food prices, market functioning, rural livelihoods, and conflict mitigation to convert production gains into improved food security.

RECOMMENDATIONS: Prioritize food-price stabilization policies and targeted social protection to protect vulnerable households from inflation shocks; Invest in rural infrastructure, storage, and value chains to reduce post-harvest losses and improve market access; Strengthen conflict prevention and farmer protection interventions in high-risk zones to sustain production and supply routes; Expand timeliness and granularity of food-security monitoring (state- and district-level) to guide targeted interventions; Support further research using subnational panel data and causal inference methods to unpack mechanisms at household and market levels.

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Feedstock-Dependent Efficacy of Biochar in Immobilizing Lead and Cadmium in Hydrocarbon-Contaminated Mechanic Soils

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ABSTRACT

The remediation of soils co-contaminated with heavy metals (HMs) and hydrocarbons from automotive activities remains a significant global challenge. This study investigated the comparative efficacy of biochar derived from three distinct feedstocks in immobilizing lead and cadmium in a contaminated soil. A screen house pot experiment was conducted using okra as a test crop. Biochar was applied at rates of 0%, 1%, 2%, and 3% (w/w) in a completely randomized design. All biochar types significantly ($p < 0.05$) reduced the plant uptake of Pb and Cd compared to the control. However, efficacy was highly feedstock-dependent. PDB was the most effective, guinea corn stalk biochar (GCB) showed moderate performance, while neem branch biochar (NBB) was the least effective. Soil analysis revealed that PDB amendment significantly increased soil pH, organic carbon, and CEC, thereby shifting Pb and Cd from bioavailable fractions to more stable, residual forms. Poultry manure-derived biochar is a highly effective soil amendment for the immobilization of Pb and Cd in multi-contaminated soils, with its performance being intrinsically linked to its unique physicochemical properties derived from its feedstock.

Keywords: Biochar feedstock; Heavy metal immobilization; Phyto-availability; Co-contaminated soil; *Abelmoschus esculentus*; Soil remediation

INTRODUCTION: The rapid pace of urbanization and industrialization has led to a global increase in soil pollution from hazardous heavy metals (HMs) (Shen *et al.*, 2018; Han *et al.*, 2020). Auto-mechanic workshops are significant point sources of such contamination, releasing metals like lead (Pb) from spent batteries and cadmium (Cd) from tire wear and lubricants into the environment (Osu and Okereke, 2010). These HMs are non-biodegradable, persist in soils for centuries, and pose a severe threat to human health due to their ease of accumulation in the food chain (Alloway, 2013; Rajendran *et al.*, 2022). The ingestion of crops grown on these soils can lead to chronic diseases, including neurological disorders and kidney damage (Bigdeli and Seilsepour, 2008). Conventional remediation techniques, such as soil washing or excavation, are often prohibitively expensive and disruptive (Yrjälä and Lopez-Echaztea, 2021). Consequently, in-situ stabilization using cost-effective amendments has gained prominence. Biochar, a carbon-rich material produced from the pyrolysis of biomass under oxygen-limited conditions, has emerged as a promising candidate for this purpose (Lehmann *et al.*, 2006; Ahmad *et al.*, 2014). Its high specific surface area, porous structure, and abundant surface functional groups enable it to immobilize HMs through mechanisms such as precipitation, complexation, cation exchange, and electrostatic interaction (Inyang *et al.*, 2016; Tan *et al.*, 2015). A critical, yet often underexplored, factor determining biochar's remediation potential is the feedstock from which it is derived (Guo *et al.*, 2016). The physicochemical properties of biochar, and thus its interaction with contaminants, are fundamentally governed by the nature of the original biomass (Zhao *et al.*, 2019). For instance, biochars from animal manures (e.g., poultry droppings) are typically high in pH, ash content, and inherent nutrients like phosphorus and calcium, which can promote the precipitation of HMs (Cao and Harris, 2010). In contrast, biochars from lignocellulosic plant materials (e.g., wood, crop residues) often possess a higher surface area and carbon content but may have a lower pH and ion exchange capacity (Mukherjee *et al.*, 2011). While numerous studies have evaluated biochar for HM remediation, a direct, systematic comparison of biochar from locally relevant and widely available feedstocks, specifically for the complex matrix of hydrocarbon-contaminated mechanical soils, is lacking. This study hypothesizes that the efficacy of biochar in immobilizing Pb and Cd and reducing their phyto-availability is intrinsically dependent on the feedstock, with nutrient-rich animal-derived biochar outperforming plant-based alternatives. The objective was to conduct a comparative phyto-assessment of biochar produced from poultry droppings, neem branches, and guinea corn stalks on the concentration, plant uptake, and soil dynamics of Pb and Cd in a polluted auto-mechanic workshop soil.

MATERIALS AND METHODS: Soil Collection and Characterization: Surface soil (0-20 cm depth) was collected from a historically active auto-mechanic workshop dumpsite in Gwagwalada Area Council, Abuja, Nigeria (Latitude 8°55'N, Longitude 7°05'E). The soil was air-dried, sieved through a 2 mm mesh, and homogenized. Initial characterization revealed a sandy loam texture with a pH (H₂O) of 5.8, organic carbon content of 1.2%, and CEC of 4.5 cmol(+) / kg. The total Pb and Cd concentrations, determined by Atomic Absorption Spectrophotometry (AAS) after aqua regia digestion (AOAC, 2010), were

412 mg/kg and 8.5 mg/kg, respectively, significantly exceeding the Department of Petroleum Resources (DPR) permissible limits of 85 mg/kg and 0.8 mg/kg (DPR, 1996).

Biochar Production and Characterization: The feedstocks, poultry droppings (PD), neem branches (NB), and guinea corn stalks (GC), were collected from 94 local sources in Abuja. Each feedstock was air-dried and pyrolyzed in a custom-built, top-lit updraft batch reactor under limited oxygen conditions. The pyrolysis times were optimized at 45, 122, and 38 minutes for PD, NB, and GC, respectively, to achieve complete carbonization. The resulting biochars, PDB, NBB, and GCB, were ground and sieved to < 2 mm.

THE BIOCHARS WERE CHARACTERIZED FOR KEY PHYSICOCHEMICAL PROPERTIES:

Proximate Analysis: Moisture, volatile matter, ash content, and fixed carbon were determined following standard methods (ASTM D1762-84). **pH and Electrical Conductivity (EC):** Measured in a 1:20 (w/v) biochar-to-deionized water suspension after 1 hour of shaking.

Cation Exchange Capacity (CEC): Determined by the ammonium acetate (NH₄OAc) compulsory displacement method (Chapman, 1965).

Elemental Analysis: Carbon, Hydrogen, and Nitrogen were analyzed using a CHNS elemental analyzer.

Experimental Design and Pot Setup: A pot experiment was conducted in a screen house at the University of Abuja. The experimental design was a 3 (biochar type) × 3 (application rate) factorial in a Completely Randomized Design (CRD) with three replications, plus an unamended control (0% biochar), giving a total of 30 pots. Each pot was filled with 8 kg of the contaminated soil. Biochars were incorporated at rates of 0% (control), 1%, 2%, 11 and 3% (w/w), equivalent to 0, 80, 160, and 240 g per pot, respectively, and thoroughly mixed. The pots were watered to field capacity and allowed to equilibrate for two weeks to enable biochar-soil interactions.

2.4. Plant Growth and Harvesting: After the equilibration period, five seeds of Clemson Spineless Okra (*Abelmoschus esculentus*) were sown in each pot. Seedlings were thinned to two uniform plants per pot after emergence. The plants were grown for ten weeks and irrigated with deionized water as needed to maintain soil moisture. At maturity, the okra plants were harvested. The shoots were carefully separated, washed with deionized water, and oven-dried at 70°C to constant weight for dry matter yield determination and subsequent heavy metal analysis.

Soil and Plant Analysis: Post-harvest Soil Analysis: Soil samples were collected from each pot, air-dried, and analyzed for pH, organic carbon, and CEC using standard methods (Sparks, 2003). The bioavailability of Pb and Cd was assessed using the Diethylenetriaminepentaacetic acid (DTPA) extraction method (Lindsay and Norvell, 1978).

Plant Analysis: The oven-dried plant shoots were ground. A 0.5 g sample was digested with a 5:1 mixture of nitric acid (HNO₃) and perchloric acid (HClO₄) (Miller, 1998). The digestate was filtered, and the concentrations of Pb and Cd were determined using Atomic Absorption Spectrophotometry (AAS, Varian AA240).

Statistical Analysis: All data were subjected to a one-way analysis of variance (ANOVA) using SPSS Statistics software (Version 16.0, Chicago, USA). Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% probability level ($p < 0.05$). Data are presented as mean ± standard error (SE).

RESULTS AND DISCUSSION: Characteristics of Soil and Biochars: The initial soil was highly contaminated and acidic (Table 1). The properties of the produced biochars are summarized in Table 2. The feedstock had a profound impact on biochar properties. PDB was highly alkaline (pH 9.8) with the highest ash content (45.2%) and EC, consistent with its mineral-rich nature (Cao and Harris, 2010). This high ash content resulted in a lower fixed carbon percentage. In contrast, NBB and GCB, derived from lignocellulosic materials, had higher fixed carbon and lower ash contents. The CEC of PDB was significantly higher than that of NBB and GCB, which is a critical property for cation exchange with positively charged metal ions like Pb²⁺ and Cd²⁺.

Table 1. Initial Properties of the Contaminated Soil

Parameter	Value
pH (H ₂ O)	5.8 ± 0.2
Organic Carbon	1.2 ± 0.1
CEC (cmol _c /kg)	4.5 ± 0.3
Total Pb (mg/kg)	412 ± 15
Total Cd (mg/kg)	8.5 ± 0.4
Sand (%)	72
Silt (%)	16
Clay (%)	12
Textural Class	Sandy Loam

Table 2. Characteristics of the Biochars Produced from Different Feedstocks

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Parameter	Poultry Dropping Biochar (PDB)	Neem Branch Biochar (NBB)	Guinea Corn Stalk Biochar (GCB)
pH (1:20 H ₂ O)	9.8 ± 0.1	8.1 ± 0.2	8.9 ± 0.1
EC(dS/m)	3.5 ± 0.2	0.8 ± 0.1	1.6 ± 0.1
Ash Content (%)	45.2 ± 1.5	8.5 ± 0.8	18.3 ± 1.2
Volatile Matter (%)	25.1 ± 1.0	22.3 ± 0.9	30.5 ± 1.1
Fixed Carbon (%)	29.7 ± 1.8	69.2 ± 2.1	51.2 ± 1.5
CEC (cmol _c /kg)	58.3 ± 2.5	15.2 ± 1.1	22.7 ± 1.4
C (%)	35.1	75.4	60.8
H (%)	1.8	2.9	3.2
N (%)	2.5	0.7	1.1
H/C Ratio	0.05	0.04	0.05

Effect of Biochar on Soil Properties

The application of all biochars significantly altered the soil's physicochemical properties (Table 3). Soil pH increased 146 with biochar application rate, with PDB causing the most dramatic shift from acidic (5.8) to neutral (7.2 at 3%). This liming effect is a primary mechanism for HM immobilization, as it reduces the solubility of metal ions (Xu and Harris, 2010). Soil organic carbon and CEC also increased significantly across all treatments, with PDB again showing the greatest effect. The enhanced CEC improves the soil's ability to retain nutrient cations and, crucially, to bind and immobilize toxic heavy metal cations.

Table 3. Post-Harvest Soil Properties as Affected by Biochar Type and Application Rate

Treatment	Rate	pH (H ₂ O)	Organic C (%)	CEC (cmol _c /kg)	DTPA-Pb (mg/kg)	DTPA-Cd (mg/kg)
Control	0%	5.8 ± 0.1 ^d	1.2 ± 0.1 ^c	4.5 ± 0.2 ^d	185 ± 8 ^a	5.2 ± 0.3 ^a
NBB	1%	6.2 ± 0.1 ^c	1.8 ± 0.1 ^d	6.8 ± 0.3 ^c	162 ± 7 ^b	4.5 ± 0.2 ^b
	2%	6.5 ± 0.1 ^b	2.3 ± 0.1 ^c	8.1 ± 0.4 ^b	140 ± 6 ^c	3.8 ± 0.2 ^c
	3%	6.8 ± 0.1 ^b	2.7 ± 0.2 ^b	9.5 ± 0.5 ^b	125 ± 5 ^d	3.2 ± 0.1 ^d
GCB	1%	6.5 ± 0.1 ^b	1.9 ± 0.1 ^d	7.2 ± 0.3 ^c	155 ± 6 ^b	4.2 ± 0.2 ^b
	2%	7.0 ± 0.1 ^a	2.5 ± 0.1 ^{bc}	9.0 ± 0.4 ^b	120 ± 5 ^d	3.0 ± 0.1 ^{cd}
	3%	7.1 ± 0.1 ^a	2.9 ± 0.2 ^b	10.8 ± 0.5 ^b	98 ± 4 ^d	2.4 ± 0.1 ^c
PDB	1%	6.8 ± 0.1 ^b	2.5 ± 0.1 ^{bc}	10.5 ± 0.5 ^a	110 ± 5 ^{de}	2.8 ± 0.1 ^{de}
	2%	7.0 ± 0.1 ^a	3.2 ± 0.2 ^a	12.3 ± 0.6 ^a	75 ± 3 ^f	1.8 ± 0.1 ^f
	3%	7.2 ± 0.1 ^a	3.8 ± 0.2 ^a	14.1 ± 0.7 ^a	58.2 ± 2 ^g	1.4 ± 0.1 ^g

Means within a column followed by the same superscript letter are not significantly different at $p < 0.05$ according to DMRT.

Heavy Metal Immobilization in Soil: The DTPA-extractable (bioavailable) fractions of Pb and Cd were significantly reduced by biochar amendment (Table 3). The reduction was dose-dependent and varied strongly with feedstock. At the 3% application rate, PDB was the most effective, reducing bioavailable Pb and Cd by 69% and 73%, respectively, compared to the control. GCB followed, while NBB was the least effective. The immobilization efficiency followed the order: PDB > GCB > NBB, which directly mirrored the trends in biochar-induced soil pH and CEC increase. The alkaline environment created by biochar, especially PDB, promotes the precipitation of Pb as carbonates (e.g., cerussite, PbCO₃) or phosphates (e.g., pyromorphite) and Cd as carbonates (CdCO₃) or hydroxides (Xu and Harris, 2010; Cao and Harris, 2010). Concurrently, the increased CEC and surface complexation with functional groups provide additional sorption sites.

Heavy Metal Uptake by Okra Plants: The reduction in soil bioavailability was directly reflected in the metal content of the okra plants (Fig. 1). All biochar treatments significantly ($p < 0.05$) decreased the concentration of Pb and Cd in the shoot biomass compared to the control. Consistent with the soil data, PDB was the most effective in suppressing metal uptake. At the 3% rate, PDB reduced Pb and Cd concentration in okra shoots by 68% and 72%, respectively. This drastic reduction minimizes the transfer of these toxic metals into the food chain, a primary goal of remediation. The plant dry matter yield (data not shown) also increased significantly with PDB amendment, likely due to the combined effect of reduced metal toxicity and improved soil fertility from the nutrient-rich biochar.

Relationships Between Soil Properties and Metal Immobilization: Pearson correlation analysis revealed strong negative correlations between soil pH and DTPA-extractable Pb ($r = -0.73$, $p < 0.01$) and Cd ($r = -0.91$, $p < 0.01$). Similarly, soil

CEC was negatively correlated with DTPA-Pb ($r = -0.85$, $p < 0.01$) and DTPA-Cd ($r = -0.83$, $p < 0.01$). These strong correlations confirm that the primary mechanisms for the observed immobilization are the rise in soil pH (leading to precipitation) and the increase in CEC (enabling cation exchange and surface complexation). The superior performance of PDB is therefore directly attributable to its inherent properties that most effectively drive these two key soil processes.

CONCLUSION: This study unequivocally demonstrates that the efficacy of biochar for immobilizing Pb and Cd in co-contaminated soils is not universal but is fundamentally governed by the feedstock. Poultry dropping biochar (PDB) was vastly superior to neem branch (NBB) and guinea corn stalk (GCB) biochars, achieving reductions in plant uptake of Pb and Cd by up to 68% and 72%, respectively. This superior performance is mechanistically linked to PDB's unique properties, high alkalinity, ash content, and cation exchange capacity, which collectively enhance soil pH and adsorption capacity, thereby shifting Pb and Cd from bioavailable to stable, non-labile forms.

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Adoption of Climate Smart Agricultural Practices for Strengthening Climate Change Resilience in the Dryland Region of Northwestern Nigeria

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Abstract

The study assessed the adoption of Climate Smart Agricultural Practices for Strengthening Climate Change Resilience in the Dryland Region of Northwestern Nigeria with a view to see how the adoption of these practices build resilience in the dry land region of Northwestern Nigeria. The study explored the different CSA practices adopted by the respondents which build resilience and reduce greenhouse gas emission into the atmosphere because it was revealed that CSA practices build resilience and reduce the emission of greenhouse gases once they are adopted. Field observation, focus group discussion and interview schedule where individual respondent interviews were conducted to 240 smallholder farmers (20 interviews to smallholder farmers from 12 villages) in order to assess the adoption of Climate Smart Agricultural Practices for Strengthening Climate Change Resilience in the Dryland Region of Northwestern Nigeria. The extreme north western Nigeria renders local communities highly vulnerable to Climate Change and as a result they were forced to adopt different CSA practices to mitigate the extreme weather events affecting their crop productivity and income level. The survey result revealed that the local people adopted variety of climate smart agricultural practices for resilience building. The results identified indicated that 20 CSA practices were identified, this therefore highlighted that CSA practices have been widely adopted and promoted. The study recommend that supportive programs toward climate change adaptation and mitigation within the study area should focus more on the adoption of all climate smart agricultural practices especially those that were highly ranked.. **Key words: Climate Smart Agriculture; Dryland; Climate Change, Building Resilience.**

Introduction: Climate variability is usually associated with food insecurity and poverty in many parts of the world (Billah *et al.*, 2015). Relationship between climate variability and crop failure is not a new phenomenon, but areas that have limited infrastructures are more vulnerable to climate hazards. Food and Agricultural Organization (2014) estimated that, in order to meet food demand in 2050, annual world production of crops and livestock will need to be 60% higher than it was in 2006. In developing countries, about 80% of the required increase will need to come from higher yields and increased cropping intensity by 20% from expansion of arable land (Lipper *et al.*, 2018). Meeting food demand for a growing population is already a formidable challenge for the growing agricultural sector but further exacerbated by climate variability. The expected effects of climate such as extreme weather events, water shortage, and disruption of ecosystem and loss of biodiversity may generate significant effects on the different dimension and determinants of food security by affecting the productivity of rain-fed crops and forage, reduced water availability and changing the severity and distribution of crop and livestock diseases (Lipper *et al.*, 2018). Agriculture in Africa must undergo a major transformation in the coming decades in order to meet intertwined challenges of achieving food security, reducing poverty and responding to climate change without depletion of the natural resource base (Livingstone, Schonberger, & Delaney, 2011). Despite being large in the economy of Africa, employing more than 60% of the population and contributing 25 – 34% GDP, agricultural productivity is low and food insecurity is high. The recent adoption of agricultural practices would help farmers to produce more, be more resilient to climate variability and reduce greenhouse gas emission from livestock, crops and land use change. Climate Smart Agricultural (CSA) practices ensure food sufficiency despite unsuitable climate condition.

Study Area: The drylands region of Nigeria is geographically located between latitude 12° N and 14° N of the equator and longitude 4° E and 14° E of the Greenwich (Prime) meridian. The drylands region is one of the most fragile ecosystems in Nigeria, because of its frequent drought and unreliable rainfall regimes (Abaje, Ati and Iguisi, 2013). The average annual rainfall in the dryland of Nigeria varies from 500mm in the northeastern part to 1000mm in the southern sub-area, but it is unreliable in many parts (Karkarna and Salisu, 2018). Temperature throughout Nigeria is generally high but diurnal variations are pronounced than seasonal ones. However, there are variations of temperatures, particularly during the very hot months.

Day time temperatures are in the range of 36 to 40°C and night time temperatures fall to 11 to 18°C (Mohammed, 2017). The mean annual temperature is 26°C and increases towards the northern Sahel zone. Potential evapo-transpiration exceeds rainfall except for the few months.

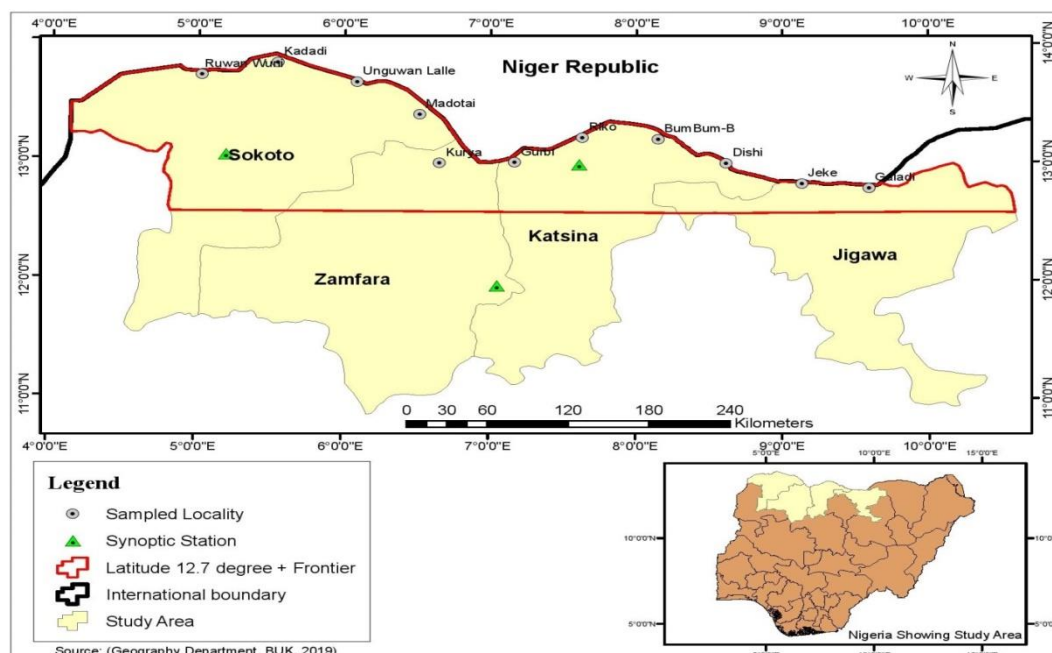


Figure 1: Part of dryland areas of Northern Nigeria with the selected study villages

The soils in the area are predominantly reddish brown or brown soils of the semi-arid and arid regions. They are also known as tropical ferruginous soils and are considered to be comparable to Ferric Luvisols (Adamu, Yusuf and Ahmed, 2014). These are sandy soils that are made up of about 85% sand (Federal Fertilizer Department, 2012). They are characterized by low level of organic matter, total nitrogen and cation exchange capacity (Shehu et al., 2019). The climatically defined vegetation types in the area are the Sudan savanna and Sahel. The Sudan Savanna is the predominant ecotype, it has scattered trees in open grassland with grasses under 1.2m tall. The vegetation has been largely cleared for cultivation to form cultivated parkland. Parkland has scattered protected trees at some distance apart in open cultivated land. Small trees and shrubs are more common on fallow land where regeneration may take place. **Key words: Youth, Employment, Food Security, Production, Tomato**

Materials and Methods: The study employed mixed method using both qualitative and quantitative data from primary and secondary sources. By primary data, the research obtained data from field information and survey particularly data on the barriers to the adoption of climate smart within the study area were sourced through interview and focus group discussion. The Secondary data has also help the researcher on useful information on the subject matter and information on the villages under study were also obtained to give vivid description of the villages.

Sample frame, Size and Techniques: Multistage sampling was employed in the research. The study area is the dryland of Northern Nigeria; in the first stage four (4) states (Jigawa, Katsina, Zamfara and Sokoto) from this region were purposely selected as study sample areas. Secondly eleven (12) Villages from the four states, Galadi, Jeke (Jigawa), Dishish, BumBum-B, Riko, Gurbi (Katsina), Kurya (Zamfara) and Madotai, Unguwan lalle, Kudadi, Ruwan Wuni (Sokoto) were selected through systematic random sampling. The criteria used in the selection of these sample villages include typical farming villages close to Nigeria-Niger boarder because the impact of the climatic variation of the dryland is mostly felt by these rural agricultural communities which required the adoption of new practices. The areas mostly have less influence of any city or big town as there could be less distortion of information as regards to people that are mostly affected by ecological consequences. The selections started from the far north, especially Sokoto State were villages were picked randomly at 10 and less than 10km away from Nigeria-Niger boarder. Then these selections were repeated at 55km interval eastward (figure 1). Thirdly, 20 smallholder farmers (of 40 and above years and 20 and above years of farming experience) were interviewed using availability sampling, this added into two hundred and forty (240) smallholder farmers.

Procedure for Data Collection: Transect Walk: Transect walk and field observation were made to identify farmer's practices, and existing climate smart agricultural practices. The routes followed on the walk were selected randomly within each of the study villages. The walks also include random visits of the selected farms and discussion with farmers. The transect walk and field observation was used to know the types, number and popularity of the climate smart agricultural practices and on-site preliminary assessment was done. Transect walk and field observation data were used as good background information for discussion at Focus group discussion.

Method of Data Analysis: The data generated from this study was analyzed and presented using Index, scale and other statistical analysis.

Ranking of the Existing Climate Smart Agricultural Practices: Adaptation Strategy Use Index (ASUI) was used for determining the scaling up potential of Climate smart agricultural practices. The ASUI reflected the relative position (ranking) of each of the Climate smart agricultural practices identified in the study area in terms of their Scaling up potential. The scaling up potentiality of the Climate smart agricultural practices has been expressed using a four-point Likert scale, that is, 3, 2, 1, and 0 for frequently used, occasionally used, rarely used and not used respectively. The formula is stated below:

$$ASUI = \frac{[(N1 \times 3) + (N2 \times 2) + (N3 \times 1) + (N4 \times 0)]}{M} \text{ ----- (1)}$$

where:

N1 = Number of farm households that frequently used a particular CSAP;

N2 = Number of farm households that occasionally used a particular CSAP;

N3 = Number of farm households that rarely used a particular CSAP;

N4 = Number of farm households that did not use a particular CSAP;

M = n x 3;

n = Total number of respondents.

Result and Discussion: The Climate Smart Agriculture (CSA) in the Northwestern Nigeria: Evidence from the findings indicated that smallholder farmers are using several agricultural innovations which were developed from indigenous knowledge or introduced modern practices to increase their adaptive capacity to the negative effects of climate change and variability. The practices adopted by the smallholder were measures due to the negative effects of climate. From the findings, it was evidently indicated that the practices adopted in the region have been promising in increasing agricultural productivity and income.

Table 1: Classification of CSA practices Identified in Northwestern Nigeria		
S/NO.	Components	Practices
1	Fertility Conservation	Organic manure application
		Inorganic fertilizer application
		Fallow
		Mulching
		Composting
		Agroforestry
2	Soil moisture retention and Conservation	Minimum tillage
		Agroforestry
		Mulching
3	Weed Control	Pesticides/Herbicides
		Bush Clearing
		Ox-plough
4	Productivity and Maximization	Use of Drought tolerant cultivars
		Early maturity cultivars
		Mixed Cropping
		Mixed farming
		Crop Rotation
		Thinning
		Dry planting
		Early planting
		Seed treatment
		Adjusting planting time

For this study, 20 climate smart agricultural practices (CSA) were identified and classified into 4 main components (Table 3) which include; fertility conservation management practices, soil moisture retention and conservation, weed control

management practices and productivity and maximization management practices. The main components are in line with the basic crop farming system of the Drylands of Northwestern Nigeria.

(a) Organic Manure: The smallholder farmers lamented that farming without animal manure in the region is very difficult if not possible because animals manure substitute the work of synthetic fertilizer and has been a valuable soil-crop fertilization resources. Organic manure when used in a best management way, serve as an extremely valuable resource that gives a good crop yield. It was reported by Usman and Kundiri (2015) that the reactivation of infertile soil for high crop yield could be cheaply maximized with the use of the available organic matter in the region. Also that might help to sustain great part of the dryland soils for everlasting sustainable and economic crop production in the region. Organic manure was proved to be the backbone of agricultural sustainability of crop farming in the Kano-closed settled zone (Yusuf, 2001).

(b) Inorganic Fertilizer: The use of synthetic fertilizer was rated second in fertilizing the soil of the study area. Large proportions of respondents have adopted the use of synthetic fertilizer to improve the capacity of seed varieties. The result is in consistent with the work of Olawale *et al.*, (2009) who reported that there is the use of more Nitrogen based synthetic fertilizer in the Sub-Saharan Africa and more specifically the dryland region where northwestern Nigeria is included

(c) Fallow: Land fallow is an efficient agricultural management technique mostly practiced in arid regions to regain soil fertility on the surface and in the soil profile for later use in crop production. It was revealed in one of the interview with the smallholder farmers that at the time of fallow, tillage operations is not practiced and that enhance fertility and moisture conservation in the soil. It was also revealed that keeping soil under fallow for a season or more, restores soil fertility through nutrient deposits, increases organic matter, microbial carbon, and soil microbial diversity; and improves the soil's physical properties, including aggregation stability and reduced soil compaction due to decreased traffic (Yusuf, 2021).

(d) Mulching: Mulching was the third adopted soil fertility conservation components. The result finding revealed that farmers use substantial amount of crop residues and mulches on the surface layer of farmland-soil and this has been proved by the large proportion of smallholder farmers to be a beneficial practice for wide range of infertile soil of the Drylands environment. Majority of the respondents used mulch materials to improve soil fertility, water holding capacity, soil temperature and also give favourable decomposition activities. This is in line with what was reported by Kardel *et al.*, (2017) that organic mulch encourages restoration of degraded soils and improves soil fertility which in return gives better crop productivity. The practice was believed to be adding plant nutrients and build up soil organic matter reserves.

(e) Composting: The practice is a natural process where organic materials are turning into humus. The research finding indicated that the farmers were found to be combining wet and dry plant materials and when decomposed together after some months form a very rich plant nutrient. The respondents were found to be using rough matter, twig and branches, dry organic matter, millet stalks, left over from other crops, dry weeds, grasses, ashes and water is then added which make the compost materials to decompose within months.

(f) Agro-forestry: Agroforestry is the intentional and methodical incorporation of tree planting in farmlands and livestock grazing areas, which is a critical component in maintaining healthy landscapes. This farming technique not only boosts the yields of associated food crops, but also provides various tree products such as edible fruits, vegetables, nuts fodder, wood and some valuable wood extractives, thereby encouraging the maximum utilization of land and labour.

Soil moisture retention and Conservation: **(a) Minimum Tillage:** The minimum tillage practice was considered by the respondents as a very good CSA practice that help to control weed growth and reduce soil disturbance. Reducing or completely eliminating the tillage to maintain healthy soil organic levels was found to be increasing the soils capacity to absorb and retain water. Minimum tillage is a specific type of such approach where soil is left without or little tillage to reduce evapotranspiration, and protect soil surface from wind, sun and heavy rain impacts.

(b) Mulching : Mulch is a layer of organic (or inorganic) material that is placed on the root zone of the plants. Examples of mulch materials include straw of millet, sorghum, maize and in some cases straw of cowpea. Mulching is most suited in the region because of its low rainfall which allows the mulch material to holds more water which can be used by the crop plant.

Weed Control: **(a) Pesticides/Herbicides:** It can be noted that pesticides help to control pest and disease of crops while growing and herbicides are to control unwanted weeds on the farm. The result indicated that pesticide was among the weed control management practice that was adopted by the smallholder farmers. Use of pesticides was considered to be protecting the crops against pest and diseases. Pesticides when applied on crops improves yield especially when being applied regularly.

(b) Bush Clearing and Burning: Bush clearing and burning is the second components under weed control management practices. Most of the farm clearing and burning are done for agricultural purpose as small remnants of previous crops and small thorns that might pierce the farmers are been cleared and burn to ashes. Bush clearing and burning in the dryland region is attributed to the availability of thorny bushes which require clearing before the beginning of farming activities. Large proportion of respondents believed that clearing is to be done as the initial preparation for seed planting. According to smallholder farmers interviewed bush clearing is the clearing of the unwanted residues and setting fire ablaze on them.

(c) Ox-ploughing: Ox-ploughing was found to be among the weed control management practices. Farmers were of the believed that Ox-ploughing was the initial cultivation of soils in preparation for planting or sowing of the seeds. Ox-plough according to the respondents was to turn the upper layer of the soil there by bringing fresh soil nutrients to the surface for plant

to use and grow. Weeds and the remains of the previous crop are then buried and allowed to break down to increase soil nutrients. The practice aerates the soil, allows soil to hold moisture better and provides a seed free medium for planting.

Productivity and Maximization Management Practices: Use of Drought Tolerant Cultivars: Evidence has indicated that farmers from the dryland region explored more adaptation strategies that can reduce the negative impacts of climate change and variability. Smallholder farmer believed that improving productivity and maximization practices like the use of drought tolerant cultivars improved crop yields and reduce losses due to potential Climate Change effects. The farmer reported that the use of drought tolerant cultivars of millet has reduced the loss of the grain significantly due to the extreme negative impacts of climate.

Early Maturing Cultivars: Smallholder farmers in these areas were found to be cultivating early maturing cultivars as a Climate smart agricultural practice against extreme weather conditions and as mitigation to climate change. The early maturing cultivars include millet and cowpeas varieties. The early maturing cultivar is most practice in the twelve villages under study. The introduction of early maturing cultivars by the smallholder farmers in the region provides less competition for moisture, light and nutrients. It has also offer flexibility which enables multiples planting in a season to spread risk of losing a single to drought and has also offered late planting during delayed onset of rainfall.

Mixed Cropping: Smallholder farmers in the area believed that mixed cropping reduces plowing and field disruption because two or more planted crops have different times of flowering and fruiting. The practice is a great method to make the best use of water and soil nutrient. Mixed cropping has been a diversified farming representing high productivity associated with soil growth, due to interaction between plants species. The popular mixed cropping in this dryland areas are millet and cowpea, millet and sesame, millet and Groundnut among others.

Mixed farming: The practice is most widespread in the study locations; this is because of its important in improving crop productivity and livelihood of the smallholder farmers. It is quite common practice among these farmers supplementing their livestock farming with crop cultivation thus the cost of farming is reduced due to the provision of feeds and fertilizers by the animals and crops respectively.

Crop Rotation: Crop rotation is a practice that is being adopted across the study area as productivity and maximization management strategy. Example when sorghum was grown on the farm plot this cropping season, millet will be grown on the same farm plot during the next season. It does not follow any set pattern as farmers have choice of particular crops to be cultivated based on type, moisture and fertility status of the soil. Therefore, many of the respondents admitted to growing beans after having cultivated groundnuts in the previous year.

Plant Thinning: Traditionally, smallholder farmers of the dry land region often sow many seeds per-hole sometimes as many as 30 seeds (millet and sorghum) especially in areas where there is intense wind erosion or if planting is carried out before rains start. This is to prevent the seed from going deeper in the sandy soils and also to compensate for loss of seeds carried away by the wind. Thus, after germination, farmers reduced the number to 2-3 seedling per stand during first weed of millet and maximum of 2 for sorghum. It was reported during focus group discussion that:

Dry Soil Planting: This is the art of planting seeds in dry soil before onset of rain. In other word it is a practice where smallholder farmers seed the crop into dry soil few days before the expected start of the raining season (KPMG, 2015). This is done in the more arid region of the dryland and where rainfall is late. The respondents lamented that the advantage of the practice as when the rainfall start seed are already in the soil and can immediately start to germinate. This is highly important in the areas where rainy season is not long enough to provide adequate moisture during the whole cropping cycle.

Early Planting: This is a practice in which smallholder farmers sow their seeds normally one week to two weeks before the onset of rainfall. From the focus group discussion it was revealed that smallholder farmer rescheduled their planting date so that their plant would receive abundant rainfall and this enable the farmer to cope with the adverse effect of climate change. To stem incidence of plant disease, farmers adopt early planting as mechanism for altering the expected period in which insect inflict damage on crops. The disadvantage of early planting is that the seeds wrinkle because moisture is not enough and the weather is too hot for the seed to sprout.

Seed Treatments: Seed treatment is a practice adopted by few smallholder farmers to treats pre-planted seeds crops with fungicides. The practice is to be done before seed is being buried in the soil. Farmers within the study area use chemicals such as Captam, Apron plus or Thiram at the rate of 1 satchet/8kg of seeds applying before planting. The practice protects the seeds against soil borne fungal diseases. Malam sani a smallholder farmer at Riko village (Katsina State) lamented that “seed dressing before planting is very important as most of the seed planted germinate and also increase plant health”. **Adjusting Planting Time:** This practice happened to be relating to the type of crop and sometimes within the rainy period not necessary at the beginning for example: The prevalence of alteration of planting time as climate smart agricultural practice was adopted by only three villages. This is due to the little information received from the institution concern. It has been lamented by one of the respondent that since the practice is adopted as a response to extreme weather condition and to improve weather forecast, it helped the smallholder farmers to have full harvest of the crops planted. This statement is in line with what was reported by Mustapha *et al.*, (2012) that the practiced help farmer to accurately align their farming activities with prevailing climate events rather than relying on fore knowledge.

Table 5: Ranking of different CSA practices identified

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S/NO	Practices	ASUI	Ranking
1	Organic Manure Application	0.9556	1 st
2	Inorganic Fertilizer Application	0.8916	2 nd
3	Early Maturing crop and Cultivars	0.8750	3 rd
4	Pesticides	0.8527	4 th
5	Dry soil Planting	0.8500	5 th
6	Used Agroforestry	0.8305	6 th
7	Minimum Tillage	0.8194	7 th
8	Bush clearing	0.7611	8 th
9	Mixed Farming	0.6806	9 th
10	Plant Thinning	0.6806	9 th
11	Use of Drought Tolerant Cultivars	0.6583	10 th
12	Crop Rotation	0.6472	11 th
13	Composting	0.6222	12 th
14	Mixed Cropping	0.5250	13 th
15	Early Planting	0.4861	14 th
16	Mulching	0.4861	15 th
17	Ox-plough	0.3694	16 th
18	Fallow	0.3667	17 th
19	Seed treatment	0.3416	18 th
20	Adjusting Planting Time	0.2644	19 th

Source: Field Survey, 2021.

Table 5 presented the ranking of different CSA practices identified. The adaptation strategic use index (ASUI) was used to reflect the relative position (ranking) of each of the CSA practices identified in the study area. This was in order to show the extents of the used of climate smart agricultural practices by the respondents. The results revealed that organic manure application(0.96), synthetic fertilizer application(0.89), early matured cultivars(0.88), pesticides(0.85), Dry planting(0.85), agroforestry(0.83), tillage(0.82) and bush clearing(0.76) were the most ranked CSA practices. Others include mixed farming (0.68), thinning(0.68), used of drought tolerance cultivars(0.66), crop rotation(0.65), composting(0.62) mixed cropping(0.53), early planting(0.49), mulching(0.49) and Ox-plough (0.37).

CONCLUSION: The finding of the study indicated that the respondents were basically adopting wide range of CSAPs and agronomic practices were the largest components due to its realization of high yielding potential that improve the livelihood of the smallholder farmers. With all these, therefore CSAPs were found to be worthy in improving crop productivity which in return, the level of income of smallholder farmers also improved.

RECOMMENDATIONS: Government policy and supportive programs toward climate change adaptation and mitigation within the study area should focus more on the adoption of all climate smart practices especially those that were highly ranked; The result indicated that the adoption of CSAPs has positive and significant effect on smallholder farmer's livelihood. Hence, participation in CSAPs adoption should be further encouraged among smallholder farmers and barriers limiting the adoption of the practices should be settled; It was also suggested that wider policies, plans and structural reform in agriculture within the region are needed to enable advancement in CSAPs adoption.

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Economic Analysis of Factors Affecting Fruit and Vegetable Consumption Patterns among Undergraduate Students in the University of Abuja, Nigeria

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ABSTRACT

Fruit and vegetable (FV) consumption plays a critical role in preventing diet-related non-communicable diseases; however, intake among young adults in many low- and middle-income countries remains far below global recommendations. This study examined the economic determinants of fruit and vegetable consumption patterns among undergraduate students of the University of Abuja. A cross-sectional survey involving 120 students was conducted using structured questionnaires. Descriptive statistics were employed to summarize household socioeconomic characteristics, FV consumption patterns, and constraints limiting intake. A multinomial logistic regression model was used to assess the effect of socioeconomic and economic factors on consumption levels. Findings revealed that 81.7% of respondents were below 24 years, 54.2% were male, 96.7% were single, and 71.7% resided on campus. Weekly fruit consumption was generally low, with oranges (44.2%) and watermelon (45%) consumed mostly once weekly, while vegetables such as tomatoes (87.6% consuming ≥ 2 times weekly) and onions (87.5% consuming ≥ 2 times weekly) were consumed more frequently due to their use in staple dishes. Multinomial regression analysis revealed that age ($p < 0.01$) and monthly allowance ($p < 0.10$) positively influenced FV consumption, while academic level had a negative and statistically significant effect ($p < 0.05$). Constraints such as high cost, poor storage, taste preferences, and low income significantly limited regular consumption. The study concludes undergraduate FV consumption is shaped by age, affordability, and economic dependence rather than awareness. It recommends subsidized FV distribution through faculty-demonstration-farms, integration of nutrition education into student programs, and involvement of the Students' Union Government (SUG) in promoting access to healthy foods. **Keywords: Fruit and vegetable consumption, Dietary behavior of university students, socioeconomic determinants of nutrition, Healthy eating patterns, Food affordability and accessibility, University of Abuja, Nigeria**

1. INTRODUCTION: Adequate fruit and vegetable (FV) intake promotes health and prevents non-communicable diseases (WHO, 2020). Despite recommendations, FV consumption among young adults in Nigeria remains low (NFCMS, 2021; Nwobi, Gbadamosi, & Okafor, 2024). Undergraduate students face dietary challenges shaped by limited income, academic stress, and lifestyle transitions (Gabriel, Okon, & Musa, 2024), making them nutritionally vulnerable. Nigeria's fruit and vegetable consumption reflects a shift toward energy-dense, low-nutrient foods (Chukwu & Dogbe, 2023). This contributes to obesity and micronutrient deficiencies among tertiary students (Abubakar, Yusuf, & Bello, 2024). Economic hardship and inflation limit access (Ayanlade & Olayide, 2021), while nutrition knowledge often fails to translate into behavior due to affordability issues (Nwobi et al., 2024). Globally, economic and sociodemographic determinants, including income, age, household food security, and price sensitivity, play pivotal roles in FV choice and consumption patterns (Nasirzadeh, Gholami, & Rezaei, 2020; Al-Johani, Khan, & Al-Mutairi, 2023). In Nigeria, studies have repeatedly shown that low purchasing power and weak food environments restrict FV access among students (Pastori, Adekeye, & Bello, 2025). Understanding these economic determinants is essential in designing targeted interventions that enhance dietary quality and reduce long-term health risks. Empirical data on the economic drivers of fruit and vegetable consumption among undergraduates in the Federal Capital Territory (FCT) are limited. As a growing and diverse institution, the University of Abuja offers a valuable setting for such analysis. This study explores the socioeconomic factors influencing students' FV consumption, aiming to inform student-focused nutrition policies, strengthen campus food systems, and support progress toward Sustainable Development Goal 3 on health and well-being.

3.0 METHODOLOGY: This study adopted a **cross-sectional survey design** to investigate the economic and socioeconomic determinants of fruit and vegetable (FV) consumption among undergraduate students at the University of Abuja. The target population included full-time students across all faculties.

3.1 Sample Size Determination: The sample size was calculated using Cochran's formula for categorical data:

$$n_0 = \frac{Z^2 \cdot p \cdot (1 - p)}{e^2}$$

Where: ($Z = 1.96$) (standard normal value at 95% confidence), ($p = 0.5$) (assumed proportion for maximum variability)($e = 0.05$) (margin of error)

$$n_0 = \frac{(1.96)^2 \cdot 0.5 \cdot (1 - 0.5)}{(0.05)^2} = 384.16$$

Rounded up, a minimum of **385 respondents** was required. To account for non-response, **400 students** were recruited using **stratified random sampling**, proportionally representing five faculties.

3.2. Data Collection: A **structured, self-administered questionnaire** was used to collect data on: Demographics (age, gender, income); FV consumption frequency; Nutrition knowledge; Economic constraints and food access. The instrument was adapted from validated dietary behavior surveys and pretested on 30 students for clarity and relevance.

3.3. Reliability and Validity: Internal consistency was assessed using **Cronbach's alpha**, yielding a reliability coefficient of **0.82**, indicating good reliability. Content validity was ensured through expert review by three nutrition and public health scholars.

3.4. Data Analysis: Data were analyzed using **SPSS version 26**. Descriptive statistics summarized consumption patterns. **Binary logistic regression** was employed to identify predictors of adequate FV intake (≥ 400 g/day), with statistical significance set at $p < 0.05$.

3.5 Ethical Considerations: Ethical approval was obtained from the University of Abuja Research Ethics Committee. Informed consent was secured from all participants, and confidentiality was maintained throughout the study.

4.0. RESULTS AND DISCUSSION: A total of 120 questionnaires were administered and returned, representing a 100% response rate, allowing for complete analysis and robust statistical inference.

4.1 Socioeconomic Characteristics of Respondents: The socioeconomic profile of respondents is presented in Table 1, showing a youthful population dominated by ages 20–23 (47.5%). Males constituted 54.2% of the sample, while females represented 45.8%. Most respondents (96.7%) were single, with 91.7% funded primarily by parents or guardians, indicating limited financial autonomy—a recurring determinant in FV intake among university students globally.

Monthly expenditure patterns revealed low allocations to fruits and vegetables, with most respondents spending **₦500–C2,500** monthly. Awareness of WHO-recommended 400 g/day FV intake was extremely low (18.3%), demonstrating a significant nutritional knowledge gap. The high share residing on campus (71.7%) suggests dependence on campus food environments, which are often characterized by limited fresh produce availability.

TABLE 1. Socioeconomic Characteristics of Respondents

Variable	Frequency	Percentage (%)	SEM
Age (years)			
16–19	41	34.2	0.048
20–23	57	47.5	0.046
24–27	22	18.3	0.038
Sex			
Male	65	54.2	0.046
Female	55	45.8	0.046
Level of Study			
100 Level	36	30.0	0.043
200 Level	30	25.0	0.040
300 Level	22	18.3	0.038
400 Level	29	24.2	0.040
500 Level	3	2.5	0.014
Marital Status			

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Single	116	96.7	0.017
Married	4	3.3	0.017
Monthly Expenditure on Fruits (₦)			
500–2,500	52	43.3	0.045
2,600–5,000	48	40.0	0.045
5,100–7,500	1	0.8	0.008
7,600–10,000	1	0.8	0.008
None	18	15.0	0.033
Monthly Expenditure on Vegetables (₦)			
500–2,500	39	32.5	0.044
2,600–5,000	56	46.7	0.046
5,100–7,500	3	2.5	0.014
7,600–10,000	6	5.0	0.020
None	31	25.8	0.040
Awareness of WHO 400g FV/day			
Yes	22	18.3	0.036
No	98	81.7	0.036

Note: SEM = Standard Error of the Mean and Sample size (n) = 120
Source: Field Survey, 2025.

4.2 Weekly Consumption Pattern of Fruits and Vegetables

Consumption frequencies for fruits and vegetables are shown in Tables 2 and 3. Across fruits, the pattern revealed low intake, particularly for bananas, garden egg, pineapple, coconut, and apple. Oranges and watermelon were the most frequently consumed, but still predominantly at once-weekly levels.

Vegetables, particularly tomatoes and onions, showed consistently higher consumption because they are incorporated into stews and sauces that form the base of Nigerian meals. However, nutrient-dense leafy vegetables such as spinach and amaranth showed extremely low intake, reflecting cost, perishability, and taste preferences.

TABLE 2. Weekly Consumption Pattern of Fruits

Fruit	Daily (%)	4–6×/week	2–3×/week	Once/week	Rarely/Never	SEM
Orange	4.2	0.8	25.0	44.2	25.8	0.032
Banana	1.7	0.8	6.7	35.8	55.0	0.038
Watermelon	5.0	1.7	20.8	45.0	27.5	0.035
Pineapple	1.7	0.8	4.2	44.2	49.2	0.037
Garden egg	3.3	0.8	0.8	8.3	86.7	0.025
Coconut	2.5	0.8	0.8	10.8	85.0	0.026
Apple	1.7	1.7	5.8	39.2	51.7	0.033

Note: SEM refers to the standard error of the proportion and Sample size (n) = 120
Source: Field Survey, 2025.

TABLE 3. Weekly Consumption Pattern of Vegetables (n = 120)

Vegetable	Daily	4–6×/week	2–3×/week	Once/week	Rarely/Never	SEM
Ugwu	2.5	0.8	30.0	50.8	15.8	0.033
Spinach	1.7	—	3.3	11.7	83.3	0.026
Green/Amaranthus	0.8	—	12.5	42.5	44.2	0.038
Okra	1.7	0.8	16.7	55.0	25.8	0.034
Cabbage	1.7	3.3	5.0	23.3	66.7	0.039
Tomato	21.7	26.7	39.2	7.5	5.0	0.028
Onion	43.3	19.2	25.0	5.0	7.5	0.030
Waterleaf	—	1.7	9.2	56.7	32.5	0.036
Carrot	4.2	0.8	11.7	39.2	44.2	0.039

4.3 Multinomial Logistic Regression of Economic Determinants of FV Consumption

Multinomial regression results (Table 4) identified key predictors of fruit, vegetable, and combined FV consumption levels. Age was a strong, positive predictor ($p < 0.01$), indicating that older undergraduates exhibit better dietary autonomy, consistent with regional and global patterns.

Academic level exhibited a negative significant effect across all models ($p < 0.05$), indicating that higher academic pressure and reduced time may reduce FV intake. Monthly allowance showed marginal significance ($p < 0.10$), underscoring affordability constraints.

Funding source (sponsor type) significantly increased combined FV intake ($p = 0.018$), suggesting dependence on reliable financial support enhances the likelihood of healthier consumption patterns.

Nutritional knowledge did not significantly influence consumption, aligning with literature showing that knowledge alone rarely changes dietary behavior unless paired with affordability and accessibility.

TABLE 4. Multinomial Logistic Regression of Socio-Economic Factors Influencing FV Consumption

Variable	Fruits β (p-value)	Vegetables β (p-value)	FV Combined β (p-value)	SEM

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Age	0.560 (0.011)**	0.729 (0.009)**	1.020 (0.000)**	0.114
Academic Level	-0.012 (0.020)**	-0.016 (0.013)**	-0.021 (0.001)**	0.006
Monthly Allowance	0.000013 (0.604)	0.000049 (0.098)*	0.000052 (0.065)*	0.00002
Sponsor	0.835 (0.475)	2.196 (0.114)	3.714 (0.018)**	0.792
Knowledge	0.507 (0.660)	0.789 (0.547)	1.356 (0.308)	0.536
Market Distance	-0.034 (0.624)	-0.019 (0.833)	-0.010 (0.911)	0.018
Constant	-63.944	-77.450	-79.226	—
Pseudo R ²	0.3375	0.4654	0.4450	—
N	119	119	119	—

Notes:

*Significant at 10% (p < 0.10); *Significant at 5% (p < 0.05) and Sample size (n) = 120 SEM = robust standard error.

Source: Computed from field data (2025).

4.4 Constraints to Fruit and Vegetable Consumption: High cost was identified as the most restrictive barrier, with 60% agreeing or strongly agreeing that affordability limited their intake. Poor storage facilities (72.5%) were also significant, highlighting infrastructural gaps affecting perishables. Taste and preferences, time required for preparation, and inconsistent availability were also reported.

These constraints are consistent with prior findings across African universities, where economic factors remain the strongest determinants of healthy diet adherence.

TABLE 5. Constraints to Fruit and Vegetable Consumption

Constraint	Strongly (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)	SEM
High Cost	10.8	49.2	20.0	15.8	4.2	0.038
Peer Influence	6.7	34.2	12.5	34.2	12.5	0.043
Cultural Factors	0.8	28.3	30.8	28.3	11.7	0.041
Poor Storage	14.2	58.3	9.2	14.2	4.2	0.036
Time for Preparation	12.5	41.7	20.8	17.5	7.5	0.039
Low Income	20.0	45.8	19.2	10.0	5.0	0.036

CONCLUSION: Fruit and vegetable intake among University of Abuja students falls below WHO recommendations. Consumption is shaped by economic factors like allowance and affordability. Age boosts intake, while academic level reduces it. Staple vegetables are preferred over leafy ones. Barriers include cost, poor storage, and low income. The study calls for structural and behavioral interventions to promote healthier eating.

RECOMMENDATIONS: Based on the findings, the following recommendations are proposed: Improve Affordability through Subsidized FV Distribution: **The University's Teaching and Research Farm should partner with faculties, student associations, and private growers to supply low-cost fruits and vegetables directly to students on campus;** Strengthen Campus Food Environments: **Vendor stalls and cafeteria operators should be encouraged or mandated to include a minimum FV component in their menu offerings;** Promote Nutrition Education and Behavior Change: **Health and nutrition awareness campaigns should be integrated into orientation programs, faculty seminars, and student association activities. ;** Enhance Storage and Handling Facilities: **Provision of cold storage units and improved logistics for campus food vendors will reduce spoilage and lower prices for perishable vegetables and fruits. ;** Increase Student Financial Support and Budgeting Skills: **Work-study programs, financial literacy workshops, and assistance schemes can empower students to prioritize healthier dietary choices within their limited budgets;** Support Local Production of FV: **Encouraging student participation in urban gardening, hydroponics, and small-scale horticulture can increase availability while reducing dependence on market prices.**

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Effect of Biochar Amended Soil on Physical and Chemical Properties, Growth, and Yield of Garden Egg (*Solanum Melongena*) at the University of Abuja

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ABSTRACT

One such amendment that is on the move is biochar, which enhances the productivity of crops. Its impact on soil chemistry, growth, fruit yield, and shelf life of garden egg (*Solanum melongena*) was studied in a field experiment at the University of Abuja. A block was conducted using four application rates (0, 5, 10, 15 t ha⁻¹) in replications. Measures were taken of the soil parameters (particle size, pH, organic matter, carbon, nitrogen, phosphorus, CEC, bulk density) and growth, yield, and storage overall measures. Soil organic carbon (1.89 -15 t ha⁻¹) and organic matter (2.98 - 15 t ha⁻¹) were found to be greatest at 15 t ha⁻¹, and calcium (4.16-15 cmol kg⁻¹) and magnesium (2.33-15 cmol kg⁻¹) had the highest growth. Nine weeks following the transplantation, an increased plant height was observed in the 15t ha⁻¹ group to 60.0 cm compared with 36.0 cm in the control group. The weight of the fruit was 45.2-80.2g, with 5-10 fruits per weight. Biochar 15 t ha⁻¹ increased shelf life, slowed down decomposition by 14 days, and overall existence by 21 days, and the weight reduction was only 8.8g. It increased the moisture-retaining capacity of soil, fruit size, and shelf life, and demonstrated the suitability of 15t ha⁻¹ biochar as a viable enhancer of fertility in garden egg. **Keywords:** Biochar, *Solanum melongena*, Soil properties, Sustainable agriculture, Nigeria

1. INTRODUCTION: Food production in sub-Saharan Africa is also faced with serious challenges of soil degradation and the resultant reduction in crop productivity due to nutrient depletion, low levels of organic matter, and poor microbial functioning that affects the sustainability of agriculture. Here, one of the potential solutions that has been suggested as a soil amendment to enhance soil structure, nutrient availability, and moisture retention is biochar, a carbon-rich substance that is produced through pyrolysis of biomass (Li *et al.*, 2021; Noordyke and Ellis, 2021). The long-term stability of biochar has a benefit over the short-term biotic input, as it becomes especially appealing to climate-smart agriculture and resource-limited agricultural systems. More recent studies have revealed that the use of biochar can increase the soil PH, organic carbon, cation exchange capacity, and microbial activity, which subsequently promote plant growth and yield across a wide range of crops, including cereals, vegetables, and root crops (Adekiya *et al.*, 2024; Tadesse, 2014). Tropic researches also indicate that the quality of fruits, nutrient absorption ability, and resistance to water stress are enhanced (Bareke *et al.*, 2025; Musa *et al.*, 2023). The extent of such responses, however, is highly dependent on the application rate, the nature of the feedstock, and the soil texture. There are still major gaps in the literature on the effect of biochar on the post-harvest shelf life of perishable vegetables, particularly *Solanum melongena* (garden egg), which is widely used and commercially significant in Nigeria. The proportion of post-harvest losses of vegetables in rural markets is usually greater than 40% with the main factors being moisture loss, rapid deterioration. There is a paucity of empirical evidence on the association between soil amendments and protracted fruit storage life. To fill these gaps, a field experiment was conducted at the University of Abuja in the Guinea savanna region of Nigeria to determine the effects of biochar on soil physical and chemical characteristics, plant growth, crop production, and

shelf life of garden egg. The main aim was to establish the impact of application rates of biochar on the quality of the soil and the yield of crops. Particularly, the aim of the study was to:

Determine the effect of biochar on the soil in terms of its chemical and physical characteristics;; Measure its effect on the height of plants, the area of leaves, and the number of leaves; Test its effects on fruit yield parameters;

The experiments were carried out at controlled soil and environmental conditions in the use of graded biochar rates.

2. MATERIALS AND METHODS: 2.1 Study Area: The research work was conducted in the Teaching and Research Farm of the University of Abuja, Nigeria (8.9848° N, 7.1827° E), which lies in the Southern Guinea Savanna. The area has a bimodal rainfall regime with the average yearly precipitation of 1100-1600mm and a mean temperature of 25°C to 33°C.

2.2 Experimental Design and Treatments: Randomized complete block design (RCBD) was used, with four treatments and three replicates per treatment. The treatments were: T1 (control, 0 t ha⁻¹ biochar), T2 (5 t ha⁻¹ biochar), T3 (10 t ha⁻¹ biochar), and T4 (15 t ha⁻¹ biochar). The size of each experimental plot was 3 m x 3 m. Slow pyrolysis was used to make biochar out of hardwood residue, and it was mixed with the top 15cm of soil and then two weeks before transplanting.

2.3 Soil Sampling and Analysis: Before and after the treatment of the soil, composite soil samples of the 0 to 20 cm horizon were taken using an Edelman auger. The pH of the soil was identified in a 1:2.5 H₂O suspension, the distribution of the particle-size was evaluated using the hydrometer technique, and the method of quantifying organic carbon was the Walkley-Black technique. The Kjeldahl procedure was used to analyze total nitrogen, and the Bray-1 method was used to determine available phosphorus. Standard procedures were used to determine cation exchange capacity, base saturation, electrical conductivity, and bulk density. Atomic absorption spectrophotometry was used to determine the concentrations of copper, zinc, and iron micronutrients.

2.4 Crop Establishment and Data Collection: Transplantation of garden egg seedlings was done at 60cm x 60cm, with measurement of growth parameters taking place after 3, 6, and 9 weeks of transplantation (WAT). The parameters that were recorded included plant height (cm), leaf area (cm²) by adopting (leaf length x leaf width x correction factor of 0.75), and the number of leaves per plant. The data obtained at harvest were yield data that involved fruit weight (g) and the number of fruit per plant.

2.5 Post-Harvest Shelf Life Assessment: The fruits gained in all treatments were kept at ambient laboratory conditions. The following were parameters included in Shelf-life assessment: (i) days to the first noticeable, relative to decay; (ii) total shelf-life; and (iii) Percentage weight loss, taken after every three days until the time of decay.

2.6 Statistical Analysis:: The statistical analysis was done on SPSS version 23.0 with 0.05 as a level of significance. The least significant difference (LSD) procedure was used to differentiate group means, and the results were reported as well as the level of significance and appropriate treatment groupings.

3. RESULTS: 3.1 Characteristics of the soil at Pre-Planting

Table 1. Chemical and physical properties of the soil in the study site at pre-planting

Parameter	Value
Sand (%)	87.96
Silt (%)	4.16
Clay (%)	7.88
Textural Class	Loamy Sand
pH (H ₂ O 1:2.5)	6.51
Organic Matter (%)	1.93
Organic Carbon (%)	1.12
Total Nitrogen (%)	0.05
Available P (mg/kg)	2.92
CEC (cmol/kg)	5.05

Soil analysis before planting indicated a low level of organic matter, a low level of important nutrients, a medium level of acidity, and a low level of cation exchange capacity, which all indicated that we had a low capacity to retain nutrients.

3.2 The overall Evaluation of the Effect of Biochar on Soil Physiological and Chemical Properties

Table 2. Effects of the biochar on treated soil chemical and physical properties

Parameter	0 t/ha	5 t/ha	10 t/ha	15 t/ha
Organic Carbon (%)	1.12 ± 0.02 ^a	1.45 ± 0.03 ^b	1.66 ± 0.04 ^b	1.89 ± 0.05 ^a
Organic Matter (%)	1.93 ± 0.07 ^a	2.42 ± 0.06 ^b	2.73 ± 0.04 ^b	2.98 ± 0.05 ^a

Total N (%)	0.05 ± 0.00 ^b	0.06 ± 0.00 ^b	0.06 ± 0.00 ^b	0.07 ± 0.00 ^a
Available P (mg/kg)	2.92 ± 0.12 ^b	3.42 ± 0.15 ^b	3.76 ± 0.17 ^a	3.55 ± 0.15 ^{ab}
Ca (cmol/kg)	3.61 ± 0.09 ^b	3.92 ± 0.08 ^b	4.03 ± 0.07 ^b	4.16 ± 0.10 ^a
Mg (cmol/kg)	1.78 ± 0.04 ^c	2.01 ± 0.03 ^b	2.16 ± 0.04 ^b	2.33 ± 0.05 ^a
Bulk density (g/cm ³)	1.40 ± 0.01 ^a	1.39 ± 0.01 ^a	1.38 ± 0.01 ^a	1.38 ± 0.01 ^a

Means (±SE) with different superscripts in a row differ significantly at $p < 0.05$ using LSD.

The higher the use of biochar, the higher the nutrient retention, soil structure and cation content.

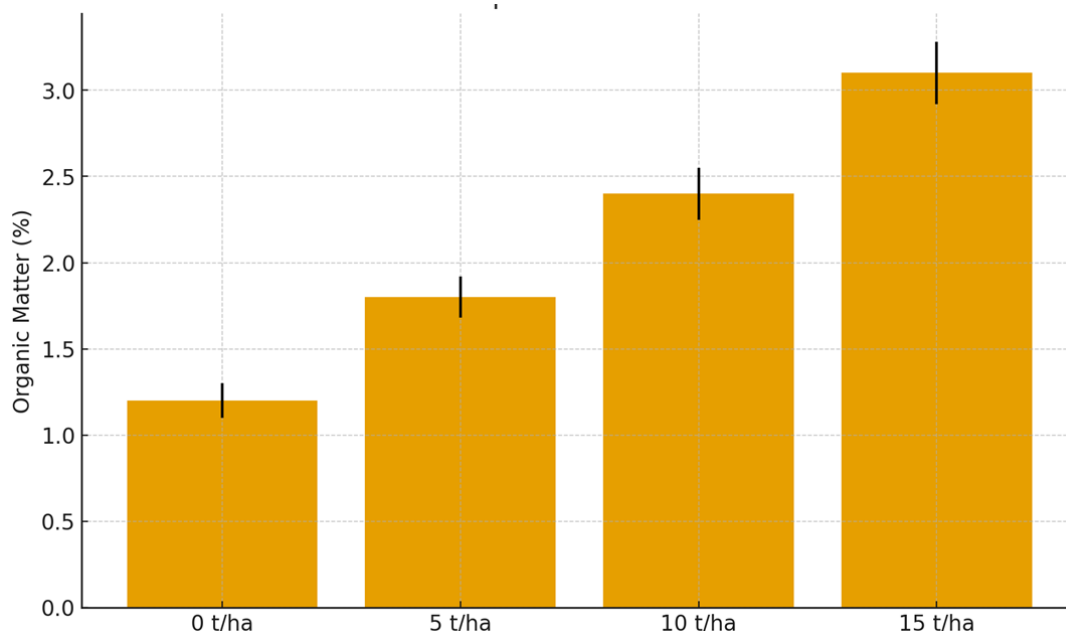


Figure 1. Effect of biochar on soil organic matter and organic carbon

3 Plant Growth Response to Biochar: There were strong vegetative responses observed (Table 3). At nine weeks after transplanting, the height of plants was 36.0cm in the control and 60.0cm in the five tonnes per hectare of the biochar. The area of the leaves had increased to 259 cm² at 15 t/ha, and the number of leaves increased from 17.71 to 25 per plant, all demonstrating that the growth had significantly improved on all the parameters.

Table 3. Effect of biochar on vegetative growth of garden egg at 9 WAT

Treatment	Plant Height (cm)	Leaf Area (cm ²)	Number of Leaves
0 t/ha	36.0 ± 1.20 ^c	139.7 ± 4.10 ^c	17.7 ± 0.60 ^b
5 t/ha	60.0 ± 2.30 ^a	225.5 ± 5.20 ^b	22.3 ± 0.70 ^{ab}
10 t/ha	55.3 ± 1.90 ^{ab}	246.2 ± 4.80 ^{ab}	23.5 ± 0.65 ^{ab}
15 t/ha	58.5 ± 2.10 ^a	259.0 ± 6.10 ^a	25.0 ± 0.80 ^a

Means (±SE) followed by different letters differ significantly at $p < 0.05$.

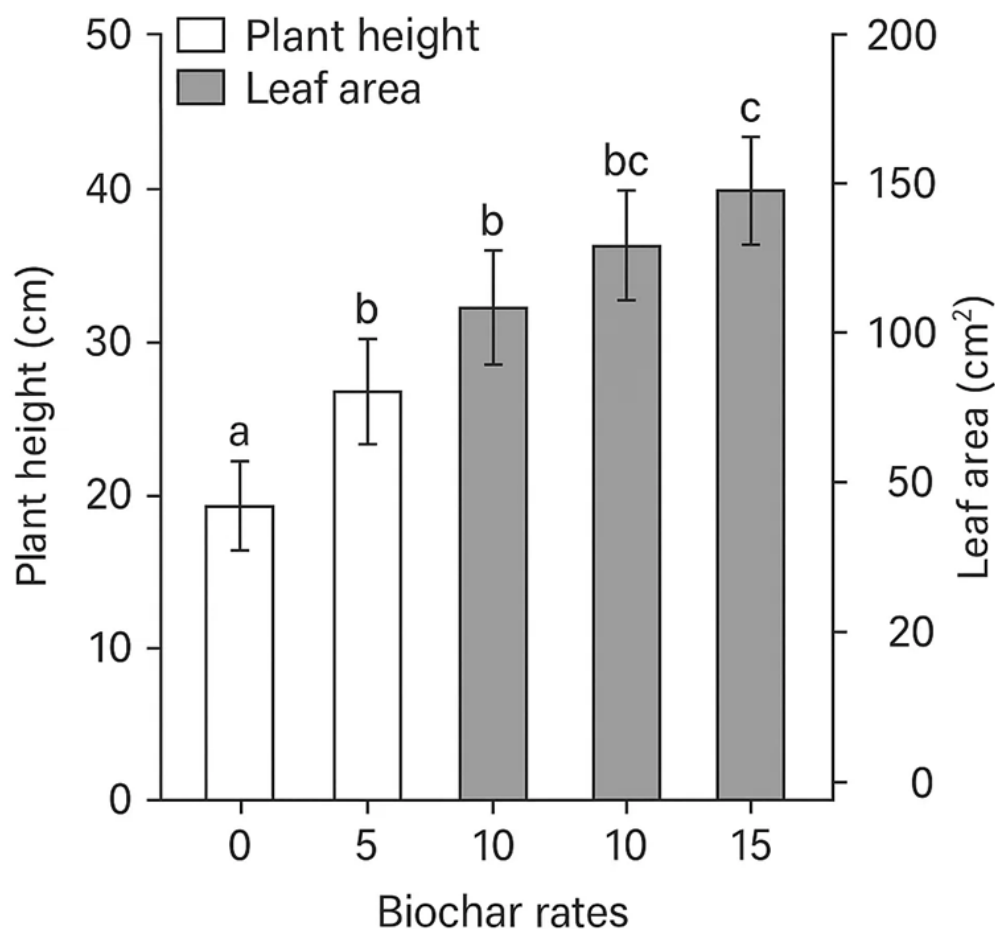


Figure 2. Plant height and leaf area at 9 WAT under different biochar rates

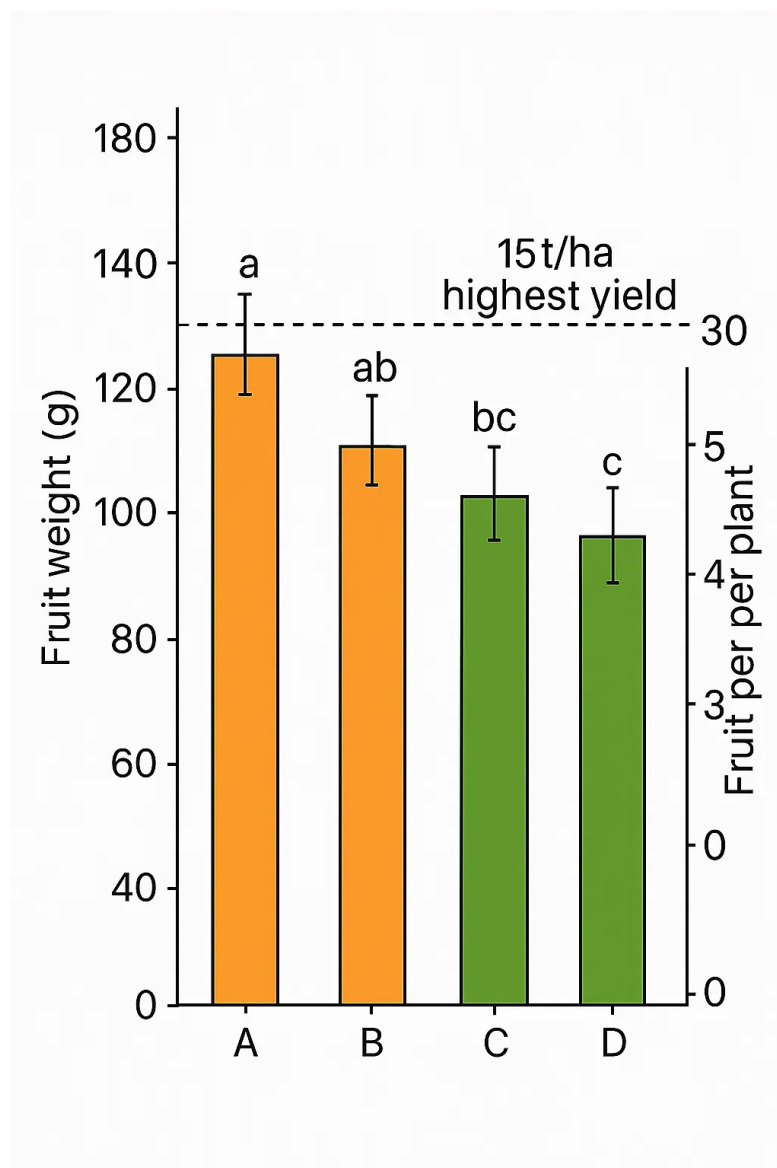
3.4 Effect on Fruit Yield

Fruit weight in the plots done with 15 t/ha also increased significantly by 45.2g -80.2g ($p < 0.05$). The number of fruit per plant was between five and ten, with a maximum being recorded in the 15 t/ha plots. This resulted in an increase in yield that was mainly due to the increase in the size of the fruit, and not the number of fruits.

Table 4. Effect of biochar on the fruit yield of garden egg

Treatment	Fruit Weight (g)	Number of Fruits/Plant
0 t/ha	45.2 ± 1.50 ^c	5.0 ± 0.30 ^b
5 t/ha	65.3 ± 2.30 ^b	7.0 ± 0.35 ^{ab}
10 t/ha	72.5 ± 2.10 ^b	8.0 ± 0.40 ^{ab}
15 t/ha	80.2 ± 2.90 ^a	10.0 ± 0.50 ^a

Means ($\pm$ SE) with different superscripts indicate a significant difference at $p < 0.05$ using LSD.



4. DISCUSSION: This paper has shown that the use of biochar significantly increased soil fertility, crop yield, and the life of fruits in a loamy-sand soil typical of the Guinea savanna. The noted growth in organic carbon and organic matter with increased biochar rates is also agreeable with the recent studies in which biochar was found to possess the ability to create stable carbon pools and promote microbial activity (Li *et al.*, 2021; Bareke *et al.*, 2021). High nitrogen and cation levels are consistent with the results that biochar is a nutrient adsorber and that biochar reduces leaching losses in coarse-textured soils (Musa *et al.*, 2023). Enhanced moisture retention and enhanced nutrient uptake can explain improvements in vegetative growth, the percentage of which depends on leaf area and plant height. The higher yields of the larger fruits at 15 t/ha-1 are attributed to the higher levels of nutrients and higher photosynthetic rates, and this supports research and findings that have been provided by Tadesse (2014) on the use of biochar in the soils as a nutrient source, as well as in the photosynthesis of fruit vegetables. One of the strengths of this study is the combination of soil characteristics, crop development and productivity, and harvest quality. The only growing season and one type of feedstock were tested; however, this is a limitation. Further studies on comparing different types of biochar and including an economic aspect of cost-benefit analysis would provide further information.

5. CONCLUSION: Biochar application significantly improved soil chemical properties, vegetative growth, fruit weight, and shelf life of garden egg under the University of Abuja conditions. The 15 t/ha rate produced the highest benefits, increasing organic matter, enhancing nutrient concentration, and promoting vigorous growth. These results confirm biochar as a sustainable soil amendment with the potential to improve productivity and reduce post-harvest losses in vegetable production systems. Adoption of biochar-based soil management can support food security and resilient agriculture in nutrient-depleted tropical soils.

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Utilization of GIS in Soil Suitability Classification for Groundnut (*Arachis Hypogaea* L.) Production: A case study of the Soils of Agriculture and Environmental Sciences Umuagwo, Imo State.

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Abstract:

This study utilized Geographical Information System in the study of soils of the University of Agriculture and Environmental Sciences (UAES), Umuagwo, Southeastern Nigeria, for Groundnut (*Arachis Hypogaea* L.) production. Ten soil mapping units (P1–P10) were identified and assessed for climatic and soil characteristics required for groundnut production. The FAO guideline for soil suitability classification and the parametric method were used to generate the aggregate suitability classes for each mapping unit. The results were digitally encoded in the GIS software for geostatistical analysis. The results revealed that climatic conditions were optimum for groundnut production. The soils were well drained and sandy loam texture dominated most of the sampling points. The fertility status of the soils revealed suboptimal results which are evidence in low C.E.C., organic carbon, available phosphorus, extractable potassium, and total nitrogen. The result of the semivariogram revealed spatial auto dependency and the cross validation results revealed blue line close to 1:1 line making a valid map. The actual suitability map indicates that soils toward the east, and close to Otammiri river are less suitable for groundnut production. The potential suitability map showed that good soil management practices that improves soil fertility are capable of improving the soils of this region for groundnut production **Keywords:** groundnut, GIS, soil suitability, crop production, mapping, low fertility.

Introduction: Groundnut (*Arachis hypogaea* L.) remains a strategically important legume crop across tropical regions due to its role in food security, soil fertility improvement, and income generation for smallholder farmers. It is a vital leguminous crop, serving as a significant source of dietary protein, oil, and income for millions in sub-Saharan Africa. Its successful production, however, is highly dependent on the interactions between climatic conditions, soil physical characteristics, topography, and intrinsic soil fertility. In Nigeria, the increasing pressure on agricultural land, coupled with declining soil fertility, has intensified the need for spatially explicit evaluation of land resources to guide sustainable crop planning. Traditional soil evaluation methods, though useful, often lack the spatial precision necessary for site-specific agricultural recommendations (Onyechere, Ukabiala M. E, et al., 2023). The advent of Geographic Information Systems (GIS) has revolutionized land suitability assessment by enabling the synthesis, analysis, and visualization of complex geospatial data (Onyechere, Onweremadu, et al., 2023). Geographical Information System (GIS) provides an efficient platform for integrating multi-criteria soil and climatic data to assess crop suitability with high spatial accuracy. Through geostatistical modeling, GIS enhances the understanding of spatial variability in soil attributes and generates suitability maps that can guide sustainable land use decisions (Onyechere, Onweremadu, et al., 2023). The soils of Southeastern Nigeria, including those in Imo State, are predominantly acidic and have undergone intensive weathering, often leading to nutrient depletion (Onweremadu et al., 2024). While the climate is generally favourable for groundnut production, the soil fertility status remains a critical constraint. This study was therefore conducted on the soils of the University of Agriculture and Environmental Sciences (UAES), Umuagwo, Imo State. This study employs FAO land evaluation guidelines and geostatistical modeling within a GIS environment to assess actual and potential soil suitability for groundnut production in UAES. The primary objectives were to identify the key soil properties limiting productivity, classify the soil's actual suitability for groundnut production using the FAO framework, assess the potential suitability after addressing these fertility constraints and demonstrate the efficacy of GIS and geostatistics in creating reliable suitability maps to guide agricultural planning and soil management interventions.

Materials and Methodology: The Study Area: The suitability analysis of the soil for groundnut production was carried out at the University of Agriculture and Environmental Sciences (UAES), Umuagwo. The university lies between latitude 5° 19'05"N and 5° 20'10"N and longitude 6° 57'0" and 6° 58'05" as indicated in the Location Map in Figure 1. The land area of the University is about 3km² with over 250 hectares of arable land. The soils are derived from Benin formation existing in the low lying part of southeastern Nigeria (Obasi, et al., 2017). The University is also bounded by the east by the Otammiri River, a major hydrological feature in Imo State (Onyechere et al., 2025). The region has a humid tropical climate and the rainforest vegetations have been drastically altered with arable crop production. The area experiences average daily minimum temperature range of about 19 – 24°C and maximum mean range of about 28 – 35°C (Ogbuagu & Okoli 2013). The mean relative humidity is up to 80% and a long wet season that starts from April and ends in November. The total mean annual rainfall is greater than 2000mm (Obasi, et al., 2017)

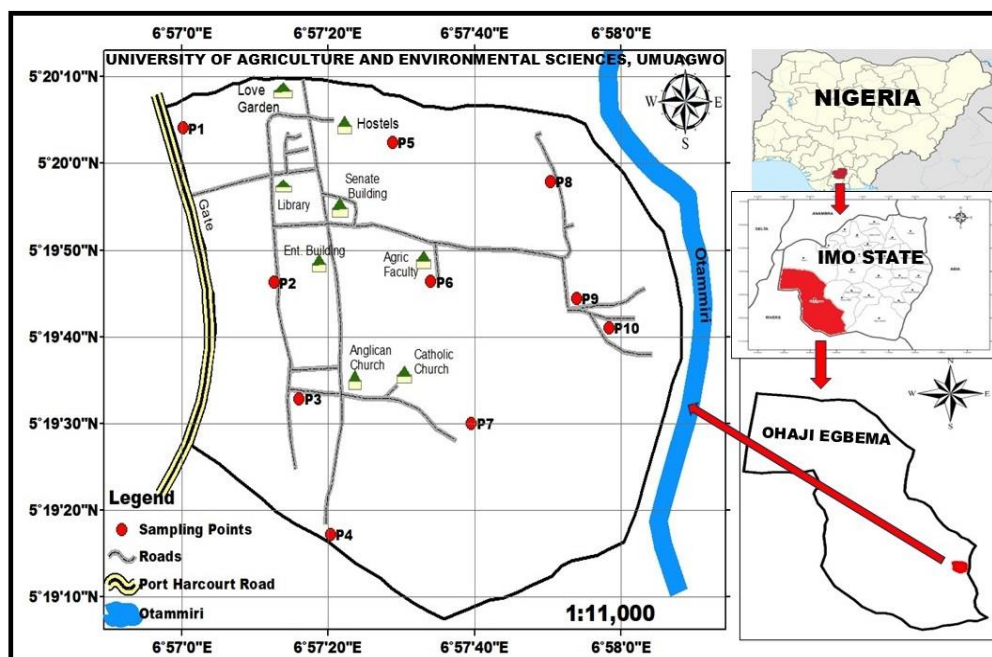


Figure 1: Location Map of the Study Area.

Ten representative soil samples (P01 to P10) were collected based on landform, vegetation cover, and apparent soil variability (Adamu et al., 2017). Auger samples were collected from the depth of 0 -15cm, 15 – 30cm, 30 – 60cm and 60 – 90cm using a Dutch auger (Okorie et al., 2020). Each site was geo-referenced using a GPS and the coordinates recorded as shown in Table 1 for geospatial analysis. The field observations also included slope, drainage, flooding, and soil depth estimation.

Soil Analysis: Soil samples were dried in air, ground, and passed through a 2mm sieve for analysis. Standard methods were followed for laboratory procedures: soil texture was assessed using the hydrometer method, pH was determined in a 1:2.5 soil-water mixture with a pH meter, and organic carbon was estimated using the Walkley–Black wet oxidation technique, the cation exchangeable capacity (CEC) was assessed using the ammonium acetate method at a pH of 7. Base saturation was derived from the exchangeable bases and CEC. Available phosphorus was evaluated through the Bray-1 extraction technique, while total nitrogen (N) was determined by the micro Kjeldahl digestion method (Okorie et al., 2020; Trigusasih et al., 2023).

Land Suitability Evaluation: The suitability of the soil was classified following FAO land evaluation framework (FOA, 2025). The land use requirement thresholds specific for groundnut production is presented in Table 1. This was adopted for placing the land unit into the appropriate suitability classes. The aggregate suitability scores were placed on suitability classes S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N1 (not suitable). Actual Suitability was based on unamended field and laboratory conditions. Potential Suitability was projected by adjusting fertility to ideal values under improved management. Limiting factors were identified using the most limiting approach (Igomu & Idoga, 2017; Obasi, et al., 2017). The aggregate suitability values for the actual and potential suitability were encoded in GIS software (Arc GIS 10.7) for the production of thematic maps.

DISCUSSION OF RESULTS: The FAO-based suitability requirements establish that groundnut thrives under warm temperatures (22–28 °C), moderate to high rainfall (>700 mm), deep soils (>120 cm), well-drained profiles, and loose to medium-textured soils such as sandy loam (SL), loamy sand (LS), and silt loam (SiL). Soil fertility is also a decisive factor, as the crop demands moderate levels of organic carbon, nitrogen, phosphorus, and cation exchange capacity (CEC) (Obasi, et al., 2017). These requirements provide the benchmark against which the UAES soils were evaluated. As shown in Table 2, the climatic conditions across all ten mapping units (P1-P10) are highly conducive to groundnut cultivation. The mean annual rainfall (>2000 mm) and temperature (28-35°C) far exceed the optimal thresholds (S1 class) defined in Table 1. Similarly, most physical characteristics are favourable. Soil depth is excellent (>120 cm, S1), topography is nearly level (0-4% slope, S1), and drainage is classified as "well-drained" (WD, S1) across all units. Soil texture, a critical factor for pod development, is predominantly Loamy Sand (LS) for units P1-P7, which falls within the "Highly suitable" (S1) class. However, units P8-P10 have a Sandy texture, which is only "Marginally suitable" (S3), posing a limitation due to lower water and nutrient retention capacity.

Table 1: Land requirements for groundnut

Land qualities/characteristics	Factor suitability rating			
	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
	(S1)	(S2)	(S3)	(N)

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Climate (C)				
Mean Annual Rainfall (mm)	>700	600-700	500-600	<500
Mean annual Temp. (°C)	22-28	18-22	15-18	<15
Soil physical characteristics (S)				
Soil depth (cm)	> 120	75-120	30-75	<30
Soil texture	SL, SiL, LS	CL, SiCL	S, SC, SiC	C
Topography (t)				
Slope (%)	0-2	20--05	05--08	>8
Drainage	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Soil fertility status (f)				
pH	5.8-6.2	5.5-5.7	5.0-5.4,	<5, > 7
Total N (g kg⁻¹)	>0.5	0.2-0.5	0.2	<0.2
Available P (mg kg⁻¹)	>20	10--20	05--10	<0.5
CEC (cmol(+) kg⁻¹)	>12	06--12	04--06	<4
Base saturation (%)	>80	50-80	40-50	<40
Organic C (g kg⁻¹)	>12	08--12	05--08	<5

Source: FAO, 2025

LS = Loamy Sand, SL = Sandy Loam, CL = Clay loam, SiL = Silt Loam, SiCL = Silt Clay Loam, C-Clay, S = Sand, SC = Sandy Clay.

The primary constraint to groundnut production in the study area is unequivocally the soil fertility status (Obasi, et al., 2017), as detailed in Table 2. The data reveal a widespread problem of soil acidity and nutrient deficiency.

Most mapping units have a pH between 4.9 and 5.7, placing them in the marginally suitable (S3) or not suitable (N) categories (Table 3). Groundnuts prefer a slightly acidic pH of 5.8-6.2 (S1); the prevalent low pH can induce aluminium toxicity and limit the availability of essential nutrients like phosphorus (Igumu & Idoga, 2017). Total Nitrogen is critically low across all units, with values ranging from <0.1 to 0.25 g kg⁻¹. This places most units in the marginally suitable (S3) or not suitable (N) class. Available Phosphorus levels are somewhat better, generally falling in the "Moderately suitable" (S2) range (10-20 mg kg⁻¹), but are still sub-optimal.

Organic Carbon is alarmingly low (4-9 g kg⁻¹), with most units rated S3 or N. This is a key indicator of poor soil health and directly impacts nutrient cycling and water retention (Adamu et al., 2017). The Cation Exchange Capacity (CEC) is also low (5.2-6.7 cmol(+) kg⁻¹), consistently rating as S2 or S3, reflecting the soil's limited ability to hold onto cationic nutrients like Potassium (K⁺), Calcium (Ca²⁺), and Magnesium (Mg²⁺).

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Table 2: Land qualities/characteristics of Soils Of UAES, Umuagwo for Groundnut Production

Climate (C)	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Mean Annual Rainfall (mm)	>2000	>2000	>2000	>2000	>2000	>2000	>2000	>2000	>2000	>2000
Mean annual Temp. (°C)	28 - 35	28 - 35	28 – 35	28 - 35	28 - 35	28 - 35	28 - 35	28 - 35	28 - 35	28 - 35
Soil physical characteristics (S)										
Soil depth (cm)	>120	>120	>120	>120	>120	>120	>120	>120	>120	>120
Soil texture	LS	LS	LS	LS	LS	LS	LS	Sand	Sand	Sand
Topography (t)	75-80	75-80	75-80	75-80	75-80	75-80	75-80	75-80	75-80	75-80
Slope (%)	0-4	0-4	0-4	0-4	0-4	0-4	0-4	0-4	0-4	0-4
Drainage	WD	WD	WD	WD	WD	WD	WD	WD	WD	WD
Soil fertility status (f)										
pH	5.3	5.3	4.9	5.6	5.7	5	5.1	5.2	5.1	4.9
Total N (g kg-1)	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Available P (mg kg-1)	19.1	20.4	18.8	14.6	14.3	15.1	14.9	13.1	14.2	15.6
CEC (cmol(+) kg-1)	6.3	6.2	6.7	5.4	5.4	5.8	5.7	5.3	5.3	5.2
Base saturation (%)	89.1	84.4	86.5	86.2	86.1	76.3	76.2	81.1	82.1	83.3
Organic C (g kg-1)	0.7	0.9	0.7	0.4	0.4	0.5	0.5	0.5	0.5	0.4

Table 3 Suitability Assessment of the Soils of UAES, Umuagwo for Groundnut Production

Climate (C)	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Mean Annual Rainfall (mm)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1

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Mean annual Temp. (°C)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Soil physical characteristics (S)										
Soil depth (cm)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Soil texture	S1	S1	S1	S1	S1	S1	S1	S3	S3	S3
Topography (t)										
Slope (%)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Drainage	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Soil fertility status (f)										
pH	S3	S3	N	S2	S2	S3	S3	S3	S3	N
Total N (g kg-1)	N	N	N	N	N	N	N	N	N	N
Available P (mg kg-1)	S2	S1	S2	S2	S2	S2	S2	S2	S2	S2
CEC (cmol(+) kg-1)	S2	S2	S3	S3	S3	S3	S3	S3	S3	S3
Base saturation (%)	S1	S1	S1	S1	S1	S2	S2	S1	S1	S1
Organic C (g kg-1)	N	N	N	N	N	N	N	N	N	N
Actual Suitability	N	N	N	N	N	N	N	N	N	N
Potential Suitability	SI	S1	S1	S1	S1	S1	S1	S3	S3	S3

The synthesis of these factors in Table 3 reveals the stark reality of the Actual Suitability. No unit is classified as highly or even moderately suitable. Six units (P1-P3, P6-P9) are "Marginally suitable" (S3), while four units (P4, P5, P10, and notably P3 due to its very low pH) are "Not suitable" (N). This is a direct consequence of the compounding effects of low pH, nitrogen, organic carbon and CEC.

In contrast, the Potential Suitability classification demonstrates a profoundly optimistic outlook. If the fertility constraints are remedied, eight of the ten units (P1-P7) could become "Highly suitable" (S1). Only the units with the limiting sandy texture (P8-P10) would remain "Marginally suitable" (S3). This dramatic improvement underscores that the limitations are not permanent but are manageable through targeted soil amendments.

The reliability of the potential suitability model is confirmed by the geostatistical analysis (Onyechere et al., 2023). The semivariogram analysis (Figure 1) indicates a strong spatial autocorrelation, meaning that points close to each other are more similar in their suitability potential than those farther apart. This validates the use of spatial interpolation techniques like Kriging. The cross-validation results (Figure 2) further strengthen the model's credibility. The regression function ($y = 0.96x + 0.087$) shows a slope very close to 1, and the predicted values closely follow the 1:1 line with a low root-mean-square error (0.087), indicating high prediction accuracy.

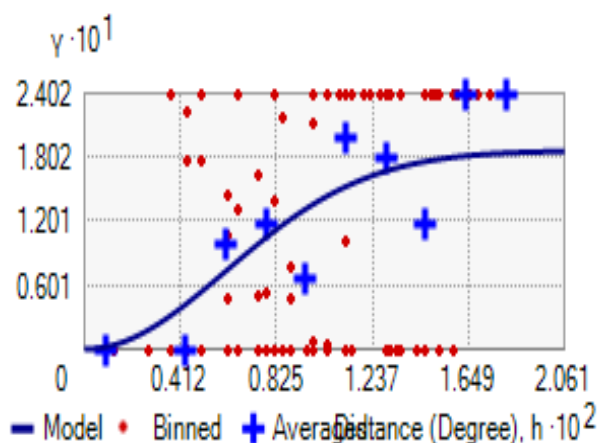


Figure 1: Semi variogram Analysis for the Potential Suitability

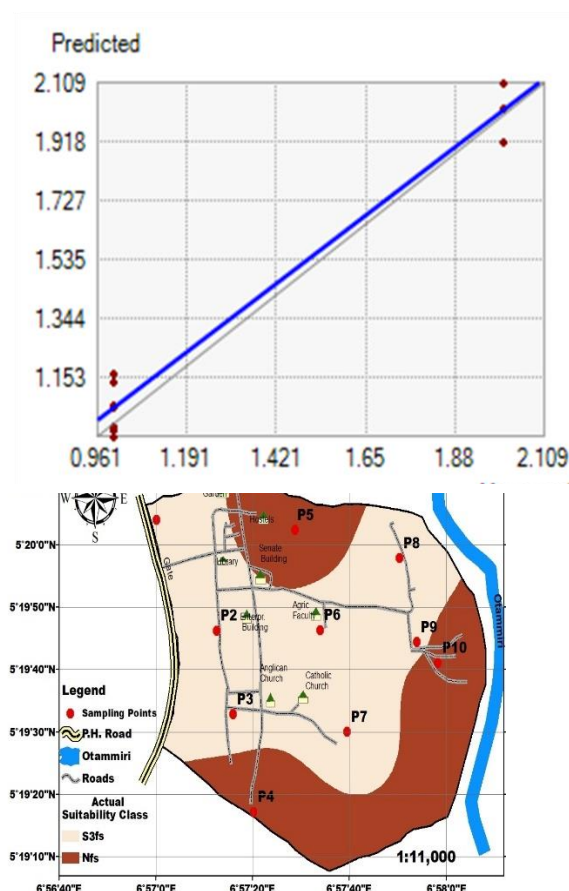


Figure 3: UAES Map for Actual Suitability Class for Groundnut Production

Regression function: $0.96 * x + 0.087$
Mean: 0.041
Root-Mean-Square: 0.087
Mean Standardized: 0.167
Root-Mean-Square Standardized: 0.6
Average Standard Error: 0.19

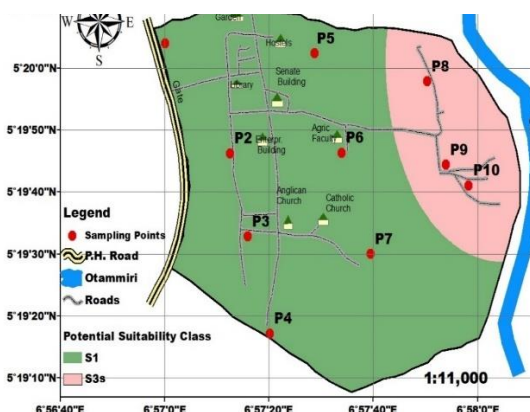


Figure 4: UAES Map for Potential Suitability Class for Groundnut Production

The spatial maps (Figures 3 & 4) effectively translate the tabular data into an actionable format for land-use planners. Figure 3 (Actual Suitability) visually confirms that the eastern parts of the campus, near the Otammiri River, are less suitable, likely due to a combination of the observed fertility issues. Figure 4 (Potential Suitability) provides a clear blueprint for intervention, showing that almost the entire area can be upgraded to high productivity with proper management, transforming it into a prime zone for groundnut cultivation.

Conclusion and Recommendations: The study reveals that while climatic and physical conditions of UAES are naturally favourable for groundnut production, soil fertility constitutes the primary limitation. Low nitrogen, acidic pH, low organic carbon, and low CEC significantly reduce actual suitability. However, the high potential suitability across most units confirms that strategic soil fertility interventions can transform the area into a highly productive groundnut zone. The validated GIS-based maps provide a spatial decision-making tool for targeted soil management and sustainable agricultural planning. The core recommendation should include application of agricultural lime to raise soil pH to the optimal range of 5.8-6.2. This will mitigate aluminium toxicity and improve the availability of phosphorus and other nutrients. Incorporate well-decomposed manure or compost and promote the use of cover crops to significantly boost soil organic carbon levels, which will, in turn, improve soil structure, water retention, and nutrient supply. Use NPK fertilizers formulated for legumes, with particular attention to nitrogen (despite its fixation capability, starter N is crucial in poor soils) and phosphorus. The use of phosphate-solubilizing biofertilizers could be explored. The GIS-generated maps should be used to implement precision agriculture. Management practices should be tailored to the specific constraints of each mapping unit. For instance, units P8-P10 with sandy texture will require more frequent but lighter irrigation and organic amendments to improve their water-holding capacity. Given the low nitrogen status, incorporating groundnut into a rotation system with other crops can help break pest and disease cycles and improve overall soil nitrogen balance through biological nitrogen fixation.

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Effect of Land Grabbing on Rural Households' Income in Akwa Ibom State, Nigeria

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Abstract

Land grabbing has become a significant issue in Akwa Ibom State, Nigeria, where there is a high demand for land for urban development, industrialization and commercial agriculture. This study investigated the effect of land grabbing on the income of rural households in Akwa Ibom State, Nigeria. Specifically, the study assessed the nature and extent of rural land grabbing, and estimated the effect of rural land grabbing on household income in the study area. The findings indicated that the 75.5% of the respondents were aware of incident of land grabbing, the average land size lost was about 1.5ha. About 43.6% of land were grabbed by government for projects. Major effect of land grabbing was displacement (18%), loss of livelihood (14.9%) and Food insecurity (14.9%). The results also showed that the higher the level of education of household head, the lesser household suffers from land grabbing. Land use policies should be enacted to protect rural farm households from illegal land grabbers. **Keywords:** Food insecurity, land, illegal, grabbers

1.0 Introduction: Land is one of the primary factors of production, along with labour and capital. It is a finite resource with an uneven distribution around the world. Land grabbing has become a significant issue in Akwa Ibom State, Nigeria, where there is a high demand for land for rural development, industrialization and commercial agriculture. Yang and He (2021) define land grabbing as the large-scale acquisition of land by investors, corporations or governments, mostly through purchase, lease, and agreement. Land grabbers often use violent or fraudulent means to acquire land, which results in the displacement of people, environmental degradation, and landlessness, marginalization of many communities and loss of livelihood (Borras and Franco, 2012). Land grabbing in Akwa Ibom state has resulted in substantial changes in land use, leading to decreased food production in rural areas and increased food insecurity among farmers (Abraham, Evelyn, Eyo, Ibanga, Ebong, Jimmy and Umana, 2021).

Agriculture is an integral part of the rural eco- system which contributes to the production of food and other products, and economic development of rural areas. The desire to increase production, maximize profits and achieve food sufficiency explains why government and non-governmental agencies, rich individuals and multinational companies are playing the leading roles in land grabbing. For instance, in some parts of Akwa Ibom State many hectares of land were recently acquired for coconut plantation. It is essential to emphasize that massive land acquisition in developing nations such as Nigeria is not a new phenomenon, since it was widely practiced during the time of colonial and postcolonial imperialist conquest (Taylor and Bending, 2009 and Bouchoung, 2019). Mayo (2010) postulated that land grabbing in Nigeria is part of a historical process in which land alienation, land accumulation strategies and dispossession of rural farmers have deconstructed Nigerian food production systems and redefined the Agrarian productive forces. Land grabbing in Nigeria in its current wave raises fundamental issues, including the consecration of land in the hands of few political actors in the state and the growing marginalization of small-holder farmers and their traditional practices in favour of industrial practices and practice capitalist modes of production (Bouchoung, 2019). The effect of land grabbing on household incomes in Akwa Ibom state is momentous, rural farmers are losing their traditional farmlands, which are located closer to markets and consumers. This has resulted in decreases in access to productive land and resources, including water and decreased yields leading to lower food production and less income. Despite the known adverse effects of land grabbing on income and the livelihood of rural farmers, government and many agencies are still acquiring land without adequate compensation to farmers. Hence, most resource poor farmers lost their source of livelihood and income. Understanding the nature and extent of land grabbing in the study area becomes a prerequisite for the reduction of poverty and food insecurity. this study bridged the information gap by describing the nature and extent of land grabbing. Again, the study estimated the effect of land grabbing on farmer's income in the study area.

2.0 RESEARCH METHODOLOGY: 2.1 Study Area: This study was conducted in Akwa Ibom State, Nigeria. Akwa Ibom State is located in the Niger Delta region of Nigeria with an estimated population of 5.451 million (NBS, 2016) and a land area of 6,900 sq. Km. It lies between latitudes 4032'N and 5033'N and longitudes 7025'E and 8025'E. It is bordered on the east by Cross River State, west by Rivers State and Abia State, and on the south by the Atlantic Ocean. It is currently the highest oil-producing State in Nigeria. Agriculture is the dominant economic activity of Akwa Ibom State. Agriculture supports 75% of households of the State's population. The various agricultural products include palm oil, cassava, yam, cocoyam, plantain, maize, rice, rubber, seafood such as varieties of fish, shrimps, crayfish, oysters, etc., poultry eggs and meats, pork, and lately snail farming.

2.2 Sampling Technique and Sample Size: Data for this study were collected through the use of structured questionnaire which were administered to farm households. Multistage sampling technique was used for the study. In the first stage, one (1) Local government Area was randomly selected from each of the six agricultural zones in Akwa Ibom State, which include: Eket, Etinan, Abak, Ikot- Ekpene, Uyo and Oron respectively. In the second stage, three (3) communities were randomly selected from each of the selected local government Areas, giving a total of 18 communities in each zone. In the third stage, 10 households were selected from each of the selected communities, giving a total of 180 farm households (30 from each zone). But due to inconsistency in data from most farm households, some copies of the questionnaire were not used for the analysis. The analysis was based on the information obtain from a total of 140 households (50 each from Uyo, 21 each from Eket, 16 each from Abak, 31 each from Ikot- Ekpene and 22 each from Oron zone). Changes in the administration of the questionnaire occurred due to the population in each zone. Data were collected through the use of structured questionnaire. The questionnaire was designed to obtain information on the socio-economic characteristics of the farming households such as age, gender, education, marital status, household size, size of land grabbed and source of income. The nature and extent of land grabbing and effect of rural land grabbing and on household income Data were analyzed using descriptive statistics, and multiple regression analysis.

2.3 Effect of rural land grabbing on household income. The ordinary least square (OLS) regression model was used to examine the effects of rural land grabbing on household income in the study area. Four functional forms were used

Linear $Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + Y$

Semi-log: $\log Y = B_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + U_i$

Double log $Y = B_0 + b_1\log X_1 + b_2\log X_2 + b_3\log X_3 + b_4\log X_4 + b_5\log X_5 + b_6\log X_6 + U_i$

Y= monthly income from rural farming (₦)

X₁= Age of the household head (in years)

X₂= Educational level (in years)

X₃= Household size (number of persons in the household sharing the same pot)

X₄= Farming experience (in years)

X₅ = Membership of social organization (1=yes, 0= No)

X₆= access to credit (1=yes, 0= No)

X₇= size of farm grabbed (ha)

X₈= Access to extension services (1=yes, 0= No)

3.0 Results and Discussion

3.1 Nature and extent of Rural Land Grabbing

The results presented in Table 1 shows the nature and extent of land grabbing in the study area. The findings showed that the majority (75.5%) of respondents were aware of incidence of land grabbing and about 58.6% of the respondents had lost land due to land grabbing. On the size of land lost to grabbing in the study area, 43.6% lost below 2 hectares, 36.5% lost land sizes within the range of 2 - 4 hectares, the remaining 22.1% of the respondents lost land sizes above 4 hectares. In addition, about 43.6% of the lands were grabbed by government for projects, followed by task force (21.2%), individual (21.2%), private companies (9.1%) and communities (4.4%).

Based on the effect of land grabbing, the findings showed that the major effect was displacement from their former land (18.6%), followed by loss of livelihood (14.9%), food insecurity (14.9%), increase in price of land (14.9%), loss of inherited land (14.9%), shortened fallow period (11.2%), and legal injustice (10.5%). On the basis of consultation before land grabbing, the result showed that majority (69.3%) of the respondents were consulted before their land were taken, 40% of the rural farmers received an average compensation of ₦290,000. The common protective measures adopted by rural farmers in the study area were acquiring certificate of occupancy (C. of O) (32.4%), community participation (24.1%), beacons and boundary marking (22.4%) and legal means (21.0%).

Table 1: Nature and extent of Rural Land Grabbing

Statements	Percentage (%)
Are you aware of any instances of land grabbing in your area that have affected agriculture	
Yes	75.7
No	24.3
Have you lost any land due to land grabbing?	
Yes	58.6
No	41.4
Size of land lost to grabbing (Mean = 1.3ha)	
Below 2ha	41.4

2ha - 4ha	36.5
Above 4ha	22.1
Agents responsible for land grabbing	
Government projects (e.g. road construction, buildings etc.)	43.6
Private companies	9.1
Task force	21.2
Community	4.4
Individual	21.2
How has land grabbing affected you?	
Loss of livelihood	14.9
Food insecurity	14.9
Displacement from former land	18.6
Shortened fallow period	11.2
Increase price of land	14.9
Legal injustice	10.5
Loss of inheritance	14.9
Were you consulted before your land was taken?	
Yes	69.3
No	30.7
Did you receive compensation for your land?	
Yes	40.0
No	60.0
If yes, how much?	
None	60.0
Below ₦600,000	13.6
₦600,000 - ₦800,000	14.9
Above ₦800,000	11.5
Mean = ₦290,000	
Measures adopted to protect land from land grabbing	
Legal means	21.0
Acquiring C. of o	32.4
Beacons and boundary marking	22.4
Community participation	24.1

Source: Field Survey, 2024.

3.2 Regression Results on Effect of Land Grabbing on rural Farmers' Income: The ordinary least square regression model was used to examine the effects of rural land grabbing on household income in the study area. Household income was used due to the direct negative effect land grabbing would have on farmers' productivity (Ibeagwa, Simonyan, Osuji, Onyenweaku, Ukoha, Tim-Ashama & Ezirim, 2022).

Four functional forms, namely linear, semi-log, double log and exponential forms were estimated (Table 2). The double log function was chosen as the lead equation. The choice of the double log function was predicated on its confirmation of a priori expectation in terms of sign magnitude of the coefficient, the number of significant variables and the coefficient of multiple determination (R^2). The diagnostic tests for the OLS estimation showed that about 44.6% of the variation in farmers' income were attributed to the specified explanatory variables. The F – statistic was significant at 1% probability level, denoting that the estimated R– square was significant and by implication, the estimated equation had goodness of fit. The empirical results showed that five variables (age, education, membership of social organization, access to credit, and farm size grabbed) were statistically significant out of eight variables included in the regression.

The findings showed that the older and highly educated the household head is, the lesser the household suffers the effect of land grabbing in the study area. The findings support the fact that land grabbing negative consequences on farmers' income (Suhardiman, Giordano, Keovilignavong & Sotoukee, 2015; Okon, Onyia, Udo & Ukpe, 2016). Older farmers may not have the physical strength to follow up possible measures in recovering their grabbed land, as their age increase, income from farming reduces due to lost of land to grabbers. Again, the highly educated farmers will generate income from off farm activities for households' survival. According to Šumane, Kunda, Knickel, Strauss, Tisenkopfs, des Ios Rios and Ashkenazy (2018), higher levels of education can provide farmers with knowledge and skills that can enhance their agricultural practices and generate money from off-farm activities.

Also, being a member of social organization had a direct relationship with income. In the case of land grabbing, where rural farmers face the threat of losing their land, membership of social organization can potentially have a positive impact on the income from farming (Nyantakyi-Frimpong & Bezner, 2017). Social organizations, such as farmer cooperatives or agricultural associations, can provide various benefits to their members, including access to resources, knowledge sharing, collective bargaining power, and advocacy for farmers' rights. By being part of a social organization, rural farmers may have a better chance of protecting their land rights and resisting land grabbing attempts. This can help them maintain their access to productive land, enabling them to continue their farming activities and generate income. Additionally, social organizations can

provide support and assistance to farmers affected by land grabbing, helping them explore alternative income-generating opportunities or seek legal remedies.

Access to credit had a negative coefficient and was statistically significant at 1%. The negative coefficient of access to credit (-0.167677) indicates an inverse relationship between access to credit of rural farmers and income realized from farming as a result of land grabbing. The result implies that farmers experiencing land grabbing may not be able to use their land as collateral for obtaining credit or loans (Cramb, Manivong, Newby, Sothorn & Sibat, 2019). This can limit their access to financial resources necessary for investing in agricultural inputs, equipment, or expanding their farming operations. Rural farmers who do not have access to credit may face challenges in improving their farming practices, adopting new technologies, or accessing necessary resources (Cafer & Rikoon, 2018). This can lead to a decrease in productivity and ultimately result in a decline in income from farming.

Farm size grabbed had a negative coefficient and statistically significant at 1%. Farmers experiencing land grabbing, lose a significant portion of their farm size which has a direct impact on their agricultural productivity and income (Abdallah, Ayamga & Awuni, 2023). A larger farm size generally allows farmers to cultivate a greater variety of crops, engage in more efficient farming practices, and potentially generate higher yields. Losing a portion of their land through land grabbing can limit their ability to engage in these activities, resulting in reduced productivity and income. Furthermore, a smaller farm size may also limit the economies of scale that farmers can achieve. With a smaller land area, farmers may face challenges in optimizing their resources, accessing markets, and benefiting from cost efficiencies. These factors can further contribute to a decrease in income realized from farming.

Table 2: Estimate of the Ordinary Least Square Model for the Effect of Rural Land Grabbing on household income

	<i>Linear</i>	<i>Semi Log</i>	<i>Double Log (L)</i>	<i>Exponential</i>
Constant	106531 (<0.0001)***	179371 (<0.0001)***	5.86631 (<0.0001)***	5.16705 (<0.0001)***
Age	-840.695 (0.0008)***	-68355.4 (0.0044)***	-0.620497 (0.0003)***	-0.00702722 (<0.0001)***
Education	-221.424 (0.5784)	-14364.5 (0.1393)	-0.120049 (0.0828)*	-0.00265973 (0.3483)
Household size	-1267.98 (0.2968)	-22241.1 (0.0479)**	-0.105210 (0.1863)	-0.00456027 (0.5971)
Experience	1320.51 (0.0689)*	29865.6 (0.0287)**	0.150977 (0.1181)	0.00522959 (0.3089)
Membership of social organization	6690.66 (0.1690)	9041.37 (0.0851*)	0.0674996 (0.0708*)	0.0504051 (0.1452)
Access to credit	-19848.2 (<0.0001)***	-22659.6 (<0.0001)***	-0.167677 (<0.0001)***	-0.147713 (<0.0001)***
Access to extension services	-1963.96 (0.6127)	-2123.75 (0.5820)	-0.0282235 (0.3042)	-0.0235861 (0.3930)
Farm size grabbed	-7242.00 (0.0006)***	-25004.0 (0.0009)***	-0.205427 (0.0001)***	-0.0580429 (0.0001)***
R-squared	0.378027	0.388136	0.445985	0.436959
Adjusted R-squared	0.340044	0.350771	0.412152	0.402575
P-value(F)	9.27e-11	3.42e-11	7.64e-14	2.07e-13
S.E. of regression	14011.21	13896.87	0.098816	0.099618

Source: Field Survey data, 2024. Using *Gretl*.

* = ($P < 0.1$) 10% level of significance, ** = ($P < 0.05$) 5% level of significance, *** = ($P < 0.001$) 1% level of significance, (L) = lead equation.

Conclusion and Recommendation: This study shows that land grabbing is a prevalent and critical issue in Akwa Ibom State, Nigeria, with a significant negative impact on rural households' income. Findings indicate that land grabbing, primarily driven by government projects and private actors, leads directly to reduced farm income, displacement, and loss of livelihood. Factors such as age of the rural farmers, years of formal schooling, size of land grabbed, and access to credit had negative effect on farmers' income. We recommend that protective land governance policies should be enacted and enforced to safeguard rural farmlands from illegal acquisition and ensure fair compensation and consultation for affected communities.

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Fadama Vegetable Farmers Attitude and Utilization of Organic Farming Practices in Akwa-Ibom State, Nigeria

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Abstract

The study sought to examine Fadama farmers' attitude towards organic farming practices and subsequent level of utilization of such practices in Akwa Ibom State, Nigeria. Relevant data were obtained from 120 vegetable farmers, selected through a multi-stage sampling procedure from a sample frame of participants in the Fadama-Additional Funding (AF) programme in the State. A set of pre-tested and validated questionnaires was used to elicit relevant information. Respondents were requested to respond to a set of 19 attitudinal statements and 17

organic practices with the aid of relevant Likert type criteria. Collated data were analysed with the aid of descriptive statistics and results indicated that an average proportion of respondents (55%) were found to possess a high, positive and favourable attitude towards organic farming practices. The general belief is that organic agriculture contributes to safe and healthy diets and improves soil structure. It was also revealed that an average proportion of respondents regularly utilized; animal manure ($\bar{x} = 3.74$), crop residues ($\bar{x} = 3.66$) and reduced/minimum tillage ($\bar{x} = 3.52$); on their farmlands. It is concluded that farmers possess a high propensity to go green and they should be encouraged in this endeavour by Fadama facilitators and extension agents.

Keywords: Attitude, utilization, organic farming, Fadama III-AF, vegetable farmers, Akwa Ibom State.

Introduction: One of the United Nations' Sustainable Development Goals (SDGs) is to create a world free of hunger by 2030. Recent trends however indicate that the world is moving farther away from meeting SDG 2 to achieve zero hunger. Food insecurity worsened in 2023 with about 282 million people worldwide, suffering from acute hunger. This number grew by 24 million when compared to 2022 figures, according to the (GRFC/FSIN (2024)). One important and often overlooked component of helping increase food security around the world in a sustainable way is supporting smallholder farmers, who produce about one-third of the world's food supply. Among this group are the world's poorest, most food insecure and most vulnerable, who are furthest from the goals of SDG 1 and SDG 2 (Woodhill, Hasnain and Griffith (2020)). Small-scale producers grow and process diverse and nutritionally rich dietary foods for local markets and fellow ruralites, thereby shortening supply chains and reducing wastage. Investing in them to engage in sustainable agricultural production can help ensure adequate food for all in a manner that will reduce environmental degradation. This calls for an enhanced focus on sustainable agricultural practices, a major plank of which is organic farming (OF). Sustainable farming not only rejects artificial methods but also emphasizes farming practices that are economically viable and supportive (Chomsky, 2023). In a similar mode OF strictly compliments sustainable agriculture because it focuses on utilizing methods that benefit the environment, without the use of synthetic pesticides, chemical fertilizers and GMOs. OF plays a key role in realizing the different sustainable agricultural goals, especially as it relates to quality human life, preservation of environmental integrity and promotion of green economy measures, especially in developing countries where smallholder agriculture forms the backbone of the economy. A key agricultural enterprise that could benefit from OF practice and ensure enhanced benefits to the smallholder farmers is vegetable production which is one of the global activities practiced in every economy, as it forms a major component of human diet. Studies discovered that not only is the global vegetable production increased by 100% in recent time, but also its trade value has exceeded that of cereals (Okonta et al (2023)). Vegetables provide essential nutrients to humans affordably with its vantage cheap and reliable sources of protein, vitamins and minerals for body development and repair. They render relished support to main cereals, root and tuber crops in the country (Oluwasusi, 2014). Smallholder farmers produce vegetables by integrating indigenous, adopted and scientific agricultural practices.

In view of the enormous benefits of OF, government intervention programmes geared toward improving the lives of the poor have consistently given priority to the inclusion of OF practices in its various programmes. The Third National Fadama Development Project (NFDPIII) and its successor, the Fadama III-Additional Financing (Fadama-AF) project followed in this trend and exposed its beneficiary vegetable farmers to OF activities. This has been done consistently through capacity building and provision of relevant inputs and other associated activities; including espousing of benefits derivable from utilisation of organic vegetable practices; as well enumerated by Mbah et al (2020) and Fanu et al (2024); among very many other researchers. Dissemination and subsequent adoption of agricultural technologies are tried and tested means of increasing farm productivity and concomitant poverty reduction among small scale farmers. Many studies, as listed by Zulqarnain et al (2020) however assert that the process of technology adoption and dissemination may be complex, challenging and consequently may affect the farmers' attitude towards agricultural technology adoption. It is however important to understand that farmers' response in terms of acceptance or rejection of technologies is an important determinant of the technology development process (Joshua, Massawe and Mwakalapuka, 2020). In essence, the attitude and knowledge of smallholder farmers towards their agricultural production and practices influence how they think and perceive their decisions (Kidane and Zwane (2022)). The tendency is to assume that people behave according to their attitudes. Pantakar (2020) opines that the concept that behaviour follows attitude is used extensively by advertising and marketing companies. In essence, when shaped in the right way, attitude can influence behaviour to achieve a favourable outcome. However, social psychologists have found that attitudes and actual behavior are not always perfectly aligned (Chaiklin, 2011). In essence, a large difference may exist between intention and actual behavior (Zhou and Ding, 2022). It is against this background that this study was conceived, to examine Fadama vegetable farmers' attitude towards OF practices and subsequent level of utilization of such practices in Akwa Ibom State, Nigeria.

Methodology: A multi-stage sampling procedure was used to select 120 respondents from a sample frame of Fadama vegetable farmers affiliated to 65 Fadama User Groups (FUGs) affiliated to 42 Fadama Community Associations (FCAs) in 16 of the 20 Local Government Areas (LGAs) participating in the programme in Akwa Ibom State. Data analyses were with the aid of frequency counts, percentages and mean counts. Farmers' attitude towards organic agriculture was evaluated using a 4-point rating scale of; Strongly Agreed (4), Agreed (3), Disagreed (2) and Strongly Disagreed (1) and consisted of nineteen (19) attitude statements; while utilization of organic practices consisted of 12 organic farming practices which were measured with the aid of a four-point Likert continuum of: Not practiced (1), Practiced but discontinued (2) Practiced- Selected Season (3) and Practiced every season (4).

Results and Discussion: Attitude of Respondents towards Organic Farming: Major attitudinal dispositions of respondents, as indicated in Table 1 were "Organic agriculture contributes to safe and healthy diets" ($\bar{x} = 3.89$; rank= 1); (ii) "Organic

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agriculture improves soil formation and composition” and ($\bar{x}$ = 3.62; rank= 2); and (iii) “Organic agriculture protects farmers’ health” ($\bar{x}$ = 3.61; rank= 3).

Table 1: Attitude of respondents towards organic farming practices (N=120)

Attitude Statements	Strongly Agreed (SA)		Agreed (A)		Strongly Disagreed (SD)		Disagreed (D)		Mean*	Rank
	F	%	F	%	F	%	F	%		
Farmers earn more money from organic farming since they use less inputs.	20	16.7	64	53.3	6	5	30	25	2.62	14 th
The environment is not polluted and degraded with chemicals.	18	15	70	58.3	5	4.2	27	22.5	2.65	13 th
Food produced organically is safe and of high quality with the absence of chemical residues.	60	50	48	40	4	3.3	8	6.7	3.33	4 th
Oxides of carbon and other harmful substances are not released into the atmosphere.	22	18.3	58	48.3	8	6.7	32	26.7	2.58	15 th
OF builds soil quality and organic matter content.	42	35	50	41.7	16	13.3	12	10	3.02	11 th
OF enhances the health of the natural environment	44	36.7	57	47.5	13	10.8	6	5	3.15	6 th
OF increases agricultural efficiency, yield and output.	25	16.7	55	45.8	5	4.2	35	29.2	2.58	16 th
With OF, there is food for all, at the right time, quantity and price (food security).	6	5	37	30.8	4	3.3	73	60.8	2.11	18 th
OF encourages retention of Carbon in the soil.	14	11.7	84	70	8	6.7	14	11.7	2.82	12 th
OF promotes agricultural sustainability.	38	31.7	60	50	9	7.5	13	10.8	3.03	9 th
There is a high demand for organic products.	2	1.7	49	40.8	16	13.3	53	44.2	2.41	17 th
OF protects farmers’ health.	90	75	20	16.7	3	2.5	7	5.8	3.61	3 rd
OF is a source of productive labour and employment.	30	25	80	66.7	6	5	4	3.3	3.13	7 th
OF contributes to safe and healthy diets.	85	70.8	25	20.8	6	5	4	3.3	3.89	1 st
OF improves soil formation and composition.	82	68.3	33	27.5	2	1.7	3	2.5	3.62	2 nd
Ground water is safe for drinking since chemicals are not leached into it.	40	33.3	60	50	10	8.3	10	8.3	3.08	8 th
OF encourages the existence of different beneficial organisms in the soil.	20	16.7	90	75	2	1.7	8	6.7	3.02	10 th
OF minimizes air pollution.	33	27.5	81	67.5	5	4.2	1	0.8	3.22	5 th
There is ready market for organic products only. (Market niche).	1	0.8	50	41.7	9	7.5	60	50	1.93	19 th

*Mean attitude = 3.0

These items revealed the potentials of organic farming practices to enhance farmers’ health, promote food safety and quality and promote soil formation and structure; among others. As noted by the respondents, organic farming contributes to safe and healthy diets because as a farming system that excludes the use of chemicals, chemical residues which cause cancer and other related diseases are absent from harvested produce. Also, the farmer’s health is protected since the farmer is not exposed to these chemicals (herbicides and pesticides) through application. Soil fauna and flora thrive in soils that are not replete with chemicals thereby improving their formation and composition. A few attitudinal statements however recorded mean values below the cut-off point of 2.5. These were: i) “there is a high demand for organic products” ($\bar{x}$ = 2.41; rank = 17), ii) “OA ensures food security” ($\bar{x}$ = 2.11; rank = 18) and; iii) “OA creates market niche” ($\bar{x}$ = 1.93; rank = 19).

These findings are an indication of the limitations of organic farming. The demand for organic products may not be high in the study area because some respondents noted that these products are generally sold at significantly higher prices than conventionally-produced food products. This secludes the product out of reach of the generality of the population, sequel to the current down-turn and generally low purchasing power in the study area. Also, to the ordinary citizens who frequent the open markets; there is no significant difference in the physical structure of both organically produced and conventionally produced vegetables. The only difference may be in price differentials on food shelves of supermarkets, many of which do not display vegetables on their shelves. Oluwasusi (2014) however reported a high demand for organic products in selected States of south west Nigeria.

Findings revealed a general moderate (average) disposition of respondents towards utilization of OF practices in their vegetable production activities. Table 2 indicates that about half (50%) of the respondents had high, positive and favourable disposition towards organic farming practices; unlike 42.5% (51) who indicated low, unfavourable attitude. These findings are consistent with those of Fanu et al (2024) Okonta et al (2023) Zhou and Ding (2022) and Oluwasusi (2014). Oyedele (2018) however reported that majority of respondents were undecided with reference to their disposition on OFP.

Table 2: A summary table of respondents’ attitude towards organic farming (N = 120)

Attitude of Respondents	Attitude score*	Frequency	Percent
Positive (Favourable)	> 54	60	50
Neutral	54	9	7.5
Negative (Unfavourable)	< 54	51	42.5

*Mean attitude score = 54

Predominant Organic Farming Practices (OFP): Table 3 indicates organic farming activities practiced by the respondents. The most prevalent OFP activities were: i) “Use of animal manure” ($\bar{x}$ = 3.74); ii) “Use of crop residues” ($\bar{x}$ = 3.66) and; iii) “Reduced/minimum tillage” ($\bar{x}$ = 3.52). On a general level, it was revealed that seven (7) of the 12 OFPs scored more than the mean cut-off point of 3.0 - indicating a moderate level utilization of introduced technologies. Findings revealed that many of the respondents are quite skeptical about the ‘much touted potentials’, of OFP based on its cumbersome nature and indifference of consumers and customers who refuse to pay higher prices for OF vegetables. Related literature reveals differing results on utilization of introduced OFPs. Mbah et al (2020) reported a high level of utilization of OFP in Imo State, with the major OFPs revealed as mixed cropping, shifting cultivation and crop rotation; while Obazi et al 2022, in Enugu State; reported a mid-level (51.6%) utilization, with animal manure, farmyard manure and composting as major applications. Owolabi, Ajayi and Akintola, (2018) with reference to Ondo State; reported a similar average utilization level with mixed cropping, minimum tillage, mulching as mainly used OFPs. On the other hand, Fanu et al (2024) revealed a low level of OFP utilization with crop rotation, mulching, application of organic fertilizer in Ekiti State. A similar low utilization trend was reported for Owerri LGA by Egwuonwu and Onyeaka (2020) with animal manure and natural weed control as most predominant. In deference to reported relative differences in the utilization of OFPs in vegetable production, Ibeawuchi et al (2015) asserted that current

practices of organic agriculture are a modification and continuation of indigenous practices that are more prominent in different respective areas in Nigeria.

The least utilized OFPs were: i) “use of off-farm organic wastes” ($\bar{x}$ = 2.08; rank= 10); ii) “intercropping” ($\bar{x}$ = 2.04; rank = 11) and; iii) “crop rotation” ($\bar{x}$ = 1.71; rank = 12). The practice of using off-farm organic wastes on the farm, such as kitchen sweepings, was low because most of the respondents lived far away from their farms. Intercropping was low too because, as asserted by some of the respondents, the design of Fadama III-AF Project allowed for each Fadama User Group (FUG) to be identified by a specific enterprise all through the lifespan of the Project, although some of the respondents (16.7%) planted a few other crops along with vegetable. This also explains why the practice of crop rotation was low.

Table 3: Distribution of respondents based on organic farming practices (N = 120)

Organic farming practices	Practiced every season		Practiced selected seasons		Practiced discontinued		Not practiced		Mean*	Rank
	F	%	F	%	F	%	F	%		
Use of animal manure	92	76.7	16	13.3	5	4.2	7	5.8	3.74	1st
Crop rotation	10	8.3	5	4.2	45	37.5	60	50.0	1.71	12th
Mulching	60	50.0	40	33.3	10	8.3	10	8.3	3.25	6th
Composting	22	18.3	70	58.3	7	5.8	21	17.5	2.78	9th
Intercropping	20	16.7	20	16.7	25	20.8	55	45.8	2.04	11th
Use of off-farm organic wastes	18	15.0	32	26.7	12	10.0	58	48.3	2.08	10th
Farm sanitation	60	50	40	33.3	9	7.5	11	9.2	3.24	7th
Reduced/minimum tillage	84	70.0	18	15.0	14	11.7	4	3.3	3.52	3rd
Cover cropping	22	18.3	78	65	12	10	8	6.7	2.92	8th
Use of crop residues	98	81.7	9	7.5	7	5.8	6	5.0	3.66	2nd
Adequate drainage system	70	58.3	35	29.2	10	8.3	5	4.2	3.42	5th
Use of local seed varieties	73	60.8	36	30	8	6.7	3	2.5	3.49	4th

*Mean value of organic farming practices = 2.5.

Conclusion and recommendations: The findings of this study are indicative of the generally moderate attitude of the vegetable farmers towards OFPs. This study also tends to affirm behavior follows attitude (Pantakar, 2020) because the farmers also recorded a moderate level of utilization of introduced OFPs. Many farmers possess a positive attitude towards OFPs because of its semblance to local, traditional farm practices. It therefore becomes imperative to leverage on the important traditional practices that share similar modes of operation with organic farming; as this will enhance its acceptability and easier diffusion through the farming system. It may also be important to understand reasons behind selective adoption of some OFPs, as to help expose related inadequacies which may need to be addressed, to enhance higher utilization levels. In essence, extension agents must be capacitated to enable them keenly perform awareness and advocacy functions that will espouse the health, economic and environmental benefits of OFPs. It is also important that the positive attitudinal traits of farmers become more enhanced and better transformed into actual behavior of adoption. This should be done by exposing them to means of generating higher income from their farms through OFPs. It is well known that organic production can create employment, transfer knowledge and improve access to high value markets. In this wise, Organic agriculture should be given priority attention in Nigeria because it is demand-driven as the products are needed in advanced countries. Nigeria needs to get its share of the lucrative global organic products market, through embarking on a process of certification of her products by the relevant authorities in the world market. A first step in this direction is through the formulation or stricter implementation of suitable policies to enhance the practice of organic agriculture. After which, a targeted focus on training and capacity building in both primary production and building a veritable value chain for organic products; will be embarked upon for enhanced sustainability.

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Gender Perception of Climate Smart Agricultural Practices by Cassava Farmers in Eket Agricultural Zone, Akwa Ibom State, Nigeria

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Abstract

The study analysed gender perceived effect of Climate Smart Agricultural Practices on cassava production in Eket Agricultural Zone, Akwa Ibom State, Nigeria. Data were collected from 60 males and 60 female's cassava farmers that were randomly selected using a multi-stage sampling procedure and analysed using descriptive statistics. Result revealed that most male (76.7%) and female (80%) farmers were married. The mean age, household size and farm size of male and female farmers were 49 and 46 years, 8 and 7 persons and 3.43 and 3.38 hectares, respectively. Also, Climate Smart Agricultural Practices were perceived to have the potential to increase food security, increase output and yield, increase farm income, reduce pest and disease, enhance resilience among others. Additionally, the use of Smart Agricultural Practices. It is recommended that awareness and sensitization campaigns should be carried out to educate farmers especially female farmers on the benefits of and the need to adopt Climate Smart practices. Farmers should be encouraged to form cooperatives as a means of accessing timely information on Climate Smart Practices. Additionally, Government and non- Governmental Organizations should give support to cassava farmers in the form of subsidies in the form of basic production inputs

Keywords: Cassava production; perceived effect and Climate Smart Practices

1.0: Introduction: Climate change is described as a change in the average conditions-such as temperature and rain falling in a region over a long period of time (FAO, 2021). Climate change is a threat to food security systems and one of the biggest challenges in the twenty-first century. The ability to contain the pace of climate change by keeping temperature rise within 2°C threshold is now curtailed, and the global population will have to deal with its consequences. This is in the context that agricultural production systems are expected to produce food for the global population that is projected to be 9.1 billion people by 2050 and above 10 billion by the year 2100 (FAO, 2021). Agricultural systems should be transformed to increase the productive capacity and stability in the wake of climate change. The ability to cope with the impacts of weather shocks and natural disasters brought by the effects of climate change depends largely on the household's resilience, or its capacity to absorb the impact of, and recover from, a shock. One way of combatting the effects of climate change is through the use of climate-smart agricultural practices (Olaoye *et al.*, 2021). Climate-smart agriculture has the potential to enhance sustainable productivity, increase the resilience of farming systems to climate impacts and mitigate climate change through greenhouse gas emission reductions and carbon sequestration (FAO, 2021). Climate-smart agriculture can have very different meanings depending upon the scale at which it is being applied. For smallholder farmers in developing countries, the opportunities for greater food security and increased income together with greater resilience was more important to adopting climate-smart agriculture than mitigation opportunities (Olaoye *et al.*, 2021).

Climate change is a serious threat to local food production and family well-being resulting in malnutrition, hunger and persistent poverty in many regions of the country (Ekanem *et al.*, 2020). Despite the multiple benefits of climate-smart agricultural practices and the deliberate efforts by the government and development partners to encourage farmers to invest in them, the rate of use of these strategies still remains low. Interestingly, most male and female farmers in the study area have adopted a wide range of Climate Smart Agricultural Practices. However, there still exist a great variation in gender perception of their effects. Accordingly, this study examines gender perceived effect of Climate Smart Agricultural Practices on cassava production in Eket Agricultural Zone, Akwa Ibom State, Nigeria. The specific objectives are to:

- (i) describe the socioeconomic characteristics of cassava farmers in the study area; and

- (ii) examine gender perceived effect of Climate Smart Agricultural Practices on cassava production in the study area

2.0: Research methodology: 2.1: Study Area: The study was conducted in Eket Agricultural Zone of Akwa Ibom State, Nigeria. The main economic activities of the people are farming, trading, fishing from riverine and coastal dwellers and white-collar services. Akwa Ibom State is made up of 31 local government areas (LGAs) with six (6) Agricultural Zones. Eket as the headquarter of the zone is located at latitude 4°39'N and longitude 7°56'E with a population of over 250,000 in 2019 but updated using 2.50% annual growth rate. The annual rainfall ranges between 2000mm and 3000mm with a temperature between 27 and 28 degrees Celsius. Some of the common food crop cultivates in the area are maize, cassava, cocoyam, okra, plantain, banana, waterleaf, fluted pumpkin, white yam and melon. In addition, some micro-livestock are usually raised at backyard of most homesteads and others fishermen in the riverine areas.

2.3: Sampling Techniques and Sampling Size: 2.3.1: Sampling Procedure: 3-stage sampling procedures was used to randomly select respondents in the study area. In the first stage, 5 blocks were randomly selected from the already existing 7 Blocks in Eket Agricultural zone. Secondly, 2 cells were selected from each of previously selected 4 Blocks making a total of 10 cells. Thirdly, 12 respondents (6 male and female respectively) were selected for each of the cells making a total of 120 cassava farmers that were used for the study. Taro Yamane statistical sampling technique was used to determine a sample size of 120.

The formula is given as:

$$n = \frac{N}{1 + N(e)^2}$$

Where; n = Sample Size, 1 = Constant, N = Population, e = Error term @ 0.05

$$\begin{aligned} n &= \frac{172}{1 + 172(0.05)^2} \\ &= \frac{172}{1 + 172 \times 0.0025} \\ &= \frac{172}{1.43} \\ &= 120 \end{aligned}$$

2.4: Method of data analysis : Objective (i) was analyzed using descriptive statistics such as means, simple percentages, standard and deviator, etc; **(iii)** was analyzed using a 4-point Likert scale rating technique with grading of strongly Agreed = 4, Agreed =3, Disagreed=2 and Strongly Disagreed = 1. The bench mark was obtained by calculating the weighted mean as $4 \times 3 + 2 \times 2 + 1 = 2.5/4$.

Hence, any effect with a mean score of 2.5 and above were regarded as strong positive effect (SPE) while those with mean score of less than 2.5 were regarded as "less effects"

3.0: Findings and discussion: 3.1: Social–Economic Characteristics of the Respondents: The result as shown in Table 1 reveals that the age distribution of farmers in the study area according to the age range presented revealed that 73.3% of the male respondent were above 40 years whereas 66.7% of the female respondents were above 40 years while 3.4% of both the male and female respondents were below 30 years respectively. The mean age of the male and female respondents are 49.12 and 46.30 years respectively which is an indication that the respondents are still very active to engage in agricultural production that will contribute to household food security and utilization of CSAP's. The result is in line with the findings of Haddabi *et al.* (2019), Yusuf *et al.* (2015) and Agom *et al.*, (2022) who claimed that at the active working age, household heads adopt innovations that positively affect their productivity and income.

Table 1 also revealed that the majority of the male (76.7%) and female (80%) respondents were married, while 2% were divorced. The findings revealed that most of the respondents were married, and it implies that farming is a stable job in the region. The result is in line with the findings of Agom *et al.*, (2022) and Ubokudom *et al.*, (2017) who found that married household's respondents especially those whose spouses are working are expected to be more food secure than single households, widowed or divorced. Most rural farmers will prefer to marry to have cheap labour for agricultural activities to enable their household to be food secure.

Table 1 also showed that about 46.7% of the male respondents had tertiary education and 38.3% of the female respondents had secondary education. The high literacy level in the area could suggest a better awareness, adoption and utilization of Climate Smart Agricultural practices. Educated farmers adopt agricultural innovations easier, and this could improve their agricultural productivity and ensure food security. This finding agrees with that of Haddabi *et al.*, (2019) but is contrary to the findings of Agom *et al.*, (2022).

Table 1 also showed that about 66.6% of the male respondents have household sizes of 5 - 10 persons, whereas 60% of the female respondents have household sizes of 5 - 10 persons. The mean household size for both male and female respondents was about 7 and 8 persons. Farm households with larger household sizes tend to have more labour from the family for farming activities even though the dependency ratio will be high. Larger household size tends to reduce per capita food expenditure and per capita household income, thus increasing their likelihood of being food insecure. The findings correspond with that of

Agom *et al.*, (2022) and Nkeme, (2021) who asserted that the larger the family size the lesser the food availability to each person within the household and also nutritional status will be affected.

Table 1 further showed that majority of both the male (75%) and female (78.3%) respondents are primarily engaged in farming, hence farming their primary occupation which may suggest a stable food security and utilization Climate Smart Agricultural Practices in the area. This finding is in line with Nkeme, (2016).

The distribution of monthly income of farming households shown in Table 4.1 revealed that the majority of the male (61.7%) and female (53.3%) earned ₦50,000-₦100,000 monthly from Cassava production. Additionally, majority of the male (46.7%) and female (38.3%) earned ₦50,000-₦100,000 monthly from non-farming activities. The result also showed that 51.7% and 66.7% of the male and female respondents respectively received lower than ₦50,000 from family and friends as source of income. The result indicates that the farming households had numerous streams of income and they would be able to afford their basic needs. Additionally, majority of the female (73.3%) and male (65%) respondents are members of cooperative and 87.9% & 83.3% of male and female respondents respectively have been a member of the cooperative below 5 years. Being a member of cooperative is an indication of access to information and resources. The result also showed that the male (50%) and female (55%) respondents' source of credit comes from families and friends; hence they have no access to credit facilities from any financial institution or cooperative. Access to credit is an important factor that can influence the likelihood of adoption of new technologies by farmers to augment their income level and attain food security. Farm credit plays an intermediate role between the adoption of farm technology and the increase in farm output vis-à-vis their income level. This finding corroborates that of Haddabi *et al.* (2019) and Agom *et al.*, (2022) who asserted that farmers cannot expand their production activities due to limitations to finance.

The survey results also revealed that the majority of the female (71.7%) respondents had access to extension agents in contrast to the male (66.7%) respondents that had no access to extension agent. Access to an extension agent of the female respondents is an indication of access to information and resources. Additionally, the female (60%) respondents were visited bi-weekly compared to the male (33.3%) respondents who were visited weekly. The distribution shown in Table 1 revealed that the majority of the female (50%) respondents land acquisition is by Rent/leased compared to the male (26.7%) respondents that own their lands. Land acquisition is a major determining factor in terms of the Climate Smart Agricultural practices employed by the farmers just as reported by Haddabi *et al.* (2019). Also, most of the female (38.3%) and male (41%) respondents had farm sizes less than 2.0 hectares. The finding revealed that food crop farmers in the study area are mainly small-scale farmers; hence, food production is at a subsistence level which could lead to diversification of income sources by farmers to food secure. This finding corresponds with the finding of Haddabi *et al.*, (2019) and Oyeбанjo *et al.*, (2013) that the majority of Nigerian farmers are small-scale farmers who cultivate less than 5 hectares.

Table 1: Distribution of Respondents Based on their Socio-economic Characteristics

Variables	Male	Percentage (%)	Female	Percentage (%)
Age	(Mean = 49years)		(Mean = 46.30years)	
Below 30	2.0	3.4	2	3.4
30 – 40	14.0	23.3	18	30.0
Above 40	44.0	73.3	40	66.6
Total	60	100	60	100.0
Marital Status				
Single	8	13.3	5	8.3
Married	46	76.7	48	80.0
Divorced	2	3.3	2	3.3
Widow	0	0.00	5	8.3
Widower	4	6.7	0	0
Total	60	100	60	100
Education	Mean		Mean	
Primary	5	8.3	18	30.0
Secondary	27	45.0	23	38.3
Tertiary	28	46.7	19	31.7
Total	60	100.0	60	100.0
Household Size	Mean = (8 persons)		Mean = (7 persons)	
Below 5	18	30.1	20	33.3
5 – 10	40	66.6	36	60.0
Above 10	2	3.3	4	6.7
Total	60	100	60	100.0
Farming Experience				
Below 5 years	10	16.7	21	35.0
5-10 years	19	31.7	21	35.0
Above 10 years	31	51.6	18	30.0
Total	60	100	60	100
Membership of Cooperative				
Yes	21	65.0	44	73.3
No	39	35.0	16	26.7
Total	60	100	60	100.0
Access to Extension Service				

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Yes	20	33.3	43	71.7
No	40	66.7	17	28.3
Total	60	100	60	100.0
Farm Size	(Mean = 3.43ha)		Mean = (3.38ha)	
Below 2ha	25.0	41.7	23	38.3
2ha – 4ha	12.0	20.0	15	25.0
Above 4ha	23.0	38.4	22	36.7
Total	60	100	60	100.0

Source: Computed using field survey Data (2023)

3.2: Perceive effects of Climate Smart Agricultural Practices on food security

Table 2a and 2b present the perceive effects of male and female farmers on the adoption of climate smart practices on food security in the study area as observed in table 4.3a, in order of priority, male farmers reported that adoption of climate smart practices increases output and crop yields (mean=3.50) improve farm household welfare (mean=3.45) increase farm income (mean=3.42), have a potential to increase food security (mean=3.40) ensures stable and consistent food supply, (mean=3.33) preserve biodiversity an ecosystem (mean= 3.15) and enhance resilience and sustainability of food system (mean= 2.90).

Additionally table 2a also shows in order of priority that women farmers reported that adoption of climate smart practices will exert strong positive effect on food production by; increasing output and crop yields (mean=3.60) having the potential to increase food security (mean= 3.57) improving farm household welfare (mean=3.53)reducing pest and disease infestation (mean= 3.48) increasing farm income (mean= 3.27), ensuring stable and consistent food supply (mean=3.23), preserving biodiversity and ecosystem (mean=3.12) and by enhancing resilience and sustainability of food system(mean=3.00). The potentials of climate smart practices in increasing crop yields and improving food security were previously reported by Nkeme (2016) Oladele 2019, Adekunle (2019) and Akinbile (2019), respectively.

Table 2a: Perceived effects of climate Smart Agricultural Practices on cassava production by male farmers

Perception statement	SA	A	D	SD	Mean	Remark
Increased output and crop yield	39	16	1	4	3.50	SPE
Potential to increase food security	38	14	5	3	3.40	SPE
Improve farm household welfare status	38	12	6	4	3.45	SPE
Increase farm income	37	15	4	4	3.42	SPE
Reduce pest and disease infestation	19	28	9	4	3.03	SPE
Enhance resilience and sustainability of food system	20	24	6	10	2.90	SPE
Ensure stable and consistent food supply	27	28	3	2	3.33	SPE
Preservation of biodiversity and ecosystem services	25	22	10	3	3.15	SPE
Mean perceived effect = 3.27						

Note: SA = Strongly Agreed, A=Agreed, D=Disqualified, S.D = Strongly Disqualified; SPE = Strong Positive Effect

Source: Computed using field survey data (2025)

Table 2b: Perceived effects of climate smart agricultural practices on cassava production by female farmers

Perception Statement	SA	A	D	SD	Mean	Remark	Rank
Increased output and crop yield	37	16	4	3	3.60	SPE	1 st
Potential to increase food security	32	15	2	1	3.57	SPE	2 nd
Improve farm household welfare status	32	26	1	1	3.53	SPE	3 rd
Increase farm income	20	30	7	3	3.27	SPE	5 th
Reduce pest and disease infestation	33	20	4	3	3.48	SPE	4 th
Enhance resilience and sustainability of food system	23	22	7	8	3.00	SPE	8 th
Ensure stable and consistent food supply	18	36	4	2	3.23	SPE	6 th
Preservation of biodiversity and ecosystem services	29	19	2	10	3.12	SPE	7 th

Mean perceived effect = 3.27

Note: SA = Strongly Agreed, A=Agreed, D=Disqualified, S.D = Strongly Disqualified; SPE = Strong Positive Effect

Source: Computed using field survey data (2023)

4.0: Conclusion : The study analyzed gender perception on the effect of Climate Smart Agricultural Practices on cassava production in Eket Agricultural zone, Akwa Ibom State, Nigeria. Findings showed that both gender perceived Climate Smart Practices as having a strong positive effect on Cassava production in the study area. Accordingly, the study concluded that there was high positive perception on the effect of Climate Smart Practices among both genders in the study area.

5.0: Recommendations: Based on the findings of the study, the following recommendations are suggested;

Awareness and sensitization campaigns should be carried out to educate farmers especially female farmers on the benefits of and the need to adopt Climate Smart practices.; Farmers should be encouraged to form cooperatives as a means of accessing timely information on Climate Smart Practices.; Government and non- Governmental Organizations should give support to farmers in the form of subsidies in the form of basic production inputs.

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Assessing the Adoption of Climate Smart Agriculture and Its Impact on Food Security in Southwest Nigeria

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Abstract

The problem of climate change is gradually becoming a significant issue for the food production system in Nigeria, particularly in the Southwest region, which relies heavily on rain-fed agriculture by smallholder farmers. Climate Smart Agriculture (CSA) provides a prospective solution to the vulnerability of resiliency, productivity, and sustainability in the context of such endangered environments. This paper will analyze the CSA practices and implications of adoption on the food security of the smallholder farmers in Ekiti, Ogun, and Oyo States. A qualitative design was used in the gathering of data, where semi-structured questionnaires were given to 45 purposely selected farmers in three Local Government Areas. The study examined the knowledge, perceptions, experience, and limitations of farmers as far as CSA practices were concerned: drought-tolerant crops, conservation agriculture, agroforestry, and integrated soil-fertility management. According to the thematic analysis, the level of adoption of climate-smart agriculture (CSA) is mediated by access to extension services, the level of education, and access to farming inputs. The respondents who embraced the practice of CSA indicated that there was increased availability of food in the household, stability in yield, and dietary diversity even when the weather was unpredictable. Nevertheless, a number of limitations were discovered, and these include access to credit, lack of proper infrastructure, and policy support, among others that hindered broader implementation. The research suggests improving the capacity-building initiatives, reinforcing the extension systems, and introducing the local policy interventions to expand the CSA practices and ensure food security among the farming communities in Southwest Nigeria.

Keywords: Climate Smart Agriculture, Food Security, Smallholder Farmers, Agricultural Adaptation, Farmer Perceptions, Sustainable Agriculture

Introduction: One of the most pressing problems facing agricultural systems all over the world is climate change. Africa is especially vulnerable to climatic risks due to Sub-Saharan Africa being highly reliant on rain-based farming and with low adaptability (FAO, 2022). Growing temperatures, inconsistent rainfall, and land degradation are putting more pressure on Nigeria, as the most populous African country, to ensure that agricultural productivity, food security, and rural poverty decrease (Akinyemi et al., 2023). The effect of the climatic variability on the southwest Nigeria region, where farmers are the small food producers, is negative and this threatens the livelihoods and the food system. The smallholder households have been reported to experience reduced yields and rise in vulnerability and the effects have been felt on the amount of food available in the household and dietary diversity (Olaniyi and Okeke, 2023). Climate Smart Agriculture (CSA) has proved to be one of the ways through which these problems can be overcome. CSA encourages the practices that can be, at the same time, more productive, resilient, and decrease greenhouse gas emissions where appropriate (World Bank, 2023). However, even with all its potential, it is not yet adopted equally in Nigeria because systemic barriers, such as the lack of access to extension services, poor infrastructure, and lack of credit facilities, limit its use (Okonkwo et al., 2022).

The study is useful in addressing the gap in empirical research on CSA adoption in Southwest Nigeria, as it focuses on the adoption and implications of food security among smallholder farmers in Ekiti, Ogun, and Oyo States. The specific objectives are; To discuss the knowledge and perception of the farmers with CSA practices.; To examine the levels of CSA practices adoption.; To evaluate the background of CSA adoption on household food security; To determine the obstacles to further implementation.

2.1 Climate Change and Food Security in Sub-Saharan Africa: According to the Intergovernmental Panel on Climate Change (IPCC, 2022), due to rising temperatures, unpredictable precipitation, and unfriendly climate conditions, there is a threat of acute agricultural degradation in Sub-Saharan Africa. Nearly 95 percent of farming is rain-based; thus, the smallholders are not the exception, which leads to frequent hunger catastrophes and poverty (Serdeczny, 2022). The yield of maize, sorghum, and cassava is already decreasing because of climate shocks, and 10-20% of the maize crop is already expected to be eradicated by mid-century unless they are adapted to climate change (FAO, 2022; World Bank, 2022). The increase in population, soil erosion, climate change, and the instability of the food system market are also linked to the rising pressure on the food system and the decrease in its resilience (Eze et al., 2023). Small holders supply more than 70 percent of domestic food in Nigeria, and this means that their consequences are dire (Adebayo and Kehinde, 2023). The Southwest records the shifting precipitation, prolonged dry seasons that diminish the ability to cultivate and buy food in the country (Oladipo, 2021; Adepoju and Salami, 2022). The variability of food insecurity can be divided into the availability, access, utilisation, and stability, which are affected by climate variability (FAO, 2022; Nwajiuba et al., 2022). The adaptive capacity of the region is also limited by the lack of infrastructure and credit facilities and unstable land tenure systems (Adedeji and Olayemi, 2023). To this end, Climate Smart Agriculture (CSA) is a mental approach that promotes the increase of productivity and resilience in addition to the reduction of emissions in order to enable Southwest Nigeria and other food security (Makinde et al., 2023; FAO, 2022).

2.2 Concept and Practice of Climate Smart Agriculture: According to the Food and Agriculture Organization (FAO, 2022), Climate Smart Agriculture (CSA) is an approach that must be in a position to enhance the productivity, render the system resilient, and sustainably minimize greenhouse gas emissions in a sustainable manner. CSA in Nigeria has been on the increase as a solution to the twin problems of climate change and food insecurity. The current approaches are the implementation of drought-resistant crops, agroforestry, conservation agriculture, mulching, water harvesting, and integrated soil fertility management (Adenle et al., 2022; Makinde et al., 2023). The following practices are not only meant to boost yields but also to safeguard the natural resources and enhance smallholder livelihoods in cases of stressful weather conditions. It has been empirically proven that CSA interventions are potentially significant in improving soil fertility, lessening water use, stabilizing crop productivity, and diversifying family food supplies despite the unpredictable rainfalls and extended dry periods (Olaniyi et al., 2023; Oyetunde-Uzman et al., 2023). Also, the literature indicates that the application of CSA decreases climate shock exposure, and agroforestry is applied to absorb carbon and increase the resilience of the rural population (Gabriel et al., 2023; Saadu et al., 2024). Nevertheless, the rates of adoption are not homogeneous because of low income, limited access to extension services, institutional insufficiency to support the experiences of smallholders, and the necessity to have persuasive policies and local-level interventions.

2.3 Factors Influencing CSA Adoption: The socio-economic, institutional, and environmental conditions all interact in a complex manner to affect the adoption of CSA in Nigeria. Environmental extension services continue to play an important role in the transmission of knowledge, building farm-based potentials, and adopting new technologies (Olaniyi and Okeke, 2023; Gabriel et al., 2023). Nevertheless, education, agricultural land, and gender roles are highly influential factors in the process of adoption, as women farmers are disproportionately disadvantaged because of the inequality in accessing productive resources, input, and training opportunities (Adebayo and Kehinde, 2023; Adenle et al., 2022). Structural issues like a lack of credit facilities, access to subsidized inputs, poor infrastructure, and high price of irrigation remain limiting the scaling activities (Okonkwo et al., 2022; Saadu et al., 2024). Poor policy frameworks and poor implementation strategies, and the lack of localized interventions are other institutional barriers that limit progress (Izuogu et al., 2025). It is also documented in terms of the fact that tenure insecurity in land reduces long-term investment in activities such as agro forestry, hence restricting the broader adoption of CSA (Eze et al., 2023). All these issues can be overcome through the integrated methods of combining specific extension services, gender-sensitive policies, investment in rural infrastructure, and credit schemes accessible to farmers (Makinde et al., 2023). There is thus a need to mainstream CSA and increase food security resiliency in Nigeria by a concerted effort on the part of the government, the private sector, and community-based institutions.

2.4 CSA and Food Security Outcomes in Nigeria: Climate Smart Agriculture (CSA) has been a growingly accepted route towards enhancing household food security in Sub-Saharan Africa. CSA facilitates the four dimensions of food security, availability, access, utilization, and stability directly through promoting the activities that enhance productivity, resiliency, and minimize emissions (FAO, 2022). Those farmers who implement the CSA techniques of drought-resistant varieties of crops, mulching, conservation farming, and intercropping state that they earn better yields, stable food supplies, and more diverse diets even during the period of climatic stress (Adenle et al., 2022; Olaniyi and Okeke, 2023). The empirical evidence of the similar agroecological zones also indicates that the implementation of CSA lessens the threat of complete crop failure during droughts and increases dietary diversity when integrated with other systems such as agroforestry and crop animal associations (Gabriel et al., 2023; Saadu et al., 2024). In addition to the direct productivity gain, CSA also facilitates management of soil fertility and water conservation, which produce long-term benefits of sustainability in the form of dividends to the rural communities. In spite of these reported advantages, there remain considerable gaps in understanding in the localized adoption in Southwest Nigeria, where ecological settings, cultural behaviors, and institutional systems are significantly different among states and among farming populations. As an illustration, smallholder farmers in Ekiti can be more concerned about soil fertility, whereas farmers in Ogun and Oyo have issues with market access and irrigation facilities (World Bank, 2023; Izuogu et al., 2025). These territorial differences highlight the need to have context-related interventions that combine the socio-economic realities of farmers, institutional capacities, and environmental realities. The lack of such delicate strategies means that CSA can never fulfill its potential of fortifying food systems and enhancing food security resilience in the area.

3. Methodology: In this research, a qualitative research design was used to get the experiences and perceptions of farmers about the adoption of CSA. The research was done in Ekiti, Ogun, and Oyo States- representing a wide range of agro-ecological and socio-economic situations in Southwest Nigeria. Forty-five (45) smallholder farmers were selected purposively in six LGAs in the three states, and selection was based on their active participation in crop farming and susceptibility to climate variability. Data on knowledge of farmers, adoption levels, and challenges associated with CSA were collected using semi-structured questionnaires. The data have been analysed thematically following the approach of Braun and Clarke (2006), which entailed coding of responses, development of themes, and formulation of patterns that reflected the views of the farmers.

4. Results: 4.1 Farmers' Knowledge and Perceptions of CSA Practices

Table 1: Awareness and Perceptions of CSA Practices

CSA Practice	Awareness (%)	Adoption (%)	Thematic Insight
Use of drought-tolerant crops (maize, cassava varieties)	78	55	"The new maize varieties mature faster and survive late rains."
Mulching and residue management	65	50	"Leaving residues on the soil helps the crops survive heat."
Crop rotation/intercropping	72	60	"Mixing maize and cassava spreads risk and gives us food variety."
Agroforestry (planting trees with crops)	60	35	"Cashew trees provide fruits, but few people combine them with food crops."
Organic manure/composting	80	67	"Animal waste improves yields without buying fertilizer."
Irrigation/water harvesting	40	18	"We depend on rainfall; irrigation is costly here."

Low-cost CSA practices like organic manure (80% awareness; 67% adoption), crop rotation (72%; 60%), and drought-tolerant crops (78%; 55%) are very high, and adoption of the expensive ones, including irrigation (40%; 18%) and agro forestry (60%; 35%), is low, by farmers in Southwest Nigeria. It is therefore the level of affordability that influences adoption rather than awareness.

4.2 Adoption Levels of CSA Practices

Table 2: Adoption of CSA Practices by State

Benefit	Frequency (n)	Percentage (%)	Thematic Evidence
Improved household food availability	30	66.7	"Cassava and yams sustain us all year, especially when rains fail."
Yield stability despite erratic rainfall	26	57.8	"The improved maize resisted the dry spell last year."

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Benefit	Frequency (n)	Percentage (%)	Thematic Evidence
Enhanced dietary diversity	21	46.7	"With vegetables and fruits from intercropping, we eat better."
Increased farm income	18	40.0	"Selling extra cassava helps us buy other foods."
Reduced vulnerability to climate shocks	15	33.3	"Before, drought wiped out crops; now at least we harvest something."

Results suggest that adoption of CSA in Southwest Nigeria increases the level of food security and food resilience, where farmers have reported higher availability of food at the household level (66.7%), no change in yield (57.8%), and increased dietary diversity (46.7%). Although adoption minimizes the susceptibility to climate shocks (33.3%), the benefits of income (40.0%) are small, limited by market and infrastructural challenges.

4.3 Implications for Household Food Security

Table 3: Reported Benefits of CSA Adoption

Constraint	Frequency (n)	Percentage (%)	Farmer Perspective
Limited access to credit/finance	34	75.6	"We cannot afford improved seeds or irrigation without loans."
Poor infrastructure (roads, storage, markets)	31	68.9	"Bad roads and no storage mean losses after harvest."
Weak extension support	29	64.4	"We hardly see extension officers; we learn from neighbors."
Land tenure insecurity	20	44.4	"Many of us farm on rented land; we can't plant trees."
Policy and institutional gaps	18	40.0	"Government promises inputs, but they never reach us."

The systemic factors influencing CSA adoption in Southwest Nigeria are based on barriers, with limited access to credit (75.6%), inadequate infrastructure (68.9%), and ineffective extension support (64.4%), having the highest impact among other factors. The lack of land tenure security (44.4%) and policy gaps (40.0%) also mitigate against long-term investment, especially in agroforestry.

4.4 Barriers to CSA Adoption

Table 4: Reported Barriers to CSA Adoption

Suggested Intervention	Frequency (n)	Percentage (%)	Respondent Voice
Strengthened extension services	36	80.0	"Regular visits will help us know which practices to adopt."
Affordable credit and loan schemes	32	71.1	"Low-interest loans will allow us to buy improved seeds."
Subsidized inputs (seeds, fertilizer, tools)	29	64.4	"Cheaper inputs will encourage more farmers."
Community-based irrigation projects	22	48.9	"If we had small dams or boreholes, we would not rely on rain only."
Localized CSA policy framework	20	44.4	"Policies must fit our conditions, not just Abuja's plans."

Priority interventions that were highlighted by farmers were to strengthen extension services (80%), affordable credit schemes (71.1%), and subsidized inputs (64.4%). Suggestions of community-based irrigation (48.9%), local CSA policies (44.4%) demonstrate a tendency to find specific solutions to the situation instead of nationalizing the initiative.

5. Discussion: The research results of this paper highlight that the adoption of Climate Smart Agriculture (CSA) in Southwest Nigeria is a potential and systemic burdened challenge. Agriculturalists were very aware and adopting low-cost farming practices (organic manure 67%), crop rotation (60%), and drought-tolerant crops (55%), although capital-intensive farming practices such as irrigation (18%) and agroforestry (35%) were low. This adoption trend is representative of the general trends in Sub-Saharan Africa, where affordability and accessibility are the key determinants of the magnitude of CSA adoption (Thornton et al., 2022; Gabriel et al., 2023). It is also in line with Okonkwo et al. (2022), who noted that structural barriers, especially the high cost of irrigation and mechanization, discourage large-scale use among smallholders. The researchers also established that CSA adoption enhanced food availability in households (66.7%), stability of yield (57.8%), and dietary diversity (46.7%). These findings are consistent with previous empirical studies that have shown that CSA increases food security by increasing productivity, resistance to unpredictable weather, and dietary diversification (Adenle et al., 2022; Olaniyi and Okeke, 2023). The same thing happened in North-Central Nigeria, where the use of various CSA practices decreased the susceptibility to weather disasters and improved nutrition results (Saadu et al., 2024). The small increases in farm income (40.0%) observed in this paper, however, indicate that the effects of CSA on livelihoods might be mediated by infrastructural and market conditions. This is in line with the results of Makinde et al. (2023), who suggest that alleviating poverty in households through CSA is limited because it helps enhance resilience, but without additional market and policy solutions.

Obstacles raised by the respondents, including inadequate access to credit (75.6%), inadequate infrastructure (68.9%), and the ineffectiveness of extension services (64.4%), reflect the problems that have been observed in the past (Okonkwo et al., 2022; Eze et al., 2023). Such restrictions hinder adoption through restricted access to inputs, technologies, and technical knowledge. The absence of extension services is also consistent with Olaniyi and Okeke (2023), who noted that insufficiently trained farmers limit their awareness about climate adaptation services. Moreover, the tenure insecurity (44.4) also had a major impact on the investments in agroforestry, as Izuogu et al. (2025) reported that tenure was a major barrier to the adoption of CSA sustainability in Nigeria. These findings indicate that the level of knowledge regarding CSA remains quite high, but institutional shortcomings still do not allow scaling. Recommendations by farmers are dominated by the need to have supportive institutional and policy structures, as demonstrated by the need to have affordable credit (71.1%), subsidized inputs (64.4%), and recommendations of strengthened extension services (80%). These correspond to the demands of the World Bank (2023) to implement the interventions in CSA in local ecological and socio-economic settings. The necessity to invest in

infrastructures to become less dependent on rain-fed agriculture is also reflected in the emphasis on community-based irrigation (48.9%), which is in line with FAO (2022) and Serdeczny (2022) arguing that, in the absence of irrigation and water management innovation, African agriculture will be extremely susceptible to climate shocks. On the whole, this paper affirms the findings that CSA has the potential to enhance food security through the enhancement of resilience, availability, and dietary diversity of smallholder farmers. Nonetheless, to fully potentialize its performance in Southwestern Nigeria, a systemic intervention is needed that would be able to cover the institutional capacity, gender inclusivity, and infrastructural development. An integrated multi-level solution involving government, the role of the private sector, and institutional bodies in the community is vital to their success in conquering the barriers to adoption and making CSA move out of the individual practices that are still practiced on a scattered basis to an adaptive approach at the regional level.

6. Conclusion and Recommendations: The paper has discussed the application of the Climate Smart Agriculture (CSA) practices and their impacts on food security among the small-scale farmers in Southwest Nigeria. The findings indicate that farmers are increasingly learning about CSA, yet it is being embraced in a biased manner, such as low cost production practices, such as organic manure, crop rotation, as well as drought-resistant crop varieties, rather than taking resource intensive production practices, such as irrigation and agroforestry. The evidence shows that the CSA implementation was positive in terms of the food security of the households in terms of the increase in productivity and stability of the yield and the dietary diversity, but the benefits in terms of the infrastructural and market constraints are low. The obstacles that still exist, like lack of access to credit, lack of extension services, lack of infrastructure, and lack of land tenure, are still a thorn in the flesh of extensive adoption. The fact that farmers needed to improve the extension services, low-cost credit, subsidized inputs, and localized CSA policies was emphasized by the farmers themselves, and thus, the role of the institution in upscaling CSA practices was very significant. One of the potential avenues towards resilience to enhance food security in southwest Nigeria would be CSA. However, its transformational ability will be seen in the combined interventions that are going to incorporate technical assistance, gender sensitive policies and infrastructures, and funds development. The future adopted policy frameworks must therefore contemplate to concentrate on the context specific and farmer-centered approaches in order to ensure that sustainable adoption and long term food system resiliency in the region is attained.

7. Recommendations: Based on the findings of the present research, the following are some of the policy measures that can be implemented that will be useful in scaling Climate Smart Agriculture (CSA) and increasing food security in Southwest Nigeria; Increase extension programs through farm-based training and demonstration programs; Increase accessibility to agricultural credit, which addresses the realities of the smallholder; Develop local CSA policies, which are grounded in local socio-economic circumstances; Enhance building farmers' capacity, such as gender inclusivity. Southwest Nigeria has an upscale CSA that is required for strong food systems.

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Evaluation of International Funds for Agricultural Development (Ifad-Vcdps) on Income Generating Activities of Women Beneficiaries on Rice Value Addition In Benue and Niger States, Nigeria.

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Abstract

The research was aimed at evaluation of international funds for agricultural development (IFAD-VCDPS) on income generating activities of women beneficiaries on rice value addition in Benue and Niger state, Nigeria. Multi-stage sampling technique was used for the study. First stage was purposive selection of Benue and Niger States in North central. At the second stage, women (producers, processors and marketers of rice) beneficiaries in the programme was purposively selected from three (3) LGAs from each of the state making a total of 6 LGAs, The third and fourth stage involved a purposive selection of LGAs and communities in each State respectively. In all, a total of 330 respondents were selected from the LGA as the sample size for the study. The results showed that the mean age of the respondents in the study area was 49 years in Benue and 47 years in Niger state while the average family size was 7 and 9 person in Benue and Niger states respectively, and 79% and 89% were married in Benue and Niger states respectively, with almost 33% in Quranic education in Niger and also 33% with primary education in Benue state. The results in table 3 shows that majority (79.1%) and (79.1%) of the women in were involved in livestock production in Benue and Niger states respectively, (54.2%) in vegetable farming and none is involved in shea-nut picking in Benue state while (4.0%) involved in vegetable farming and (4.5%) were involved in shea-nut picking in Niger State. This implies that women in the study area were involved in **Agribusiness** but at varying degree of their interest. This study has also identified and analyzed the various VCDP activities mostly carried out by women in Benue and Niger States. The results show that: rice production (69.3%); rice processing (59.5%); rice marketing (62.7%); were the VCDP activities mostly involved by women in Benue State. In Niger State, the results show that: rice production (72.5%); rice marketing (71.0%); rice processing (63.9%) were the VCDP activities mostly patronized by women. The study recommends that Empowering women through education and awareness will reduce resistance to their active involvement in the value chain.

Keywords: International, Evaluation, Funds, Development and Communities.

INTRODUCTION: For years, the International Fund for Agricultural Development (IFAD) has been financing projects that seek to develop value chain with the specific aim of improving smallholder livelihoods and seeking to achieve gender equality, youth and women empowerment. Value chain development programme (VCDP) is one of such projects by the Federal Government of Nigeria (FGN) and IFAD which aims at enhancing productivity, promotion of agro-processing, access to markets and opportunities to facilitate improved engagement of the private sector and farmers' organization in the development of effort. This programme takes a holistic and demand-driven approach to addressing constraints along the cassava and rice value chains, also aiming at poverty alleviation in the rural areas focusing more on the vulnerable group of which youths and women are part and in order to lift these set out of the poverty line, entrepreneurs trainings become important components in

IFAD programmes National Bureau of Statistics, (2022). While the FGN/IFAD assisted VCDP programme has continued to invest in rural people, most programmes benefits have always skewed in favor of men with the men being more visible than the females. This is because empowering women and girls can lead to the health and social development of families, communities, and countries as well as achieving gender equality. Value Chain Development Programme (VCDP) has earmarked thirty-five percent of the matching grants for women, enabling them to upgrade their production and processing technologies and capacities. In addition, the programme has applied the Gender Action Learning System, a community-led methodology for rural livelihood development and gender equality VCDP supervision report (2024).

Factors that positively influence the participation of women in value chain Development programme among others are early and timely supply of farm inputs (improved seeds and fertilizers) at a subsidized rate, access to farming tools like tractors, tractorizing their farm lands, Regular and prompt trainings on different aspects of farming and value chain (processing and marketing), provided trusted, reliable and efficient networking platforms like aggregators, financial institutions, marketers and processors (Nkiruka, 2021). Participation is an obvious strategy for the success of any development project. It is a powerful tool for mobilizing new and additional resources. Participation is the act of working with others, making value judgments and determining causes of actions within a social situation or structure. Therefore, the research work tends to determine the effect of the programme on the income-generation and diversification strategies among the women beneficiaries along the rice value chain to enhance women participation in agricultural value chain activities.

FAO has also been working to strengthen rural women's engagement and leadership in agri-food systems. FAO has also engaged with farmers' organizations to ensure that rural women's voices are heard and promotes gender-transformative approaches to challenge unfair socio-cultural norms in rural communities. **Evidence has shown that one in every 10 women is living in extreme poverty** (10.3 percent). Empowering women and girls can lead to the health and social development of families, communities, and countries as well as achieving gender equality. These things are important to create an equal world where all gender is safe. In addition, women living safe, fulfilled, and productive lives can reach their full potential and contribute their skills to the workforce. They can fuel sustainable economies and benefit societies and humanity.

Aim and Objectives of the study: The aim of this study is to critically evaluate international funds for agricultural development (IFAD-VCDPS) on income generating activities of women beneficiaries on rice value addition in study area.

Specifically, objectives of the study are to; describe the socio-economic characteristics of the women in the study area.; determine the income-generating activities carried out by women in the study area.; describe the specific agribusiness that the women were involved before the programme

Methodology: Study Area : The study was conducted in two States, namely: Benue and Niger in north central, Nigeria, concentrating on cassava and rice value chains including rural infrastructure, capacity building, and advisory services. Benue state lies between latitudes 6° 25' and 8° 8'N and longitudes 7° 47' and 10° 0'E. It occupies an area of 33,955 km². Having a population of 4,253,641 people in 2006 while the projected population is 6,141,300 (National Bureau of Statistics, 2022). Niger state is a state in the North Central region of Nigeria and the largest state in the country by area, it lies between latitude 09°61', 09°37' north of the equator and longitude 06°56', 06°32' east of the Greenwich meridian. The town shares boundary with the Federal Capital Territory from the north-west direction (Mohammed et al., 2025). The population was 201,429 at the 2006 while the projected population is 6,783,300 (National Bureau of Statistics, 2022).

Sampling Procedure and Sample Size: The primary data was obtained through the use of pre-tested structured interview schedule. The instrument was designed to gather relevant information on the socio-economic characteristics of the women that participated in the Programme, identified the income-generating activities of the respondents, determined the specific agribusiness women were involved before the programme and identified the constraint faced by women and strategies put in place that influenced women participation in the study area. Multistage sampling procedure was used to obtain sample from the study area. Other stages involved. Purposive sampling technique was used in selection of beneficiaries. First stage was purposive selection of Benue and Niger States in North central. At the second stage, women (producers, processors and marketers of rice) beneficiaries in the programme was purposively selected from three (3) LGAs from each of the state making a total of 6 LGAs, The third and fourth stage involved a purposive selection of LGAs and communities in each State respectively. In all, a total of 330 respondents were selected from the LGA as the sample size for the study

Table 1: Sampling procedure and sample size

S/N	STATE	LGA	VILLAGES SELECTED	NUMBER WOMEN SELECTED 15%	OF @
1	Benue	Kwande	Jato Adaji Ikyogen	12 8	

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PROCEEDINGS

2	Niger	Gwer East	Anwase	14
			Adikpo	13
			Agbagbe	13
			Agana	13
				11
			Agano	12
			Ugba	12
			Nanev	11
			Abeda	5
			Akpajir	4
			Anyin	12
			Naka	13
		Logo	Ikpe Nagi	6
		Bida	Edogifu	12
				12
			Mansaba	15
				15
			Zukogi	2
			Esozhi	
			Efu chiroma	
		Katcha	Tsadoyagi	15
	11			
Kataeregi	15			
	16			
Shabawoshi	5			
Badeggi				
Kakakpangi				
Kontagora	Ung/yamma	12		
	Nasara	4		
	Adarawa	15		
	Ung/Tukura	18		
	Usubu	4		
TOTAL			330	

Source: Field survey, 2025

RESULTS AND DISCUSSIONS : The socio-economic characteristics of the respondents under consideration include age, marital status, household size, and level of education. The result in table 2 revealed that the average age of women participating in the Value Chain Development Programme (VCDP) was 49 years in Benue State with 45.8% and 47 years in Niger State with 43.5%. This implies that a majority of the respondents are in their economically active and productive years. This finding is consistent with the research conducted by Damisa *et al.* (2024), which reported a mean age of 36 years among women involved in rice processing under the IFAD-VCDP in Nasarawa State, Nigeria. The distribution of marital status as presented in Table 2, indicates that a significant proportion (79.7%) and (89.8%), of the respondents were married. A smaller percentage (7.2%) and (3.4%) were single, while (13.1%) and (6.8%) were widows. Notably, there were no respondents reported as divorced in both Benue and Niger states respectively. This finding aligns with the study by Yelwa *et al.* (2025), which emphasized that active involvement in such programmes leads to increased productivity, creativity, self-worth, and empowerment among women. The findings further showed that the average household size in Benue State was 7 persons, while in Niger State, it was 9 persons. This suggests that, on average, respondents in both states had fairly large household sizes. This finding aligns with the results of Ahmad (2023), who identified that large family sizes can serve as a source of unpaid or family labour, reducing the cost of hiring external labour and increasing the capacity for farming and processing activities. The results on the level of education, as presented in Table 2 below, reveals that women in both Benue and Niger States had one form of education or another, although the distribution varied across the states. In Benue State, the educational distribution indicates that (11.8%) of the respondents had no formal education, while (7.2%) of the women had tertiary education, and (5.9%) reported receiving Qur'anic education. In Niger State, findings show that (14.1%) of the respondents had no formal education, while another (14.1%) had only primary education. Interestingly, the highest proportion of respondents in this state, (33.9%), reported Qur'anic education, which reflects the socio-cultural and religious context of the region. This agrees with the assertion by Usman (2025) that education equips rural women with the necessary knowledge to manage resources, adopt technology, and contribute meaningfully to agricultural development.

Table 2: Socioeconomic Characteristics of Respondents in Niger and Benue States

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PROCEEDINGS

Variables	Niger (n=177) Freq (%)	Benue (n=153) Freq (%)
Age (years)		
15-25	6 (3.4)	3 (2.0)
26-36	71 (40.1)	38 (24.8)
37-47	77 (43.5)	41 (26.8)
48-58	20 (11.3)	70 (45.8)
60 and above	3 (1.7)	1 (0.7)
Mean	47	49
Marital Status		
Married	159 (89.8)	122 (79.7)
Single	6 (3.4)	11 (7.2)
Widow	12 (6.8)	20 (13.1)
Household Size		
5-Jan	48 (27.1)	69 (45.1)
10-Jun	105 (59.3)	66 (43.1)
15-Nov	23 (13.0)	17 (11.1)
16 and above	1 (0.6)	1 (0.7)
Mean	9	7
Primary education	25 (14.1)	51 (33.3)
Qur'anic education	60 (33.9)	9 (5.9)
Secondary education	36 (20.3)	64 (41.8)
Tertiary education	31 (17.5)	11 (7.2)

Source: Field Survey, 2025

Income-generating activities carried out by women in the study area

Table 3 below shows the distribution according to Income-generating activities carried out by women in the study area, The VCDP activities mostly carried out by women in Benue and Niger States. The results show that: rice production (69.3%); rice processing (59.5%); rice marketing (62.7%); were the VCDP activities mostly involved by women in Benue State. In Niger State, the results show that: rice production (72.5%); rice marketing (71.0%); rice processing (63.9%) were the VCDP activities mostly patronized by women. This findings implies that women in the study area were involved in rice value chains but at varying degree of their interest. This result is in line with (Ebuka, *et. al.*, 2024) who stated that agriculture has huge and diverse opportunities and potentials that cannot only create employment and transform the national economy but also tremendously impact the personal lives of the women. The VCDP activities that were also involved by women in Benue state, for additional income include: weeding (12.4%), harvesting (11.1%), threshing (11.1%), cleaning (12.5%), sorting (9.2%), rice parboiling (17.6%), drying (16.3%), winnowing (13.7%), de-stoning (12.4%), grinding (12.4%), nutrient dense recipes (39.2%), petty trading (49.0%), Hair dressing (3.9%), food vendor (25.5%), stone crushing (0.7%) and tailoring (3.9%) and in Niger States for additional income also include: weeding (17.5%), harvesting (22.0%), threshing (25.4%), cleaning (26.6%), sorting (25.4%), rice parboiling (39.0%), drying (41.8%), winnowing (54.2%), de-stoning (39.5%), grinding (35.6%), nutrient dense recipes (5.6%), petty trading (32.2%), food vending (2.8%), stone crushing (0.6%) and tailoring (3.4%). This is in line with (Malik and Jerry, 2023) who reported from their study that one way to increase income while decreasing household vulnerability to shocks is to take advantage of different, diversified sources of income, To take advantage of more attractive income strategies, households need to overcome barriers to entry, such as insufficient skills, contacts, and capital. Women participating in VCDP (Value Chain Development Programme) activities in, Niger and Benue States engage in various income-generating activities related to rice and cassava. These include production, processing, and marketing of these crops, with VCDP focusing on enhancing their productivity and market access. Malik and Jerry, (2023). Specifically, activities involved includes, Production that is growing rice and cassava. Processing, including milling rice and processing cassava into various forms like gari, fufu, or other products. Marketing that is Selling their rice and cassava products, either directly to consumers or through established market channels. Value Addition, transforming raw materials into finished products, such as making flour, snacks, or other value-added items from rice and cassava. Agricultural Supply, some women may establish agricultural supply stores, selling seeds, fertilizers, and farming equipment. Agricultural Consulting, Providing agricultural consulting services to other farmers. Malik and Jerry, (2023).

Table 3: Income-generating activities carried out by women after the programme in the study area

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Income-Generating Activities	Niger (n=177)	Benue (n=153)
Rice Production	64 (36.2%)	106 (69.3%)
Rice Processing	103 (58.2%)	91 (59.5%)
Rice Marketing	12 (6.8%)	96 (62.7%)
Weeding	31 (17.5%)	19 (12.4%)
Harvesting	39 (22.0%)	17 (11.1%)
Threshing	45 (25.4%)	17 (11.1%)
Cleaning	47 (26.6%)	16 (10.5%)
Sorting	45 (25.4%)	14 (9.2%)
Rice Parboiling	69 (39.0%)	27 (17.6%)
Drying	74 (41.8%)	25 (16.3%)
Winnowing	96 (54.2%)	21 (13.7%)
Rice De-stoning	70 (39.5%)	19 (12.4%)
Rice Grinding	63 (35.6%)	19 (12.4%)
Nutrient-dense Recipe	10 (5.6%)	60 (39.2%)
Petty Trading	57 (32.2%)	75 (49.0%)
Hair Dressing	0 (0.0%)	6 (3.9%)
Food Vendor	5 (2.8%)	39 (25.5%)
Stone Crushing	1 (0.6%)	1 (0.7%)
Tailoring	6 (3.4%)	6 (3.9%)

Source: Field Survey, 2025

Specific Agribusiness Involved Before the Programme: The distribution according to specific Agribusiness women were involved before the Programme in table 4.5 below are the women in Benue and Niger States. The results show that: majority (79.1%) of the women in Benue state were involved in livestock production, (69.9%) involved in marketing of agricultural commodities, (56.9%) Subsistence farming (56.2%), commercial farming, (54.2%), processing of crop, (54.2%), vegetable farming and none is involved in shea-nut picking while results show that: majority (79.1%) of the women in Niger state the majority of the women (42.0%) were involved in livestock production, (33.5%) marketing of agricultural commodities, (35.8%) Subsistence farming (7.4%) commercial farming, (23.9%) processing of crop, (4.0%) involved in vegetable farming and (4.5%) were involved in shea-nut picking. This implies that women in the study area were involved in Agribusiness but at varying degree of their interest. Mahmud, *et al.*, (2024).

Table 4: Distribution of Specific Agribusiness Involved Before the Programme

Agribusiness Activity	Niger (Frequency (%))	Benue (Frequency (%))
Commercial farming	13 (7.4%)	86 (56.2%)
Subsistence farming	63 (35.8%)	87 (56.9%)
Processing of crops	42 (23.9%)	83 (54.2%)
Vegetables farming	7 (4.0%)	83 (54.2%)
Livestock production	74 (42.0%)	121 (79.1%)
Marketing of agricultural commodities	59 (33.5%)	107 (69.9%)
Sheanut picking	8 (4.5%)	0 (0.0%)

Source: Field survey, 2024

Before the implementation of the Nigeria Value Chain Development Programme (VCDP), women in Niger and Benue states were primarily involved in agricultural production, but not in agricultural development. Their contributions were mainly domestic in nature, focusing on activities like sowing, transplanting, weeding, and harvesting. (Abel, S., 2024). Production Focus: Before VCDP, women were heavily involved in the initial stages of agricultural production, often within the context of household food security. Limited Development: While their contributions were significant for subsistence agriculture, they were not fully integrated into agricultural development activities that would enhance their livelihoods and economic empowerment Ebuka, *et. al.*, (2024). Domestic Contributions: Women's work in agriculture was largely seen as a domestic task, supporting family needs rather than a commercial venture. Dayo, F., (2025). Specific Activities: Women's activities included tasks like sowing, nursery management, transplanting, weeding, irrigation, fertilizer application, plant protection, harvesting, winnowing, and storing. Livestock as a Livelihood: Livestock rearing was also a primary livelihood activity for women, supplementing household income and providing food. Grace, A., (2024).

CONCLUSION AND RECOMMENDATIONS: This study has identified and analyzed the various factors influencing women's participation in rice value chain of production, processing and marketing activities under the IFAD Value Chain Development Programme (VCDP) in Benue and Niger State, Nigeria with 97 percent women participation. It was found that while the VCDP has positively impacted in the lives of the women in the agricultural value chain, women's participation in rice value chain is still limited by several socio-economic, cultural and structural barriers. These include inadequate low level of education, access to capital, technological challenges, limited land ownership rights, and deeply rooted gender norms that restrict women's mobility and decision-making power. The study highlights the need for targeted interventions that address these challenges and promote women involvement as strategies within agricultural development programs. The study recommends that introduction of appropriate and affordable technologies for rice value chain businesses, such as improved and good practices machines/techniques, would greatly enhance women's productivity and efficiency. Training women on these technologies should be a priority under the VCDP. The women should be involved in Community-based sensitization programs to challenge and change social norms and gender biases that limit women's mobility, participation and leadership in rice value chain activities. Empowering women through education and awareness will reduce resistance to their active involvement in the value chain.

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Effect of Some Nutrients and Rhizobium on the Nodulation and Yield of Cowpea *Vigna unguiculata* (L) Walp in Some Nigerian Soils.

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ABSTRACT

This study was conducted using soils from nine selected locations (Agege, Amassoma, Bakolori, Nsukka, Onne, Olupano, the polytechnic Ibadan, University of Ibadan and Zaria) to determine the effect of some nutrients and rhizobium on the nodulation and yield of cowpea [*Vigna unguiculata* (L.) Walp]. Four field and four greenhouse experiments were conducted. The treatments consisted of control, boron, zinc, copper, manganese, combination of micronutrients, combination of micronutrients + Nitrogen (all with inoculant) and Combination of micronutrients – inoculant. The control for the third greenhouse experiment was without micronutrients and inoculant. The fourth greenhouse experiment was on effect of NPK on nodulation and growth of cowpea. The field experiments were laid out in a Randomized Complete Block Design while the greenhouse experiments were laid out in Completely Randomized Design and replicated four times. The results revealed that the inoculant had no significant effects generally on nodulation and cowpea yield in all the soils both in the greenhouse and in the field. Agege soil had the highest leaf dry weight, residue dry weight, total dry weight, number of nodules, nodule weight and nodule volume while Bakolori recorded the least ($p>0.05$). The treatment Combinations without the inoculant had the highest leaf dry weight (1.51 g/plt), residue dry weight (2.64 g/plt), total dry weight (4.14 g/plt), nodule weight (0.69 g/plt), zinc (1.29 g/plt) and boron (1.92 g/plt). The effect of treatments on pod length, pod filling and 100 grain weight were not significantly different ($p>0.05$), treatment combination with 100 kg N had the highest pod length and pod filling (13.14 cm) and (84 %) while manganese had the least (12.88 cm). Addition of phosphorus in the field experiments was not significantly different ($p>0.05$) in yield, pod filling, pod length and 100 grain weight. Phosphorus had the highest pod length (13.03 cm), pod filling (0.82 %) and without phosphorus (15.88 g) had the highest 100 grain weight. The added nitrogen benefitted the cowpea crop where organic matter was very low in the soil. The native Rhizobial count in Amassoma soil was very low and ineffective. After seven weeks of four greenhouse experiments, the nodulation was very low despite additions of nutrients.

Keywords: Greenhouse, micronutrients, nodulation, organic matter, treatments.

1.0 INTRODUCTION: Nigeria's population growth and food production are not moving in tandem. The increasing mouths have to be fed without depending on food imports. Food insecurity and malnourishment has assumed an alarming level globally and more seriously in Nigeria. At the root of all these food problems is the soil. Soil is the natural capital asset upon which the agricultural system is based. Soil quality is the capacity of a soil to sustain ecological productivity, maintain environmental quality and promote plant and animal health (Ogunkunle, 2015). The inherent quality of Nigerian soils is generally low (Agboola, 1978). The soils are easily degraded in their physical, chemical and biological properties as soon as they are opened up for cultivation.

In recent decades, global warming has caused climate change resulting in increased flooding, leading to erosion, landslides, leaching losses of nutrient elements, longer dry periods, shrinking water supplies (as in Lake Chad), desertification and unpredictable and changing seasonal weather resulting in reduced crop yields and lower farm production (Ogbigesan, 2015). The government of Nigeria and Scientists need to put on their thinking caps to attempt to bridge the gap between population growth and food production. Nitrogen is the key to plant growth (Isirimah, 2001). The soils are low in organic matter and consequently Nitrogen. The inorganic and organic fertilizers applied to meet N needs are washed or leached away due to the heavy down pour and flooding common in the humid tropics. There are also the problems of ground and surface water pollution from the leachates and run off. Yet, N is needed principally, in addition to other nutrient elements to make the crops grow and yield bountifully to feed the teeming population.

Aims and Objectives: The main aim of this study was to determine the effect of some nutrients and Rhizobium (Nitrogen strain) on the Nodulation and Yield of Cowpea (*Vigna unguiculata* (L) Walp) in Some Nigerian Soils.

Specific Objectives: The specific Objectives of the study is to; Assess the effect of Nitragin strain of rhizobium on growth, nodulation and grain yield of cowpea.

MATERIALS AND METHODS: 3.1 Study Area: This study was conducted in nine selected locations (Agege, Bakolori, Nsukka, Onne, Olupona, University of Ibadan. The Polytechnic Ibadan. Amasoma and Zaria). The coordinates of the project sites are shown in Table 2

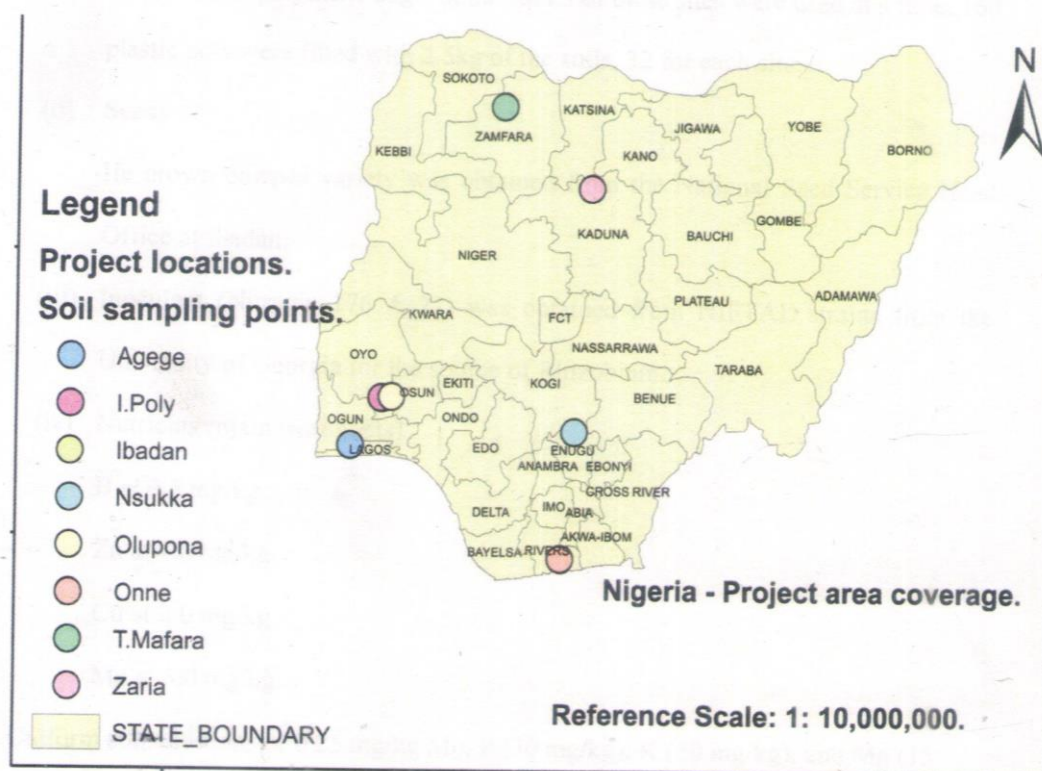


Fig 1: Map Showing Project Sites

3.2 Phase 1

Collection of Materials

- (i.) Bulk soil samples were collected from Umudike, Umudike, Mokwa, Ikenne, Onne, Nsukka, Zaria, Bakolori, Agege, Olupona, University of Ibadan, and the Polytechnic, Ibadan. One hundred kg of top soil, 0-15cm was collected from each site. Clean plastic bags were used to avoid micronutrient contamination. These soils were air-dried, ground, sieved through a 2mm sieve and stored in well labelled polythene bags. Soils from 5 of these sites were used at a time. 160 plastic pots were filled with 2.5kg of the soils. 32 for each site
- (ii.) **Seeds**
Ife brown cowpea variety was obtained from the National Seed Service Head Office at Ibadan.
- (iii.) Inoculant (Nitragin 176 A 22) was obtained from NIFTAL strains from the university of Georgia for the source of Rhizobium.
- (iv.) Nutrients (main treatments)
B at 0.5 mg/kg

Zn at 4.0 mg/kg
Cu at 2.0 mg/kg
Mn at 5.0 mg/kg

Uniform soil additions of 0.25 mg/kg Mo, P (30 mg/kg), and Ma (15 mg/kg) were supplied as KH_2P (30 mg/kg), K (50 mg/kg), MgSO_4 (reagent grade) respectively.

(v.) Distilled water

3.3 Phase II

Experiment 1: 2.5 kg of soil from each of five sites, Agege, Bekolori, Nsukka, Onne and Zaria were put into 160 pots (32 pots per site).

There were 8 treatments for each soil replication four times as follows:

1. Micronutrients control
2. +B at 0.5 mg/kg
3. +Zn at 4.0 mg/kg
4. +Cu at 2.0 mg/kg
5. +Mn at 5.0 mg/kg
6. +B, +Zn, +Cu, +Mn all at the above rates
7. Same as No.6 except add 100 g/kg N as NH_4NO_3
8. Inoculated control- same as No.6, but no inoculant.

The uniform soil addition earlier mentioned were added to all soils. These materials were dissolved in distilled water and equal portions were put into each of the 160 pots

3.4: Planting Procedure: Ten Ife Brown cowpea seeds were planted in each pot. After emergence, they were thinned to 5 uniform plants per pot. One gram by volume of inoculant was distributed over the seeds except treatment No.8, which is the inoculant control (combination of micronutrient less inoculant) The plants were watered with distilled water throughout the experiment. The 32 pots for each site were arranged on a rack in the greenhouse a completely randomized design.

3.5: Harvesting and Data Collection: The plants were harvested at full bloom stage (at 6 weeks). Leaves 2,3 and 4 (counting from the top of the plant) from all plants were removed from each pot. These were dried in the oven at 65°C for 48 hours, weighed and designated as leaf sample. They were ground for analysis. The remaining portions of plant tops from each pot were dried at same conditions weighed and labeled as remaining plant sample and ground for analysis.

Leaf N, P, K, Ca, Mg, Zn, Mn, Cu, and Fe on both leaf samples and remaining plant samples were determined.

3.6: Nodulation Data: Roots were carefully removed from each pot to minimize nodule loss. Water was used to tease out the soil. The nodules were removed from the roots, counted, volume determined and the fresh weights were taken.

RESULTS

4.1 Mean Cowpea Dry Matter and Nodule Production

Table 2 show cowpea dry matter and nodule production: Agege had the highest leaf dry weight of 1.584 g while the least dry weight was recorded in Bakolori. The highest dry weight residue was in Agege and lowest was in Bakolori. Agege site recorded the highest the dry weight total while Bakolori had the least tota dry weight. Agege had the highest nodule number and least number of Nodules was obtained in Zaria. The highest nodule weight (0.825 g) was recorded in Agege while the lowest nodule weight (0.119 g) was recorded in Zaria. Agege had the highest nodule volume while Zaira had the least

4.2 Effect of Treatments on the Dry Matter and Nodule Production.

Table 3 shows the cowpea dry matter and nodule production. The treatment with combination-inoculant had the highest leaf dry weight 1.506g and the least leaf dry weight was in treatment with copper 0.689 g. The highest residue dry weight was in the treatment with combination-inoculan with copper 0.689g. The highest residue dry weight was in the treatment with

combination-inoculant with a mean of 2.635 g and the least mean residue dry weight was recorded in zinc 1.285. The total dry weight ranged from 1.957 g to 4.140 g but the highest was recorded in combination-inoculant 4.140G while copper had the least dry weight total 1.957 g. The highest nodule number with a mean of 16.45. The treatment with combination-inoculant and the highest nodule weight with a mean of 0.597 g and the least was in the treatment with zinc with a mean of 0.251 g. Combination-inoculant had the highest nodule volume with a mean of 0.581 cm³ while zinc had the least nodule volume with a mean of 0.247cm³

Table 2: Mean Cowpea Dry Matter and Nodule Production in Different Locations

Location	Leaf dry weight	Dry weight residue	g			Nodule weight	Number of Nodules	Volume Nodules (cm ³)
			←	→	→			
Agege	1.584a	3.788a		5.731a		0.825a	29.84a	0.799a
Bakolori	0.580c	0.595c		1.179c		0.153c	17.22bc	0.148c
Nsukka	1.037b	1.619b		2.655b		0.240c	17.31bc	0.233c
Onne	1.030b	1.893b		2.910b		0.540b	21.09b	0.520b
Zaria	0.630c	0.672c		1.259c		0.119c	14.75c	0.11c

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using Duncan Multiple Range Test (DMRT)

Table 3: Effect of Treatments on Mean Dry Matter and Nodule Production

Treatment	Leaf dry weight	Dry weight residue	Dry weight total	Nodule weight	Number of Nodules	Volume Nodule (cm ³)
	← g →					
Control	0.728d	1.576bc	2.303cd	0.444ab	21.45ab	0.433ab
B + inoculant	0.699d	1.286c	1.984de	0.300b	16.45b	0.293b
Zn + inoculant	0.700d	1.285c	1.918e	0.251b	18.00b	0.247b
Mn + inoculant	1.004c	1.718bc	2.721bcd	0.286b	18.15b	0.276b
Cu + inoculant	0.689d	1.270c	1.957de	0.275b	17.60	0.262b
Combination	1.152bc	1.886b	3.038bc	0.408b	18.80	0.394b
Combination + N	1.303ab	2.054b	3.339b	0.445ab	27.35a	0.425ab
Combination - inoculant	1.506a	2.635a	4.140a	0.597a	22.55ab	0.581a

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using Duncan Multiple Range Test (DMRT), B = Boron, Zn = Zinc, Mn = Manganese, Cu = copper and N = Nitrogen

4.3 Effect of Treatments on Nodules Weight (g) of Cowpea: The results of the nodule weight as shown in table 6. In Olupona the check had the highest nodule weight of 0.72 g and copper had the least nodule weight of 0.35g. The check had the highest nodule weight of 0.58 g in Bakolori while boron was the least at 0.34 g. The highest nodule weight was recorded in check with a mean of 0.48 g while copper had the least nodule weight of 0.11 g in Zaria. In University of Ibadan soil, the highest nodule weight was in Combination, with a mean of 0.62 G and the least nodule weight was in copper with a mean of 0.30 g. The treatment with combination was recorded the highest nodule weight of 0.53 g in poly Ibadan while copper had the least nodule weight of 0.21 g.

4.4 Effect of Treatments on Nodule Volume (cm³) of Cowpea.: Table 8 show the effect of the treatment on the nodule volume of cowpea in the different site. In Olupona the highest nodule volume was recorded in check with a mean of 0.76 cm³ while the lowest nodule volume was obtained in copper with a mean of 0.35 cm³. The check in Bakori was recorded the highest nodule volume of 0.56cm³ and combination-inoculant was recorded the least nodule volume of 0.35 cm³. In Zaria the check had the highest nodule volume in University of Ibadan was obtained from the treatment with combination and Combination + N with a mean of 0.60cm³. Combination + N had the highest nodule volume of 0.51cm³ in Poly Ibadan while copper had the least nodule volume of 0.22cm³.

Table 7 Effect of Treatments on Mean Nodule Weight (g) of Cowpea

Treatment	Olupona	Bakolori	Zaria	University of Ibadan	Poly Ibadan
Control	0.72a	0.58a	0.48a	0.38b	0.33bc
B + inoculant	0.63ab	0.34a	0.26Bcd	0.38b	0.23c
Zn + inoculant	0.63ab	0.40a	0.28bc	0.43ab	0.27c
Mn + inoculant	0.52abc	0.52a	0.37abc	0.35b	0.31bc
Cu + inoculant	0.35c	0.49a	0.11d	0.30b	0.21c
Combination	0.64ab	0.50a	0.33abc	0.62a	0.53a
Combination + N 100kg/ha	0.62ab	0.53a	0.41ab	0.60	0.52a
Combination-inoculant	0.42bc	0.37a	0.22cd	0.46ab	0.46ab

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using Duncan Multiple Range Test (DMRT), B = Boron, Zn = Zinc, Mn = Manganese, Cu = copper and N = Nitrogen

Table 8 Effect of Treatments on Nodule Volume (cm³) of Cowpea

Treatment	Olupona	Bakolori	Zaria	University of Ibadan	Poly Ibadan
Control	0.76a	0.56a	0.45a	0.34b	0.30b
B + inoculant	0.64ab	0.38a	0.26bc	0.39b	0.24b
Zn + inoculant	0.58abc	0.41a	0.30ab	0.43ab	0.26b
Mn + inoculant	0.52bcd	0.53a	0.35ab	0.36b	0.30b
Cu + inoculant	0.35d	0.48a	0.14c	0.28b	0.22b
Combination	0.64ab	0.50a	0.33ab	0.60a	0.50a
Combination + N	0.62abc	0.55a	0.43a	0.60a	0.51a
Combination- inoculant	0.41cd	0.35a	0.21bc	0.43ab	0.38ab

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using Duncan Multiple Range Test (DMRT). B = Boron, Zn = Zinc, Mn = Manganese, Cu = copper and N = Nitrogen

4.6 Number of Nodules at 7 Weeks After Planting at Amassoma

Table 12 shows nodulation at 7 weeks in Amassoma soil. Zero treatment had the highest number of nodules with a mean of 2.75 while 10kg/ha and 60 had the least with zero number nodules.

Table 11: Effect of Treatments on Dry Weight (g) of Cowpea

Treatments	2 weeks	4 weeks	6 weeks	8 weeks
Control 1	0.33b	0.55b	0.84b	1.54c
Combination + N 100kg/ha	0.32b	1.41a	2.65a	4.47ab
Combination	0.35ab	1.26a	2.22a	4.07b
Boron + inoculant	0.36ab	1.25a	2.64a	4.13b
Control 2	0.37ab	1.29a	2.54a	4.46ab
Manganese + inoculant	0.38ab	1.31a	2.63a	4.64ab
Combination – inoculant	0.38ab	1.51a	2.62a	4.82a
Zinc + inoculant	0.38ab	1.36a	2.50a	4.41ab
Copper + inoculant	0.45a	1.39a	2.38a	4.24ab

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using Duncan Multiple Range Test (DMRT). Control 1 = natural soil, control 2 = uniform additions of Mo, P, K and Mg.

Table 12: Mean Number of Nodules at 7 Weeks After Planting at Amassoma

Treatment level Kg/ha	Number of Nodules at 7 Weeks
0	2.75
20	2.25
30	2.00
40	1.50
50	1.25
10	0.0
60	0.0
	NS

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using Duncan Multiple Range Test (DMRT)

DISCUSSION: Dry weight of 2.60 g/plt. According Javaid and Mahmood (2010) *B. Japonicum* inoculation had significant effect on plant growth, nodulation, yield and dry weight of soyabeans. Daza *et al.*, (2003) also reported that the beans seed inoculation and microelement application in vetch increased nodule dry weight.

On the total top nitrogen content, boron had the highest 118.3 mg/plt in Olupona while the combination-inoculant had the least 68.5 mg/plt. Eraslan *et al.* (2007) reported that increasing levels of applied B significantly increased N concentration and Lopez-Lefebvre *et al.* (2002) reported positive effect of B on N uptake on metabolism.

In Bakolori combination + N had the highest 93.7 mg/pot while combination-inoculant had the least 46.2 mg/plt. In Zaria the highest total pot nitrogen was recorded in combination + N with a mean of 89.9 mg/pot and the least was in the control with a mean of 40.6 mg/pot. Combination + N had the highest top nitrogen in the University of Ibadan soil with a mean of 100.9 mg/pot and the least was recorded in control with a mean of 32.2 mg/pot. Hulagur and Dangalawa (1983) reported that N and micro nutrient interaction has also been reported to increase N concentration in different crops.

Zinc had the highest 118.8 mg of total top nitrogen in the Poly, Ibadan soil while the control had the least of 85.5 mg/pot. Upadhyay (2015) reported that zinc influenced the synthesis of plant which indirectly enhanced the growth, development and uptake of nutrient. Similar trend was also observed by Singh, Shukla (1986), Wani and Khan (2006).

In Olupona, boron had the highest total top nitrogen of 118.3 mg/pot and the least was in combination-inoculant 68.5 mg/pot. Eraslan *et al.* (2007) reported that increasing levels of applied boron significantly increased nitrogen concentration.

In Bakolori, combination + N had the highest 93.7 mg/pot while combination-inoculant had the least 46.2 mg/pot. In Zaria, the highest was in combination + N (89.9 mg/pot) and the least was in the control 40.6 mg/pot. In both Bakolori and Zaria. The addition of nitrogen benefited the symbiotic process because of the very low organic matter levels of these soils (Agboola, 1978).

Combination +N had the highest 100.9 mg/pot of total nitrogen in the University of Ibadan soil while the least was in control 32.2 mg/pot. According to Sakal *et al* (1988) reported the N and micronutrients have a beneficial effect on the uptake of each other in plants.

The treatment with zinc had the highest total top nitrogen in the Poly, Ibadan soil with a mean of 118.8 mg/pot while control had the least with a mean of 85.5 mg/pot. Singh *et al* (1986) reported that Zn stimulated all morphological parameters via plant height, number of branches, number of leaves and dry matter in g/plant.

In Olupona control had the highest nodule weight 0.72 g/plt while copper had the least 0.35 g/plt. The control had the highest nodule weight of 0.58 g/plt in Bakolori while boron had the least 0.34 g/plt. The highest nodule weight was in the control with a mean of 0.48 g/plt while copper had the least 0.11 g/plt in Zaria. That the control had the highest nodule weight in these locations means that the indigenous rhizobium is more effective than the introduced one. Fening and Danso (2002), reported that the control treatment had a higher nodule number, nodule weight than inoculated treatment for some of the soils, this may be an indication of the presence of native Rhizobia in the soil that was efficient and more competitive.

In the University of Ibadan soil, the highest nodule weight was in the treatment combination 0.62 g/plt while the least was in copper 0.30 g/plt. The treatment with combination recorded the highest nodule weight of 0.53g/plt in Poly, Ibadan while copper had the least 0.21 g/plt. Giller (2001), reported that cowpea and some other tropical legume have rarely been found not to respond to inoculation unless they are grown in a soil where the conditions are not conducive for survival of rhizobia.

The effect of the treatment on nodule volume was significantly different ($P>0.05$). In Olupona the highest nodule volume was in control with a mean of 0.76 cm³ while the lowest was in copper with mean of 0.35cm³. The control in Bakolori had the highest nodule volume of 0.56cm³ while the combination-inoculant had the least 0.35cm³. In Zaria the control had the highest nodule volume of 0.45 cm³ while copper had the least 0.14 cm³. That the control had the highest nodule volume in these locations means that the indigenous rhizobium are more effective than the introduced rhizobium. Again, fening and Danso (2002), reported that the control treatment having a higher nodule volume than inoculated treatments for some of the soils may be an indication of the presence of native Rhizobia in the soil that were efficient and more competitive.

The highest nodule volume in the University of Ibadan soil was in combination and combination +N (0.60cm³) while copper had the least 0.28cm³. Combination + N had the high nodule volume of 0.51cm³ in poly Ibadan soil while copper had the least 0.22 cm³. Shibru and Mitiku (2000) reported that inoculating grain legumes with strains of rhizobium is widely reported to increase the number, mass and volume of nodules.

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The Impact of Climate Change on Wildlife in Gashaka-Gumti National Park, Nigeria

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ABSTRACT

This study assessed the impact of climate change on wildlife in Gashaka-Gumti National Park, Nigeria, focusing on data from field surveys and satellite image analysis. The study adopts a **descriptive survey design**. Purposive sampling that ensures only individuals with relevant knowledge and experience about the Park, was included in the study.. A total of 100 respondents were selected, including: park management staff, conservation experts, local community members, researchers and field experts. Descriptive statistics such as frequency distributions, percentages, and means were used for data analysis. **Temperature and Rainfall Patterns:** According to the data, 30% of respondents observed increased temperatures, while 27% reported changes in rainfall patterns. **Species Diversity and Abundance:** Respondents highlighted major changes in wildlife abundance: 35% confirmed a decline in species population, 33% reported the disappearance of species like elephants and lions, and 22% observed increased migration of some species. **Adaptation and Conservation Measures:** Among respondents, 30% reported the use of reforestation campaigns, 25% mentioned awareness creation, 18% highlighted sustainable livelihood. Satellite data confirms gradual environmental stress over the last 30 years. The study concluded that Climate change has significantly impacted the ecological balance of Gashaka-Gumti National Park. Rising temperatures, irregular rainfall, and environmental stress have led to habitat degradation, decline in wildlife populations, and shifts in species distribution. While some efforts have been made to mitigate these effects, much remains to be done. Based on the findings, the following recommendations are proposed: Investigate the impacts of climate change on communities around the park, Study the adaptive behavior of wildlife species under changing climate conditions and examine the effectiveness of current park policies and laws in protecting biodiversity under climate stress. Key words: Climate change , Wildlife, Environment, Migrat

INTRODUCTION

Background of the Study: Climate change is a global environmental phenomenon that has emerged as one of the most significant threats to biodiversity and natural ecosystems. It refers to long-term shifts in temperatures and weather patterns, primarily due to human activities such as burning fossil fuels, deforestation, and industrial processes, which have drastically increased the concentration of greenhouse gases in the atmosphere (IPCC, 2021).

Globally, climate change has contributed to habitat fragmentation, species migration, and increased extinction risks. In the Amazon rainforest, for example, prolonged droughts and temperature increases have contributed to tree mortality and reduced biodiversity (Phillips *et al.*, 2009). In Asia, particularly the Himalayas, climate-induced glacial melt has disrupted alpine ecosystems, threatening snow leopards and other cold-adapted species (Xu *et al.*, 2009). Similarly, in Europe, shifts in vegetation zones and insect outbreaks have been linked to warming trends, affecting species composition in national parks (Walther *et al.*, 2002).

In Africa, the effects of climate change are particularly severe due to limited adaptive capacity. Protected areas such as Kruger National Park in South Africa have recorded changes in animal behavior and species range due to warming and reduced water availability (Van Wilgen *et al.*, 2016). In East Africa, recurring droughts have significantly impacted the Serengeti-Mara ecosystem, reducing grazing lands and forcing migratory changes in wildebeest and zebra populations (Ogutu *et al.*, 2014).

In West Africa, rising temperatures and irregular rainfall patterns have increasingly affected biodiversity hotspots. A study by Nchanji and Plumptre (2011) in the Cross River National Park of Nigeria and adjacent Cameroon revealed that chimpanzee populations were declining partly due to changing forest conditions linked to climate stress. Likewise, in W-Arly-Pendjari Complex (shared by Benin, Burkina Faso, and Niger), research shows that prolonged dry seasons and bushfires have limited water resources and changed animal distributions (Bouché *et al.*, 2012). These regional insights help place Nigeria's conservation challenges within the broader West African context (Nchanji & Plumptre, 2011).

Gashaka-Gumti National Park, the largest national park in Nigeria, is located in the mountainous region of northeastern Nigeria, spanning parts of Taraba and Adamawa States. It is renowned for its rich biodiversity, serving as a critical habitat for various wildlife species, including chimpanzees (*Pan troglodytes*), African elephants (*Loxodonta africana*), and the endangered African wild dog (*Lycaon pictus*) (Ogunjemite *et al.*, 2020). The park's diverse ecosystems, ranging from montane forests to savannahs and grasslands, provide a sanctuary for numerous species and contribute significantly to the ecological balance of the region (Olaniyi *et al.*, 2020).

Over the years, however, climate change has posed a serious threat to the sustainability of Gashaka-Gumti National Park. The region has experienced rising temperatures, altered rainfall patterns, prolonged droughts, and increased frequency of extreme weather events, all of which have affected the park's ecosystems. These climatic changes have led to habitat loss, reduced availability of water, changes in vegetation patterns, and disruptions in wildlife breeding and migration cycles (Oguntunde *et al.*, 2019).

One of the most critical impacts of climate change on wildlife in the park is the loss of habitat. As rainfall patterns become increasingly unpredictable, water bodies within the park dry up more frequently, leading to the scarcity of drinking water for animals and the degradation of aquatic ecosystems. For example, amphibians, which are highly sensitive to environmental changes, are particularly vulnerable to droughts and temperature fluctuations, resulting in population declines and increased risk of extinction (Olaniyi *et al.*, 2020). Similarly, changes in vegetation cover have forced herbivores to migrate in search of food, increasing their vulnerability to predation and reducing population sizes (IPCC, 2021).

Moreover, climate change has contributed to the spread of invasive species and diseases that threaten native wildlife. Warmer temperatures and altered precipitation patterns have created favorable conditions for disease-carrying organisms such as ticks and mosquitoes, leading to outbreaks of diseases such as trypanosomiasis and avian malaria among wildlife populations (Woin *et al.*, 2018). Invasive plant species have also encroached on native habitats, reducing the availability of food resources for herbivores and altering the park's ecological balance.

The impact of climate change extends beyond wildlife, affecting the socio-economic well-being of local communities living around Gashaka-Gumti National Park. These communities rely heavily on the park's natural resources for their livelihoods, including fishing, farming, and hunting. The depletion of these resources due to climate-related changes has increased competition for limited resources, leading to conflicts between wildlife and humans. For instance, the destruction of crops by wildlife searching for food and water has become more frequent, resulting in economic losses for farmers and fostering negative perceptions toward wildlife conservation (Adewale *et al.*, 2019). Similar challenges have been reported in southern Mali and northern Ghana, where drought-related crop failures and water scarcity have increased human-wildlife interactions and pressures on protected lands (Tschakert *et al.*, 2008).

In response to these challenges, several conservation and adaptation strategies have been proposed to mitigate the impact of climate change on wildlife in Gashaka-Gumti National Park. These strategies include habitat restoration, water resource management, community-based conservation initiatives, and the promotion of climate-resilient livelihoods among local communities (Gandiwa *et al.*, 2019). However, the success of these efforts depends on the active participation of all stakeholders, including park management, conservation experts, policymakers, and local communities (Van Wilgen *et al.*, 2016). Understanding the impact of climate change on wildlife in Gashaka-Gumti National Park is crucial for developing effective conservation strategies that ensure the sustainability of this critical ecosystem. (IPCC, 2021; Olaniyi *et al.*, 2020).

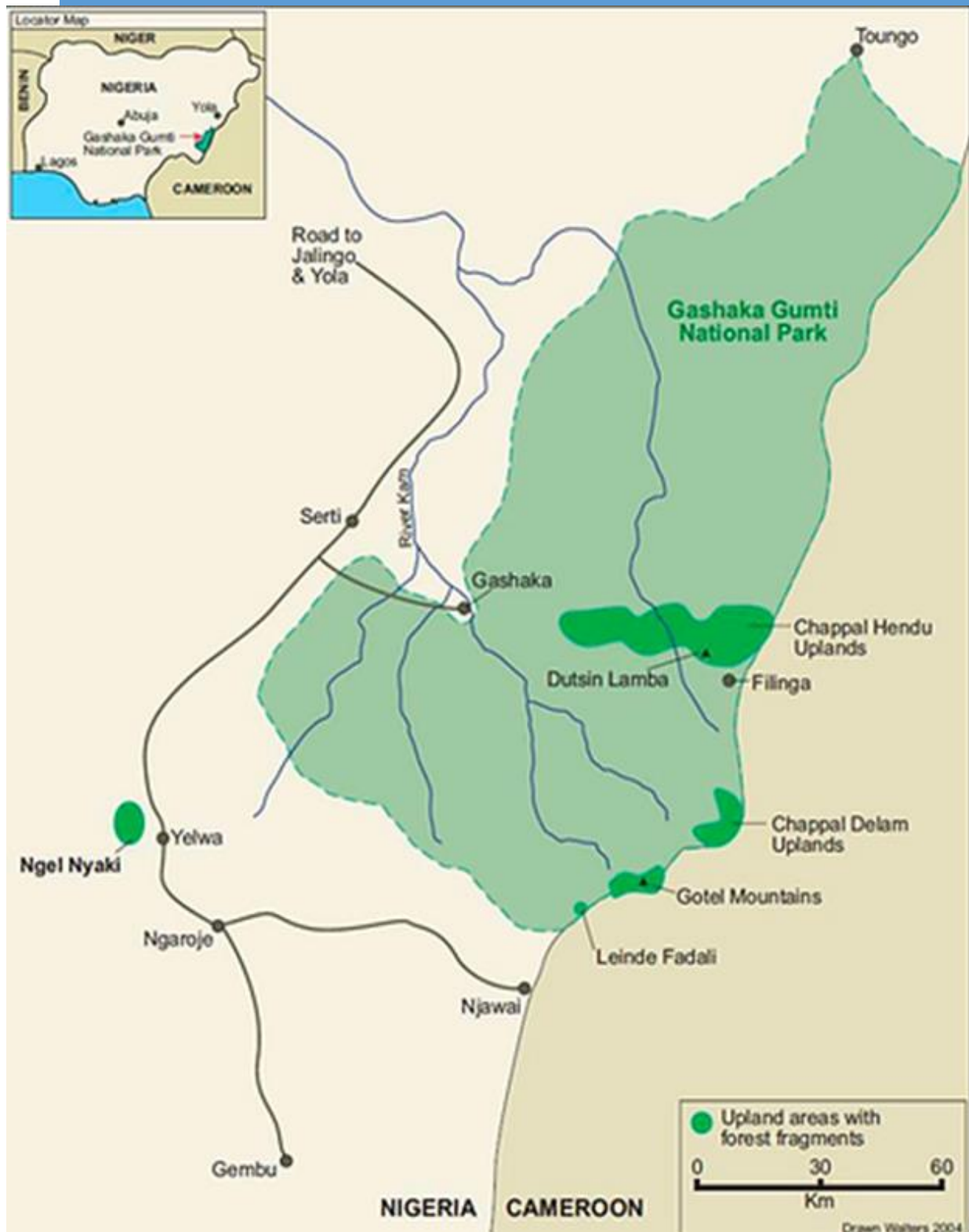
Despite the importance of the park as a biodiversity hub, there is limited research on the specific effects of climate change on wildlife in this region. Key problems include habitat degradation, increased mortality rates, and altered migration patterns of species (Ogunjemite *et al.*, 2020). These changes have far-reaching consequences on both the wildlife and the local communities that depend on the park's resources. This study seeks to bridge the gap in understanding by assessing the extent to which climate change is impacting on wildlife diversity, abundance, and adaptation strategies in Gashaka-Gumti National Park.

This study is significant for several reasons. First, it contributes to the growing body of knowledge on the effects of climate change on wildlife, particularly in West Africa. By focusing on Gashaka-Gumti National Park, the study provides specific data on how climatic changes are impacting local wildlife populations. The findings will be useful to conservationists, park management authorities, and policymakers in developing evidence-based strategies for wildlife conservation and climate adaptation (Oguntunde *et al.*, 2019).

Furthermore, the study will help raise awareness among local communities and stakeholders about the importance of preserving wildlife in the face of climate change. Understanding the threats posed by climate change and implementing appropriate adaptation measures is crucial for ensuring the long-term survival of species and the sustainability of the park's ecosystems.

METHODOLOGY: Study Area: Gashaka-Gumti National Park is the largest national park in Nigeria, covering about 6,402 square kilometers. It is located in the northeastern part of Nigeria, straddling Taraba and Adamawa States. The park is characterized by diverse ecosystems, including montane forests, savannahs, and grasslands, which host a wide range of wildlife species such as chimpanzees, leopards, African elephants, and various bird species (Ogunjemite *et al.*, 2020).

The park's climate is typically tropical, with distinct wet and dry seasons. However, recent climatic changes have caused increased temperatures and irregular rainfall patterns, affecting the park's ecosystems and wildlife (Oguntunde *et al.*, 2019).



Map of Gashaka-Gumti National Park.

Research Design: The study adopts a **descriptive survey design**, which is suitable for collecting data on the perceptions and experiences of respondents regarding the impact of climate change on wildlife in Gashaka-Gumti National Park. This design enables the researcher to gather both qualitative and quantitative data, providing a comprehensive understanding of the research problem (Kothari, 2019).

Population of the Study: The population of this study includes park management staff, conservation experts, local community members living around the park, and researchers who are familiar with the park's biodiversity and climate conditions. These groups were selected because they have firsthand knowledge of the park's wildlife and are well-positioned to provide reliable information on the effects of climate change.

Sampling Techniques: A purposive sampling technique was used to select respondents for this study. Purposive sampling ensures that only individuals with relevant knowledge and experience about Gashaka-Gumti National Park, local community included in the study (Creswell, 2014).

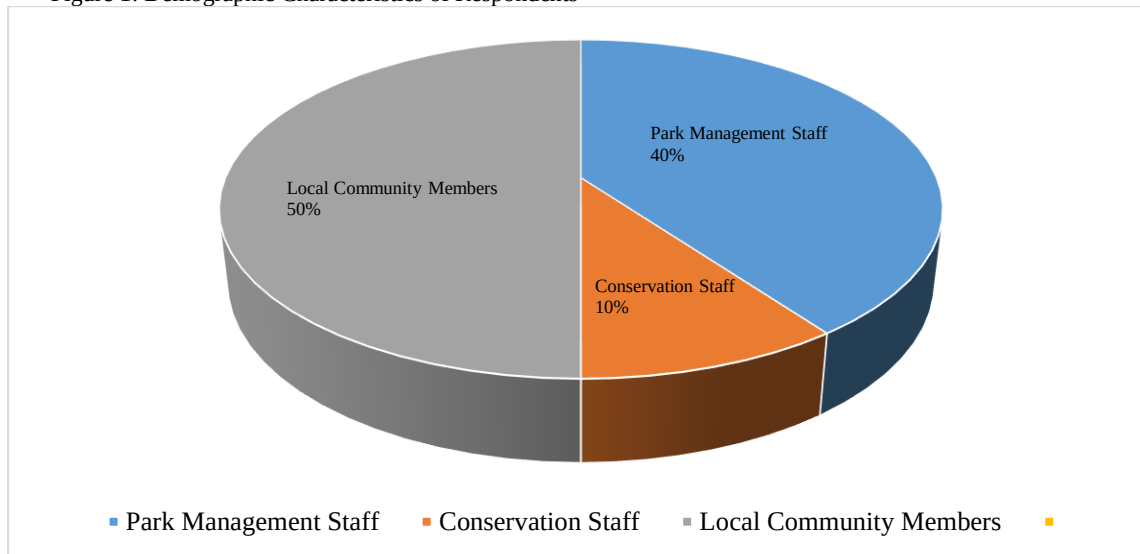
Sample size: The sample size was determined based on the population of stakeholders and the scope of the study. A total of 100 respondents were selected, including: 20 park management staff; 10 conservation experts; 50 local community members; 20 researchers and field experts

Data Collection Methods: Data was collected using a structured questionnaire. The questionnaire consists of both closed-ended and open-ended questions. It was administered to selected respondents through face-to-face interviews and self-completion methods, depending on the availability and preference of respondents.

Data Analysis: The collected data was analyzed using both qualitative and quantitative methods. Descriptive statistics such as frequency distributions, percentages, and means were used for quantitative data, while analysis was applied for respondent. The results were presented in tables, charts, and narratives to ensure clarity and comprehensiveness.

RESULTS : The data collected from 100 respondents, including park management staff, conservation experts, local community members, and researchers. The aim is to assess the impact of climate change on wildlife in Gashaka-Gumti National Park. The data was gathered through structured questionnaires and is presented using tables, and percentages. The analysis includes both quantitative and qualitative interpretations.

Figure 1: Demographic Characteristics of Respondents



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Table 1: Respondents' Observations of Climate Change Effects

Observed Effects	Frequency	Percentage (%)
Increased temperatures	30	30%
Changes in rainfall pattern	27	27%
Loss of wildlife species	19	19%
Shrinkage of water bodies and habitats	16	16%
Increase in invasive species	8	8%
Total	100	100

Most respondents observed changes in temperature and rainfall, as well as a loss in wildlife species and habitat degradation—confirming key signs of climate change.

Table 2: Changes in Wildlife Species Diversity and Abundance

Indicator	Responds	
	Yes (%)	No (%)
Decline in species population	35%	28%
Disappearance of species (e.g., lions, elephants)	33%	12%
Increase in migration of certain species	22%	35%
Emergence of unknown species	10%	25%
Total	100	100

There's clear evidence of species decline, disappearance of iconic animals (elephants, lions), and shifts in animal behavior like migration—all aligning with global climate impacts.

Table 3: Perceived Climatic Factors Affecting Wildlife

Climatic Factor	Frequency	Percentage (%)
Rising temperature	25	25%
Irregular rainfall	23	23%
Drought and dry spells	21	23%
Flooding in lowland areas	19	19%
Windstorms and vegetation damage	12	12%

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Total	100	100%

Rising temperature and unpredictable rainfall were the most mentioned factors, believed to have direct and indirect effects on vegetation and animal life.

Table 4 Adaptation and Mitigation Strategies Reported

Strategy Used by Community or Staff	Frequency	Percentage (%)
Reforestation campaigns	30	30%
Awareness creation on climate change	25	25%
Sustainable Livelihood	18	18%
Anti-poaching and wildlife monitoring patrols	14	14%
River and water source preservation	8	8%
Introduction of climate-resilient species	5	5%
Total	100	100%

Table 5: Key Quantitative Environmental Changes (Secondary Data)

Environmental Indicator	Observed Change
Forest cover (1991–2021)	+5.6% increase
Grassland/shrub areas (1991–2021)	-8.8% decrease
Built-up/bare surfaces (1991–2021)	+3.8% increase
NDVI, GNDVI, ARVI (Vegetation Health)	General decline (2000–2020)
MSI (Moisture Stress Index)	Increased stress (2000–2020)
Locally extinct species (past 30 years)	Elephants, Lions, Giraffes, antelope and crocodile.

Environmental data validates community perceptions. Declines in habitat health and biodiversity confirm that climate change is impacting the park at multiple levels.

4.8 Summary of Key Findings

- i. Majority of respondents (above 70%) recognize climate-related changes in species and habitat.
- ii. Key threats include rising temperatures, irregular rainfall, and habitat degradation.
- iii. Wildlife populations, particularly large mammals, have been significantly impacted.
- iv. Conservation efforts exist but are not yet comprehensive or sufficiently supported.
- v. Satellite data confirms gradual environmental stress over the last 30 years.

Discussion: Species Diversity and Abundance: Respondents highlighted major changes in wildlife abundance: 35% confirmed a decline in species population, 33% reported the disappearance of species like elephants and lions, and 22% observed increased migration of some species. These findings are consistent with the work of Ezealor (2020), who found that large mammals are disproportionately vulnerable to habitat fragmentation and climate extremes in Nigeria's protected zones. Moreover, satellite-based ecological indices in this study, such as the Normalized Difference Vegetation Index (NDVI) and Moisture Stress Index (MSI), confirmed reduced green biomass and increased moisture stress — reinforcing perceptions of ecosystem degradation. Thomas *et al.* (2017) similarly found that such reductions in NDVI correlate with declining animal densities and reduced ecosystem productivity in savanna environments.

Land Use and Vegetation Change: The 5.6% increase in forest cover observed may suggest afforestation or regrowth in less accessible zones, possibly due to park enforcement or community-based tree planting. However, the 8.8% decline in grassland and shrub areas, along with a 3.8% increase in bare or built-up surfaces, indicates habitat conversion and fragmentation. This observation mirrors findings by Adamu and Isa (2019), who noted that land use changes in Taraba and Adamawa States were primarily driven by agricultural expansion and population growth, thereby shrinking wildlife corridors and increasing human-wildlife conflict.

Adaptation and Conservation Measures: Among respondents, 30% reported the use of reforestation campaigns, 25% mentioned awareness creation, 18% highlighted sustainable livelihood. These figures indicate some level of resilience and engagement. However, the relatively low adoption of certain strategies points to institutional and financial limitations. This is echoed by Gandiwa *et al.* (2019), who noted that African park authorities often face funding shortages, poor infrastructure, and limited technical capacity, hindering comprehensive climate adaptation strategies.

Species Extinction and New Discoveries: The reported local extinction of flagship species such as elephants, lions, giraffes, antelopes, and crocodiles is alarming and points to an ecosystem under significant stress. However, the emergence of unknown species (as observed by 10% of respondents) suggests that the park still holds untapped biodiversity. This paradox reflects observations by Chidumayo and Gumbo (2018), who noted that while climate change may drive some species to extinction, it may also facilitate the appearance or migration of others into new territories, altering biodiversity baselines.

Conclusion: Climate change has significantly impacted the ecological balance of Gashaka-Gumti National Park. Rising temperatures, irregular rainfall, and environmental stress have led to habitat degradation, decline in wildlife populations, and shifts in species distribution. While some efforts have been made to mitigate these effects, much remains to be done.

The disappearance of iconic species such as elephants and lions underscores the urgent need for stronger conservation policies. Moreover, the park's potential for biodiversity discovery highlights the importance of preserving it as a climate-resilient ecological zone.

Recommendations: Based on the findings, the following recommendations are proposed:

1. Investigate the socioeconomic impacts of climate change on communities around Gashaka-Gumti.
2. Study the adaptive behavior of wildlife species under changing climate conditions.
3. Examine the effectiveness of current park policies and laws in protecting biodiversity under climate stress.

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Assessment of the Multifunctional Applications of Some Lactic Acid Bacteria in Silage Production

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Abstract

The need for large scale food production is real. However, due to poor soil fertility, pasture can no longer make a significant part of the animal diets. The aim of this research was to assess the applications of some wild Lactic acid bacteria (LAB) in enhancing safety, quality, and nutritional value of silage used as ruminant feed stuff. A total of 60 Lactic acid bacteria strains were isolated from fermented silage, screened for functional and technological properties. Out of these, six strains (LB06, LB03, LB45, LB12, LB98 and LB71) with high acidification properties were selectively combined in ration 1:1 and used to argue the fermentation of chopped, fresh forage in polyethylene bags kept for forty days in warm environment to produce silage feed. The results revealed that the highest crude protein content occurred in the LAB- treatment group. The contents of neutral detergent fiber and acid detergent fiber in the control were lower than other treatment. Similarly, group with inoculation treatments had decreased pH during ensiling, increased lactic acid content after ensiling for 10 days, and the acetic acid contents of all the inoculation groups increased during the fermentation storage than the control group. Therefore, the selected strains used in this study were suitable as inoculants for silage production under the warm and humid climate in Nigeria. **Keywords:** Lactic Acid Bacteria (LAB), Preservation, Silage, Inoculant and Feed

Introduction: In both human food processing and animal feed production, Lactic Acid Bacteria (LAB) have received significant attention giving their various roles in enhancing safety, quality, and high nutritional value. When used as starter cultures, several strains of LABs are probiotics and antimicrobial (bacteriocin) producers. Some LABs are known to immensely contribute to the production of high-quality foods and animal feeds that meet the growing consumer demand. Onsite animal feed processing, especially in the intensive animal production, large quantities of forage must be produced in order to meet the feed intake of large number of animals. The use of fresh grass as ruminant feed in the farm sector is shifting to the use of more natural bio-processed silage products in the Sub-Saharan countries due to obvious insecurity and land claim ownership.

The need for expansion of animal production globally has increased due to ever-increasing population. The present insecurity and urbanization have led to reduced open grazing system thereby reducing animal production on a large scale in many parts of the developing world. Also, balanced nutrition for grazing ruminants, is necessary for meeting nutritional needs especially of high-production animals. However, due to poor soil fertility, pasture can no longer make a significant part of the animal diets.

Lactic acid bacteria as starter cultures are essential for fermentation of food and feed products. In this approach, carefully selected LAB strains with robust adaptation to the food environment are utilized. These cultures, often in addition to being probiotics, contribute beyond their basic fermentation roles by improving the safety, nutritional value, and health-promoting properties of the processed feed stocks. Silage as ruminant feeds can thus be carefully selected for controlled fermentation and preservation of the integrity, quality, and nutrition of the feeds. Aside preservation, the fermented products also contain some varieties of probiotic strains. As a result of the LAB in the feeds, the organoleptic and nutritional quality of the feeds are significantly altered for better with extended shelf life. Therefore, the aim of this research was to assess the applications of some wild Lactic acid bacteria (LAB) in enhancing safety, quality, and nutritional value of silage used as ruminant feed stuff.

Materials and Methods: A total of 60 Lactic acid bacteria strains were isolated from fermented silage, screened for functional and technological properties. Out of these, six strains (LB06, LB03, LB45, LB12, LB98 and LB71) with high acidification properties were selectively combined in ration 1:1 and used to argue the fermentation of chopped, fresh forage in polyethylene bags kept for forty days in warm environment to produce silage feed. The chemical composition, fermentation quality and aerobic stability were analyzed forthrightly and documented.

Results and Discussion: The results revealed that the highest crude protein content occurred in the LAB- treatment group. The contents of neutral detergent fiber and acid detergent fiber in the control were lower than other treatment. Similarly, group with inoculation treatments had decreased pH during ensiling, increased lactic acid content after ensiling for 10 days, and the acetic acid contents of all the inoculation groups increased during the fermentation storage than the control group. The obvious changes were as a result of the activities of the LAB inoculants which were positive as reported earlier (Ayivi *et al.*, 2020). Within the fermentation days, pH was liberated from the metabolic activity of the lactic acid bacteria used. The roles of decreased pH in silage have been documented. They are defined as the product of organic compound breakdown resulting in simpler products being formed with acid formation in several cases mostly by lactic acid bacteria. The organisms that adhere to the surfaces of living or non-living organisms are able to perform this naturally in order to survive and thrive in the ecological environment it finds itself (Gupta *et al.*, 2018). They represent a distinct growth mode that microorganisms adopt in response to stress and stimuli in various environments (Karakas-Sen *et al.*, 2018). This phenomenon also enhances the production of biofilm, a structure that when well formed, exhibit the rheological properties of viscoelastic solids, silage. The pH characteristic can mitigate interference from various physical and chemical factors, thereby safeguarding the cellular structure within the membrane from invasion (). Previous studies on pH by LAB have primarily concentrated on their antibacterial properties. This observation came from the knowledge the ability of LAB-produced pH to inhibit various harmful bacteria, including *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella typhimurium*, which exhibit significant inhibitory or antagonistic effects (Rizqiati *et al.*, 2025). This ability makes the lactic acid bacteria (LAB) as having considerable potential applications in the food industry (Bennani *et al.*, 2021). In addition, the application of LAB in fermented products has been extensively studied with renewed interest. Thakur *et al.*, 2017 cultivated of *Lactobacillus delbrueckii* using mesh polyurethane foam (PUF) and established a lactic acid fermentation system, which significantly enhanced the production rate of lactic acid in the product.

In a similar research, inoculation of homofermentative LAB results in a rapid drop in pH value due to the increased production of lactic acid during ensiling forage maize (Crancer *et al.*, 2018). *Lactobacillus rhamnosus* is homofermentative bacteria, which has been primarily isolated from silage produced by Italian ryegrass at 45°C has been recognized for its heat tolerance (Green *et al.*, 2021). This species has demonstrated a greater capacity to produce antifungal agents, inhibiting fungal growth and mycotoxin production in silage more effectively

than other bacteria. Therefore, giving the results from this work, LAB is considered a favourable inoculant for forage ensiling, particularly in tropical and humid areas Like Nigeria (Karakas-Sen *et al.*, 2018).

Conclusion and Recommendations: Silage is a well-established and effective method for feed preservation. Based on our current research findings, the use of screened LAB for silage fermentation appears to reduce the activity of harmful microorganisms, increased the probiotic content as well as increasing the general well-being of the products under anaerobic conditions. The selected strains used in this study were suitable as inoculants for silage production under the warm and humid climate in Nigeria. Also, Silage preservation is a very viable means of ensiling fresh forage crops or other kinds of biomass for future use. From our results, silage quality is improved by adding a variety of LAB inoculants, which work effectively during fermentation, storage, and feed-out by improving the fermentation characteristics, promoting beneficial microbial diversity, and preventing pathogenic microorganisms. Modern biotechnological approaches as a powerful tool in identifying, improving, and developing high-performing LAB strains applicable in silage production in order to reduce pH, improve fermentation characteristics and aerobic stability, prevent unwanted microorganisms, and enhance animal performance for sustainable animal production need to be encouraged at all levels.

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Enterotoxigenic Potential of Multi-Drug Resistant Bacteria Isolated from Ready-To-Eat Fruit Salads Using Rabbit Ileal Loop Assay

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ABSTRACT

Ready-to-eat (RTE) fruit salads are increasingly popular due to their nutritional benefits, convenience, and freshness. However, their minimal processing and lack of thermal treatment make them highly susceptible to microbial contamination, including enterotoxigenic and multi-drug resistant (MDR) pathogens. This study evaluated the enterotoxin production potential of multi-drug resistant bacterial pathogens isolated from ready-to-eat (RTE) fruit salad using the rabbit ileal loop assay. Enterotoxins were prepared by inoculating each isolate into nutrient broth followed by culture in liquefied milk at pH 8 and incubation at 37°C for 48 hours. Cell-free supernatants were obtained via centrifugation and used as crude toxin preparations. The rabbit ileal loop assay, conducted according to the method of Everest et al. (2017), involved the surgical creation of ligated ileal loops in anaesthetized rabbits, each injected with 0.5 mL of crude toxin or sterile water (control). After 18 hours, fluid accumulation in each loop was measured, and the dilatation index (DI) was calculated as the ratio of fluid volume to loop length. A DI > 0.2 mL/cm indicated a positive enterotoxin response. All four tested isolates—*Bacillus cereus* BCGS, *Salmonella enterica* NOA, *Enterobacter cloacae* SCA, and *Vibrio cholerae* TCB—induced positive enterotoxin reactions, with DI values ranging from 0.26 to 0.40 mL/cm. The control segment showed minimal fluid accumulation (0.02 mL/cm), confirming test validity. These results affirm the enterotoxigenic nature of the isolates, supporting their role as potential causative agents of foodborne gastroenteritis. Coupled with prior molecular characterization, this study highlights the virulence and public health risks associated with consuming contaminated RTE fruit salads. Routine microbial surveillance and control measures are therefore crucial to ensure food safety and protect consumers from outbreaks of toxin-mediated foodborne illnesses.

Keywords: Enterotoxin, Rabbit ileal loop assay, Ready-to-eat (RTE) fruit salad, Multi-drug resistant bacteria, Foodborne pathogens

INTRODUCTION: Fruit salads are widely consumed due to their health benefits and convenience, particularly in urban areas such as Owerri Metropolis, Imo State, Nigeria. However, their minimal processing, lack of preservatives, and absence of heat treatment make them highly susceptible to microbial contamination. Factors such as poor sanitation, inadequate storage, and unsafe handling practices by street vendors further increase the risk. Globally, foodborne illnesses affect approximately 600 million people annually, causing over 400,000 deaths (WHO, 2020). In Nigeria, the risks are amplified by weak food safety regulations and infrastructure.

Several studies across Nigerian cities have documented high microbial contamination in fresh cut fruits. For instance, research in Lagos and Abuja revealed bacterial and fungal contamination, including *E. coli*, *Staphylococcus aureus*, *Aspergillus*, and *Penicillium* (Adeyemi et al., 2017; Olorunfemi et al., 2020). Enteric bacteria such as *Salmonella* spp., *Vibrio parahaemolyticus*, *Shigella* spp., and *Listeria monocytogenes* are frequently implicated in foodborne outbreaks and are capable of producing toxins and evading antibiotics (Nazir et al., 2024; Oyeyipo et al., 2022).

Contamination may also stem from pesticide residues, heavy metals, and poor hygiene in processing facilities. Despite widespread consumption, there is limited data on the bacterial quality and pathogenic traits of fruit salads in Owerri Metropolis. This gap prompted the current study to investigate the presence, virulence traits, and antimicrobial resistance of enteric bacteria in fruit salads, thereby informing public health strategies to improve food safety in the region.

2.0 MATERIALS AND METHODS

2.1 Study Area: The study was carried out in Owerri Metropolis, Imo State, Nigeria. It involved markets, retail shops, supermarkets, roadside retailers and markets within Douglas Road, Relief Market, IMSU Junction, Port Harcourt Road, as these urban areas have high foot traffic and diverse food vending sites.

2.2 Fruit Salad Source, Collection and Processing: A Total of 44 fruit salad samples consisting of mixed fruit samples of pineapple (*Ananas comosus*) and watermelon (*Citrullus lanatus*), bananas, apples, pawpaw; from different areas of Owerri Metropolis. These samples were collected from different clusters of retailers, supermarkets, roadside retailers in Orji Flyover, Ama JK, Douglas Market, IMSU Junction, Portharcourt Road, and Relief Market. They were collected in sterilized sampling bags aseptically following the method of American Public Health Association (APHA, 1998) and transported under aseptic conditions to the laboratory, as soon as possible for processing on the same day of collection. Samples were classified into two categories such as A (Salad with milk) and B (Salad without milk).

2.3 Preparation of the media : The following media were used for culturing: Nutrient agar (total heterotrophic aerobic bacterial counts), MacConkey Agar (Total coliform counts), Chromocult Coliform agar (CCA), Oxoid Salmonella – Shigella Agar, Mannitol Yolk Polymyxin Agar and Thiocitrate Bile Salt Sucrose Agar. All the media were prepared according to the Manufacturer's specification.

2.4 Sterilization of materials: As stated in Willey et al. (2008), conical flasks (Pyrex), prepared media and other plastic materials were sterilized by autoclaving at 121°C for 15 minutes at a pressure of 15 Psi. Glass wares such as pipettes, glass spreader, petri dishes, measuring cylinder, and other glass materials were sterilized in the laboratory hot air oven at a temperature of 160°C for 1 hr before use.

2.5 Pre- Enrichment and Enumeration of Enteric Bacteria: Following Budiarso et al. (2021), 25 g of ready-to-eat fruit salad (with or without milk) were aseptically mashed and pre-enriched in buffered peptone water and Rapport Vassiliadis media at 37°C for 16–24 h to revive stressed cells (Sangadkit et al., 2016). The cultures were serially diluted to 10⁻⁴ in 0.85% phosphate saline buffer, and 0.1 mL of the diluted cultures was spread onto selective media: Chromocult Coliform Agar for coliforms, Oxoid Salmonella Agar for Salmonella, Thiocitrate Bile Salt Sucrose Agar for Vibrio, Mannitol Yolk Polymyxin Agar for *Bacillus cereus*, and Nutrient Agar for total aerobic mesophilic bacteria. Plates were incubated at 30–37°C for 48 h, and colonies were counted to calculate colony-forming units per gram (CFU/g) of fruit salad.

2.6 Isolation and Maintenance of Stock Cultures of Pure Bacterial Isolates: Discrete colonies of bacterial isolates were respectively and repeatedly sub-cultured onto petri dishes containing freshly prepared nutrient agar to obtain pure (cultures) isolates. Thereafter, the pure microbial isolates were stocked in Bijou bottles containing 10 % of sterilized glycerol solution (autoclaved at the temperature of 121°C for 15 minutes) and kept refrigerated at 4 °C for subsequent characterization and further use (Umana et al., 2017).

2.7 Antimicrobial susceptibility testing: The antibiotic susceptibility of *Bacillus cereus*, *Shigella* sp., *Pseudomonas aeruginosa*, *Salmonella* sp., *Staphylococcus aureus*, and *E. coli* isolates was determined using the CLSI (2005) disc diffusion method. Bacterial suspensions of 1.5 × 10⁸ CFU/mL were swabbed onto Muller Hinton agar, and discs containing various antibiotics—including Ciprofloxacin, Ceftazidime, Gentamicin, Azithromycin, Peflacin, Ceporex, Amoxicillin, Rifampicin, Cefuroxime, Levofloxacin, Erythromycin, Streptomycin, Ofloxacin, Augmentin, and Ceftriaxone—were aseptically placed on the inoculated plates. After 30 minutes, plates were inverted and incubated for 24 hours at room temperature (Umana et al., 2017). Zones of inhibition were measured, and susceptibility was interpreted according to CLSI guidelines: resistant (1–10 mm), moderately susceptible (11–19 mm), and susceptible (20–30 mm).

2.7.2 Multiple antibiotics resistance (MAR) index determination: The multiple antibiotic resistances (MAR) index was determined for each of the selected bacterial strains by dividing the number of antibiotics to which the strains were resistant by the total number of antibiotics tested (Umana et al., 2017).

2.8 Plasmid Curing Experiment: Plasmid curing of bacterial strains was conducted following a modified method of Njoemena et al. (2025). Four strains from each bacterial group exhibiting the highest Multiple Antibiotic Resistance (MAR) phenotypes were selected. Overnight cultures in Nutrient Broth were prepared, and 1 mL of inoculum was added to 30 mL of Nutrient Broth (pH 7.6) with 1 mL of 10% sodium dodecyl sulfate (SDS). Cultures were incubated for 24 hours, then diluted with sterile distilled water. Adjusted pure cultures were swabbed onto Mueller Hinton agar containing the antibiotics to which they were resistant. Antibiotic resistance that persisted after curing was considered chromosome-mediated, while resistance lost after curing was considered plasmid-mediated.

2.9 Characterization and Identification of Bacterial Isolate: Four bacterial strains from each group with the highest multiple antibiotics resistant indices were selected and identified further by microscopic technique, biochemical tests and molecular methods.

2.9.1 Preparation of Enterotoxin Supernatant: The Abbas et al. (2013) approach was used to determine the pathogens' preparation of enterotoxin. Each of the bacterial isolates was put into a 15 × 125 mm sterile screw cap test tube containing 5 mL of nutritional broth. For twenty-four hours, the cultures were incubated at 37°C. After that, 10 mL of liquefied milk at pH 8 was inoculated with 0.1 mL of each test organism, and the mixture was pasteurized by heating it to 80°C for 30 minutes (Abbas et al., 2013). After that, the cultures were cultured for 48 hours at 37°C. After five minutes of centrifugation at 5000 rpm, the cell-free supernatants were collected and decanted into sterile test tubes. The cell free supernatant of the test organisms were then used as crude toxin preparations (Khudor et al., 2012).

2.9.2 Enterotoxin Production using Rabbit Ileal Loop Assay : The production of enterotoxins by the bacterial pathogens was assessed using the rabbit ileal loop assay, following Everest et al. (2017). Two healthy adult rabbits were anesthetized, and their peritoneal cavities were aseptically opened. The intestines were cleaned with sterile preheated water, and 5-cm ileal loops were ligated at 2-cm intervals. Each loop was injected with 0.5 mL of crude toxin supernatant from the test organisms, while control loops received sterile water. After 18 hours, the rabbits were re-anesthetized, and fluid accumulation in each loop was measured. The dilatation index (DI) was calculated as the volume of fluid per unit length of ileal loop; a DI > 0.2 mL/cm was considered positive for enterotoxin activity (Abbas et al., 2013; Idahosa et al., 2017).

3: RESULTS

3.1 Bacterial Load of Fruit Salad with Milk Samples: Microbiological analysis of fruit salad with milk sold across Owerri Metropolis showed high bacterial contamination. Five samples had THBC values that were Too Numerous to Count, while the others ranged from 7.18–7.50 Log CFU/g, indicating unacceptable microbial loads. All samples contained high coliform counts (5.85–7.30 Log CFU/g), suggesting poor hygiene and possible fecal contamination. Salmonella/Shigella were detected in 12 of 16 samples, with the highest levels in samples Q and D. Vibrio species were also widespread, peaking in sample D, while some samples showed no Vibrio presence. Bacillus cereus occurred in 11 samples, again highest in sample D. Overall, sample D was the most contaminated and hazardous, while sample Θ showed comparatively lower microbial levels, though still contaminated with coliforms and THBC.

3.2 Bacterial Load of Fruit Salad without Milk Samples: Fruit salad samples without milk sold in Owerri Metropolis showed extensive microbial contamination. Many samples recorded TNTC values for total heterotrophic bacteria, while the remaining samples had high THBC levels (7.08–7.41 Log CFU/g). Coliforms were present in all samples, indicating poor hygiene and possible fecal contamination. Salmonella/Shigella were detected in 13 of 21 samples, with sample M showing the highest levels. Vibrio species appeared in 14 samples, suggesting contamination from unsafe water sources. Bacillus cereus occurred in 16 samples, reaching a peak of 7.23 Log CFU/g in sample V. Overall, sample M had the highest overall microbial load, testing positive for all pathogens and indicators, making it the most contaminated sample.

3.3 Antibiotic Resistance Profile of the Bacterial Strain (Gram-negative): Antibacterial susceptibility testing of 15 Gram-negative isolates against ten antibiotics showed very high resistance to several commonly used drugs. All isolates (100%) were completely resistant to Ceporex, Gentamicin, Augmentin, and Cefuroxime, indicating these antibiotics are ineffective for treating infections caused by these organisms. Ciprofloxacin (CPX) was the most effective antibiotic, inhibiting 13 of 15 isolates with zones of 14–40 mm. Ofloxacin (OFX), Ceftazidime (CTZ), Ceftriaxone (TRX), and Streptomycin (S) also showed good activity against most isolates, though a few isolates (ΘOA, SCA, NOA, and ΩTCB) remained resistant. Multidrug resistance (MDR) was prominent. Isolates NOA and ΩTCB were the most resistant: NOA was only sensitive to CPX and S, while ΩTCB responded only to S. In contrast, isolates such as KCA, RTCB, PCA, NTCB, WTCB, and ACA showed broad sensitivity to seven or more antibiotics, indicating lower resistance levels.

Table 3.1: Antibacterial susceptibility pattern of the selected Gram - negative bacterial pathogen (mm)

	CEP	OFX	AU	PEF	CTZ	CN	CPX	TRX	S	CEF
ΘOA	0.00	24.00	0.00	24.00	0.00	15.00	25.00	0.00	20.00	0.00
RTCB	13.00	28.00	0.00	28.00	0.00	22.00	28.00	20.00	28.00	0.00
KCA	0.00	28.00	0.00	26.00	0.00	22.00	24.00	28.00	28.00	0.00
NOA	0.00	0.00	0.00	0.00	0.00	18.00	0.00	13.00	22.00	0.00
ΕOA	0.00	22.00	0.00	20.00	0.00	14.00	34.00	16.00	10.00	0.00
SCA	0.00	30.00	0.00	0.00	0.00	26.00	30.00	0.00	0.00	0.00
YOA	0.00	26.00	12.00	26.00	0.00	28.00	40.00	16.00	28.00	0.00
SOA	0.00	15.00	0.00	16.005	0.00	20.00	22.00	28.00	24.00	0.00
MTCB	0.00	24.00	0.00	28.00	0.00	24.00	26.00	22.00	26.00	0.00
PCA	0.00	26.00	0.00	26.00	0.00	24.00	24.00	30.00	22.00	0.00
ΕCA	0.00	30.00	0.00	26.00	0.00	20.00	22.00	22.00	24.00	0.00
NTCB	0.00	30.00	0.00	28.00	0.00	20.00	30.00	28.00	26.00	0.00
ACA	0.00	24.00	0.00	26.00	0.00	22.00	28.00	26.00	26.00	0.00
WTCB	0.00	28.00	0.00	30.00	0.00	22.00	30.00	30.00	26.00	0.00
ΩTCB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.00	0.00

Key: CEP = Ceporex, OFX = Ofloxacin, AU = Augmentin, PEF = Peflacin, CTZ =Ceftazidime, CN = Gentamicin, CPX = Ciprofloxacin, TRX = Ceftriaxone, S = Streptomycin, CEF= Cefuroxime

Table 3.2: Antibacterial susceptibility patterns of the isolated Gram-positive bacterial pathogen (mm)

	RD	CTZ	S	AZM	AMX	CPX	E	LEV	CN	CEF
WBCS	-	-	-	-	-	-	-	-	-	-
GBCS	-	-	-	-	-	-	-	-	-	-
ΕBCS	15.00	14.00	20.00	-	24.00	34.00	30.00	36.00	20.00	-
R ² BCS	-	-	-	-	-	-	-	-	-	-
IVBCS	12.00	-	20.00	-	-	30.00	-	30.00	18.00	-
ΘBCS	20.00	-	30.00	18.00	-	36.00	20.00	36.00	24.00	-

Key: RD = Rifampicin, CTZ = Ceftazidime, S = Streptomycin, AZM = Azithromycin, AMX = Amoxil, CPX = Ciprofloxacin, E = Erythromycin, LEV = Levofloxacin, CN = Gentamicin, CEF= Cefuroxime

3.4 Antibiotic Resistance Profile of the Bacterial Strain (Gram-positive)

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Antibiotic susceptibility testing of five Gram-positive isolates (WBCS, GBCS, CBCS, R2BCS, IVBCS, and ØBCS) showed mixed responses across ten antibiotics. Overall, the isolates displayed high resistance to many β -lactam and macrolide antibiotics, while only a few drugs demonstrated strong activity.

Ciprofloxacin (CPX), Levofloxacin (LEV), and Gentamicin (CN) were the most effective, with 60% of isolates showing good susceptibility (18–36 mm zones). Streptomycin (S), Rifampicin (RD), and Erythromycin (E) showed moderate effectiveness, with 40–60% susceptibility. Ceftazidime (CTZ), Azithromycin (AZM), Amoxil (AMX), and Cefuroxime (CEF) were the least effective, with 80% or more of the isolates resistant.

Overall, the results reveal widespread resistance to commonly used first-line antibiotics among Gram-positive bacteria. Fluoroquinolones and aminoglycosides remain the only reliably active drug classes. CBCS was the most susceptible isolate, responding to 9 out of 10 antibiotics, while WBCS and GBCS were the most resistant, showing little or no sensitivity.

3.5 Multiple Antibiotic Resistance (MAR) Index of the Bacterial Strains

The Multiple Antibiotic Resistance (MAR) index values of the bacterial isolates showed varying levels of resistance, reflecting different degrees of exposure to antibiotics. A MAR index ≥ 0.2 indicates bacteria from environments where antibiotics are commonly misused.

High **MAR Index** ≥ 0.7
Several isolates—NOA (0.7), SCA (0.7), ØTCB (0.9), and the Gram-positive isolates WBCS, GBCS, and R2BCS (all with MAR = 1.0)—showed extremely high resistance, indicating exposure to high-risk environments and posing serious public health concerns.

Moderate **MAR Index** (0.4–0.6)
Most isolates (12 out of 21) fell within this range, including ØOA, KCA, ØOA, SOA, MTCB, PCA, ØCA, NTCB, ACA, WTCB, and IVBCS. These values suggest frequent antibiotic exposure but not complete resistance.

Low **MAR Index** ≤ 0.3
A few isolates—RTCB, YOA, and ØBCS—showed low resistance, suggesting minimal exposure to antibiotics.

Overall, the MAR index results indicate that **a large proportion of both Gram-negative and Gram-positive isolates are multidrug resistant**, especially NOA, SCA, ØTCB, WBCS, GBCS, and R2BCS. This points to widespread antibiotic misuse in the environment and underscores the need for stronger antimicrobial stewardship and improved food hygiene practices.

Table 3.3: Multiple antibiotics resistance (MAR) index of the selected bacterial strains

Exposed to gram negative and positive antibiotics

Isolate code	Total number of antibiotics tested	Number of resistance	MAR index
ØOA	10.0	5.0	0.5
RTCB	10.0	3.0	0.3
KCA	10.0	4.0	0.4
NOA	10.0	7.0	0.7
ØOA	10.0	4.0	0.4
SCA	10.0	7.0	0.7
YOA	10.0	3.0	0.3
SOA	10.0	4.0	0.4
MTCB	10.0	4.0	0.4
PCA	10.0	4.0	0.4
ØCA	10.0	4.0	0.4
NTCB	10.0	4.0	0.4
ACA	10.0	4.0	0.4
WTCB	10.0	4.0	0.4
ØTCB	10.0	9.0	0.9
WBCS	10.0	10.0	10.0
GBCS	10.0	10.0	10.0
CBCS	2.0	0.2	2.0
R ² BCS	10.0	10.0	10.0
IVBCS	10.0	5.0	0.5
ØBCS	10.0	3.0	0.3

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3.6 Plasmid Curing Profile of the Selected Multi-Resistant Bacterial Strains

Plasmid curing of four multidrug-resistant bacterial isolates showed a marked reduction in antibiotic resistance, indicating that several resistance traits were plasmid-borne.

NOA (*Salmonella enterica*): Originally resistant to seven antibiotics but retained resistance to only four after curing. Loss of resistance to Ofloxacin, Peflacin, and Ciprofloxacin indicates these resistances were plasmid-mediated.

SCA (*Enterobacter cloacae*): Initially resistant to seven antibiotics but remained resistant to only three after curing. Loss of resistance to Ceporex, Peflacin, Ceftriaxone, and Streptomycin confirms plasmid-borne resistance.

QTCB (*Vibrio cholerae*): Showed resistance to nine antibiotics before curing but retained only four afterward. Loss of resistance to five drugs—including Gentamicin, Ciprofloxacin, Ofloxacin, Peflacin, and Ceftriaxone—indicates plasmid-mediated resistance.

GBCS (*Bacillus cereus*): Originally resistant to ten antibiotics but retained resistance to only four after curing. Loss of resistance to drugs such as Rifampicin, Streptomycin, Ciprofloxacin, Levofloxacin, Erythromycin, and Gentamicin suggests plasmid involvement.

Overall, the plasmid curing results demonstrate that **a significant portion of the antimicrobial resistance in these foodborne isolates is carried on plasmids**. This underscores the role of mobile genetic elements in the spread of AMR and highlights the importance of surveillance and informed antibiotic selection in managing resistant pathogens.

Table 3.4: Plasmid curing profile of the selected multi - resistant bacterial strain

Isolate code	Antibiotics resistant gene marker before curing					Antibiotics resistant gene marker after curing				
NOA	Ceporex, Ofloxacin, Augmentin, Peflacin, Ceftazidime, Ciprofloxacin, Cefuroxime					Ceporex, Augmentin, Ceftazidime, Cefuroxime				
SCA	Ceporex, Augmentin, Peflacin, Ceftazidime, Ceftriaxone, Streptomycin, Cefuroxime					Augmentin, Ceftazidime, Cefuroxime				
QTCB	Ceporex, Cefuroxime	Ofloxacin, Augmentin, Peflacin, Ceftazidime, Gentamicin, Ciprofloxacin, Ceftriaxone,				Ceporex, Augmentin, Ceftazidime, Cefuroxime				
GBCS	Rifampicin, Ceftazidime, Streptomycin, Levofloxacin, Gentamicin, Cefuroxime	Azithromycin, Amoxil, Ciprofloxacin, Erythromycin,				Ceftazidime, Azithromycin, Amoxil, Cefuroxime				

3.7 Enterotoxin Production Assay

Table 4.3: Enterotoxin Production by the Selected Multi-Drug Resistant Bacterial Pathogens

The **rabbit ileal loop assay** was conducted to evaluate enterotoxin production. All four isolates elicited a **positive enterotoxin response**, evidenced by the presence of turbid, viscous intestinal fluids and significant fluid accumulation in the loop segments.

Table 4.12: Enterotoxin production by the selected multi – drug resistant bacterial pathogens

Test organism	Content of ileal loop	Length of segment (cm)	Measurement of fluid (mL)	Dilution index	DI	Enterotoxin response
<i>Bacillus cereus</i> BCGS	Yellow slightly turbid fluid	5.00	2.00±0.12	0.40		+
<i>Salmonella enterica</i> NOA	Brownish red viscous fluid	5.00	1.50±0.06	0.30		+
<i>Enterobacter cloacae</i> SCA	Yellow slight viscous fluid	5.00	1.70±0.08	0.34		+
<i>Vibrio cholerae</i> TCB	Very brownish and viscous fluid	5.00	1.30±0.10	0.26		+
Distilled (Control)	water Whitish to colourless viscous fluid	5.00	0.10±	0.02		-

The enterotoxin screening validated both the identity and virulence of the multidrug-resistant bacteria recovered from fruit salad samples. These results highlight a serious public health risk and emphasize the importance of regular microbial monitoring of ready-to-eat foods.

4. Discussion The study revealed widespread multidrug resistance among bacterial isolates from fruit salads. Gram-negative isolates showed complete resistance to several β -lactam antibiotics, while fluoroquinolones remained the most effective findings consistent with earlier reports (Akinyemi et al., 2005; Okorie-Kanu et al., 2016; Chijioke et al., 2018). Gram-positive isolates showed similar resistance trends, supporting previous observations of rising AMR in foodborne pathogens (Elhadi et al., 2013). Most isolates had MAR index values ≥ 0.4 , indicating exposure to high-risk, antibiotic-contaminated environments, in agreement with Krumperman (1983) and Adesokan et al. (2015). Highly resistant isolates (MAR 0.7–1.0) pose significant public health risks.

Plasmid curing revealed that much of the resistance especially to Ciprofloxacin, Gentamicin, and Streptomycin was plasmid-mediated, aligning with Okeke et al. (2000). However, persistent β -lactam resistance suggests chromosomal mechanisms such as ESBL production (Iroha et al., 2011). Overall, the results confirm serious MDR challenges in foodborne bacteria and underscore the need for stronger antibiotic stewardship and improved food hygiene practices.

5. Conclusion: Street-vended fruit salads in Owerri Metropolis are heavily contaminated with multidrug-resistant bacteria. MAR indices range from 0.3–1.0, and plasmid-mediated resistance is common, indicating potential for horizontal gene transfer. All tested MDR isolates produced enterotoxins, confirming virulence. These findings emphasize the urgent need for:

Improved food hygiene and vendor education; Enforcement of food safety regulations; Regular microbial monitoring; Antimicrobial stewardship programs to mitigate public health risks

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Assessment of the Role of Community-Based Structures in Flood Disaster Management in Kaduna Metropolis

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ABSTRACT

This study examined the role of community-based structures in flood disaster management in Kaduna Metropolis, Nigeria. The research sought to assess how socio-economic and demographic characteristics influence community participation, preparedness, and response to flood disasters. Krejcie and Morgan's (1970) table was used to determine the sample size which recommends a sample size of 384 at a 95% confidence level and 5% margin of error. A multistage sampling technique was adopted. In the first stage, purposive sampling was used to select four flood-prone communities—Ungwar Rimi and Rafin Guza (Kaduna North LGA), and Barnawa and Bashama Road (Kaduna South LGA)—known for having established Community-Based Disaster Management Committees (CBDMCs). In the second stage, purposive sampling identified respondents aged 30 years and above who had lived in these areas for at least ten years and had experience in flood response training. Data were analyzed using descriptive statistics including frequencies, percentages, and weighted means. Findings revealed that the socio-economic and educational characteristics of the respondents significantly influenced the level of community participation in flood disaster management activities. Although community-based structures play vital roles in awareness creation, early warning dissemination, and post-flood recovery, their effectiveness is limited by poor economic capacity and inadequate education among residents. Overall, the mean values (ranging from 3.13 to 4.25) show that respondents generally agree that Community-based structures play significant roles in flood management—particularly in prevention, awareness, and coordination. Lack of motivation among volunteers (3.86) and poor coordination with government agencies (3.81) were the most critical challenge, showing that volunteer fatigue, inadequate incentives, or lack of recognition weaken CBS effectiveness. The study concludes that strengthening community-based structures requires socioeconomic empowerment, improved environmental education, and stronger institutional collaboration. It recommends targeted livelihood support, capacity building, and infrastructural investments to enhance resilience and ensure sustainable flood disaster management in Kaduna Metropolis.

Keywords: Community-Based Structures, Flood Disaster Management, Socio-Economic Characteristics, Kaduna Metropolis, Nigeria

INTRODUCTION: Floods are among the world's most frequent and damaging natural hazards, causing extensive loss of life, long-term displacement, damage to infrastructure, and economic disruption. A flood is an overflow of water onto land that is normally dry, while a flood disaster occurs when such an event overwhelms local coping capacities and requires external intervention (Centre for Research on the Epidemiology of Disasters [CRED], 2021). Disaster risk reduction and disaster management therefore aim to prevent, reduce, and manage the risks associated with such events. Globally, the increasing frequency and intensity of extreme rainfall events have been linked to climate change, urban expansion, and land-use change, which significantly increase flood risks in urban and peri-urban areas (IPCC, 2022).

Nigeria has in recent decades experienced some of the most severe flood disasters in Sub-Saharan Africa. The 2022 national floods were particularly destructive, affecting more than 4.4 million people, displacing over 2.4 million, causing about 662 deaths, and damaging more than 569,000 hectares of farmland (NEMA, 2022; World Bank, 2023). These catastrophic events demonstrate the limitations of top-down

emergency responses and highlight the urgent need for localized, community-led risk reduction and preparedness initiatives (Adelekan, 2020).

Kaduna State which is located in northwestern Nigeria, has consistently witnessed flood disasters that have caused significant human and material losses. Rapid urbanization, unregulated settlement in flood-prone areas, inadequate drainage systems, and encroachment on natural floodplains have intensified the city's vulnerability (Aliyu and Amadu, 2017). Reports indicate that between 2018 and 2022, flooding in Kaduna State displaced thousands of residents and damaged farmlands and property worth millions of naira (Adeoye, 2009). These recurring incidents make Kaduna Metropolis an important case for studying how community-based structures contribute to flood disaster management.

Community-based structures (CBS) in disaster management refer to grassroots institutions such as neighbourhood associations, religious groups, youth and women's organizations, traditional leadership councils, and local volunteer committees. Community-based disaster risk management (CBDRM) is a participatory approach that empowers at-risk populations to identify hazards, assess vulnerabilities, and implement risk reduction and preparedness measures suitable for their context (Adelekan, 2012). It integrates indigenous knowledge with scientific forecasts while ensuring inclusive participation in planning, implementation, and monitoring (Aliyu and Amadu, 2017).

Evidence from empirical studies shows that community-based structures play crucial roles in flood disaster management. First, they act as key channels for early warning dissemination, where trusted leaders translate technical meteorological forecasts into locally understandable messages (Madugu and Ushama, 2015). Second, they mobilize rapid life-saving responses such as evacuation, provision of temporary shelters, and distribution of relief items before external agencies arrive (Olorunfemi and Raheem, 2008). Third, during post-disaster recovery they support needs assessments, identify vulnerable households, and coordinate neighborhood clean-up or drainage restoration activities (Ojo, 2004). These roles demonstrate the unique strengths of CBS in leveraging social capital and local knowledge that external responders often lack.

Nevertheless, CBS face significant constraints that limit their effectiveness in managing urban flood disasters. Common challenges include limited financial resources, weak institutional linkages with formal agencies, lack of technical training in first aid and evacuation, and inadequate infrastructure such as poorly maintained drainage systems (Adelekan et al., 2015). In Kaduna Metropolis, the pressures of rapid population growth and land-use change have heightened community exposure to floods, while CBS continue to operate with minimal support and resources. These systemic limitations help to explain the recurring cycle of vulnerability, impact, and partial recovery experienced by affected communities.

To address these challenges, global frameworks such as the Sendai Framework for Disaster Risk Reduction emphasize strengthening local capacities and integrating CBS into formal disaster governance structures (UNISDR, 2015). This requires formal recognition of CBS roles in early warning, hazard mapping, emergency funds management, and coordination with agencies such as the National Emergency Management Agency (NEMA). In Kaduna, while government relief distribution and joint assessments with communities already exist, these collaborations are often ad hoc rather than systematically institutionalized (Al-Qudah and Ibrahim, 2022).

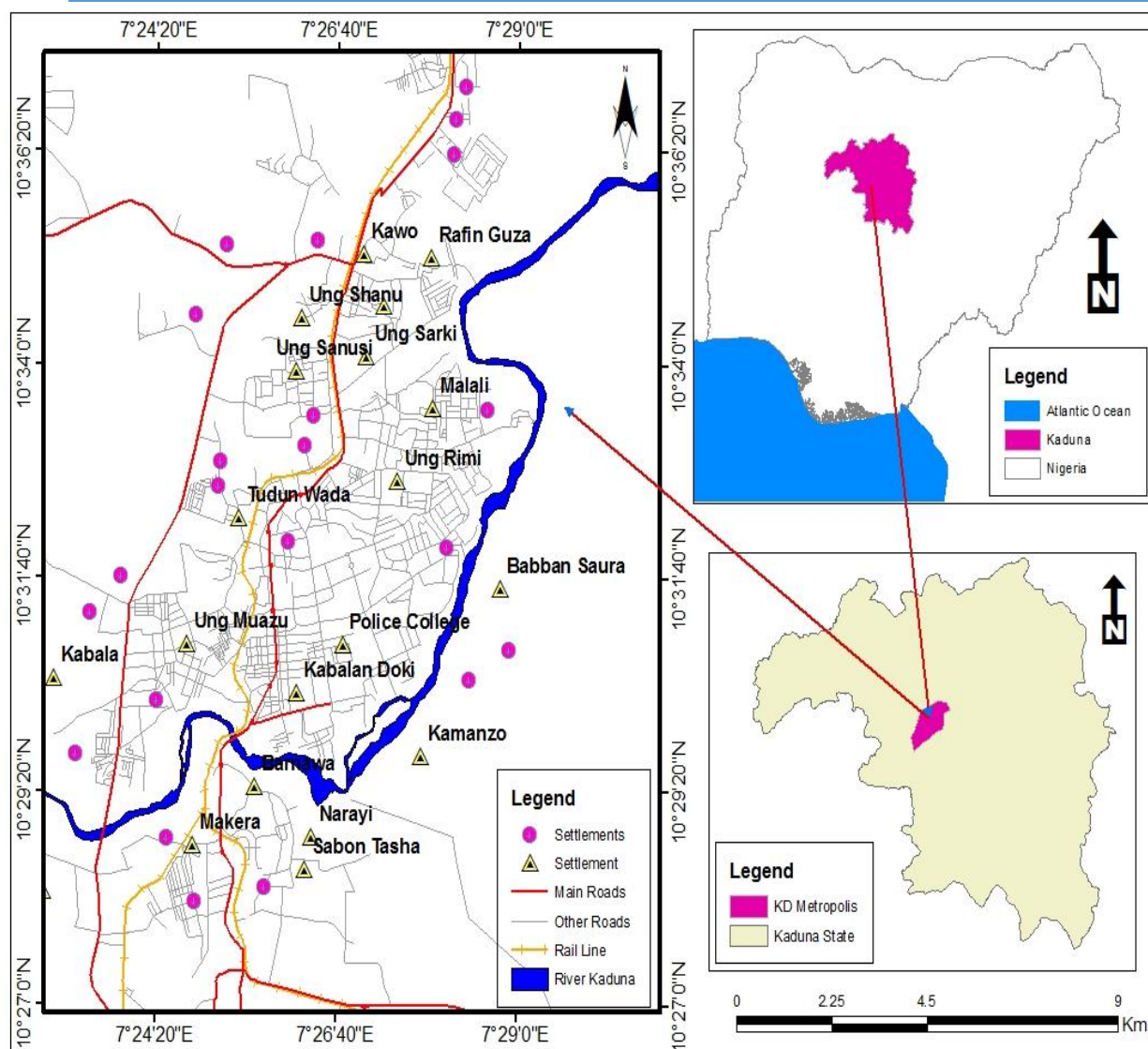
Given the recurrent flood exposure in Kaduna Metropolis and the mixed evidence on the strengths and weaknesses of CBS, there is a clear gap in knowledge and practice. This study therefore, assessed the role of CBS in flood disaster management focusing on Kaduna metropolis as a case study. To achieve this, the study raised the following questions:

- i. What roles do community-based structures play in flood disaster management in Kaduna Metropolis?
- ii. What are the key challenges and capacity gaps faced by community-based structures in managing flood disasters in the study area?

MATERIALS AND METHODS

The Study Area: Kaduna Metropolis is located between Latitudes 10° 20' 00" and 10° 40' 00" North of the Equator and Longitudes 7° 20' 00" and 7° 30' 00" East of the Greenwich Meridian (see Figure 1). It is the capital of Kaduna State, situated in the Northwestern region of Nigeria. The metropolis comprises four Local Government Areas (LGAs); Kaduna North, Kaduna South, Chikun, and Igabi. It is bounded by Kajuru and Kachia LGAs to the South, Birnin Gwari LGA to the West, Giwa LGA to the North, and Zaria LGA further to the Northeast (Abaje et al., 2016). The climate of Kaduna Metropolis is Tropical continental, classified as Aw in the Köppen climatic classification, characterized by distinct wet and dry seasons. Rainfall is largely influenced by the seasonal movement of the Tropical Maritime (mT) and Tropical Continental (cT) air masses. The area receives an average annual rainfall ranging between 1, 100 mm and 1, 500 mm, beginning around April or May and ending in October (Umar et al., 2015). Temperature varies between 18°C during the cold Harmattan season and 34°C at the peak of the dry season.

Economically, Kaduna Metropolis serves as a major industrial and commercial hub in Northern Nigeria. The city hosts textile industries, food processing plants, military establishments, service sectors, and informal trading networks, making it one of the most economically diverse urban centers in the region (Joel, 2012). Agriculture is still practiced on the peri-urban fringes, with crops such as maize, sorghum, millet, and vegetables cultivated mainly during the rainy season. The metropolitan area also holds political and administrative importance as the seat of Kaduna State Government. Its urbanization has led to the expansion of settlements, infrastructural development and the rapidly growing population which is put at 1.3 million people according to World Population Review (2025). Rapid population growth and unregulated land use have, however, contributed to environmental challenges, especially frequent flooding in low-lying neighbourhoods.



Figure

1: The Study Area; Kaduna Metropolis

Source: Modified from Administrative Map of Kaduna State (2025)

Sample Size and Sampling Technique: The total population of Kaduna metropolis (1.3 million) was used to determine the sample size for the study. According to Krejcie and Morgan's (1970) technique, where a population is between 1, 000, 000 and 2, 500, 000, the sample size to use is 384 at 95% confidence level with a 5% margin of error. Since the population is within this range, the study used 384 as sample size.

A multistage sampling technique was adopted for this study. It is the process in which samples are taken in steps (Sedwick, 2015). In the first stage, therefore, purposive sampling technique defined as the deliberate choice of an informant/area due to the quality the informant possesses (Bernard, 2002) was used to select communities who have an established Community-based Disaster Management Committees. Therefore, in Kaduna North LGA, Unguwar Rimi and Rafin Guza were sampled while in Kaduna South LGA, Barnawa and Bashama Road were purposively sampled (Table 1).

Table 1: Sampled Communities in Kaduna Metropolis

Sampled Communities	1991 Population Figures	Projected (2025)	Sample Size
Barnawa	31, 831	59, 332	93
Bashama Road	18, 346	34, 196	54
Rafin Guza	28, 142	52, 457	82
Unguwan Rimi	52, 717	98, 264	155
Total	131, 036	244, 249	384

Source: NPC (1991)

In the second stage, purposive sampling was used to select respondents from the sampled communities within the study area. Residents who are above thirty (30) years of age and have lived for at least ten (10) years within areas liable to flood disasters, and who have been receiving trainings on flood disaster response were identified with the help of heads of communities. The reason for this is that those within this age bracket may perhaps possess the information needed about the situation before the establishment of such Community based disaster management structures and after it is being established. However, in order to obtain proportionate number of respondents for each of the sampled communities, the 1991 population figure was used. This is because the 2006 population data do not provide figures for communities (see Table 1).

Data generated were analyzed using descriptive statistics in form of frequencies, percentages and weighted mean with a formula as follows:

$$\bar{X}_w = \frac{\sum (w_i \times x_i)}{\sum w_i} \quad \text{----- 1}$$

Where:

$\bar{X}_w$ = Weighted mean
 x_i = Each data value (score, response, or variable)
 w_i = Weight assigned to each data value (e.g., frequency or importance)
 $\sum (w_i \times x_i)$ = Sum of the products of each value and its weight
 $\sum w_i$ = Sum of all weights

A 5-point Likert scale was used to rate the respondents' perceptions on flood and other issues in the area: SD = Strongly Disagree; D = Disagree; I = Indifferent; A = Agree, and SA = Strongly Agree.

Mean scores were used to reflect the overall level of agreement:

- 1.00–1.49 = Strongly Disagree
- 1.50–2.49 = Disagree
- 2.50–3.49 = Indifferent
- 3.50–4.49 = Agree
- 4.50–5.00 = Strongly Agree

RESULTS: The socio-demographic/economic characteristics of the respondents are presented in Table 2. The results show that majority of the respondents (26.1%) were within the ages of 30 – 35 years. Fifty-three percent of the respondents were male; 56% were married, and 27% have an average family size of 11-15 members.

Table 2: Socio-demographic Characteristics of the Respondents

Variables	Category	Frequency	Percentage
	30–35	97	26.1
	36–40	55	14.8
	41–45	73	19.6
	46–50	41	11
	56–60	33	8.9
	61–65	21	5.6
	More than 65 years	51	14
	Total	371	100
Gender	Male	197	53
	Female	174	47
Marital Status	Total	371	100
	Single	56	15
	Married	209	56
	Divorced	78	21
	Widowed	28	8
Family Size	Total	371	100
	< 5 members	67	18
	6-10 members	51	14
	11-15 members	102	27
	16-20 members	90	24
	20-25 members	21	6
	26 and above	40	11
	Total	371	100

Source: Field Survey, 2025

The economic characteristics of the respondents were examined in terms of their occupation, monthly income, and educational attainment. These variables (Table 2 and 3) provide insight into the socio-economic background of the study population and their potential influence on livelihood, economic decision-making, and engagement in environmental or developmental activities.

The occupational distribution of respondents shows that the unemployed constituted the largest category with 110 respondents (30%). This indicates a relatively high level of unemployment among the study population, which may have implications for their economic well-being and dependence on external support. Civil servants accounted for 87 respondents (23%), reflecting a moderate representation of individuals in government employment. Respondents engaged in the organized private sector were 61 (16%), while 62 (17%) were artisans involved in informal sector activities such as tailoring, carpentry, or mechanics. Housewives represented 51 respondents (14%), highlighting the presence of non-income-earning individuals who depend largely on their spouses or family members. Overall, the data suggest a mix of formal and informal employment, with a dominance of low-income or irregular sources of livelihood.

Table 3: Economic Characteristics of the Respondents

Variable	Category	Frequency	Percentage
Occupation	Unemployed	110	30
	Housewife	51	14
	Civil servant	87	23
	Organized Private Sector	61	16
	Artisan	62	17
Monthly Income	Total	371	100
	Less than ₦70,000	167	45
	₦71,000 – ₦170,000	108	29
	₦171,000 – ₦270,000	62	17
	More than ₦270,000	34	9
Education	Total	371	100
	Primary	114	31
	Secondary	126	34
	Tertiary	79	21
	No formal education	52	14
	Total	371	100

Source: Field Survey, 2025

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The income distribution (Table 3) reveals that the majority of respondents, 167 (45%), earned less than ₦70,000 monthly. This indicates a low-income bracket and suggests that many respondents may struggle with meeting basic needs. Those earning between ₦71,000 and ₦170,000 formed 29% (108 respondents), while 17% (62 respondents) earned between ₦171,000 and ₦270,000. Only 9% (34 respondents) earned more than ₦270,000 monthly, showing that relatively few respondents belong to higher-income categories. This pattern underscores a general prevalence of low to moderate income among the population, which may influence their capacity for investment, participation in entrepreneurship, or adoption of innovative practices.

The educational profile of respondents (Table 3) shows that 126 (34%) had secondary education, representing the largest category. This is followed by 114 respondents (31%) with primary education, while 79 respondents (21%) attained tertiary education. A smaller proportion, 52 respondents (14%), reported no formal education. This distribution suggests a fairly literate population, with most respondents having at least basic or secondary-level education. The presence of tertiary-educated individuals indicates some level of intellectual capacity and awareness, which can enhance understanding and participation in socio-economic and environmental activities.

The economic characteristics reveal that most respondents are either unemployed or engaged in low-income occupations, with limited financial capacity. Although a fair proportion have attained secondary or tertiary education, the prevailing low-income levels may restrict their access to resources and opportunities for improved livelihoods. These findings reflect the socio-economic realities typical of many semi-urban and rural settings in Nigeria, where employment opportunities are limited and income inequality remains pronounced.

Table 4 shows respondents' opinions on the various roles played by CBS in flood management. The results classified the community-based roles into three categories: high performing roles, moderately performing roles and low performing roles.

Table 4: Roles of Community-Based Structures in Flood Disaster Management

S/N	Roles of CBS	SD (%)	D (%)	I (%)	A (%)	SA (%)	Mean
1	Give early flood warnings	34	26	6	11	29	3.93
2	Organize flood awareness campaigns	12	14	7	21	46	3.75
3	Clear and maintain drainage channels	14	15	8	18	45	3.67
4	Coordinate evacuation during floods	15	17	5	22	41	3.57
5	Rescue victims and protect property	11	12	7	31	39	3.15
6	Distribute relief materials	16	25	8	24	27	3.21
7	Provide temporary shelters	22	19	11	20	28	3.13
8	Conduct post-flood clean-up	22	12	6	26	34	3.38
9	Liaise with government agencies	21	10	4	21	44	3.57
10	Identify vulnerable households	23	15	5	25	32	3.28
11	Use traditional knowledge for prevention	24	21	4	11	40	3.22
12	Mobilize community funds	32	27	5	14	22	4.25
13	Educate residents on waste disposal	12	14	5	21	48	3.79
14	Advocate for government support	13	16	8	25	38	3.59
15	Monitor flood-prone areas	21	14	5	27	33	3.37

Source: Field Survey, 2025

High-performing roles (Mean ≥ 3.50)

Community-Based Structures (CBS) were perceived as effective and active in:

- Mobilizing community funds (Mean = 4.25) – the highest-rated role, showing CBSs' strong capacity to rally financial support locally for flood management.
- Giving early flood warnings (3.93) – suggests that local knowledge and communication channels are well utilized.
- Organizing flood awareness campaigns (3.75) and educating residents on waste disposal (3.79) – indicate CBS effectiveness in sensitization and preventive education.
- Clearing and maintaining drainage channels (3.67) and coordinating evacuation (3.57) – show CBSs play an important role in operational flood response.
- Liaising with government agencies (3.57) and advocating for government support (3.59) – highlight CBSs' intermediary role between the community and government authorities.

Moderately performing roles (Mean = 3.00–3.49)

Respondents were neutral or moderately positive about CBS involvement in:

- Post-flood clean-up (3.38), monitoring flood-prone areas (3.37), identifying vulnerable households (3.28), and using traditional knowledge (3.22). This indicates that while CBSs may engage in these activities, their efforts are inconsistent or insufficiently coordinated.

Low-performing roles (Mean < 3.30)

- Rescue victims (3.15), distribute relief materials (3.21), and provide temporary shelters (3.13) had lower means. This suggests limited capacity of CBSs in emergency response and relief provision, possibly due to lack of equipment, training, or funding.

Overall, the mean values (ranging from 3.13 to 4.25) show that respondents generally agree that CBSs play significant roles in flood management—particularly in prevention, awareness, and coordination.

However, their emergency response and post-disaster recovery roles remain weak or underdeveloped, requiring capacity building and government support.

Implications

- Strengthening CBS capacity in logistics, rescue, and relief delivery would improve community resilience.
- Government and NGOs should collaborate with CBSs for early warning dissemination and post-flood rehabilitation.
- Continuous training and resource mobilization are essential to sustain CBS engagement in flood risk reduction.
- Community funding and education roles should be leveraged as strong foundations for grassroots disaster management.

Table 5 presents respondents' perceptions of major challenges faced by CBS in managing floods.

Table 5: Challenges and Capacity Gaps of Community-Based Structures

SN	Challenges	SD (%)	D (%)	I (%)	A (%)	SA (%)	Mean
1	Lack of funds for flood management	14	11	8	28	39	3.67
2	Poor coordination with government agencies	12	10	5	31	42	3.81
3	Inadequate technical training	14	15	6	21	44	3.66
4	Limited access to early warning information	22	14	8	25	31	3.29
5	Weak community participation	24	17	7	36	16	3.03
6	Shortage of emergency equipment	22	18	4	32	24	3.18
7	Poor drainage and infrastructure	21	11	4	32	32	3.43
8	Lack of disaster response plans	12	14	6	21	47	3.77
9	Low awareness of disaster risks	22	15	9	29	25	3.20
10	Dependence on external assistance	12	32	4	31	21	3.17

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11	Weak leadership and organization	11	14	9	26	40	3.70
12	Gender imbalance in decision-making	15	16	7	23	39	3.55
13	Poor record-keeping and data management	22	14	10	21	33	3.29
14	Inadequate communication channels	21	15	6	28	30	3.31
15	Lack of motivation among volunteers	13	12	5	12	58	3.86

Source: Field Survey, 2025

The results in Table 5 show that the respondents strongly agreed that the following are major obstacles to effective CBS performance:

1. **Lack of motivation among volunteers (3.86)** – This is the most critical challenge, showing that volunteer fatigue, inadequate incentives, or lack of recognition weaken CBS effectiveness.
2. **Poor coordination with government agencies (3.81)** – Indicates weak institutional linkages and limited collaboration between CBS and formal disaster management structures.
3. **Lack of disaster response plans (3.77)** – Reflects poor preparedness and absence of structured emergency response strategies.
4. **Weak leadership and organization (3.70)** – Suggest internal management issues within CBSs that hinder efficient decision-making and implementation.
5. **Lack of funds for flood management (3.67)** – Reveals financial constraints as a major limiting factor for proactive flood control measures.
6. **Inadequate technical training (3.66)** – Suggests that CBS members lack skills in flood monitoring, risk mapping, and emergency operations.
7. **Gender imbalance in decision-making (3.55)** – Shows that exclusion of women limits inclusivity and reduces the community's collective problem-solving capacity.

Moderate Challenges (Mean = 3.00–3.49)

Respondents were **moderately in agreement** that CBSs also face challenges such as:

- i. **Poor drainage and infrastructure (3.43)** – Structural problems in the environment worsen flooding.
- ii. **Limited access to early warning information (3.29)** and **inadequate communication channels (3.31)** – Indicate information flow problems that affect timely response.
- iii. **Poor record-keeping and data management (3.29)** – Points to weak data systems for planning and monitoring flood activities.
- iv. **Weak community participation (3.03)** – Suggests community apathy or lack of collective ownership of flood control activities.
- v. **Shortage of emergency equipment (3.18)** and **dependence on external assistance (3.17)** – Reflect limited local resources and overreliance on external agencies.
- vi. **Low awareness of disaster risks (3.20)** – Indicates insufficient community sensitization.

Overall, the mean scores (ranging from 3.03 to 3.86) indicate that respondents generally agree that CBSs face multiple and interrelated challenges in managing floods. The findings reveal that while CBSs are vital in community-level flood response, their efforts are hindered by institutional, financial, motivational, and technical limitations. The lack of motivation, poor coordination, and absence of clear disaster response plans emerge as the most significant constraints, suggesting a need for stronger institutional support and empowerment.

Implications

- i. **Capacity building** is crucial — CBS members require continuous training in disaster management, early warning systems, and leadership.
- ii. **Government collaboration** should be strengthened to improve coordination and access to resources.
- iii. **Incentive schemes** or recognition programs could motivate community volunteers and sustain engagement.
- iv. **Gender inclusion** should be emphasized to enhance decision-making diversity and local innovation.
- v. **Improved data management and communication systems** are necessary for effective planning and early response.

Conclusion: This study has assessed the role of community-based structures in flood disaster management in Kaduna Metropolis. The findings revealed that socio-economic and demographic characteristics such as occupation, income, and education significantly influence the capacity and participation of residents in flood management initiatives. The economic characteristics of the respondents showed a predominance of unemployed individuals (30%) and low-income earners, with 45% earning less than ₦70,000 monthly. This indicates a generally low economic base, which limits the ability of community members to invest in preventive or adaptive flood control measures. Furthermore, the relatively high number of those with only primary or no formal education (45%) suggests limited awareness and technical knowledge required for effective disaster preparedness and response. The dominance of low-income and informally employed respondents also implies a dependency on government and external assistance during flood events. Overall, the study concludes that while community-based structures play a vital role in mobilization, early warning dissemination, and post-disaster recovery, their effectiveness is constrained by the low economic and educational status of community members. Strengthening these structures therefore requires targeted empowerment programmes, public education, and sustainable livelihood initiatives. Enhancing the socio-economic capacity of residents will not only improve community resilience but also foster proactive participation in flood risk reduction and environmental management efforts within Kaduna Metropolis.

Recommendations: Based on the findings of this study, the following recommendations are proposed to strengthen community-based flood disaster management in Kaduna Metropolis:

- i. Empowerment of Community Members:
The high rate of unemployment and low-income levels among respondents indicate the need for targeted economic empowerment programs. Government and non-governmental organizations should support skill acquisition, micro-credit schemes, and small-scale enterprises to enhance income levels and reduce vulnerability to flood impacts.
- ii. Capacity Building and Education:
Since a significant proportion of respondents possess only primary or secondary education, regular training and sensitization

- programs should be organized to improve community awareness of flood risks, preparedness measures, and mitigation techniques. Such programs should use local languages and culturally relevant communication strategies.
- iii. **Strengthening Community-Based Structures:**
Community associations, religious groups, and neighborhood committees should be formally integrated into local flood management frameworks. These structures should receive technical and logistical support from local and state government agencies to enable them to coordinate early warning, evacuation, and post-flood recovery effectively.
 - iv. **Infrastructure Development:**
Government should invest in sustainable flood control infrastructure such as improved drainage systems, embankments, and proper waste management. Community participation in the maintenance of these facilities should be encouraged to promote ownership and sustainability.
 - v. **Policy Implementation and Institutional Collaboration:**
The Kaduna State Emergency Management Agency (SEMA), Local Government Authorities, and community-based organizations should collaborate closely to ensure that policies on flood risk reduction are effectively implemented at the grassroots level. This will enhance coordination, resource mobilization, and accountability in flood disaster management.
 - vi. **Public Awareness and Environmental Education:**
Continuous public enlightenment campaigns should be carried out through media, schools, and community meetings to promote environmental stewardship, proper waste disposal, and climate change adaptation practices that reduce flood risks.

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Survey on Vermitechnology Practice by Farmers for Organic Crop Production and Food Security in Riversstate

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ABSTRACT

This study examined vermitechnology practice by farmers for organic crop and food security in Rivers State. Two objectives and two research questions were formulated to guide the study, while two hypotheses were postulated and tested at 0.05 level of significance. The study adopted research survey design and the population of the study comprised of all the crop farmers in the study area. The sample size for the study was 54 using multi-stages sampling technique. Instrument for data collection was self-structured questionnaire titled "Vermitechnology Practice for Organic Crop Production" with 4-point rating scale. The instrument was subjected to reliability test using Cronbach Alpha and reliability coefficient index of 0.92 was obtained. The instrument which was 54 copies were readministered to the respondents and all were equally retrieved immediately after completion. Data were analysed using mean and standard deviation as statistical tool while hypotheses were tested using z-test. Result from the findings showed that the farmers were of low extent on the awareness of the vermitechnology for organic crop production and food security, while material selection skills required in vermitechnology for organic crop production and food security were of high extent. However, it was recommended that government through Rivers State Ministry of Agriculture and Non-governmental Organisations in the states should organize training for farmers in order to increase their awareness on the knowledge and skill requirements in vermitechnology for organic crop production in the state.

Keywords: Vermitechnology, Organic Crop Production & Food Security

Introduction: Nigeria is one of the nations that depend on agriculture production for food security and foreign exchange earning thereby bridging the nutritious gap of her citizenry and boasting the Gross Domestic Products (GDP) of the country. However, agriculture production practice involves rearing of livestock and cultivation of crops for the purpose of food and raw materials for man's use either through direct consumption as food or industrial material utilization for value addition. The agricultural production also demands practices that will guarantee healthy environment and food as output in the process of rearing animal and cultivation of food crops. The output of agricultural produce in terms of healthy and high nutritional value is determined by the materials inputs used at the production stages especially food crops.

Hence, food crops when cultivated need the support of soil amendment through the use of fertilizers application, pesticides for control of pests and diseases attack on the crops and herbicides for the control of weeds among growing crops in order to reduce soil nutrient competition which would have direct impact on the growth and quality of yield of the farm produce.

Therefore, these inputs used could be organic or inorganic materials. When it is organic, it implies that no synthetic materials are required by the farmers in every stages of the cultivation till harvest. The output is then referred as organic farm produce. In support of this, view Huber and Schneider (1982) in Raji et al., (2011) affirmed that organic farming is geared towards producing fertilizer that are biological based (bio-fertilizer), and bio-control of pests and diseases (bio-

pesticides) with the intention of restoring biologically active diseases suppressive fertile soil with beneficial microbes, and nematodes that are capable of protecting plant health, while promoting growth. Organic farming system according to the author has the capacity to support nutritive biofertilizers like earthworm vermicompost that gives high food productivity with significantly high nutritional quality while also improving the physical, chemical and biological properties of soil when compared with synthetic fertilizers or inorganic manure.

Earthworm vermicompost is highly nutritive and powerful plant growth promoter and protector, with crop produce (organic food) that guarantees and protect human health, even against colon cancer and breast cancer (Olsson, 2006).

The concept of using earthworms especially the red earthworm for composting is derived from its behavioural pattern. Earthworm feeds on a variety of organic materials and produce "vermicastings" in its natural habitat. This vermicast contains more micro-organisms, organic matter and inorganic materials in the form that it can be used by the plant (Kaladhar, 2017). Hence, when earthworms are cultured for the purpose of producing manure is referred as vermiculture while vermicomposting demands the use of earthworms to convert organic materials into a humus-like material. The concept of growing earthworm for the purpose of composting organic materials through interactions between earthworms and microorganisms, under aerobic conditions enhance the release of nutrients which has been converted into soluble form according to Ndegwa & Thompson (2001) in Jayanta, (2015) provides macro-nutrients such as nitrogen (N), soluble potassium (K), exchangeable calcium (Ca), phosphorus (P), magnesium (Mg) and microelements such as iron (Fe), zinc (Zn) and copper (Cu) that is easily taken up by the plant (Edward & Fletcher, 1988 in Jayanta, 2017).

The process by which earthworms are used to decompose organic materials especially *Eudrilus eugeniae*, *Eisenia foetida*, *Perionyx excavates*, *Lampit mauritii* and *Dravidasilare* are cultured and intentionally used for decomposing of diverse range of organic residues or waste which yield rich vermicompost for crop production and enhancement of soil fertility is referred as vermitechnology (Kaladhar, 2017).

Vermitechnology according to Jambhika, (2002) in Kaladhar (2017) uses the following materials; breeder worms, like red wigglers, a wooden bed or concrete bed and organic wastes. The bed should be of desired length of about 75cm high x 120cm wide, while worms should be introduced to every part of the waste. The author recommended other steps in process of vermitechnology practice which include:

- i. Sieving and shredding skill implies that decomposing can be accelerated by shredding of raw materials into small pieces such as fresh green plant waste.
- ii. Blending skill this requires the combination of carbonaceous substances such as sawdust, paper and straw mixed with nitrogen rich materials such as sewage sludge, biogas, slurry and fish scrap to obtain an nearly optimum carbon and nitrogen (C:N) ratio. This mixture produces good quality compost, rich in macronutrients and micronutrients.

- iii. Half digestion skill: application demand that the mixed materials should be kept in piles under temperature ranged between 50-55°C for ten days.
- iv. Maintaining moisture, temperature and P^H : These skills enhance the optimum moisture level required for aerobic condition which is 40-45 percent. This can be achieved by mixing fibrous with nitrogen rich materials, while the temperature of the piles should be ranged between 28-30°C. Higher or lower temperature reduces the activity of microflora and earthworms. The height of the bed is an added advantage in controlling temperature. Similarly, the P^H of the raw materials should not exceed 6.5-7. Hence, the compost is ready after about granular, high weight and humus rich (Jambheka, 2022) in Kaladhar, 2017. In order to facilitate the separation of worms from the compost, watering should cease two to three days before emptying the beds because this will force the entry of the earthworms to the bottom of the bed (Kaladhar, 2017). The author added, that the remaining worms can be removed for the next production stage while the vermicast or vermicompost can be used for field to enrich the soil, thereby supporting crop/plant growth and yield and discouraging the use of inorganic fertilizer.

However, the adoption of vermiculture technology for organic crop production by farmers is affected by their level of awareness on the skills required. Hence, the use of bio-fertilizers and bio-pesticides in crop production on the part of the farmers is referred to organic crop production (Twarawi & Ranjan, 2006). The adoption of organic crop farming will enhance soil quality, high yield, and improved income to the farmer and protection of the environment which will guarantee healthy food there for contributing to food security. Food security according to Food and Agricultural Organization (2001) refers to a situation where all individuals, irrespective of their social class at all times have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Statement of the Problem: Nigeria as a nation depends on agriculture for food and raw materials and farmers are saddled with the responsibility of accomplishing this noble task. The quality and quantity of food produced by farmers is dependent on the agronomic practices that they are exposed to in the cultivation process. The farmers most times in an attempt to increase yield, control pests and diseases including weeds in their farms, resort to the use of synthetic fertilizers, pesticides and herbicides. These farm inputs significantly contaminate food stuff long after they are taken away from farm for human consumption (Sinha et al., 2009). The author indicated that consistent use of residual pesticide in soil of crop lands such as phosphamidon, DDIP, methyl parathion, malathion, chlorpyrifos when absorbed by plant will contaminate the food crops with toxin or heavy metals that is detrimental to human health. Reported by Lloyed, (2011) showed that persistent toxic chemicals in the US food supply, daily exposes consumers to organic pollutants such as dioxin through their food. Regrettably, most crop farmers in Rivers State that cultivate crops in their farmland have adopted the use of inorganic chemical for the control of pests and diseases, herbicide for control of weeds while inorganic fertilizers are used for soil amendment in order to increase yield of their crops as against organic bio-fertilizer and bio-pesticides. The pertinent question is that does the farmers really utilized vermiculture technology concepts for crop production in order to produce high quality food crops free from toxin? Answer to this question, emanated this study on the utilization of vermiculture technology practice by farmers for organic crop production and food security in Rivers State.

Aim and Objectives of the Study

The aim of the study is to determine the level of utilization of vermiculture technology practice by farmers for organic crop production and for food security. Specifically, the objectives are to:

- i. determine the awareness of vermiculture technology practice by farmers for organic crop production and food security in Rivers State.
- ii. ascertain material selection skills required by farmers in vermiculture technology practice for organic crop production and food security in Rivers State.

Research Questions

1. To what extent do the farmers are aware of vermiculture technology practice for organic crop production and food security in Rivers State?
2. To what extent do the farmers require vermiculture technology skills for organic crop production and food security in Rivers State?

Hypothesis

1. There is no significant difference in the mean rating on male and female farmers on the extent of awareness on vermiculture technology practice for organic crop production and food security.
2. There is no significant difference in the mean responses of male and female farmers on the required vermiculture technology skills for organic crop production and food security.

Methodology: The study adopted descriptive survey design while population of the study comprised all the crop farmers in the Rivers State. However, using multi-stages sampling techniques, entire state were clustered into three groups according to the senatorial districts Rivers South East. Purposively, two local government were selected from each districts while, randomly, 4 male farmers and 5 female farmers were selected from each local government as respondents. Instrument for data collection is titled: Vermiculture technology practice for organic crop production questionnaire (VSQCPQ). However, instrument was designed using 4-point rating scale and response attached to the items were Very High Extent (4), High Extent (3), Low Extent (2) and Very Low Extent (1). Instruments were also subjected to reliability test and reliability coefficient of 0.92 was obtained using Cronbach Alpha. Although, all the instrument which are 54 copies were readministered to the respondents and were all retrieved, and used for data analysis. Data were analyzed using descriptive statistics of mean and standard deviation in answering the research questions while hypotheses were tested using z-test statistics at 0.05 level of significance. Mean rating weighed 2.50 and above were considered high extent and those weighted below 2.50 were considered low extent. Z-test for the hypotheses were rejected when $z_{cal} \geq z_{crit}$ and accepted when $z_{cal} \leq z_{crit}$.

Result Presentation and Discussion of Findings

Research Question One: To what extent do farmers are aware of vermiculture technology practice for organic crop production and food security in Rivers State?

Table 1: Data analyzed on the awareness of farmers on vermiculture technology

S/N	ITEMS	Male Farmer N=24		Female Farmer N=30		Remark
		$\bar{X}^2$	SD ¹	$\bar{X}^2$	SD ²	

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1.	knowledge of vermicompost as organic manure source	2.46	0.63	2.35	0.57	Low Extent
2.	Awareness on role of earthworms especially red wigglers for conversion of organic material to nutrients.	2.49	0.71	2.44	0.60	Low Extent
3.	Knowledge of soil nutrients derived from vermicomposting such as macro and micronutrients.	2.48	0.60	2.39	0.55	Low Extent
4.	Information on toxic input found in food crops after harvest due to the inorganic chemicals	2.40	0.56	2.46	0.61	Low Extent
5.	Awareness of materials required in vermicomposting	2.47	0.72	2.45	0.62	Low Extent
6.	Informed knowledge of the various steps in vermicomposting	2.42	0.49	2.30	0.49	Low Extent
7.	Awareness of residual effect of inorganic chemicals presence in soil after consistent use.	2.44	0.60	2.15	0.35	Low Extent
Grand Mean		2.10	0.62	2.36	0.54	Low Extent

Field Report, 2025

Data analyzed in table 1, shows the level of awareness of farmers in vermicomposting with mean values that ranged between 2.15 to 2.49 in research item one to seven. However, with the grand mean values of 2.10 and 2.36 for both male and female farmers showed, Low Extent on the level of awareness by farmers on vermicomposting practice for organic crop production and food security in Rivers State. Therefore, with standard deviation that ranged between 0.35 to 0.72, and grand standard deviation of 0.62 and 0.54, showed closeness in the opinion of the respondents.

Research Question Two: To what extent do the farmers require vermicomposting skills in organic crop production for food security?

Table 2: Data analyzed on the vermicomposting skills required by farmers for organic crop production among farmers and food security

S/N	ITEMS	Male Farmer N=24 $\bar{X}^1$	SD ¹	Female Farmer N=30 $\bar{X}^2$	SD ²	Remark
8.	Capacity to construct vermicomposting bed with right dimension	3.54	0.65	3.59	0.95	High Extent
9.	Skill of material selection for vermicomposting	3.70	0.89	3.13	0.71	High Extent
10.	Ability to identify the right time to introduce earthworms	3.04	0.81	3.09	0.89	High Extent
11.	Sieving and shredding skill in vermicomposting	3.05	0.84	3.61	1.03	High Extent
12.	Blending skill of carbonaceous substances and nitrogen rich materials	3.14	0.90	3.63	0.79	High Extent
13.	Knowledge of half digestion skill in vermicomposting	3.12	0.89	3.20	0.92	High Extent
14.	Moisture and temperature maintenance skill in vermicomposting	3.06	0.72	3.10	0.83	High Extent
15.	Knowledge of the required level of vermicomposting	3.41	0.92	2.99	0.88	High Extent
16.	Duration of vermicomposting processes before use in field	3.36	1.03	3.54	0.93	High Extent
17.	Skill to culture and manage earthworm before and after vermicomposting	3.03	0.78	3.09	0.70	High Extent
Grand Mean		3.25	0.84	3.24	0.79	High Extent

Field Report, 2025

Table 2, shows data analyzed on the vermicomposting skills required by farmers for organic crop production. The mean values obtained ranged between 2.99–

3.61 from item 8 to 17. The grand mean values of the male and female farmers were 3.25 and 3.24 which indicated High Extent on the required vermicomposting skills by farmers for organic crop production and food security in Rivers State. Similarly, with the standard deviation that ranged between 0.61–1.03 and a grand standard deviation of 0.84 and 0.79, showed closeness in the opinion of the respondents.

Hypotheses Test

The null hypotheses were tested at 0.05 level of significance using z-test.

- There is no significant difference in the mean rating of the male and female farmers on the extent of awareness in vermicomposting practice for organic crop production and food security in Rivers State.

Table 3: Z-test on awareness of vermicomposting practice by farmer

N=54	$\bar{X}$	SD	df	Sig.	Z-cal	Z-crit	
Male Farmers	2.10	0.62	52	0.05	1.56	1.96	Accepted
Female Farmers	2.36	0.54					

The z-test in table 3 was tested at 0.05 level of significance at df of 52, while z-cal is 1.56 and z-crit 1.96. Hence, the null hypothesis is that there is no significant difference in the mean rating of the male and female farmers on the awareness of vermicomposting practice for organic crop production for food security in Rivers State was upheld.

Table 4: Z-test on vermicomposting skill required by farmers

N=54	$\bar{X}$	SD	Df	Sig.	Z-cal	Z-crit	
Male Farmers	3.25	0.84	52	0.05	1.72	1.96	Accepted
Female Farmers	3.24	0.79					

The Z-test in table 4 was tested at 0.05 level of significance at df of 52 while z-cal is 1.72 and z-crit 1.96. Since the z-cal was less than z-crit, the null hypothesis was accepted. This shows that there is no significant difference in the mean rating of the male and female farmers on the vermicomposting skills required for organic crop production and food security in Rivers State.

Discussion of Findings: Findings in research question one in table 1, revealed that the farmers are of Low Extent on the awareness of vermicomposting practice for organic crop production and food security in Rivers State. The study further revealed Low Extent on the following items: knowledge of vermicompost as organic manure source, awareness on role of earthworm in conversion of organic material to nutrients, knowledge of soil nutrients derived from vermicomposting, information on toxic input found in food crops after harvest due to inorganic chemicals, awareness of materials required in vermicomposting, knowledge of various steps in vermicomposting and awareness of residual effect of inorganic chemicals presence, in soil after persistent use. This implies that crop farmers lack information that would have created awareness on the benefit of vermicomposting practice among them for organic crop production and food security in Rivers State.

The study supports the findings of Sinha et al (2009), they indicated that consistent use of pesticides in Indian soils of crop lands such as DDVP, methyl, parathion, malathion, chlorpyrifos when absorbed by plant contaminates the crops with toxin that is detrimental to human health. In the same vein, Lloyd (

2011) reported that persistent toxic chemicals in U.S. food supply, daily exposes consumers to persistent organic pollutants such as Dioxin through food that will impact negatively on human health.

Hence, the findings of Ndegwa and Thompson (2001) in Jayanta (2015) stressed that the purpose of growing earthworms is to convert organic materials into humus-like materials under aerobic condition. This enhances the release of macronutrients such as nitrogen; soluble potassium, exchangeable calcium and micronutrients such as zinc, copper, iron among others in which farmers are not aware in the study area.

Findings in research question two in table 2, showed that the farmers were of High Extent on the vermiculture technology skills required in organic crop production for food security in Rivers State. The study further indicated that farmer requires skills to construct vermiculture composting bed with right dimension, material selection for vermiculture composting, sieving and shredding skill in vermiculture technology, blending skill, moisture and temperature maintenance among others.

The study supported the submission of Jambhheka (2002) in Kaladhar (2017) who outlines skills required in vermiculture technology for organic crop production on practice which includes skill to breed earthworms like red wigglers, construct wooden bed for organic waste composting, sieving and shredding skill, blending skill by combining nitrogen rich materials with carbonaceous substances, half digestion skills and skill in maintaining moisture, temperature and pH at optimal level. Hence, skill is required for vermiculture technology for organic crop production by farmers in the study area.

Conclusion: The study examined vermiculture technology practice by farmers for organic crop production and food security in Rivers State. Based on the data analyzed and findings from the study, it is concluded that farmers in River State are not fully aware of vermiculture technology practice and they also lack basic skills required in vermiculture technology. Hence, this enhances the use of inorganic fertilizers for the enrichment of the soil nutrients, use of chemical pesticides for control of pests and diseases that are highly detrimental to the environment and human health.

Recommendations

1. The Government of Rivers State through Ministry of Agriculture in partnership with NGOs that are into agriculture, should promote organic crop production by creating awareness on the benefits of organic farming through vermiculture technology among farmers in the state.
2. Training and demonstration workshop should be organized for the farmers by Rivers State Ministry of Agriculture on skills required for vermiculture technology practice for organic crop production in the State.

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Fishery Value Chain in River Benue Valley Nigeria, A Livelihood Approach for Fishermen Economic Sustainability and Resources Management

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Abstract

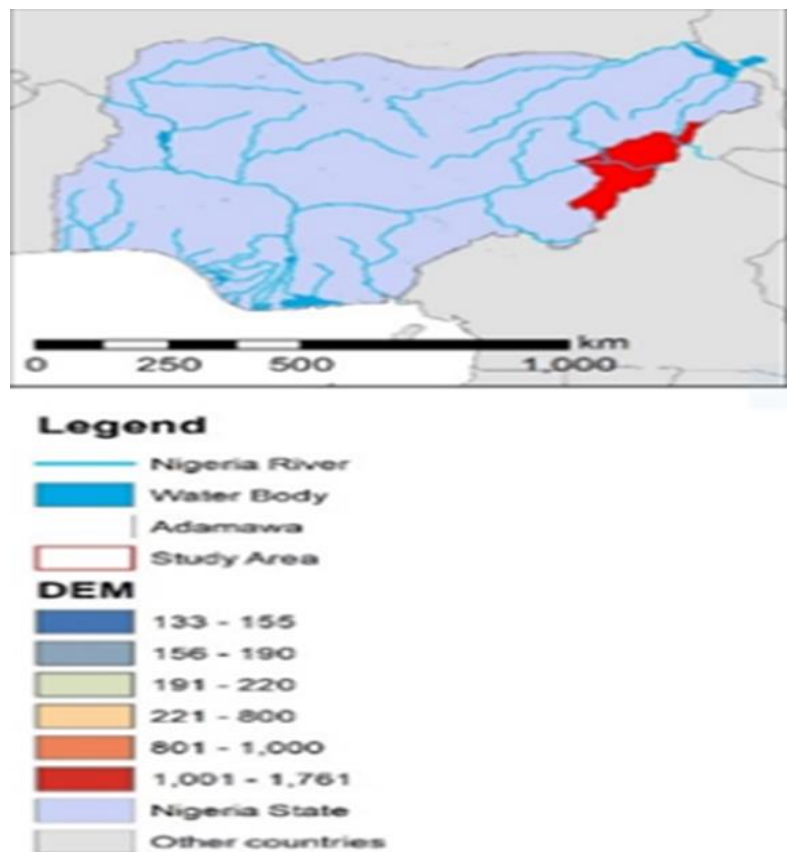
This study, identified, examined and analysed 200 fish value chain actors in Fufore, Yola, Girei, and Numan local government areas of Adamawa state, Nigeria. The Data were subjected to descriptive statistics. Results were presented in tables and charts. Findings, revealed (11.9 %) fishers (14.42 %) traders, (17.72 %) processors, (29.63 %) labourers, (26.33 %) consumers. (75 %) were males, (25 %) females. (65%) were married with an average household size of 5 persons and (35 %) single. (82 %) of the women were on fish processing and trading while 18 % fishing and trading. (65 %) were in their active and productive age bracket of 21-50. (18 %) were formally educated. (67 %) used their personal savings while 33 % on borrowed money. (90 %) had 15-45 years of fishing and trading experiences. (59 %) diversified into crops and livestock production. (41 %) depends on fishing and fish related businesses. Fishing, trading, processing and fishing cum livestock management were profitable with a gross margin of ₦1500, ₦1800, ₦2000 and ₦2500 respectively. The analysis showed a high-level profit and economic sustainability. Therefore, government and private donors are advised to provide good linkages with community organisations especially, cooperative societies in promoting wellbeing of the actors and enhanced sustainable livelihood.

Keywords: Sustainability, Diversifications, Composition, Overfishing, Value-chain.

Introduction: Fish value chain describes the full range of activities which are required to bring a fish product or services from conception, through the different phases of production involving a combination of physical transformation and inputs of various producer services delivery to final consumers, and final disposal after use. Livelihood diversification is a survival method among rural families. Its analysis complements activities that would permit fishermen to diversify profits sources and decrease poverty (Marsden, 2000). Trade in fish and fish products is vital for expanding the economy, increasing fish consumption, and maintaining global food security by connecting producers with distant markets where local supply may be insufficient (FAO, 2018). It also employs and profits hundreds of thousands of people worldwide, mainly in developing nations, in a range of fields and sports

Materials and methods

Map of the study areas



Research tools : This study was achieved using questionnaire and semi-structured interviews on weekly meetings. General section of the questionnaires displayed the fishermen's age, gender, religion, marital status, educational level, literacy, fishing experience and the number of household members (Adeleke.,2013, Billah 2018, Zainudin, 2019, Yadav, 2020, Ghosh, 2015).

Income analysis

To analyse the income of fishermen, data was calculated by using the following formula:

$$TR = P \times Q$$

Where TR= Total Revenue (₦), P= Price of fish (₦), Q= Quantity of fish catch (kg)

Next, the total production cost was calculated by using the following formula:

$$TC = VC + FC$$

Where TC= Total production cost (₦), VC= Variable cost (₦), FC= Fixed cost (₦)

After total revenue (TR) and total cost (TC) has been calculated, the income of fishermen was calculated by income formula (Limi, 2017) as follow:

$$TI = TR - TC$$

Where TI= Total income of fishermen

Results and Discussion: In this study, the focus was solely on catch fisheries, and four broad kinds of actors were identified and involved in the various value chain operations. Producers, traders, processors, and some additional workers, or wage labourers, participate in the activities.

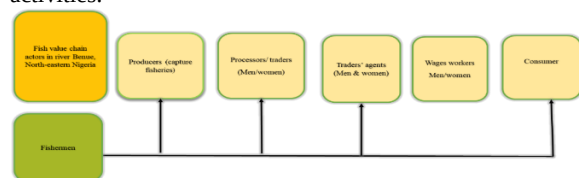


Fig. 1 Fishery value chain actors in river Benue

Producers: A variety of producer types were identified in this study, each with differing levels of social and economic standing, access to fish and markets, and general well-being. Fishing areas, fishing length and quantity of fish captures, gender, size of fishing operations, nature of involvement in fishing, seasonality of fishing activities, and level of reliance on traders for advances were all used to classify these producers.

Traders: During the research, two types of wholesale fish sellers catering to the distant fish trade were identified, those with high catches and those with seasonal fish landings. The first were the community collecting agents, who are employed by the community traders in exchange for a commission on the supply. The traders, who were mostly found in smaller or more remote villages with seasonal/small fish landings, were the second group. They get their fish from a variety of sources, including collecting agents or independent merchants, as well as aqua culturists, whose contribution to the traders' turnovers is growing.

Processors: In the study locations, women and children were seen working as fish processors. They were involved in the preparation of dried fish or fish sauce, as well as the smoking of fish in smoking kilns.

Wage workers: In the study locations, there were several types of wage labourers in the fishing value chains. The majority of these people work in small-scale fisheries, with daily earnings of around N1000.

Socio-economic status of value chain actors: Findings, revealed (11.9 %) fishers (14.42 %) traders, (17.72 %) processors, (29.63 %) labourers, (26.33 %) consumers fig. 1. (75 %) were males, (25 %) females. (65%) were married with an average household size of 5 persons and (35 %) single fig. 2 &3. (82 %) of the women were on fish processing and trading while 18 % fishing and trading. (65 %) were in their active and productive age bracket of 21-50 fig. 4. (18 %) were formally educated fig. 6. (67 %) used their personal savings while 33 % on borrowed money, fig. 7. (90 %) had 15-45 years of fishing and trading experiences. (59 %) diversified into crops and livestock production, (41 %) depends on fishing and fish related businesses. Fishing, trading, processing and fishing cum livestock management were profitable with a gross margin of ₦1500, ₦1800, ₦2000 and ₦2500 respectively.

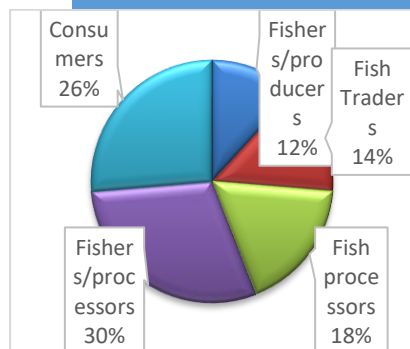


Fig. 1 Percentage composition of value chain actors

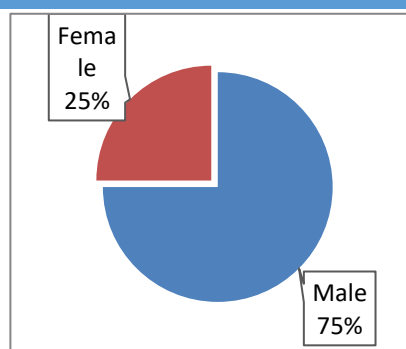


Fig. 2 Percentage composition by sex

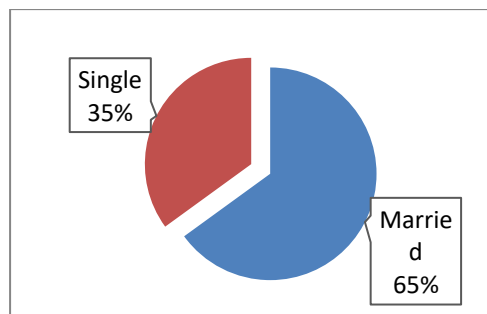


Fig. 3 Composition of married and single

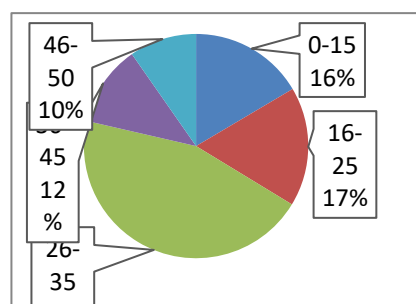


Fig. 4 Composition by age

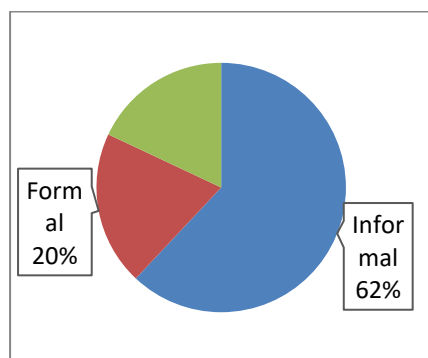


Fig. 5 Educational status of actors

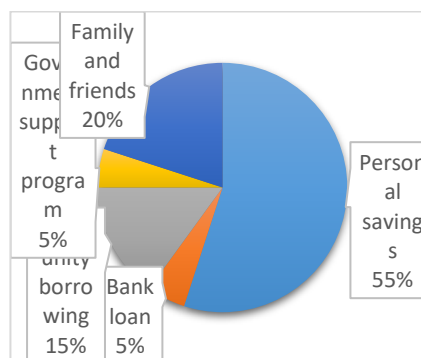


Fig. 6 Actors sources of capital

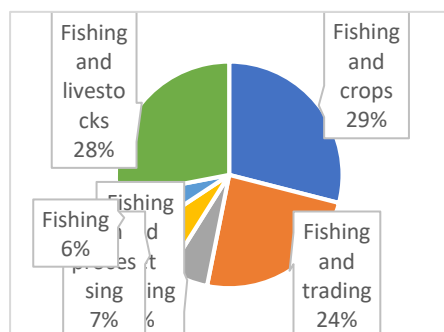


Fig.7 livelihood diversification

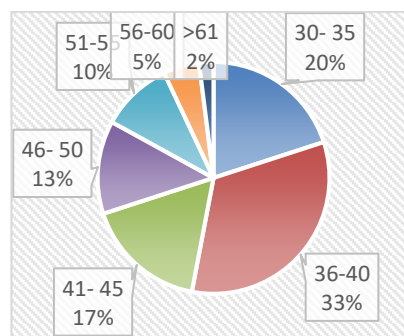


Fig. 8 fishing experience

Clarias spp, *Allestes*, *Heterotis niloticus*, *Lates niloticus*, *synodontis spp*, *tilapia spp*, *polipterus sennegalus* etc, are the commercially valued fishes in the Upper Benue River Valley and the handling, grading, processing and packaging, attract good market prices (Sogbesan and Baka., 2017). The income of the fishers reflects differently and did not agree that family size of fishers determines their income either in fishing or other livelihood activities, all these did not signify any change in the fisher's economic status in all the fishing communities as their annual income did not meet UN/FAO standard of \$20,000 per annum, which is equivalent to ₦10,000,000 (Olaoye., 2012 and FAO., 2016). The low daily fish consumption of 10.5 kg per household means the annual fishing household consumption does not reach the required 40 kg of fresh fish Omojowo *et al.*, (2010). The annual profit of fishers did not correspond with its annual gain, total expenses, and annual sales of fishes, this was highly attributed to proximity. The Fish sellers and buyers are controlled by third tier of business transaction pattern called commission agents (Yan Baranda) (Ladu., 2015).

Conclusion: The analysis showed a high-level profit and economic sustainability. Therefore, government and private donors are advised to provide storage and credit facilities to the actors and advanced good linkages with community organisations especially, cooperative societies in promoting wellbeing of the actors and enhanced sustainable livelihood management.

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Growth and Yield of Cowpea (*Vigna Unguiculata* L. Walp) As Influenced by Variety and Poultry Manure in Dutse's Ferralitic Soil.

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ABSTRACT

Field experiments were conducted during the 2022 and 2023 raining seasons at the Research Farm, Department of Crop Science, Federal University Dutse. Treatments consisted of five (5) levels of poultry manure (PM) (0, 2.5, 5.0, 7.5 and 10 t/ha) and two (2) cowpea varieties (IAR-48 & SAMPEA-7) V₁ and V₂, respectively. Treatments were laid out in a complete block design replicated three times. Poultry manure (PM) at rate 2.5t/ha significantly produced more number of leaves /plant, longer vines/plant, more total dry matter (TDM), more pods/plant but had no significant effect ($P \leq 0.05$) on 100 - seed weight. Poultry manure also at rate 5t/ha significantly produced larger leaf area index (LAI) and more number of leaves. Variety and interactions between poultry manure and variety were not significant ($P \leq 0.05$) on number of leaves (NL), LAI, number and length of vines/plant, 50% days to flowering, number of pods/plant and 100 - seed weight. Interactions between poultry manure and variety on seed yield /plant (kg/plant) and seed yield per hectare (kg/ha) were not significant ($P \leq 0.05$). The effect of variety on seed yield/plant (kg/plant) and seed yield/ha (kg/ha) was only significant in 2022 where variety IAR-48 (V₁) significantly produced more seed yield/plant and more seed yield per hectare of (17.61a) and (880.06a) respectively. Application of PM at (2.5t/ha) and variety IAR-48 is recommended for farmers growing cowpea in the Dutse's ferrelitic soil and similar environments.

Keywords: Cowpea, variety, growth, yield and poultry manure.

Introduction: Cowpea (*Vigna unguiculata* L. Walp) is a vital grain legume, prized for its high protein content (23-25%) in dry seeds, making it a crucial, affordable nutritional supplement to staple cereals and a key source of dietary protein (Stanton et al., 1966). Extensive research has demonstrated that organic amendments, particularly poultry manure (PM), significantly enhance cowpea growth and yield. Studies by Agyenim et al. (2006) and Seth et al. (2008) confirm that PM application boosts key parameters like plant height, leaf area index (LAI), total dry matter (TDM), and final grain yield. Furthermore, Modukwe et al. (2006) reported that PM incorporation improves soil fertility by increasing nitrogen, phosphorus, and potassium content, leading to higher nodulation and a mean grain yield of 744.7 kg/ha compared to unamended plots. This study aims to investigate the growth and yield responses of two cowpea varieties to different PM application rates in the ferralitic soils of Dutse, Nigeria.

Materials and Methods: Field experiments were conducted over the 2022 and 2023 rainy seasons at the Research Farm of the Federal University Dutse, located in the Sudan savanna agro-ecological zone (11° 70' N, 9° 34' E). The region experiences an average annual rainfall of 743 mm and a temperature of 26.5°C. The experimental soil was a sandy loam, classified as ferralitic, with an acidic pH (4.53 – 4.68) and low inherent fertility, characterized by low total nitrogen (0.049 g/kg), organic carbon (0.69 mg/kg), and available phosphorus (5.90 mg/kg). The experimental design was a randomized complete block with three replications. Treatments consisted of a factorial combination of five PM rates (0, 2.5, 5.0, 7.5, and 10 t/ha) and two cowpea varieties (IAR-48 and SAMPEA-7). The PM was incorporated into the soil 10 days before sowing to allow for partial decomposition. Seeds were treated with Apron-Star fungicide and sown on ridges at a spacing of 75 cm x 30 cm. Standard agronomic practices, including weeding and pest control using permethrin, were diligently followed. Data collection was conducted at specific growth stages. At 50% flowering, growth parameters—including number of leaves, number and length of vines, LAI, and TDM—were recorded. At physiological maturity, yield components such as pods per plant, seed yield per plant and per hectare, and 100-seed weight were measured. All collected data were subjected to analysis of variance (ANOVA) using SAS version 9.4, and treatment means were separated using the Least Significant Difference (LSD) test at a 5% probability level.

RESULTS

Table 1. Number of leaves and leaf area index (LAI) of cowpea varieties as affected by poultry manure and variety at Dutse during the 2022 and 2023 wet seasons

Treatments	Number of leaves/plant at flowering			Leaf area index (LAI)		
	2022	2023	Means	2022	2023	Means
<u>PM (t/ha)</u>						
0	52.5C	61.0b	56.8b	1.27C	1.81b	1.55b
2.5	51.3c	118.7a	85.0a	2.56bc	2.33b	2.45ab
5.0	68.7ab	85.3ab	77.0ab	3.24a	2.93a	3.09a
7.5	73.8a	76.0b	74.9ab	3.16ab	3.11a	3.14a
10	61.1b	5.7b	57.4b	3.08ab	2.96a	3.02a
SE±	8.12	15.04	11.26	0.443	0.311	
Significance	*	**	**	*	**	**

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PROCEEDINGS

Variety

V1	69.2	79.2	74.2	2.88	2.06	2.47
V2	70.1	75.5	72.8	2.79	2.92	2.86
SE±	3.96	2.77	3.37	0.382	0.322	0.352
Significance	NS	NS	NS	NS	NS	NS

Interaction

P X V	NS	NS	NS	NS	NS	NS

Mean followed by unlike letter(s) within a treatment and column differ significantly using LSD ($P \leq 0.05$)

From table 1, poultry manure at rate 2.5t/ha significantly produced ($P \leq 0.01$) more number of leaves/plant (85.0a), statistically similar with 5 and 7.5 t/ha (85.0a) and (74.9ab) respectively. **Leaf area index was significantly enhanced at 7.5 t/ha (3.14a) which is at par with 5 and 10 t/ha (3.09a) and (3.02a) respectively.** The variety and interactions effect of poultry manure and variety on number of leaves/plant and LAI were not significant in the two years ($P \leq 0.51$).

Table 2. Number and length of vines of cowpea varieties as influenced by poultry manure and variety at Dutse during the 2022 and 2023 wet seasons

Treatments	Number of vines/plant			Length of vines/plant		
	2022	2023	Means	2022	2023	Means
<u>PM (t/ha)</u>						
0	8.0	10.5	9.3	70.0b	92.7	82.4
2.5	11.3	10.8	11.1	96.0a	103.9	100
5.0	10.7	13.4	12.1	95.6ba	113.4	104.3
7.5	7.3	11.6	9.5	69.2b	114.8	92.0
10	9.0	10.1	9.6	76.0ab	103.1	89.6
SE±	2.18	1.08	1.63	8.74	9.64	9.19
Significance	NS	NS	NS	*	NS	NS

Variety

V1	8.8	10.3	9.6	88.1	96.8	92.5
V2	9.1	9.4	9.3	96.3	107.7	102.0
SE±	2.07	1.11	1.59	5.66	8.83	7.25
Significance	NS	NS	NS	NS	NS	NS

Interaction

P X V	NS	NS	NS	NS	NS	NS

Means followed by unlike letter(s) within a treatment group and column differ significantly using LSD ($P \leq 0.05$)

Table 2 shows the effect of poultry manure and variety on number and length of vines/plant/ in 2022 and 2023 seasons at Dutse, Jigawa State, Nigeria. From the table, poultry manure had no significant effect on the number and length of vines/plant except in 2022 where poultry manure at rate 2.5 t/ha produced longer vines (96.0a) which is at par with rates 5 and 10 t/ha (95.6ba) and (76.0ab) respectively. There was no significant effect ($P \leq 0.05$) of variety on number and length of vines/plant and interactions between poultry manure and variety.

Table 3. Total dry matter and days to 50% flowering of cowpea varieties as affected by poultry manure and variety at Dutse during the 2022 and 2023 wet seasons

Treatments	Total dry matter			Days to 50% flowering		
	2022	2023	Means	2022	2023	Means
<u>PM (t/ha)</u>						
0	57.2c	51.6a	54.4c	56.9	49.2	51.2
2.5	78.1a	66.4b	72.3a	56.3	51.4	53.9
5.0	68.5b	74.0a	71.3a	59.1	50.8	55.0
7.5	50.8a	69.2b	60.0b	52.9	52.1	52.5

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10	51.8a	61.7c	56.8bc	55.1	54.8	55.0
SE±	2.46	1.18	1.82	8.16	6.37	7.27
Significance	*	**	*	NS	NS	NS

Variety

V1	69.8	70.1	70	56.7	48.8	52.8
V2	73.4	68.7	71.1	61.6	52	56.8
SE±	2.16	1.19	1.68	7.11	5.55	6.33
Significance	NS	NS	NS	NS	NS	NS

Interaction

P X V	NS	NS	NS	NS	NS	NS

Mean followed by unlike letter (s) within a treatment group and column differ significantly using LSD ($P \leq 0.05$)

From the table 3, poultry manure at rate 2.5 t/ha significantly enhanced total dry matter (72.2a) comparable with rate 5 t/ha (71.3a). There was no significant effect of variety and interactions between poultry manure and variety on the total dry matter and 50% days to flowering. In the pooled data, plots that received 2.5 and 5.0 t/ha of PM produced similar significantly higher TDM than the control which did not differ significantly with the highest rates of PM (10t/ha). Further increase in the levels of PM from 5.0t/ha to 7.5t/ha decreased TDM ($P \leq 0.05$) (Table 3)

Table 4: Number of pods and 100 - seed weight of cowpea varieties as influenced by poultry manure and variety at Dutse during the 2022 and 2023 wet seasons

Treatments	Number of pods			100 - seed weight		
	2022	2023	Means	2022	2023	Means
PM (t/ha)						
0	6.1b	5.1c	5.6b	18.1	19.3	18.7
2.5	8.0ab	7.8b	7.9a	23.2	21.9	22.6
5.0	8.3ab	10.3a	9.3a	20.4	21.3	20.4
7.5	7.4ab	8.8ab	8.1a	20.4	20.3	19.7
10	8.8a	9.2ab	9.0a	19.1	20.3	19.7
SE±	0.83	0.77	0.80	2.15	1.92	2.04
Significance	*	**	**	NS	NS	NS
Variety						
V1	7.9	8.2	8.1	20.1	19.8	20.0
V2	8.1	8.7	8.4	21.3	20.7	21.0
SE±	0.63	0.67	0.65	1.93	1.76	1.85
Significance	NS	NS	NS	NS	NS	NS
Interaction						
P X V	NS	NS	NS	NS	NS	NS

Mean followed by unlike letter (s) within a treatment group and column differ significantly using LSD ($P \leq 0.05$)

From the table 4, poultry manure at rates 10 and 5 t/ha significantly recorded more number of pods/plant in 2022 and 2023 seasons (8.8a0 and (10.3a) respectively. However, the pooled data for rates 2.5 - 10 t/ha were statistically similar. Poultry manure had no significant effect on 100 - seed weight. The effect of variety and poultry manure and variety interactions on number of pods/plant and 100 - seed weight were significant.

Table 5: Seed yield of cowpea varieties at Dutse as influenced by poultry manure and variety during the 2022 and 2023 wet seasons

Treatments	Seed yield (kg/plant)			Seed yield (kg/ha)		
	2022	2023	Means	2022	2023	Means
PM (t/ha)						
0	17.05b	12.23b	14.6b	852.4b	611.4b	731.9b
2.5	21.1b	14.20ab	17.7ab	1055.0a	710.6ab	882.8a
5.0	21.03ab	16.00a	18.5a	1051.3ab	800.3a	925.7a
7.5	17.41ab	11.86b	14.6b	870.7b	593.1b	732.0b
10	22.84a	13.23ab	18.0ab	1142.3a	661.5ab	901.8b
SE±	1.574	1.185	1.38	78.71	62.23	70.47
Significance	*	*	*	*	*	**
Variety						
V1	17.61a	11.83	14.72	880.6a	591.3	736.0
V2	13.87b	12.25	13.06	693.7b	612.7	653.2
SE±	1.077	0.984	1.031	53.86	48.18	51.02
Significance	NS	**	NS	NS	**	NS
Interaction						
P X V	NS	NS	NS	NS	NS	NS

Mean followed by unlike letter (s) within a treatment group and column differ significantly using LSD ($P \leq 0.05$)

From the table, seed yield/plant was only significant in 2022 where IAR -48 (V₁) significantly produced more seeds/plant (kg/plant) and more seeds/ha (kg/ha) of (17.61a) and (880.6a) respectively. Interactions effect between poultry manure and variety on seed yield/plant and seed yield/ha were not significant.

DISCUSSIONS: The application of poultry manure (PM) significantly enhanced cowpea growth and yield components. A rate of 2.5 t/ha significantly ($P \leq 0.01$) increased the number of leaves per plant, vine length, total dry matter, and pods per plant, while 5 t/ha produced a larger leaf area index and more leaves. However, the 100-seed weight was not significantly affected by PM. The cowpea variety and its interaction with PM were generally non-significant for most parameters, including leaf area, vine characteristics, and pod number. A notable exception occurred in 2022, where the IAR-48 (V₁) variety produced significantly higher seed yield per plant (17.61a) and per hectare (880.06a). Therefore, applying PM at 2.5 t/ha with the IAR-48 variety is recommended for farmers in Dutse's ferrelitic soil. The positive growth response is likely due to PM-induced improvements in soil physical conditions and nutrient availability. The manure enhances soil organic matter, moisture retention, and aeration, followed by the gradual mineralization and release of essential nutrients like nitrogen and phosphorus (John et al., 2006; Bationo et al., 2007). This process boosts the crop's photosynthetic capacity (source) and supports pod development (sink), explaining the increased yield and components like pod number, as corroborated by Agyenim et al. (2006) and Seth et al. (2008). The lack of response in 100-seed weight and certain vine traits suggests these are genetically conserved characteristics or influenced by environmental factors like temperature and soil moisture, rather than nutritional amendments. The non-significant PM-variety interaction confirms that both varieties responded similarly to the treatment.

SUMMARY AND CONCLUSION: It is concluded that the application of PM (2.5t/ha) was found to be optimum for cowpea production, and is hereby recommended to farmers at Dutse and similar environments.

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Behavioral Alterations and Histological Changes in the Gill and Liver of Juvenile *Clarias Gariepinus* Exposed to *Justicia Extensa* Leaf Aqueous Extracts

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Abstract

Justicia extensa is an ichthyotoxic plant extensively used to stun fish by artisanal fisher folks in south-south Nigeria. The effect of aqueous extract of this plant leaf was investigated on behavior and histology of juvenile *Clarias gariepinus*. The plant leaf extract was administered to the fish specimens at different acute doses (0, 25, 35, 45, and 60 mg L⁻¹) for 96 hours. During this time, the grouped animals' behavioral and histological (liver, gill) changes were evaluated. Based on our findings, the 96-h LC₅₀ value of 46.59 mg L⁻¹ was obtained. The study also shows that, with the exception of temperature, the plant influenced the test media's water quality parameters in a concentration-dependent manner. After 96 hours of exposure, *J. extensa* caused gill (necrosis, hyperplasia and hypertrophy of secondary lamella, mucous secretion, cartilaginous core and cellular degeneration) and liver (central vein congestion, coagulation necrosis, sinusoidal spaces dilation and inflammatory cells infiltration) histological abnormalities as well as noticeable behavioral aberrations (air gulping, abnormal opercula ventilation, loss of equilibrium, erratic swimming, sluggish movement and change in skin color) in *C. gariepinus*. Therefore, caution should be applied in the use of *J. extensa* to avert possible disaster in the aquatic ecosystem.

Keywords: Plant toxins, *Justicia extensa*, African catfish, Toxicity, Behavior, Fish tissues

Introduction: The demand for fish and fish products in Nigeria have increased over the years with approximately 1.5 million metric tons consumed annually (Akinsanya et al. 2016). Apart from importing over 900,000 metric tons of fish per year (Emmanuel et al. 2014) and increasing aquaculture activities, which is said to be responsible for increased fish production (FDF 2013), capture fisheries has played a significant role in meeting the country's growing demand for fish (Thilsted et al. 2016). This method of fish production and exploitation involved in catching fish from the wild, often times using natural and synthetic ichthyotoxins (Oribhabor and Akanse 2020), raises important questions or worries about the short and long term eco toxic consequences on aquatic life and the ecosystem, even at low concentrations. Synthetic ichthyotoxins such as gammadin 20, cyanide etc have been connected to aquatic pollution and non-biodegradability (Praveen et al. 2016) which makes natural ichthyotoxins derived from plants better and safer for the environment because of their easy availability and biodegradability (Adeyemo 2003, kavitha et al. 2012). Both have been shown to have negative effects on the growth, physiology, behavior, biochemistry and survival of organisms exposed to them (Ullah 2015, Okoro et al. 2019, Oribhabor and Akanse 2020).

Plants such as *Justicia extensa*, *Adenium obesum*, *Ipomoea aquatica*, *Parkia biglobosa*, *Derris elliptica*, *Psychotria microphylla* and *Enydra fluctuans* commonly used to catch fish (Corrêa and Alcantara 2012, Orji et al. 2014, Abalaka et al. 2015, Jessa et al. 2015, Xavier and Kripasana 2020), have various parts that contain and produce poisonous substances effective in destroying aquatic life (Olufayo 2009). Depending on the type of plant, extraction method, and the animal species involved, different extracts from plants have different toxicity levels (Ayuba et al. 2012). *Justicia extensa* is a plant of the Acanthaceae family. The leaf, fruit and crushed bark of the plant are usually extracted and introduced in surface waters to anaesthetize fish particularly in Nigeria's coastal areas. The plant, locally known as Oto, has been observed to have an ichthyotoxic effect on the fish respiratory system (Abalaka et al. 2015). This plant's piscicidal activities with other species of the genus *Justicia* have also been documented (Corrêa and Alcantara 2012).

Fish is an excellent animal model for assessing the ecotoxicological impacts of various toxicants in aquatic environments (Sayed et al. 2020, Iheanacho et al. 2021). The most straightforward technique to studying the impact of toxicants on fish in the aquatic ecosystem is to observe morphological and behavioral changes in exposed fish (Yaji et al. 2021, Ogueji et al. 2024). Histological analysis of exposed fish can also aid in the evaluation of toxicant effects on various fish tissues (Ogueji et al. 2023, Adeolu et al. 2024). African Catfish of the species *C. gariepinus* belongs to the family Clariidae. The fresh water species is one of sub-saharan Africa's most cultured species (Iheanacho et al. 2021). This is due to its hardiness, capacity to survive stress, high disease resistance, and rapid growth (Okey et al. 2022). As a result, it was chosen as the study's primary choice.

Many authors have looked into the histological changes in *C. gariepinus* induced by various plant extracts (Abalaka et al. 2015, Akinsanya et al. 2016, Idowu et al. 2019, Owolabi and Abdulkareem 2021, Audu et al. 2021) but there are no scholarly reports on such changes caused by acute exposure to aqueous extract of *J. extensa* leaf. As a result, the current study focused on behavioral and histological abnormalities in the gill and liver of *C. gariepinus* exposed to varying levels of *J. extensa*.

Materials and methods

Collection and conditioning of experimental animal: A total of 100 healthy juvenile *C. gariepinus* (average length 11.57 ± 0.05 cm; average weight 10.00 ± 1.25 g) obtained from Kenlaurel Farm and Agro Resources Limited, Ebonyi State, Nigeria were immediately transported to the Department of Fisheries and Aquaculture research (wet) laboratory where the experiment was carried out. The fish were acclimated in a 1000 L plastic tank for two weeks containing 100 L of dechlorinated tap water under laboratory conditions. During acclimation, the fish were fed protein-rich commercial fish diet (45% protein; 3 mm Coppens feed - Afrimash, Lagos, Nigeria) two times every day (8.00 am and 5.00 pm) based on 3% body biomass. Aerator pumps were used to aerate the tank, ensuring an adequate supply of oxygen. To avoid pollution, faeces and other waste products were removed every day.

Plant collection and preparation of aqueous extract: A private farm in Bakassi Local Government Area of Cross River State, Nigeria provided fresh leaves of the plant which was authenticated in the University of Uyo's Botany Department by a registered botanist after which a specimen (Voucher No. 3513) was deposited in the herbarium of the University. Within 7 days at room temperature, the plant leaves were air dried under a shade with good ventilation after washing with clean running water. One kg of the air-dried leaves were weighed and

blended in 1 L of distilled water using electric blender to obtain crude aqueous extracts. Filtration was carried out using a muslin cloth and subsequently through Whatman filter paper No 1. The filtrate was concentrated using a vacuum drying oven for 72 hours at 40°C (Akinsanya et al. 2016, Owolabi and Abdulkareem 2021). The solid extract was weighed, wrapped in aluminum foil and refrigerated at 4 °C until required for further use (Owolabi and Abdulkareem 2021).

Experimental procedure and acute exposure: To determine the right concentrations for the final (acute bioassay) test, a preliminary (range-finding) test was performed. The following acute concentrations of extracts (0, 25, 35, 45 and 60 mg L⁻¹) were selected for definitive exposures based on the result of the range finding test. The test medium for toxicant exposure was static and non-renewable. One hundred (100) experimental fish were divided into five treatment groups including control and four others treated with toxicant at acute concentrations. Each group consisted of 10 fish in duplicates and was exposed for 96 hours. The investigation started 24 hours after feeding was terminated while the test fish remained unfed during the experiment. To keep the test tank free from contamination, dead fish were removed immediately (Ekpenyong et al. 2022). The number of deaths was noted at 24, 48, 72 and 96 hours. The fish was deemed dead and taken out of the test medium as soon as its opercula stopped moving and did not react to moderate probing.

Behavioral responses: Behavioral responses of juvenile *C. gariepinus* treated to plant extracts were observed daily and recorded (OECD 2014). The control groups devoid of toxicant were also observed along with the acute doses in order to evaluate any behavioral changes brought on by toxicant exposure. The behavioral responses that were observed included erratic swimming, unusual opercula breathing, increased air gulping, loss of static equilibrium, skin color changes and excessive mucous secretion. Careful observations of the experimental tanks were made throughout the duration of the study. Measurements of behavioral indices were assessed subjectively in conformity with Iheanacho et al. (2022).

Histological examination: At the conclusion of the experiment, fish from each treatment group were investigated to determine the toxicity to juvenile *C. gariepinus* occasioned by exposure to plant extract. The tissues were thoroughly removed and preserved at room temperature for 48 hours in 10% phosphate-buffered formalin (Ogunji et al. 2021). The tissues were cut and dehydrated in increasing alcohol concentrations (70%, 80%, 90%, and 100%), cleared in xylene for one hour and embedded in molten wax. With a clean albuonized slides, the embedded tissues (5-µm-thick) were fixed and stained with hematoxylin (H & E) and eosin for 15 min. With xylene, tissues were further cleared and rehydrated in decreasing alcohol concentrations (90%, 80%, and 70%) after staining. A digital picture exchange (DPX) was used to make permanent mounts on degreased glass slides. The prepared slides were examined using a MoticTM compound light microscope with 4×, 100× and 160× objective lenses. A semi quantitative histological scoring system [0%, none (-); <10%, Mild (+); 10–50%, Moderate (++); >50%, Severe (+++)] was used to assess the extent of severity (Ekpenyong et al. 2022, Ogueji et al. 2023).

Data analysis: Statistical Package for the Social Sciences (SPSS) IBM version 26 was used to analyze the data collected during the experiment. Analysis of variance (ANOVA) was utilized to see if there were any significant differences between the means of the acute concentrations at different exposure durations. Where differences in means occurred, Duncan multiple range test (DMRT) method was performed and significance reported at 95% confidence limit. The lethal concentration (LC) was determined using probit regression analysis. Results obtained were presented as mean ± standard deviation.

Results

Acute toxicity of *J. extensa* to juvenile *C. gariepinus*: The study recorded no mortality in the control group while the exposed fish experienced significant increase in mortality ($p < 0.05$) with increasing extract concentration and exposure durations. The percentage mortality of the fish after 96-h exposure to 0 mg L⁻¹, 25 mg L⁻¹, 35 mg L⁻¹, 45 mg L⁻¹ and 60 mg L⁻¹ of toxicant was 0%, 10%, 25%, 35% and 80% respectively. The LC₅₀ values at 24, 48, 72, and 96 hours were 56.15 mg L⁻¹, 48.88 mg L⁻¹, 46.59 mg L⁻¹ and 46.59 mg L⁻¹ respectively (Table 1).

Table 1: Lethal concentration (LC) and associated 95% confidence limits of *J. extensa* on *C. gariepinus* at exposure duration intervals

Lethal Conc	Concentration (mg L ⁻¹) at various exposure durations (hours)				
	24 h	48 h	72 h	96 h	Log of Conc
LC ₃₀	51.43 (25.29-63.18)	38.33 (23.85-48.44)	37.33 (20.46-48.10)	37.33 (20.46-48.10)	1.57 (1.31-1.68)
LC ₄₀	53.82 (37.95-79.30)	43.46 (25.30-76.35)	41.86 (29.27-60.76)	41.86 (29.27-60.76)	1.62 (1.46-1.78)
LC ₅₀	56.15 (46.03-88.13)	48.88 (35.95-83.90)	46.59 (36.19-85.40)	46.59 (36.19-85.40)	1.67 (1.55-1.93)
LC ₆₀	58.58 (50.37-95.06)	54.97 (41.86-94.39)	51.86 (41.31-90.04)	51.86 (41.31-90.04)	1.72 (1.61-2.11)
LC ₇₀	61.30 (53.33-96.99)	62.33 (46.64-95.01)	58.16 (45.79-92.95)	58.16 (45.79-92.95)	1.77 (1.66-2.32)

Behavioral responses: The behavioral responses of *C. gariepinus* to the test plant at different concentrations and exposure durations were measured subjectively as presented in Table 2. During the acute exposure, normal behavioral activities were noted in the control group (devoid of toxicant) for most of the indices observed. Behavioral changes in the treatment group (25 - 60 mg L⁻¹) observed at 24 - 48 hours were mild and moderate for all indices except loss of equilibrium and sluggish movement which was severe in the fish treated with 60 mg L⁻¹. After 72 hours exposure to the plant extract, severe behavioral abnormalities were also evident in the treatment group but minimal at 25 - 35 mg L⁻¹. At the end of the experiment (96 hours), mild, moderate and severe cases were noted in treatment group, while the control group recorded no behavioral abnormalities.

Table 2: Effect of *J. extensa* leaf extract acute concentration on behavior of *C. gariepinus* juveniles at exposure duration intervals

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Time (hrs)	Conc (mg L ⁻¹)	Gulping of air	Abnormal opercula ventilation	Loss of equilibrium	Erratic swimming	Sluggish movement	Change in skin color
24	Control	-	-	-	-	-	-
25	25	+	+	-	-	-	-
35	35	++	++	+	+	+	+
45	45	++	++	++	++	++	++
60	60	++	++	++	++	++	++
48	Control	-	-	-	-	-	-
25	25	+	+	+	+	+	+
35	35	++	++	++	++	++	++
45	45	++	++	++	++	++	++
60	60	++	++	++	++	++	++
72	Control	-	-	-	-	-	-
25	25	++	++	++	++	++	++
35	35	++	++	++	++	++	++
45	45	++	++	++	++	++	++
60	60	++	++	++	++	++	++
96	Control	-	-	-	-	-	-
25	25	++	++	++	++	++	++
35	35	++	++	++	++	++	++
45	45	++	++	++	++	++	++
60	60	++	++	++	++	++	++

None - (0%); + Mild (<10%); ++ Moderate (10–50%); +++ Severe (>50%)

Histopathology: After the experiment, the liver and gill tissues were examined histologically to determine the impact of acute dosages of plant extract on juvenile *C. gariepinus*. Based on the semi-quantitative scoring conducted (Table 3), the primary and secondary lamella was seen to be normal in gills of the control group. Mild to moderate histologic lesions such as mucous secretion, necrosis of secondary lamella and cartilage core degeneration were noted in gills exposed at 25 and 35 mg L⁻¹ after 48 and 96 hours exposure. Furthermore, at higher concentrations (45–60 mg L⁻¹), ichthyotoxic plant elicited moderate to severe lesions such as desquamated cells in inter-lamellae spaces, necrosis, hyperplasia and hypertrophy of secondary lamella in exposed groups. Fish liver in control group displayed normal histological features following evident hepatocytes appearances and mild cytoplasm vacuolation. The histology of toxicant-exposed fish (25–35 mg L⁻¹) revealed mild to moderate histological lesions in liver such as infiltration of inflammatory cells and central vein congestion after 48 and 96 hours exposure. Occurrence of histological lesions such as congestion of central vein, anisokaryosis, coagulation necrosis and sinusoidal spaces dilation were moderate to severe in 45 mg L⁻¹ treated fish and severely prominent in 65 mg L⁻¹ treated groups.

Table 3: Semi quantitative analysis of histological changes in the liver and gill of *C. gariepinus* fingerlings exposed to acute doses of *J. extensa* leaf extract

Tissue	Time	Lesion	Control	25 mg L ⁻¹	35 mg L ⁻¹	45 mg L ⁻¹	60 mg L ⁻¹
Liver	48 h	Hypertrophy of hepatocytes (HH)	-	-	+	++	+++
		Congestion of central vein (CC)	-	-	+	++	+++
		Anisokaryosis (A)	-	-	+	++	+++
		Coagulation necrosis (CN)	-	-	-	+	++
		Sinusoidal spaces dilation (SSD)	-	-	-	+	++
		Infiltration of inflammatory cells (IC)	-	-	-	++	+++
	96 h	Hypertrophy of hepatocytes (HH)	-	+	+	+++	+++
		Congestion of central vein (CC)	-	-	+	+++	+++
		Anisokaryosis (A)	-	-	++	+++	+++
		Coagulation necrosis (CN)	-	+	++	+++	+++
		Sinusoidal spaces dilation (SSD)	-	+	++	+++	+++
		Infiltration of inflammatory cells (IC)	-	-	++	++	+++
Gill	48 h	Necrosis of secondary lamellae (NSL)	-	-	-	+	++
		Hyperplasia & Hypertrophy of secondary lamellae (HHSL)	-	-	+	++	+++
		Cartilaginous Core degeneration (CCD)	-	-	-	+	++
		Mucous secretion	-	-	+	++	+++
		Desquamated cells in inter-lamellae spaces (DCI)	-	-	-	+	++
	96 h	Necrosis of secondary lamellae (NSL)	-	+	++	+++	+++
		Hyperplasia & Hypertrophy of secondary lamellae (HHSL)	-	++	++	+++	+++
		Cartilaginous Core degeneration (CCD)	-	-	+	++	+++
		Mucous secretion	-	+	+	++	+++
		Desquamated cells in inter-lamellae spaces (DCI)	-	-	+	++	+++

None - (0%); + Mild (<10%); ++ Moderate (10–50%); +++ Severe (>50%)

Discussion: Studies on the safety of *J. extensa* on animal models are relatively uncommon, despite the piscicidal significance of the plant. The crude water extracts are the primary method through which artisanal fisher folks employ the plant in traditional fishing which informed our decision to assess the toxicological profile of *J. extensa* aqueous extract. Acute toxicity test is a necessary test to evaluate the adverse

effects of toxicants on fish species (da Silva Moreira et al. 2019). According to Xavier and Kripasana (2020), the most reliable basis for determining the acute toxicity test is by estimating the median lethal concentration (LC₅₀) of toxicants on animal models. At the end of the test which lasted for 96 hours, the median lethal concentration of plant extract that resulted in the mortality of 50% of the fish population was 46.59 mg L⁻¹ which indicates that the plant is toxic to the exposed fish. Ekpenyong et al. (2022) reported median lethality in *C. gariepinus* fingerlings caused by *J. extensa* ethanol leaf extract. Zebra fish have been found to experience a median lethal effect at a concentration of 92.95 mg L⁻¹ after 96 hours exposure to *Enydra fluctuans* leaf extract (Xavier and Kripasana 2020). Oribhabor and Akanse (2020) and Ikpesu (2014) reported 0.65 mg L⁻¹ and 2.8 mg L⁻¹ 96-h LC₅₀ of *Lanchocarpus cuanescans* and *Garcinia Kola* to *C. gariepinus* respectively. The acute toxicity of seven different plant extracts against *C. gariepinus* has also been reported by Akinsanya et al. (2016) with the least 96-h LC₅₀ value of 115.26 mg L⁻¹ (*Aframomum melegueta*) greater than the median lethal concentration of 46.59 mg L⁻¹ obtained in the present study. The chemical composition of the plants and the sensitivity of the fish employed in the experiment determine the differences in the LC₅₀ value of various plant species to fish (Kavitha et al. 2012).

Changes in the behavior of animals exposed to toxicants can be used to measure the harmful effects of toxic substances on important tissues and organs (Okoro et al. 2019). In the present study, *C. gariepinus* juveniles treated to toxic doses of *J. extensa* leaf extract exhibited aberrations in their behavior in a duration and concentration dependent manner. The hypoxic condition possibly caused by aqueous leaf extract of *J. extensa* may have been responsible for the abnormal behavioral patterns observed in the exposed fish. The treated groups displayed toxicant-induced stress symptoms like air gulping, irregular swimming, loss of stability, and restricted motility, which could further compromise physiological processes and lead to mortality (Oribhabor and Akanse 2020, Audu et al. 2021). Xavier and Kripasana (2020) reported behavioral abnormalities such as reduced swimming and hyperactivity in *Enydra fluctuans* exposed zebra fish (*Danio rerio*). In agreement with this study, loss of equilibrium, air gulping, and erratic movement have also been observed in *L. cuanescans* exposed *C. gariepinus* fingerlings (Oribhabor and Akanse 2020) and *A. leiocarpus* exposed *C. gariepinus* juveniles (Audu et al. 2021).

Histology is a crucial measure that reflects alterations in animal tissues brought on by exposure to the environment or toxins (Iheanacho and Odo 2020, Ogueji et al. 2020). Gills are considered important markers of aquatic exposure to environmental contaminants because of their direct and early contact with them (Ekpenyong et al. 2022). In the current work, dose-dependent cyto-architectural degenerations in the gills such as mucous secretion, hyperplasia and hypertrophy of secondary lamellae (HSL), necrosis of secondary lamellae (NSL), desquamated cells in inter-lamellae spaces (DCI) and cartilaginous core degeneration (CCD) were seen in fingerlings treated to acute doses of *J. extensa* leaf extract. Therefore, the observed moderate to severe gill histo-architectural alterations further established the toxic potential of *J. extensa* extract. The current findings are consistent with Abalaka et al. (2015), who reported proliferated and hypertrophied mucous cells, lamellar oedema, lamellar fusion, haemorrhage, mononuclear cellular infiltration and fusion of secondary lamellar after acute exposure of *C. gariepinus* to *Adenium obesum* stem bark ethanol extract. The degeneration of gill filaments and the cartilaginous core observed at the highest acute doses of toxicant suggests that the blood vessels collapsed, reducing the amount of food and oxygen reaching the cells and compromising the fish's health (Ogueji et al. 2018). *C. gariepinus* treated to leaf extract from *Euphorbia hirta* exhibited severe histopathological abnormalities, including degraded lamella and deteriorated epithelial cells (Idowu et al. 2019). Audu et al. (2017) and Audu et al. (2021) reported dose-dependent distortions in the gill of *Vernonia amygladina* and *Anogeissus leiocarpus* exposed *C. gariepinus* respectively. The liver is an important organ in charge of detoxifying toxins (Okey et al. 2021). The exposed liver in the present study experienced mild to severe histological lesions such as hypertrophy of hepatocytes (HH), central vein congestion (CC) and infiltration of inflammatory cells (IC). The observed histological alterations are all evidence of liver inflammation, damage and possible dysfunction. Ekpenyong et al. (2022) reported hyperplasia, necrotic hepatocyte and hepatic coagulative necrosis in *C. gariepinus* exposed to *J. extensa* ethanolic extract. Similar histological lesions were reported in the liver of *Anogeissus leiocarpus* (Audu et al. 2021) and *Adenium obesum* (Abalaka et al. 2015) exposed *C. gariepinus* after 96 hours of exposure.

Conclusion: In Nigeria, aqueous extracts of *J. extensa* leaf is extensively used in artisanal fisheries. *C. gariepinus* displayed behavioral abnormalities in response to the plant, which also caused dose and time-dependent histological lesions in the liver and gill morphology. The study proved helpful in predicting potential impacts of regularly and widely used ichthyotoxins on aquatic life. Consequently, indiscriminate use of *J. extensa* aqueous extract by farmers in aquatic ecosystems should be discouraged.

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Assessing the Information Needs of Dry Season Vegetable Farmers in Akwa Ibom State, Nigeria

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Abstract

Dry season vegetable farming is a vital agricultural activity in Akwa Ibom State, Nigeria, providing food and income for many rural households. However, the productivity and profitability of this farming practice are often hindered by limited access to relevant information. This study assessed the information needs of dry season vegetable farmers in Akwa Ibom State, Nigeria. A survey research design was employed, and data were collected from 180 dry season vegetable farmers using a structured questionnaire. The results showed that waterleaf (70.5%), fluted pumpkin (65.5%) and cucumber (45.5%) were the most planted dry season vegetables. The farmers had high information needs on sources of herbicides ($\bar{x}$ =2.84), irrigation management ($\bar{x}$ = 2.75), method of fertilizer application ($\bar{x}$ =2.62), marketing outlet ($\bar{x}$ = 2.57), sources of improved varieties ($\bar{x}$ =2.45) and tractor hiring services ($\bar{x}$ =2.34). The major sources of information for the farmers were fellow farmers ($\bar{x}$ =2.85), neighbors and friends ($\bar{x}$ =2.82), and radio ($\bar{x}$ = 2.65). However, the farmers faced challenges in accessing and using information including limited access to extension services ($\bar{x}$ = 2.83), doubt of vegetables farmers towards government ($\bar{x}$ = 2.76), inadequate knowledge of information and communication technologies (ICTs) ($\bar{x}$ = 2.65), poor storage and preservation ($\bar{x}$ =2.54) and Poor access to irrigation facilities ($\bar{x}$ = 2.36). The study recommends that policymakers and stakeholders should prioritize the provision of relevant and timely information to dry season vegetable farmers in Akwa Ibom State, Nigeria, through multiple channels, including extension services, ICTs, and farmer-to-farmer networks.

KEY WORDS: Dry season vegetable Farmers, Information needs

Introduction: Agriculture remains a significant sector in Nigeria's economy, employing about 34.3% of the labor force and contributing approximately 22.7% to the nation's Gross Domestic Product (GDP) (National Bureau of Statistics, NBS, 2023). However, food production in Nigeria is heavily dependent on seasonal rainfall, resulting in a notable decline in agricultural output during the dry season. In response, dry season farming has gained momentum, particularly among smallholder farmers seeking to bridge the food supply gap and sustain livelihoods during the off-season (FAO, 2021).

Vegetable production is a growing aspect of agriculture in recent times. Its production has continued to increase over the years. For instance, in Nigeria, annual vegetable production stood at 16.4 million tons in 2017 and a general capacity of over 1.5 million metric tons according to a 2020 report (Food and Agricultural Organization (FAO) 2020). The awareness to consume vegetables for good health is also increasing. Several studies Daramola et al. (2016); Osei et al. (2017) have shown that vegetables widely grown as a cheap and reliable source of carbohydrates, protein, vitamins, zinc, and iron in most of sub-Sahara Africa. They contain essential minerals, vitamins and fiber not present in large quantities in starchy staple foods. Vegetables are tasty, healthy and add flavors to meals. In resource-poor diets, they make up between 30% and 50% of iron and Vitamin A (Balana et al., 2020).

In Nigeria, vegetables such as tomatoes, okra, pepper, cabbage among others are widely grown along the banks of the river which stretch across villages, towns, and cities mostly by small scale farmers. This practice has been going on for decades as a basic source of food and income for women farmers, providing employment, offers opportunities for the disables and reduces food insecurity particularly during the long dry season to the growing population in Nigeria (Yunusa et al., 2025). In the South-South region of Nigeria, prominent vegetable crops include water leaf, fluted pumpkin (*Telfairia occidentalis*), pepper, cucumber, bitter leaf (*Vernonia amygdalina*), Amaranthus spp. and okra among others. The significance of vegetables makes the production an all-season crop. However, the consumption of vegetables and fruits generally in Nigeria is far less than the World Health Organization recommended standard (WHO, 2025) and productivity of dry season vegetable farmers remains constrained by limited access to timely, relevant, and location-specific agricultural information.

Agricultural information plays a pivotal role in improving farmers' decision-making and boosting productivity (Acheampong et al., 2017). It is an important component in the adoption of farming practices and it is the building block for effective extension services delivery (Demet-Soylu et al., 2016). Thus, dry season vegetable farmers need information to improve and sustain their production and make well-informed decisions. Relevant information is required at every stage of the production cycle from seed selection and pest control to irrigation techniques, market access, and postharvest handling. Additionally, information must be available and accessible to all farmers in order to bring the desired outcomes. According to Thuo & Njoroge (2018), access to information has a great influence on the practices of farmers. It also helps to bridge the gap and deficiencies in relation to the knowledge of certain practices especially the marketing of farm produce. The quality of an agricultural information can however be measured based on three factors which are timeliness, accuracy, and relevance (Riaz et al, 2022).

However, without an accurate understanding of the information needs of farmers, extension services risk providing generalized or outdated advice, resulting in suboptimal adoption of practices and resource misuse. Momoh & Adewojo (2025), has confirmed that the needs of a particular person or group may be different from another. This concluded that farmers' information is highly contextual, influenced by ecological conditions, production cycles, gender, education, and enterprise scale. Therefore, assessing these needs is essential for tailoring demand-driven and effective agricultural advisory services.

Unfortunately, empirical data on the specific information needs of dry season vegetable farmers in Akwa Ibom State is lacking. This study, therefore, seeks to bridge this gap and provide actionable insights to support effective extension programming and policy formulation.

Problem Statement: Despite the increasing importance of dry season vegetable farming in Akwa Ibom State, many farmers continue to record low yields, encounter pest and disease outbreaks, and face challenges in accessing profitable markets. These inefficiencies are often linked to inadequate access to accurate, timely, and relevant agricultural information (Umeh et al., 2018). The existing extension system tends to be generalized, rain-fed focused, and insufficiently tailored to the realities of dry season producers.

Preliminary observations and anecdotal evidence suggest that many vegetable farmers in the state rely on informal sources of information such as fellow farmers, input dealers, and traders which may not always be reliable or scientifically valid (Edeh et al., 2021). Furthermore, formal channels such as agricultural extension services are limited by staffing shortages, inadequate training, and poor logistics, further widening the information gap (Ayanwu et al., 2022).

The lack of a clear understanding of what information farmers specifically need, how they prefer to receive it, and the constraints they face in accessing such information undermines the effectiveness of extension efforts. Without this knowledge, stakeholders including government agencies, NGOs, and private sector actors are unable to design effective interventions that respond to the real needs of dry season vegetable farmers.

Given the strategic role of vegetables in dry season agriculture, household nutrition, and income generation, it is imperative to assess the specific information needs of this category of farmers. Such a study will contribute to the development of a responsive agricultural information delivery system and support policies that promote sustainable agricultural intensification in Akwa Ibom State and beyond.

Objectives of the Study: The main objective of this study is to assess the information needs of dry season vegetable farmers in Akwa Ibom State, Nigeria.

The specific objectives are to; Examine the socioeconomic characteristics of dry season vegetable farmers in the study area; identify types of dry season vegetables grown in study area; determine the source of information; information needs on dry season vegetable production in the study; Determine the constraints farmers face in accessing agricultural information.

Methodology: The study was conducted in Akwa Ibom State. It is one of the 36 states in the Federal Republic of Nigeria with a total land area of approximately 7,246 square kilometres. Akwa Ibom State is located in the South-South geopolitical zone of the country, situated between latitudes 4°32' and 5°33' North and longitudes 7°25' and 8°25' East. According to the National Population Commission (NPC, 2006), Akwa Ibom State had a population of about 3.9 million people, but recent estimates put the figure at over 5.8 million. The state is divided into 31 Local Government Areas (LGAs) and these LGA are grouped into six main agricultural zones (Uyo, Eket, Oron, Ikot Ekpene, Etinan and Abak). Each zone has distinct ecological and economic characteristics that influence agricultural practices in the area. The state lies within the humid tropical rainforest zone with two distinct seasons: the wet (April to October) and the dry (November to March) seasons. The soils of Akwa Ibom are predominantly ferrallitic and alluvial, which are generally sandy loam and well-drained, suitable for a variety of crops including cassava, yam, maize, cocoyam, and various vegetables. Agriculture is the main occupation of the rural populace in Akwa Ibom State. During the dry season, vegetable farming has become increasingly popular, especially along the FADAMA lands and riverbanks where irrigation water is available. Vegetables commonly produced include tomato, pepper, fluted pumpkin (ugu), waterleaf, okra, and amaranthus.

A multi-stage sampling technique was employed. The first stage involved the purposive selection of three (3) Agricultural zones (Abak, Ikot Ekpene and Uyo) from the six zones available in the state. The second stage involved random selection of four (4) blocks from the selected zones making a total of 12 blocks. The third stage, was random selection of three (3) cells making a total of 36 cells. Finally, 5 respondents were randomly selected giving a total of 180 respondents.

Method of Data Collection : Data were collected using structured questionnaire and was complemented by personal interviewed to ensure consistency and accuracy of collected data. The structured questionnaire was administered to 180 respondents in the study area. Series of cross- sectional data were collected, scrutinized and use for data analysis.

The analytical tools that were used in this study was descriptive statistics, where mean, frequency and, percentages was used to analyze the socio-economic variables of the respondents and 3-point likert scale was also used to rate the respondents' challenges to accessing information on dry season vegetable production namely; very severe = 3, severe = 2 and not severe = 1. The mean value of 2.0 was considered as a severe challenge whereas those below 2.0 were not. Data were analyzed using percentage and mean score.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of Dry season vegetable farmers: Table 1 presents the socioeconomic profiles of vegetable farmers. The majority of the vegetable farmers were female, which accounted for about 95% of the respondents. This implies that dry season vegetable production is a female dominated ventures. It could be observed that more than half (52%) of the dry season vegetable farmers were middle aged farmers within the age of 31 to 50 year with an average age of 45 years. This shows that the dry season vegetable farmers were still active to perform farming activities. In terms of the drudgery associated with peasant agriculture, age is an important factor when considering the quality and type of labour available on the farm. Regarding the educational status of the respondents, less than 50% of the dry season vegetable farmers did not have formal education while 32.1%, only 21.1% and 3.3% had primary, secondary and tertiary education, respectively (see Table 1). This suggests that the level of formal education among the farmers was very low.

The majority (81.7%) of the dry season vegetable farmers had a household size of 5-8 persons and an average of 7 persons per household. This shows that the household had enough members to use as family labour in vegetable production. This confirms that saying that rural household always go for cheap labour. Half (50%) of dry season vegetable farmers earned an annual income between N51,000-100,000, but the average annual income in the study area was N60,474,22. Regarding the farm size, majority (83.9%) of the dry season vegetable farmers

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produced their vegetables on farm size below 1 hectare. The average farm size was 0.9 hectares, which implies that the farmers were operating on small scale farming. This is in line with the findings of Wakil *et al.* (2018), who reported that vegetable farmers had a small farm size lower than 2 hectares. Also, findings revealed that the dry season farmers did not own farm rather they have been operated on shared (44%) and leased (56%) farmland. Majority of them (79.4%) reported farming as their primary occupation and had been farming between 21-30 years as revealed by half (52%) of the farmers. Their average farming experience was 21 years, this suggests that the dry season vegetable farmers can be described as experienced farmers, who are knowledgeable about its farming activities and that vegetable production is not a new venture in the study area.

Again, majority (76.1%) of the dry season vegetable farmers never had contacts with extension services and that only (17.2 %) were members of cooperative society. This contributed to their low access to credit, as a cooperative society can make available and accessible credit to them. Lack of access to credit suggests the financial status of these rural farmers.

Table 1 Percentage Distribution of the farmers according to their socio-demographic characteristics (N = 180)

Variables	Respondents Categories	Frequency (N = 180)	Percentage (%)	Mean
Sex	Male	9	5.0	
	Female	171	95.0	
Age (years)	Young (< 30)	26	14.4	
	Middle-aged (31-50)	94	52.2	45
	Old aged (>50)	60	33.3	
Educational status	No formal Education	78	43.3	
	Primary	58	32.2	
	Secondary	38	21.1	
	Higher	6	3.3	
Farming experience	Low (< 10years)	41	22.7	
	Medium (11-20 years)	94	52.2	21
	High (> 20 years)	45	25.0	
Annual Income	Low (< 50,000)	83	46.1	
	Medium (51,000-100,000)	90	50.0	N60,472.22
	High (> 101,000)	7	3.9	
Household size	Small (< 4	10	5.6	
	Medium (5-8)	147	81.7	7
	Large (> 8)	23	12.7	
Farm size	Small (< 1)	151	83.9	
	Medium (1.1-5 ha)	29	16.1	0.91
	Large (> 5.1 ha)	0	0	
Primary Occupation	Farming	143	79.4	
	Civil Servant	4	2.2	
	Trading	26	14.4	
	Artisan	7	3.9	
Land ownership	Own	0	0	
	Shared	80	44.4	
	Leased	100	55.6	
Cooperative Membership	Non-Member	149	82.8	
	Member	31	17.2	
Extension Contact	Frequently	0	0	
	Occasionally	10	5.6	
	Rarely	33	18.3	
	Never	137	76.1	

Source: Field Survey, 2025

Types of vegetables produced in study area

The result in table 2 showed that majority (70.5%) of the farmers reported waterleaf as their major vegetable produced during dry season, followed by Fluted pumpkin (65.5%), and Cucumber (45.5%). Vegetables like Bitter leaf (48.3%), Curry leaf (43.4%) and Okra (36.1%), were reported as minor production while majority (60%) did not plant Garden eggs as well as Tomatoes (55.5%). This finding revealed that waterleaf, fluted pumpkin and cucumbers were the major dry season vegetables produced in the study area.

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Table 2 Percentage Distribution According to the Types of Dry Season Vegetables Produced

Types of vegetables produced	Major Production		Minor Production		Does not produce	
Waterleaf	127	(70.5)	53	(29.4)	0	0
Fluted Pumpkin	118	(65.5)	56	(31.1)	6	(3.3)
Cucumber	82	(45.6)	95	(52.7)	3	(1.6)
Bitter Leaf	72	(40.0)	87	(48.3)	21	(11.7)
Leafy greens	76	(42.2)	31	(17.2)	73	(40.6)
Garden Eggs	51	(28.3)	21	(11.7)	108	(60.0)
Okra	69	(38.3)	65	(36.1)	46	(25.6)
Curry leaf	67	(37.2)	71	(39.4)	42	(23.3)
Pepper	36	(20.0)	55	(30.6)	89	(49.4)
Tomatoes	32	(17.8)	48	(26.7)	100	(55.5)

Source: Field survey, 2025

Information needs of farmers on Dry Season Vegetable Production

The farmers' information needs on dry season vegetable production in the study area is indicated in Table 3. The Information needs was measured using a mean score on a 3-point Likert type scale of Mostly needed =3, Needed =2 and Not Needed =1 respectively. A mean score of 2.0 was obtained. Any score equal to 2.0 or above imply "needed" while mean scores less than 2.0 imply "Not Needed". Results from table 3 shows that farmers needed all the information presented to them for their dry season vegetable production. Result in table 4 revealed that the "most needed" information on dry season vegetable production by farmers in the study area were; Information on sources of herbicides ($\bar{x}$ =2.84), information on irrigation management ($\bar{x}$ = 2.75), information on method of fertilizer application ($\bar{x}$ =2.62), information on marketing outlet ($\bar{x}$ = 2.57), information on sources of improved varieties ($\bar{x}$ =2.45) and information on tractor hiring services ($\bar{x}$ =2.34).

Table 2. Mean Distribution According to the types of information required by dry season vegetable farmers (n=180)

Information Needs	Mostly Needed	Needed21	Not Needed	Total Mean	Mean Score
Information on tractor hiring services (soil preparation)	98	45	37	421	2.34
Information on planting time	77	70	33	404	2.24
Information on sources of improved seeds varieties	118	26	36	441	2.45*
Information on irrigation management	147	19	16	495	2.75*
Information on weather forecast	89	33	58	391	2.17
Information on when and how to apply fertilizer	131	29	20	471	2.62*
Information on herbicides	156	19	5	511	2.84*
Information on market outlet	121	41	18	463	2.57*
Information on proper grading and packaging	38	4	138	260	1.44
Information on harvesting & post harvesting handling	68	69	43	385	2.14
Information on storage and preservation strategies	86	33	61	384	2.13

Source: Field survey, 2020 *Decision rule: $X \geq 2.38$ indicates (mostly needed) while $x < 2.38$ indicates ('Not needed)

Sources of information by Dry Season Vegetable Farmers

The distribution of the respondents by source of information according to table 4, reveals that dry season vegetable farmers sourced their information majorly through fellow farmers ($\bar{x}$ =2.85) as it ranked first, followed by neighbors/ friends ($\bar{x}$ =2.82) that ranked 2nd, and radio with a mean score $\bar{x}$ = 2.65 which ranked 3rd. By implication, there is an inadequate extension service to dry season vegetable farmers as it ranked 9th in the study area. This challenge may deny the respondents access to information on modern agricultural techniques. This finding is in line with the findings of Masele, (2024) and Zoundji et al. (2018) found that vegetable growers rely more on fellow farmers, relatives and personal experiences in their farming activities.

Table 4: Mean Distribution According to Sources of Information Accessed by Farmers in the study area. (n= 180)

Sources of Information	Agreed	Disagreed	Undecided	Total	Mean	Remark
Friends/family/Neighbours	158	12	10	508	2.82	2 nd
Fellow farmers	158	17	10	513	2.85	1 st
Radio	139	19	22	45	2.65	3 rd
Farmers association	105	13	62	403	2.23	6 th
Television	116	22	42	434	2.41	4 th
Social media	115	20	45	430	2.38	5 th
Researchers	64	18	98	326	1.81	9 th
Input dealers	32	24	124	268	1.48	10 th
Extension Agents	69	29	82	347	1.92	8 th
Social media	86	33	61	384	2.13	7 th

Source: Field survey, 2024

Constraints to access of information on dry season vegetable Production

Table 5 A ranking technique was used to determined constraints affecting access to dry season vegetable production in the study area. The constraints were realized using a three-point Likert type scale of: Very severe (3), Severe (2), and not severe (1). The perception of the respondents towards these constraints is given in Table 5. According to the results, limited access to extension services ($\bar{x}$ = 2.83 ranked 1st as a severe constraint affecting access to dry season vegetable production, followed by lack of irrigation facilities ($\bar{x}$ = 2.76), financial problems ($\bar{x}$ = 2.65), inadequate knowledge of information and communication technologies (ICTs) ($\bar{x}$ = 2.54), unsuitable market channel ($\bar{x}$ = 2.36). However, the farmers indicated that poor storage facilities and preservation and inadequate land for dry season farming were not severe problems in dry season vegetable cultivation. This finding is in line with Olabanji et al. (2018) who revealed that inadequate fund (65.6%), poor provision of extension services (47.9%), and poor access of irrigation facilities (40.6%) were the most serious constraints faced by the fluted pumpkin farmers in Yola North Local Government Area of Adamawa State.

Table 5: Mean Distribution According to Constraints to Access of Information on Dry Season Vegetable Production in the study area (n= 180)

Constraints	Very severe	Severe	Not Severe	Total	Mean	Rank
Pest and disease problems	77 (43)	70 (39)	33 (18)	404	2.24	6 th
Inadequate land for dry season farming	86 (48)	33 (18)	61 (34)	384	2.13	7 th
Inadequate knowledge of information and communication technologies (ICTs)	127 (71)	23 (13)	30 (17)	457	2.54	4 th
Unsuitable market channel	101 (56)	43 (24)	36 (20)	425	2.36	5 th
Poor storage facilities and preservation	61 (34)	34 (19)	85 (47)	336	1.86	9 th
Financial problems	139 (77)	19 (11)	22 (12)	477	2.65	3 rd
Poor pricing system	56 (31)	77 (43)	47 (26)	369	2.05	8 th
Poor provision of extension service	159 (88)	11 (6)	10 (6)	509	2.83	1 st
Poor access to irrigation facilities	152 (84)	13 (7)	15 (8)	497	2.76	2 nd

Conclusions: The dry season vegetable producers require information on sources and application of fertilizer and herbicides, irrigation management, marketing outlet, and tractor hiring services to help them boost their vegetable production. Furthermore, they farmers were challenged by lack of irrigation facilities, financial problems, inadequate knowledge of information and communication technologies (ICTs) and unsuitable market channel.

Recommendations: Vegetables farmers are encouraged to join cooperatives societies in order to source funds from government, NGO's as well as credit facilities from financial institutions to boost irrigated vegetables production. Information needed regarding market access, could be made available through the radio and television for wider coverage. Government should construct boreholes to farmers at subsidized rate to ensure steady supply of water for irrigation. Provision of adult literacy programme to farmers in order to acquire basic skills and knowledge for better decisions and improved irrigated vegetables production and marketing

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Growth and Yield Response of Sorghum (*Sorghum Bicolor* L.) Varieties as Influenced by Mycorrhiza in Jigawa State, Nigeria.

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Abstract

Sorghum production is constrained by soil fertility problems caused by climate change causing severe yield reduction, reducing nutrient uptake by roots and causing nutrient deficiencies by reducing the rate of nutrient diffusion from soil to roots. In view of the above an experiment was conducted at the Faculty of Agriculture Teaching and Research Farm, Federal University Dutse and Maigatarin Bawa village of Garki local government, Jigawa State. The experiment consisted of two mycorrhiza levels (0g and 40g per hole) and three sorghum varieties laid out in a split plot design and replicated thrice. Data analyses revealed significant varietal differences in growth and yield, with mycorrhiza application showing limited impact. At Dutse, increasing mycorrhiza from 0 to 40g hole⁻¹ reduced plant height. At Garki, 40g hole⁻¹ increased plant height. Leaf number decreased at Dutse, but increased at Garki. Mycorrhiza application (40 g hole⁻¹) slightly reduced flowering time. Dutse-kaura showed the highest yield increase while Samsorg-45 and Samsorg-50SW had moderate yields. The results showed that mycorrhiza improved yield, particularly in Dutse-kaura, with limited effect on flowering time. Harvest index was highest in Dutse-kaura.

Keywords: Mycorrhiza, Sorghum, Growth, Yield, Varieties

INTRODUCTION: Sorghum (*Sorghum bicolor* L.) belonged to the *Poaceae* family and it is the 5th most important world cereal crop after maize, wheat rice and barley (FAO 2019). Sorghum is an important staple food crop well adapted to harsh and dry environmental condition. Its deep root system makes it more drought tolerant than rice, corn, and wheat. This allows it to adapt to growing in water-scarce environments (Ajeigbe *et al.*, 2024), particularly in the drier parts of Africa, China, Brazil, Mexico and India.

In the year 2023, Nigeria planted 5.9 million hectares of sorghum with an estimated production of 6.66 million tonnes, equivalent to 1.4 tonnes ha⁻¹ (FAOSTAT, 2023), making the country the second leading sorghum producer in Africa after Ethiopia with equivalent to 2.1 tonnes ha⁻¹.

Sorghum production is constrained by soil fertility problems caused by ongoing climate change that has caused severe yield reduction and crop failure (Kabubo *et al.*, 2019; Manzi and Gweyi-Onyango, 2020; Gweyi-Onyango *et al.*, 2021). Similarly, low soil moisture (drought) reduces nutrient uptake by roots and causes nutrient deficiencies by reducing the rate of nutrient diffusion from soil to roots, resulting in limited transpiration rates and affecting active transport and membrane permeability (Assefa, 2010). This implies that soil moisture or rainfall distribution of an area, combined with nutrient availability, plays a crucial role in a crop water use efficiency (WUE). According to Sinclair *et al.* (1984), WUE is the ratio of biomass accumulation to water use, and it is an important indicator of plant productivity in water-scarce environments especially where crop yields are highly dependent on rainfall. The ever-increasing demand for food has intensified the quest for more production per unit area and for an increase in land under arable cultivation. These production challenges can be alleviated by incorporating beneficial micro-organisms (biofertilizers) in symbiotic association during sorghum production. Beneficial soil microorganisms such as Arbuscular Mycorrhizal Fungi (AMF) perform a great role in biodiversity and environment management in sustainable crop production. They increase tolerance to abiotic stresses and biotic stress, recycling of nutrients and mineralization of the soil organic matter (Nkereuwem *et al.*, 2021; Wehandaka *et al.*, 2021).

MATERIALS AND METHODS

Description of the Experimental Site: The study was to evaluate the effects of mycorrhiza and variety on the growth and yield of sorghum varieties, and the interaction between the factors. The study was conducted during the 2023 rainy season at two locations: Faculty of Agriculture Teaching and Research Farm, Federal University Dutse (11°42' N, 9°23' E, and 434 m above sea level) and Maigatarin Bawa village of Garki local government (12°19' N, 9°14' E, and 377 m above sea level). The study area lies within the Sudan and Sahel savannah agroecological zones of Nigeria respectively.

Experimental Design: The experiment consisted of two (2) mycorrhiza inoculation levels (0 g and 40 g per hole) and three (3) sorghum varieties (Dutse-kaura, Samsorg-45, and Samsorg-50SW) which were laid out in a split plot design.

Field Management, Data Collection and Analysis: The experimental sites were well prepared; thereafter it was demarcated into three blocks each consisting of 6 plots measuring 4.5 m by 2 m, whereas a spacing of 1 m and 0.5 m was maintained between the blocks and between the plots respectively. Healthy sorghum seeds were sown at recommended seed rate is 10-13 kg/ha, sown at 2.5-3.0 cm deep three seed per hole and later thinned two per hole. Crops grow in the prevailing day and night weather conditions that was held constant. Mycorrhiza inoculum was applied during planting at the rate of 0g and 40g per planting hole, per treatment plots respectively. Five (5) plants were tagged randomly on the sampling rows (2nd and 5th) in each plot and they were used for data collection on growth characters. The 2 inner rows (3rd and 4th) were used for final yield assessment (net plot).

Different plant growth and yield parameters were assessed from planting, up to the harvesting of the crop. These parameters included; plant height, leaf numbers, days to 50% flowering and panicle weight, and grain yield. The data obtained were subjected to analysis of variance ANOVA using SAS (version 9.4). The means found to be significant were separated using DMRT at 5% level of significance.

RESULTS

Plant Height (cm): The effect of mycorrhiza (g) on plant height of sorghum varieties during the 2023 raining season at Dutse and Garki is shown in Table 2. At Dutse, mycorrhiza application 40 g hole⁻¹ generally reduced plant height at 6WAS and 9WAS (224.07 cm to 190.00 cm and 312.22 cm to 285.56 cm, respectively), with P-values (< 0.0001). However, at 12WAS in Dutse, the difference was not statistically significant. At Garki, mycorrhiza application (40 g hole⁻¹) significantly increased plant height at 6WAS, (184.30 cm) compared to the control (169.96 cm; P = 0.0050). This trend of taller plants with 40 g hole⁻¹ significantly continued at 9WAS and 12WAS (P < 0.05). There was a significant difference (<0.0001 and 0.0002) in plant height at 6WAS and 9WAS in Dutse, SAMSORG-50 recorded the highest height (242.78cm and 313.33cm) followed by SAMSORG-45 with 198.89cm and 303.33cm respectively. However, in Garki samsorg-45 and Dutse-kaura showed significant variation (0.0035 and 0.0521) at 9WAS and 12WAS. Similarly, samsorg-45 gave the tallest height (255.72cm and 327.39cm) followed by Dutse-kaura which recorded 234.06cm and 294.61cm at 9WAS and 12WAS respectively. The interactive effects between mycorrhiza inoculation (g) and sorghum varieties on plant height (PH) at 6WAS in Dutse is presented in Table 3. The result from Table 3 showed that, there was a significant difference in sorghum height at 6WAS in Dutse between the control and 40g of mycorrhiza. However, increasing the mycorrhiza content per hole from 0g to 40g did not significantly increase the height in samsorg-50SW. The interaction between no AMF and samsorg-50SW recorded the highest plant height (250cm) followed by AMF.

Number of Leaves: Effect of Mycorrhiza (g) on Number of leaves of Sorghum Varieties during the 2023 Raining Season at Dutse and Garki is shown in Table 4. At Dutse, the application of 40 g hole⁻¹ of mycorrhiza at 6WAS resulted in a significantly lower number of leaves (12.04) compared to 0 g hole⁻¹ (13.04; p = 0.0051). No significant differences were observed at 9WAS and 12WAS. In the same vein, under Garki At 6WAS, 40 g hole⁻¹ significantly increased the number of leaves (12.07) compared to 0 g hole⁻¹ (11.48; p = 0.0345). Similarly, no significant differences were observed at 9WAS and 12WAS. The effect of mycorrhiza on the number of leaves varied between locations. At Dutse, it reduced leaf numbers at early stages (6WAS), while at Garki, it increased leaf numbers at 6WAS.

Panicle Weight per Plant (g): Panicle Weight per Plant (g) as Affected by Mycorrhiza and Sorghum Varieties during the 2023 Raining Season at Dutse and Garki is shown in Table 7. Statistically at Dutse there was no significant effect on panicle weight due to the application mycorrhiza. However, at Garki, the application of mycorrhiza significantly (P = 0.0060) reduced panicle weight (from 0.72 g to 0.63 g), implying a negative interaction due to soil microbial imbalance, or environmental stress. Statistically, the inoculation mycorrhiza did not significant affect (P = 0.5865) panicle weight of sorghum. However, the result from Dutse, showed that there was a significant difference among the sorghum varieties (P = 0.0042), Samsorg-45 and Dutse-kaura were statistically similar and they had better panicle weight (1.03 g and 0.94 g respectively) than Samsorg-50. Moreover, at Garki site, there was a significant difference (P = 0.050), in panicle weight among the sorghum varieties. Dutse-kaura produced panicle with more weight followed closely by Samsorg-45 (Table 7).

Grain yield of Sorghum (Kg/ha): Yield (Kg/ha) as affected by Mycorrhiza (g) and Sorghum Varieties during the 2023 Raining Season at Dutse and Garki shown in Table 8. Mycorrhiza application slightly improved yield at both locations (Dutse and Garki) but did not produce statistically significant effects (P = 0.2124 and 0.2777 respectively). This could be due to soil conditions, nutrient availability, or other environmental factors that limited the effectiveness of Mycorrhiza in enhancing nutrient content. Statistically at Dutse there was a significant difference (P = 0.0008 and <0.0001) among the sorghum varieties both at Dutse and Garki. At Dutse site, Dutse-kaura had the highest grain yield (7.77t/ha) while Samsorg-45 and Samsorg-50 were statistically similar with a grain yield of 6.67t/ha and 5.67t/ha respectively. However, at Garki site, Samsorg-45 had the highest grain yield (5.67t/ha) while Samsorg-50 (3.70t/ha) and Dutse-kaura (4.17t/ha) were statistically similar (Table 8). The interactive effects between mycorrhiza inoculation and sorghum varieties on grain yield (kg ha⁻¹) in Garki is presented in Table 9. The result showed that, there was a significant difference (P = 0.0361) in grain yield (kg ha⁻¹) among the sorghum varieties due to mycorrhiza inoculation. Under control condition (0 g hole⁻¹), Dutse-kaura performed best (4888.9 kg ha⁻¹), though not significantly different from Samsorg-50SW. Samsorg-45 had the lowest yield (4000.0 kg ha⁻¹), significantly lower than Dutse-kaura. However, the inoculation of 40 g hole⁻¹ of mycorrhiza led Dutse-kaura to have the highest yield increase from 4888.9 to 6444.4 kg ha⁻¹. Samsorg-45 and Samsorg-50SW had moderate yields (4333.3 kg ha⁻¹ and 3333.3 kg ha⁻¹), and were statistically similar.

Table 1: Effect of Mycorrhiza (g) on Plant Height (cm) of Sorghum Varieties during the 2023 Raining Season at Dutse and Garki.

Treatment	DUTSE			GARKI		
	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Mycorrhiza (g hole⁻¹)						
0	224.07a	312.22a	400.37	169.96b	229.78b	289.93b
40	190.00b	285.56b	381.11	184.30a	251.85a	318.59a
SE±	4.256	4.207	9.034	3.389	4.098	9.170
P-value	<0.0001	<0.0001	0.1404	0.0050	0.0005	0.0335
Dutse-kaura	179.44c	280.00b	380.56	172.44	234.06b	294.61b
Samsorg-45	198.89b	303.33a	407.78	184.22	255.72a	327.39a
Samsorg-50SW	242.78a	313.33a	383.89	174.72	232.67b	290.78b
SE±	5.212	5.152	11.065	4.150	5.019	11.231

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P-value <0.0001 0.0002 0.1797 0.1184 0.0035 0.0521

Interaction

M X V 0.0038 0.1933 0.6061 0.4050 0.9265 0.9352

Means followed by the same letter (s) in a column are not significantly different at 5% probability level using DMRT.

Table 2: Interactive Effects Between Mycorrhiza (g) and Sorghum Varieties on Plant Height (cm) at 6 WAS during the 2023 Raining Season in Dutse.

Treatments	Mycorrhiza	
	0	40
Variety		
Dutse-kaura	191b	168c
Samsorg-45	231a	167c
Samsorg-50SW	250a	236a
SE±	7.4	

Means followed by the same letter(s) are not significantly different at 5% probability level using DMRT.

Table 3: Effect of Mycorrhiza (g) on Number of leaves of Sorghum Varieties during the 2023 Raining Season at Dutse and Garki.

Treatment	DUTSE			GARKI		
	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Mycorrhiza (g hole⁻¹)						
0	13.04a	14.26	15.44	11.48b	13.00	14.26
40	12.04b	14.22	15.70	12.07a	13.41	14.70
SE±	0.237	0.234	0.318	0.191	0.201	0.365
P-value	0.0051	0.9116	0.5673	0.0345	0.1603	0.3946
Variety						
Dutse-kaura	11.78b	14.17	15.56	11.56b	12.78b	14.00
Samsorg-45	12.83a	14.22	15.83	12.33a	13.72a	14.89
Samsorg-50SW	13.00a	14.33	15.33	11.44b	13.11ab	14.56
SE±	0.291	0.287	0.389	0.234	0.246	0.447
P-value	0.0103	0.9164	0.6635	0.0211	0.0324	0.3742
Interaction						
M X V	0.1143	0.3319	0.2082	0.5941	0.3659	0.6619

Means followed by the same letter (s) in a column are not significantly different at 5% probability level using DMRT.

Table 4: Panicle Weight per Plant (g) as Affected by Mycorrhiza (g) and Sorghum Varieties during the 2023 Raining Season at Dutse and Garki.

Treatment	DUTSE	GARKI
Mycorrhiza (g hole⁻¹)		
0	0.87	0.72a
40	0.91	0.63b
SE±	0.052	0.021
P-value	0.5865	0.0060
Variety		
Dutse-kaura	0.94a	0.72a
Samsorg-45	1.03a	0.67ab
Samsorg-50SW	0.72b	0.63b
SE±	0.063	0.025
P-value	0.0042	0.0760
Interaction		
AMF X V	0.2474	0.6711

Means followed by the same letter (s) in a column are not significantly different at 5% probability level using DMRT.

Table 5: Yield (Kg/ha) as affected by Mycorrhiza (g) and Sorghum Varieties during the 2023 Raining Season at Dutse and Garki.

Treatment	DUTSE	GARKI

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Mycorrhiza (g hole ⁻¹)		
0	6439.50	4321.00
40	6963.00	4703.70
SE±	291.546	245.52
P-value	0.2124	0.2777
Variety		
Dutse-kaura	7770.40a	4166.70b
Samsorg-45	6666.70b	5666.70a
Samsorg-50SW	5666.70b	3703.70b
SE±	357.070	300.700
P-value	0.0008	<0.0001
Interaction		
AMF X V	0.4588	0.0360

Means followed by the same letter (s) in a column are not significantly different at 5% probability level using DMRT.

Table 9: Interactive Effects Between Mycorrhiza (g) and Sorghum Varieties on grain yield (kg ha⁻¹) during the 2023 Raining Season in Garki.

Treatments	Mycorrhiza (g hole ⁻¹)	
	0	40
Variety		
Dutse-kaura	4888.9ab	6444.4a
Samsorg-45	4000.0b	4333.3b
Samsorg-50SW	4074.1b	3333.3b
SE±	601.40	

Means followed by the same letter(s) are not significantly different at 5% probability level using DMRT.

DISCUSSION: The study was to evaluate the effects of mycorrhiza and variety on the growth and yield of sorghum varieties, and the interaction between the factors.

Response to Mycorrhiza: Mycorrhiza application at Dutse significantly reduced plant height, but the effect was not significant. Mycorrhizal fungi often alter carbon allocation in plants, prioritizing root growth and symbiotic establishment over shoot growth in the initial stages (Smith and Read, 2008). This reallocation of resources could lead to reduced plant height during early growth phases. At Garki in contrast, mycorrhiza application (40 g hole⁻¹) significantly increased plant height at all growth stages. This implies that the symbiotic relationship between mycorrhiza and the plant was more effective in Garki, possibly due to favourable soil conditions, such as better nutrient availability or pH, which enhanced nutrient uptake and overall plant vigor. Mycorrhiza improves phosphorus uptake, which is critical for plant growth and development. In nutrient deficient soils, mycorrhiza can significantly enhance plant height by improving nutrient availability (Smith and Smith, 2011).

The contrasting responses in leaf number (in Dutse and Garki) due to mycorrhizal inoculation might be attributed to soil fertility, environmental conditions, and host plant-microbe interactions. Mycorrhizal fungi improve plant nutrient absorption, particularly phosphorus, which influences leaf development (Smith and Read, 2008). However, their effectiveness depends on soil conditions, as seen in other studies where mycorrhiza increased leaf numbers in *Arachis pinto* (Silva *et al.*, 2016). Additionally, previous research has shown that mycorrhiza effects can vary across different soil types and environmental conditions (Berruti *et al.*, 2016).

Mycorrhiza did not significantly affect the number of days to 50% flowering in either Dutse or Garki. This shows that mycorrhiza might not influence the timing of flowering in sorghum under these experimental conditions. According to Smith and Read (2008) mycorrhiza primarily enhances nutrient uptake, particularly phosphorus, which is more critical for vegetative growth and yield rather than reproductive timing. The ineffectiveness of mycorrhiza on flowering time aligns with findings that mycorrhiza does not significantly alter phenological stages in some crops (Mäder *et al.*, 2000).

Response of Varieties: The plant height of both improved and the local variety of sorghum increased considerably with the use of mycorrhiza inoculum. The height of sorghum plant is largely controlled by its genetic makeup (Shukla *et al.*, 2017). While genetic factors set the potential height of a sorghum plant, environmental conditions also play a significant role. Factors like soil fertility, water availability, and climate can influence how well a variety reaches its full height potential. Hence, the height of sorghum plants can vary widely depending on the variety as well as the growing conditions (Yoseph and Sorsa, 2014). According to May *et al.* (2015) plant height varies from one variety to another due to variation in the adaptation to weather conditions or due to their genetic differences. Similarly, Mwamahonje and Maseta (2018) reported a significant variation in plant height between local and improved sorghum. However, the result is contrary to the findings of Omoregie *et al.* (2021) in their work, evaluation of the growth and grain yield of sorghum in Ekpoma, reported samsorg-45 with least plant height. The results obtained indicated that, there is a difference in genetic bases with variation in the gene action expressing phenotypes among varieties tested (Mwamahonje and Maseta, 2018). The result is contrary to the findings of Omoregie *et al.* (2021) in their work, evaluation of the growth and grain yield of sorghum in Ekpoma, reported Samsorg-45 with least number of leaves compared to other sorghum varieties.

Among the varieties tested at Dutse, Samsorg-45 and Dutse-kaura produced statistically similar panicle weights, both outperforming Samsorg-50. This shows that Samsorg-45 and Dutse-kaura are better suited for higher panicle yield under the given conditions. This corroborates with the findings of Omoregie *et al.* (2021). Similarly, at Garki, Dutse-kaura produced panicles with the highest weight, followed closely by Samsorg-45.

The results from Dutse site showed that, the variety Dutse-kaura had the highest grain yield, while Samsorg-45 and Samsorg-50 produced statistically similar yields. This implies that Samsorg-45 and Samsorg-50 might perform comparably under the same conditions. This implies that Samsorg-45 and Samsorg-50 might perform comparably under the same conditions. This shows that factors like variety characteristics and environmental factors might have played a more dominant role over the treatment effects in determining the yield of sorghum (Amare *et al.*, 2015; Ati and Akinyemi, 2018; Mundia *et al.*, 2019; Chadalavada *et al.*, 2021; Abreha *et al.*, 2022). At Garki, however, Samsorg-45 recorded the highest yield, with Samsorg-50 and Dutse-kaura showing statistically similar results. This agrees with the findings of Ati and Akinyemi (2018) who reported Samsorg-45 to be the best performing variety in agronomic characteristics and yield. Most importantly, the application of cattle rumen digesta significantly affected the yield, implying that soil conditions or environmental factors at Garki made the digesta more effective in enhancing crop performance (Cobb *et al.*, 2017). Samsorg-50 and Samsorg-45 had a potential yield of 3.0t/ha and 3.5t/ha respectively. The yield obtained from both locations is almost twice more than the potential yield of these varieties (Samsorg-50 and Samsorg-45).

CONCLUSION: The results revealed varying responses depending on the growth stage, sorghum variety, and location. Mycorrhiza application reduced plant height at Dutse but increased it at Garki, influenced leaf production differently across sites, and had significant effect on flowering time. Panicle weight remained largely unaffected at Dutse but decreased at Garki, while grain yield showed slight improvements. Dutse-kaura consistently produced higher yields and harvest indices, followed by Samsorg-45 highlighting their potentials for broader cultivation.

RECOMMENDATIONS: SAMSORG-45 is the most adaptable and stable variety across locations and treatments, showing consistent yield performance even under varying soil amendments. It should be prioritized for Garki and other locations with similar soil conditions; The reduction in plant height and panicle weight called for further research should investigate optimal mycorrhiza application rates to maximize positive effects while minimizing potential negative impacts.

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Sustainable use of High Quality Cassava Peels in Broiler Chicken Starter Diets

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Abstract

The rising cost of conventional feed ingredients is a major constraint to broiler chicken production in Nigeria. This study evaluated nutrient utilization, growth and economics of broiler chicken production with the use of high-quality cassava peels (HQCP) as sustainable, lower-cost feed alternatives. 150 day-old chicks of the Ross strain broiler chicken were randomly distributed to five dietary treatments of three replicates each in a 28-day trial. Each replicate consist of ten birds. HQCP replaced 25%, 50%, 75% and 100% maize in the control diet (T1) as T2, T3, T4 and T5 respectively. A 5-days digestibility trial was performed when birds were 21 days. Two birds of uniform body weight from each of the fifteen (15) replicates were picked at random and fed test diets in the digestibility cage. Body weight changes were recorded during the digestibility trial. Performance indices were measured. Results showed a significant ($P < 0.05$) effect of HQCP on all growth parameters, digestibility coefficients and economic indices. The final body weight, daily weight gain and daily feed intake increased as HQCP in the diets increased up to 25% and decreased ($P < 0.05$) between 50% and 100% of HQCP replacements. Digestibility of nutrients was affected ($P < 0.05$) by inclusion of high-quality cassava peel in the diets. Cost of feed decreased ($P < 0.05$) with increased HQCP inclusions in diets. The result of the study indicated that unit gain of weight was sacrificed on 75% and 100% HQCP diets. 50% HQCP replacement for maize with HQCP is hereby recommended in broiler starter diets.

Keywords: broiler, digestibility, growth, high-quality cassava peel, maize, utilization,

Introduction: Sustainable poultry production emphasizes not only economic efficiency but also environmental responsibility and animal health. Sustainable feeding practices contribute to reduced environmental impact. The cost of conventional livestock/poultry feed ingredients has continually be on the increase in recent times. Of particular importance is the cost of maize which contribute the largest portion of poultry rations as a major energy source. Major conventional poultry feed ingredients, particularly maize are expensive in the tropical countries as they are also in high demand for human consumption, and may be used for other industrial production (Morgan *et al.*, 2016, Chauynarong *et al.*, 2009). The increased demand for maize in most countries of the world has forced many poultry farmers to explore viable alternatives that can replace maize at a lower cost without significant deleterious impacts on the production and performance of birds. The shift toward using **lower-cost, sustainable feed ingredients** is a crucial strategy in making broiler production more resilient and accessible, particularly for small- and medium-scale poultry producers in resource-limited settings. Most non-ruminant animals especially Broiler chickens rely on highly digestible feedstuffs, such as maize being used as energy source (Mutayoba *et al.*, 2011, Swick *et al.*, 2013). Maize is the most commonly used energy source for poultry feeding worldwide Ngiki *et al.*, 2014) because it has a higher metabolizable energy (ME) content than other cereal grains (Okike *et al.*, 2015). The recent introduction of cassava products as energy feed ingredient in poultry diets is a welcome development that had helped to change the narrative. Several studies have suggested the use of cassava as a replacement for maize meal as an energy source in poultry diets because it is produced in great quantities and has high energy content (Buitrago *et al.*, 2002, Morgan *et al.*, 2016, Broch *et al.*, 2017). These studies have demonstrated that cassava peels can be a good energy feed base in poultry feed because of the high metabolizable energy. Cassava's low protein content, imbalanced amino acid profile, dustiness, and presence of anti-nutritional elements, however, limit its utilization in chicken diets.

High-quality cassava peel (HQCP) was reported to have been used to replace maize up to a 30% level. Replacement of 20% maize with cassava peel did not have any detrimental effect on broiler chicken growth (Abu *et al.*, 2015). Several authors reported varied proximate values for cassava products. Cassava peel has 3.1–5% and 9–12% crude protein and crude fibre, respectively (Babatunde, 2013), low energy, protein and high in fibre (Ngiki *et al.*, 2014). This study was conducted to explore viable alternative in the name of high-quality cassava peel that can replace maize and be utilized at a lower cost without significant deleterious impacts on the production and performance of broiler chickens.

Materials and Methods

Animals and Experimental Design: The research work was conducted at the Poultry Unit of the Teaching and Research Farm of Ekiti State Polytechnic, Isan Ekiti. HQCP with fine particle size was used in this trial (**Table 1**). Proximate composition of high quality cassava peels was carried out as described by AOAC, (2005).

Proximate Composition of High Quality Cassava Peels HQCP

Table 1: Proximate composition of HQCP

Parameters	HQCP (Whole)	HQCP (Fine)	HQCP (Coarse)
Starch	66.70	69.00	55.00
Protein (%)	4.50	4.60	2.80
Fat (%)	1.40	1.20	1.20
Crude Fibre (%)	9.80	8.20	15.60
Crude Ash (%)	5.80	6.60	3.50
ME (kcal/kg)	2947	3039	2495

HQCP – High Quality Cassava Peels

In a completely randomized design, one hundred and fifty-day-old Ross broiler chicks were randomly placed into five diets. A Control diet was formulated (T1). Four other diets (T2, T3, T4 and T5) were formulated with 25%, 50%, 75% and 100% replacement of maize in diet T1 with HQCP (**Table 2**). 0%, 25%, 50%, 75% and 100% HQCP translated to 0%, 14.75%, 29.50%, 44.50% and 59.00% inclusion level of HQCP in broiler starter diets on weight basis.

Table 2: Gross Composition of Experimental diets of broilers starter fed High Quality Cassava Peels

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Ingredients	REPLACEMENT LEVELS				
	0% HQCP	25% HQCP	50% HQCP	75% HQCP	100% HQCP
Maize	59.00	44.25	29.50	14.75	0.00
HQCP	0.00	14.75	29.50	44.25	59.00
Soy Bean Meal	31.00	31.00	31.00	31.00	31.00
Wheat offal	4.19	4.19	4.19	4.19	4.19
Bone meal	2.20	2.20	2.20	2.20	2.20
Fish meal	3.00	3.00	3.00	3.00	3.00
Broiler premix	0.01	0.01	0.01	0.01	0.01
Table salt	0.50	0.50	0.50	0.50	0.50
Methionine	0.05	0.05	0.05	0.05	0.05
Lysine	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00

Note – ME- Metabolisable energy, HQCP – High Quality Cassava Peel

Diets were formulated and compounded with no other feed additives. Birds were brooded on a floor pen in an open-sided wall building with heat provided from burning charcoal in pots. Nutrient digestibility studies were conducted in the fourth week of the trial and lasted five days. In a completely randomized design arrangement of five dietary treatment replicated thrice, two birds (2 per replicate) with total number of fifteen (15) birds were randomly selected, and placed in digestibility cages. Birds were fasted for 24 hours to empty the digestive tract after which they were fed the formulated diets. *Ad libitum* feeding and clean drinking water were provided. The standard technique of total fecal collection was followed. Faecal samples and data on feed intake were collected daily over a period of five days by placing faecal trays under each cage. The collected faecal samples were weighed on wet and dry basis to determine moisture and dry matter content. The final body weight was recorded at the end of the trial. Growth changes and feed consumed calculated.

Chemical Analyses: Proximate composition of high quality cassava peels, experimental diets and faecal samples were carried out as described by AOAC, (2005).

Statistical Analysis: Data generated were subjected to one-way analysis of variance (ANOVA) using the SAS (2008) package for Windows. To separate significant differences among means, Duncan multiple range test was used.

Results and Discussion: Calculated and Proximate composition of experimental diets.

Table 2: Calculated and Proximate composition of experimental diets

Ingredients	REPLACEMENT LEVELS				
	0% HQCP	25% HQCP	50% HQCP	75% HQCP	100% HQCP
Calculated nutrient values					
Crude protein (%)	21.93	21.82	21.78	20.86	19.77
ME (kcal/kg)	2903.32	2860.43	2814.52	2790.13	2765.73
Ether extract	2.96	2.45	2.26	1.90	1.55
Crude fibre	3.64	4.51	5.40	6.34	7.24
Analyzed Proximate values					
Crude Protein (%)	21.90	21.31	20.69	20.08	19.48
Crude Fibre (%)	5.85	6.55	8.32	9.10	11.48
Ether Extract (%)	5.89	4.01	4.94	3.69	3.43
Ash (%)	6.91	5.41	5.12	5.21	3.84
NFE (%)	59.45	62.72	60.93	61.92	61.77
ME (kcal/kg)	3097.87	3039.84	3028.69	2940.01	2891.43

Note – ME- Metabolisable energy, HQCP – High Quality Cassava Peel

Calculated and Proximate composition of experimental diets are presented in Table 3. Proximate data obtained were similar to the calculated values obtained.

Growth performance characteristics of Broiler Starter fed High Quality Cassava Peel

Table 4 shows the performance characteristics of broiler starter fed HQCP for the digestibility trial.

Table 4: Growth Performance Characteristics of Broiler starter fed varying inclusion levels of HQCP

PARAMETERS	REPLACEMENT LEVELS OF HQCP FOR MAIZE						p-value
	0%	25%	50%	75%	100%	SEM	
Initial body weight (g/bird)	110.05	111.85	115.40	110.00	110.75	1.46	0.8434
Final body weight (g/bird)	669.95 ^a	691.95 ^a	611.55 ^{ab}	392.80 ^b	357.30 ^b	52.65	0.0525
Daily weight gain (g/bird)	111.98 ^a	116.02 ^a	99.23 ^{ab}	56.56 ^b	49.31 ^b	10.39	0.0442
Daily Feed Intake (g/bird)	70.80 ^e	82.83 ^b	77.53 ^d	91.36 ^a	79.41 ^c	2.25	<.0001
Feed Conversion Ratio	1.58 ^a	1.40 ^a	1.28 ^{ab}	0.62 ^b	0.62 ^b	0.15	0.0316
Fc/kg feed (₹)	368.18 ^a	346.05 ^b	323.92 ^c	301.80 ^d	279.68 ^e	10.43	<.0001
Fc/wg/b (₹)	3.41	3.02	3.29	5.52	5.96	0.49	0.1354

HQCP – High Quality Cassava Peel, Fc- Feed Cost, SEM: Standard Error of Mean

There was a significant ($P < 0.05$) effect of HQCP on all growth parameters. The final body weight, daily weight gain and daily feed intake increased by the increase HQCP in the diets up to 25% and thereby decreased ($P < 0.05$) between 50% and 100% of HQCP. Performance characteristics were significantly similar for birds on 0%, 25% and 50% HQCP diets. The differences ($P < 0.05$) for feed intake was not consistent with HQCP increase across treatments. Birds on diet 2 (25% HQCP) replacement recorded the highest final body weight, daily weight gain and daily feed intake. The higher daily feed intake in 75% and 100% HQCP diets did not translate to improved weight gain. This could be attributed to higher fibre content which resulted in poor utilization of crude protein and metabolizable energy in the diet. The final body weight, daily weight gain, and FCR among birds fed diets with 25% and 50% were not ($P < 0.05$) different. Also, the deteriorating

effect of feeding HQCP diets noticed in the final body weight, daily weight gain, and FCR for birds were not different ($P < 0.05$) on 75% and 100% HQCP. The low ($P < 0.05$) FCR values recorded for birds that were fed diets with higher levels of HQCP might be attributed to higher non-soluble starch component of HQCP (Adekeye *et al.*, 2021). Cost of feed decreased ($P < 0.05$) with increased HQCP inclusions in diets. The cost per unit weight gain were lower on 25% and 50% than on 0% HQCP diet. However, it is expensive to achieve a unit gain of weight when 75% and 100% of maize in diets was replaced with HQCP than on the other diets because the nutrient was not better utilized.

Nutrient Digestibility Parameters: Nutrient digestibility parameters of Broiler Starter fed High Quality Cassava Peel are shown in **table 5**. The digestibility of inherent nutrients of diets was influenced ($P < 0.05$) by addition of high-quality cassava peel into the test diets. The utilization of crude protein, crude fibre, ether extract, and nitrogen-free extract were also affected ($P < 0.05$). Crude protein digestibility increased ($P < 0.05$) up to 25% HQCP inclusion level, which was then observed to reduce significantly from 50% to 100% HQCP inclusion. However, the utilization of Metabolizable energy, crude fibre and ether extract decreased ($P < 0.05$) with increasing levels of HQCP in the diets. The result showed a drop in the digestibility of crude protein and ether extract after the 25% HQCP level. The least metabolizable energy value (2894.08 kcal ME kg⁻¹) recorded in this study are adequate for starting broiler in the tropics (Olomu, 2005). The attendant weight reduction recorded with HQCP increase in the diets could be attributed to the poor utilization of the crude protein, crude fibre, ether extract and metabolizable energy of the diets at higher levels of HQCP inclusion.

Table 5: Utilization of High Quality Cassava Peel Nutrient by Broiler starter

PARAMETERS	REPLACEMENT LEVELS					SEM	p-value
	0% HQCP	25% HQCP	50% HQCP	75% HQCP	100% HQCP		
Moisture (%)	7.22 ^a	6.50 ^{ab}	5.54 ^{bc}	5.44 ^{bc}	5.10 ^c	0.2493	0.0415
Dry Matter (%)	92.79 ^c	93.50 ^{bc}	94.46 ^{ab}	94.56 ^{ab}	94.90 ^a	0.2492	0.0415
Crude Protein (%)	3.16 ^{bac}	4.39 ^a	3.42 ^{ab}	2.03 ^{bc}	1.72 ^c	0.3289	0.0249
Crude Fibre (%)	11.93 ^a	11.90 ^b	9.92 ^b	9.98 ^c	9.40 ^c	0.4760	0.0035
Ether Extract (%)	3.85 ^a	3.62 ^{ab}	2.77 ^{bc}	2.02 ^{cd}	1.35 ^d	0.3242	0.0029
ASH (%)	5.35 ^c	5.78 ^c	6.79 ^b	7.71 ^a	8.35 ^a	0.3803	0.0004
NFE (%)	75.71 ^{cd}	74.32 ^d	77.05 ^{bc}	78.85 ^{ab}	80.14 ^a	0.7281	0.0064
ME	3116.31 ^a	3093.33 ^{ab}	3085.91 ^{ab}	2948.98 ^c	2894.08 ^d	18.2015	0.0409

Note – NFE – Nitrogen Free Extract, ME- Metabolisable energy, HQCP – High Quality Cassava Peel

Conclusion and Application : High Quality Cassava Peel are poorly utilized by broiler chicken when added to diets at higher level. Broiler chicks can thrive well on diets in which up to 50% of maize is replaced with High Quality Cassava Peel without impairing performance. Thus, HQCP can be incorporated into broiler starter diets at 29.50% on weight basis.

The use of HQCP as an alternate energy feed source in poultry feed will help to mitigate the ever increasing cost of broiler feed in Nigeria.

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Effect of Government Subsidies on the Profitability and Environmental Sustainability of Agricultural Enterprises in Ekiti State, Nigeria

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Abstract

This study examines the effect of government agricultural subsidies on the profitability and environmental sustainability of small and medium-sized agricultural enterprises in Ekiti State, Nigeria. This research adopts a mixed-method approach of descriptive survey design, using structured questionnaires. Data were collected from 300 agricultural enterprises across the state. The collected data were analysed using descriptive statistics and multiple regression. Results revealed that most small and medium-sized agricultural enterprises in Ekiti State received fertilizer input. Input Subsidy provisions significantly ($p < 0.05$) improved the income of small and medium-sized agricultural enterprises in Ekiti State. Thus, this indicates that while government subsidies significantly enhance farm profitability, especially through input and equipment support, only training-related subsidies and eco-friendly inputs show a positive influence on the adoption of sustainable farming practices. The use of Mechanization subsidies, however, were not statistically significant in this study and thus have an insignificant effect on environmental sustainability/profitability. In contrast, subsidy programs tied to sustainable farming education and organic inputs, with low environmental impact demonstrated dual benefits of improved profitability and increased adoption of sustainable practices. The study concludes that government subsidy programs in Ekiti State must be redesigned to effectively promote sustainability alongside profitability. Integrating sustainability indicators into subsidies, promoting farmer training on sustainable agricultural production, and ensuring transparency and equity in subsidy distribution are major policy recommendations from this study. These findings offer critical insights for policymakers, agricultural stakeholders, and development agencies working to promote climate-smart and economically viable farming systems at the state level

Keywords: Government, Subsidies, Profitability, Environmental, Sustainability, Ekiti, Farming

Introduction: Agriculture remains the backbone of many developing economies, particularly in Sub-Saharan Africa, where it had contributed significantly to employment, food security, and rural livelihoods. Agricultural sector in Nigeria accounts for about 25% of Gross Domestic Product (GDP) and employs over 60% of the labor force, most of whom are smallholder farmers (World Bank, 2022). Notwithstanding these importance, Nigerian Agriculture, according to FAO, (2021) report, challenges, including low productivity, high input costs, inadequate access to credit, and vulnerability to climate change continues to persist.

To address these challenges, governments have historically implemented subsidy programs as policy instruments to enhance farm productivity, reduce production costs, and stabilize rural incomes. Agricultural subsidies (input, equipment, credit, and training supports) are a common policy tool in low- and middle-income countries to raise productivity, reduce input costs, and protect smallholder livelihoods. Subsidies are generally designed to reduce production costs, stimulate output, and protect smallholders from market volatility. According to Jayne & Rashid, (2013), agricultural subsidies typically include support for fertilizer, seeds, pesticides, farm machinery, training programs, and eco-friendly inputs. Subsidies aim to increase output and farmer incomes, but they may also shape farmers' input choices and land-management practices; with consequences for environmental sustainability. In Nigeria, initiatives such as the Growth Enhancement Support Scheme (GES) and subsequent e-wallet input distribution reforms were designed to improve transparency, reduce leakages, and ensure that genuine farmers benefited from input support programs (Liverpool-Tasie, Omonona, Sanou, & Ogunleye, 2017). Empirical research findings has shown that subsidies can improve farmers' access to productive inputs, improve crop yields, and enhance farmer's household welfare (Mason & Ricker-Gilbert, 2013; Chibwana, Fisher, & Shively, 2012). A major limitation of subsidy programs in Nigeria is their narrow focus on short-term profitability, often overlooking long-term sustainability. Thus, while the profitability dimension of subsidies is well recognized, their environmental impact and consequences remain disputed. Conventional subsidies for chemical fertilizers and pesticides, while reducing costs and improving yields, have been associated with soil nutrient imbalance, land degradation, and water pollution when misapplied (Wu, 2018; Huang *et al.*, 2010). Scholars have observed that their broader impact extends beyond profitability to environmental outcomes, depending on the type and design of the subsidy program Chibwana *et al.* (2012). The misuse of subsidies for inputs such as chemical fertilizers and pesticides by over-application may cause devastating effects on the soil leading to soil degradation, loss of biodiversity, and water contamination (Wu, 2018; Huang, Wang, & Rozelle, 2010). However, subsidizing eco-friendly practices, such as organic inputs, sustainable mechanisation, and conservation training, have shown greater potential in enhancing profitability and safeguarding the environment (Schader, Stolze, & Lampkin, 2015; Pimentel & Burgess, 2014). Several studies in Nigeria focus on productivity or profitability, with limited attention given to ecological outcomes (Oluwatayo & Adedeji, 2019). State-level evidence further illustrates the dynamics of input subsidy. Studies focusing on improved technology adoption in Ekiti and neighbouring states report profitability gains where farmers accessed subsidized inputs and extension services (Akinbode & Bamire, 2015; Oluwatayo & Adedeji, 2019). However, environmental sustainability outcomes remain less documented, with most studies emphasizing financial performance over ecological indicators. Agriculture remains a vital sector in Ekiti State despite being dominated by small and medium-sized enterprises that rely heavily on government support for inputs and training. Despite these insights, there is limited empirical work that jointly measures profitability and environmental sustainability in Ekiti State, Nigeria. Although many farmers benefit from subsidies, there has been little empirical evidence to show how subsidy interventions jointly influence profitability and environmental sustainability at the state level. This creates a critical knowledge gap that this study seeks to fill. Without a clear understanding of how subsidies influence both profitability and environmental sustainability, policymakers risk implementing interventions that deliver short-term economic gains at the expense of long-term ecological balance. Therefore, this research examines the effect of government subsidies on both the profitability and environmental sustainability of agricultural enterprises in Ekiti State. Thus, this study contributes by evaluating both dimensions simultaneously in Ekiti

State, with particular attention to how different subsidy types (input, equipment, training, eco-friendly support, and credit) influence farm outcomes.

Objectives of the Study: The main objective of this study is to examine the effect of government agricultural subsidies on the profitability and environmental sustainability of agricultural enterprises in Ekiti State, Nigeria.

The specific objectives are to: Examine the effect of government subsidies on the profitability of agricultural enterprises in Ekiti State; Evaluate the effect of government subsidies on the environmental sustainability of agricultural enterprises in Ekiti State; Determine which categories of subsidies (input, equipment, training) have the greatest influence on profitability and sustainability outcomes.

Research Hypotheses

H₀₁: Government subsidies have no significant effect on the profitability of Agricultural Enterprises in Ekiti State.

H₁₁: Government subsidies have a significant effect on the profitability of agricultural enterprises in Ekiti State.

H₀₂: Government subsidies have no significant effect on the environmental sustainability of agricultural enterprises in Ekiti State.

H₁₂: Government subsidies have a significant effect on the environmental sustainability of agricultural enterprises in Ekiti State.

Significance of the Study: This study contributes to the literature by integrating profitability and sustainability perspectives in assessing subsidy impacts, providing insights for policymakers, development partners, farmers, and researchers. It will guide subsidy reforms, support sustainable agricultural practices, and align with Nigeria's food security and climate resilience goals

Scope of the Study: The study covers small and medium-sized agricultural enterprises in Ekiti State, focusing on input, equipment, training, eco-friendly, and financial subsidies. Profitability is measured by income, return on investment (ROI), yield, cost reduction, and sales revenue, while sustainability is assessed through eco-practice adoption, soil management, waste recycling, renewable energy use, and land conservation.

Methodology

Research Design: This study adopted a **mixed-method approach** anchored on a **descriptive survey design**. The survey method was considered appropriate because it allows the collection of first-hand data on the effects of government subsidies on agricultural enterprises from across Ekiti State. The mixed-methods approach provided both quantitative insights into profitability and sustainability outcomes, and qualitative perspectives on farmers' experiences with subsidy programs.

Population of the Study: The study population comprised **registered small and medium-sized agricultural enterprises in Ekiti State, Nigeria**. These enterprises were targeted because they are the primary beneficiaries of government subsidy programs such as input support, mechanisation services, training, and eco-friendly farming incentives.

Sample size and Sampling Technique: A total of **300 agricultural enterprises** were selected across the state. A **multistage sampling technique** was employed. Ekiti State was stratified into agricultural zones. Registered enterprises were identified within each zone. A proportionate random sampling method was used to select respondents to ensure fair representation across zones.

Data collection Methods: Primary data were collected using **structured questionnaires**. The **questionnaire** captured quantitative information on types of subsidies accessed (inputs, equipment, training, eco-inputs, financial aid), indicators of profitability (farm income, ROI, output per hectare, cost reduction), and indicators of environmental sustainability (eco-practice adoption, soil and waste management, renewable energy use).

Research Instruments: The questionnaire was divided into two sections:

Section A: Demographic information (age, gender, enterprise type, size, years in operation).

Section B: Measures of profitability and environmental sustainability, structured on a **5-point Likert scale** ranging from *Strongly Disagree* (1) to *Strongly Agree* (5).

The instrument was validated by experts in Agricultural Economics and Accountancy.

Measurable indicators are:

Independent Variable (Government Subsidies) such as **Input Subsidies** (fertilizer, seeds, pesticides, herbicides), **Equipment/Mechanisation Subsidies** (tractors, irrigation equipment), **Training/Extension Subsidies** (government-sponsored training on sustainable farming), **Eco-friendly Input Subsidies** (organic manure, improved seedlings) and **Financial Subsidies** (grants, subsidized credit facilities).

Dependent Variable A (Profitability) such as **Farm income (net farm income, gross margin)**, **Cost reduction due to subsidy usage**, **Output/yield per hectare and Return on Investment (ROI) in farming**.

Dependent Variable B (Environmental Sustainability) such as **Adoption of eco-friendly farming practices** (organic manure, reduced chemical usage), **Soil fertility management practices**, **Use of renewable energy in farming (solar-powered irrigation)** and **Long-term crop yield stability or reduced land degradation**.

Data Analysis Techniques

Quantitative data were analyzed using **Descriptive statistics** (frequency, percentages) to summarize responses. **Multiple regression analysis** was employed to examine the effect of government subsidies on profitability and environmental sustainability proxies. Qualitative data from interviews were transcribed and analyzed thematically to complement the quantitative findings.

Ethical Consideration

Respondents were assured of the confidentiality of their information and informed consent was obtained prior to participation. Data collected were used strictly for academic purposes.

Results and Discussion

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Descriptive Statistic: Descriptive statistics were used to describe the demographic information (age, gender, enterprise type, size, year in operation). Likert rating scales were used for objectives (2&3). Table 1 shows the Distribution of respondents according to their Socio-economic characteristics.

Table1: Demographic Information of Respondents

Variable	Categories	Frequency	Percentage
Gender	Male	157.00	52.33
	Female	143.00	47.67
	Below 25	62.00	20.67
Age group	25-34	74.00	24.67
	35-44	52.00	17.33
	45-54	75.00	25.00
	55 and above	37.00	12.33
	Single	150.00	50.00
Marital Status	Married	126.00	41.88
	Divorce	9.00	3.00
	Widowed	15.00	5.00
Educational Qualification	SSCE	189.00	63.00
	OND/NCE	47.00	15.67
	HND/B.Sc	39.00	13.00
	M.Sc. and above	25.00	8.33
	Less than 5 years	40.00	13.33
Years in agricultural enterprise	6-10 years	78.00	26.01
	11-15 years	100.00	33.33
	Above 15 years	82.00	27.33
	Crop farming	120.00	40.00
	Livestock	60.00	20.00
Types of agricultural enterprise	Mixed farming	90.00	30.00
	Other (specify)	30.00	10.00

SOURCE: Field Data 2025

The respondents interviewed were of mixed sexes. 52.33% and 47.67% were male and female respectively. This result showed that men often engages in agricultural enterprises than women. Age group 45-54 (75.00%) were more involved in agricultural enterprise, followed by 25-34 (74.00%) and 35-44 ears (52.00%). 50.00% of respondents were single, 41.00% were married, 5.00% widowed and 3.00% had divorced. Majority of the people involved in agricultural enterprise (63.00%) were SSCE holders and had been in the business for 11-15 years (33.33%). Crop farming was the favourite agricultural enterprise (40.00%) by majority of the respondents while only 20.00% were involved in livestock enterprise.

Test of Hypotheses

H₀₁: Input subsidies have no significant effect on the profitability/sustainability of agricultural enterprises in Ekiti State.

H₀₂: Mechanization subsidies have no significant effect on the profitability/sustainability of agricultural enterprises in Ekiti State.

H₀₃: Training subsidies have no significant effect on the profitability/sustainability of agricultural enterprises in Ekiti State.

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.975a	.950	.950	1.23709

a. Predictors: (Constant), Input, Mechanization, Training

The R = 0.975 obtained from the result indicated that there is a very strong relationship between subsidies (inputs, mechanization, training) and the profitability/sustainability of agricultural enterprises.

The R Square (R²) = 0.950 suggested that the model explains **95% of the variation** in profitability/sustainability. This means government subsidies are a highly reliable predictor of enterprise performance in Ekiti State.

Adjusted R² shows the explanatory power of the model. The **Adjusted R² = 0.950 value obtained** even after adjusting for predictors, indicates that the explanatory power remains strong, showing the robustness of the model.

Std. Error = 1.237: The prediction error is small, confirming accuracy.

Regression Analysis

A regression analysis was carried out on the panel data to confidently determine which variables are significant to the subject matter, which variables can be overlooked and how these variables influence each other.

Model Testing

Table 3: Regression (ANOVA): Model Testing

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8629.671	3	2876.557	1879.623	.000b
	Residual	452.996	296	1.530		
	Total	9082.667	299			

a. Dependent Variable: Output

b. Predictors: (Constant), Input, Mechanization, Training

The model shows that subsidies play a critical role in boosting the profitability and sustainability of agricultural enterprises in Ekiti State. This is in line with the findings of Schader, Stolze, & Lampkin (2015).

F (3,296) = 1879.623, p < 0.001: The model is statistically significant. Input, mechanization, and training subsidies jointly have a strong effect on agricultural profitability/sustainability.

Table 4: Regression Coefficients of Dependent Variables

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.

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		B	Std. Error	Beta		
1	(Constant)	4.226	.272		15.551	.000
	Mechanization	-.002	.067	-.002	-.023	.981
	Training	.641	.075	.740	8.543	.000
	Input	.300	.084	.240	3.563	.000

a. Dependent Variable: Output

Training subsidies are the most impactful ($P < 0.0001$) as they build farmers' knowledge and skills, leading to better adoption of modern practices and sustainable farming techniques.

Input subsidies also significantly ($P < 0.0001$) improve performance by reducing production costs and ensuring access to critical resources in agreement with the findings of Akinbode & Bamire, (2015); Oluwatayo & Adediji, (2019) who reported profitability gains where farmers accessed subsidized inputs and extension services in Ekiti State. Mechanization subsidies, however, were not statistically significant ($P = .981$) in this study. This may be due to challenges like high maintenance costs, poor accessibility, or lack of technical know-how among farmers.

Conclusion: The study revealed that Crop farming was the favourite agricultural enterprise in Ekiti State. It was concluded that provision of government agricultural subsidies: Input and training, improved profitability and sustainability of agricultural enterprises in Ekiti State.

Recommendation: It is hereby recommended that government subsidy programs such as Mechanization subsidy in Ekiti State should be redesigned to effectively promote sustainability alongside profitability. Sustainability indicators should be integrated into subsidies, and, transparency and equity in subsidy distribution should be ensured.

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Causes of Post- Harvest Losses among Small Scale Holder Millet and Sorghum Farmers in Jigawa State, Nigeria

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ABSTRACT

This study identified the causes of post - harvest losses among small scale holder millet and sorghum farmers in Jigawa state. One hundred and eighty four farmers were used for the study. The result revealed the mean age of 40 years, majority, (79.3%) of them are married. About 44.6% of them had primary education and most, (73.3%) of them were having contact with the extension agents. major source of millet and sorghum post-harvest management information are, family and friends (64%). while major causes of post-harvest losses of millet and sorghum in the study area are insects/pest/diseases (69%), farm storage (44.6%) and theft (44.6%). Major limitation of the respondents on post-harvest losses are lack of modern storage infrastructural facilities like silos (90.8%) while theft accounted for (10.0%). This study recommends that extension agents should be pro-active by creating more awareness to millet and sorghum farmers and encouraging them to harvest their crops when fully dried at the right time for home storage. There is also need for the Jigawa State Government to provide silos storage facility at the State headquarters for grains storage.

INTRODUCTION: Development in the agricultural sector, at all levels, is confronted with a huge challenge of how to feed the growing populations sufficiently. In attempts to surmount this challenge, considerable attention is directed toward increasing food production by 50–70% to achieve the Sustainable Development Goal 2; food security and right to food (Affognon *et al.*, 2015). Unfortunately, one of the important and complementary factors to the attainment of food security, which is oftentimes forgotten is the minimization of post-harvest food loss and food waste (GIZ, 2013). According to Food and Agriculture Organization, FAO (2010), out of the USD 940 billion that is needed for the eradication of hunger in Sub-Saharan Africa in 2050, 47% will be required in the post-harvest sector alone. Even in industrialized countries, food losses and waste amounts to about USD 680 billion. This analysis thus underscores the importance of PHL management in enhancing farm-level productivity and access to food.

In concept, post-harvest loss entails all measurable decrease or change in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption, with minimum loss, maximum efficiency and maximum return (Aulakh *et al.*, 2013). According to Ansah and Tetteh (2016), the possibility of feeding the teeming population is shrouded in uncertainty unless serious attention is given to post-harvest losses. Evidently, one of the most important pathways to increasing food availability and strengthening food security is by reducing post-harvest losses and wastes (Tanye, 2016), preventing food loss and increasing production remains the two realistic alternatives by which the world can meet its ever-rising food demand. It is important therefore to note that food production system consists of two sub-systems – crop production and post-harvest operations systems. While the efficiency of the food production system centers on increasing the technical efficiency of the crop production system, the efficiency of post-harvest operations is focused on reducing the post-harvest losses associated with the crop. In line with this, the SDG 12.3 target by 2030 is to halve food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses. However, barely eight years to 2030, over one-third of the food produced globally for human consumption (about 1.3 billion tons) is lost or wasted each year along the food supply chain. On the African continent, one of the seven commitments made by the Heads of State and Governments in Malabo, was on ending hunger in Africa by 2025 through direct efforts to reduce Post-Harvest Loss (PHL) by 50% (African Union Commission, 2018). The Malabo Declaration also identified the knowledge management and skill factors including research and development, skills and human development, and awareness and communication as integral components of Post-Harvest Loss management.

In attempt to achieve either of the crop production objectives in particular, concerted policy on information and technical services are needed at all levels to improve efficiency. According to Christiansen *et al.* (2018), targeting Post-Harvest Loss interventions to improve post-harvest handling techniques (especially those on the farm) is key to reducing post-harvest losses. Thus, Agricultural Extension Service (AES) delivery is considered as an indispensable tool in the prime objective of minimizing post-harvest losses in cereal crops, especially in developing economies where the percentage losses are huge. Agricultural extension services are therefore referred to all the different activities that provide the information and services needed and demanded by farmers and other actors in rural setting to assist them in developing their own technical, organizational, and management skills and practices to improve their livelihoods and well-being (Global Forum for Rural Advisory Services (GFRAS, 2016). Agricultural extension services are also referred to the different programs, projects or recommendations, which the extension service make available to their clientele through the use of extension education process (Anaeto *et al.*, (2012).

Materials and methods

The Study Area: The study was conducted in Dutse Local Government Area located in the North western corner of Nigeria on Latitude 11° 704'N and Longitude 9° 34'E of the Greenwich Meridian. Dutse is bounded in the North by Taura local government, Birminkudu in the south and eastward by Kiyawa local government area while the eastern flank is bordered by Kano State. It has a projected population of 431,800 (NBS, 2022).

Sampling Techniques and Sample Size: A multi-stage sampling procedure (a three-stage) was used for this study. In the first stage, a purposive sampling of the neighboring communities to Federal University Dutse was made (Maja, Madobi, Gurungu, Sherifai, Hausawa, Bulori and Kargo) on the basis of their proximity to the University and the Jigawa State Agricultural Development Authority (JARDA), where it is expected that agricultural extension services are incubated and delivered. Secondly, is a census of all households in the selected communities, where a total of 1,916 households were obtained through a survey. In the third stage, probability proportion to size (PPS) sampling method (a sampling procedure under which the probability of a unit being selected is proportional to the size of the ultimate unit) was employed to select a sample size of 184 households in the communities in accordance to stringent statistical considerations for sample size selection (Table 1). The sample size was systematically determined by the use of Yamane's and Bowley's proportion allocation formula at 7% margin of error and 95% confidence interval. This selection is supported by Nyarki (2009) who postulated the use of an error margin of less than 10% as a representative sample typical of agricultural socio-economic research.

Yamane's formula expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where

n = sample size

N = sample frame

e = precision level (7%).

The Bowley's proportion allocation formula was used to select respondents at each of the villages selected;

$$n_i = n \frac{N_i}{N}$$

Where

n_i = Sample size at i^{th} strata

n = total sample size.

Table 1: Sample Size

SN	Community	No. of Households (N)	Sample Size (n)
1	Maja	117	11
2	Hausawa	635	61
3	Sherifai	154	15
4	Bulori	163	16
5	Kargo	317	30
6	Gurungu	530	51
	Total	1,916	184

Source: JARDA 2022

Method of Data Collection: Primary data was collected from Millet and Sorghum farmers in the study area using a structured questionnaire. The questionnaire was segmented into different sections including a section where the socioeconomic characteristics of the household was assessed; information on the available agricultural extension service options that are meant for the minimization of post-harvest losses of Millet and Sorghum was gathered; the information on the availability of extension services on PHL management to Sorghum farmers in the study area was gathered, the causes of postharvest loss of Sorghum in the study area were identified and the limitations of farmers in accessing AESs in the study area was also identified.

Validity of the instrument: The questionnaire for the study was given to experts in the Department of Agricultural Economics and Extension of my University to ensure its validation. The comments and suggestions made by these experts were thoroughly used to modify the questionnaire before proceeding to the field for the data collection.

Method of Data Analysis

Objectives	Analytical Tool
Describe the socio-economic characteristics of Millet and Sorghum farmers in the study area.	Descriptive Statistics
Identify the sources of postharvest information in the study area.	Descriptive Statistics
Assess the availability of extension services on PHL management to Millet and Sorghum farmers in the study area.	Descriptive Statistics
Identify the causes of postharvest loss of Millet and Sorghum in the study area.	Descriptive Statistics

Identify the limitations of farmers in accessing AESs in the study area.

Descriptive Statistics

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Respondents

Table 3A: Socioeconomic Characteristics of the Respondents

Variables	Frequency	Percentage (%)	Mean $\pm$ SD
Age (Years)			
20-30	21	22.8	36.8 $\pm$ 12.8
31-40	89	39.1	
41-50	47	27.2	
51-60	20	10.9	
61 and above	7		
Total	184	100	
Gender			
Male	184	100	
Female	0	0	
Total	184	100	
Marital Status			
Single	38	20.7	
Married	146	79.3	
Divorced	0	0	
Total	184	100	
Educational Qualification			
No Formal Education	67	36.4	
Primary Education	82	44.6	
Secondary Education	30	16.3	
Tertiary Education	5	2.7	
Total	184	100	

Source: Field Survey 2023

As shown in Table 3A all the respondents were male and are within the average age range of 31-40 years. This shows that the respondents are within their active productive age range where energy is available for economic purposes, effective memory alertness and agility is higher. This is in line with the findings of Asaduet al who posited average ages of 40 for farmers in their study areas.

Most of the respondents (79.3%) were married. This is in line with the work of Oladipo, *et al.*, (2017), who agreed that 78.0% of the respondents in Sea Nut processing activity in Niger state were married. About average (44.6%) of the Millet and Sorghum farmers had primary education, 36.4% had no formal education, while 16.3% had secondary education. This implies that the respondents were not really educated as such may affect their understanding and adoption of Postharvest loss management Technology from Extension agents. Only few (2.7%) had tertiary education. This is in line with the findings of Asare *et al.*, (2015) that the education level of tomato farmers in Ghana was low.

Table 3B: Socioeconomic Characteristics of the Respondents continued

Variables	Frequency	Percentage (%)
Main Occupation		
Farming	57	31.0
Artisan	31	16.8
Traders	28	15.2
Civil servants	30	16.3
Others	38	20.7
Total	184	100
Frequency of contact with Extension		
Monthly	22	12.0
Quarterly	69	37.5
Yearly	93	50.5
Total	184	100
Availability of Agricultural Extension Service with regards to postharvest loss management		
Access	19	10.3
No access	165	89.7
Total	184	100
Membership of farmers' group		
Member	127	69.0
Not a member	57	31.0
Total	184	100

Source: Field Survey 2023

Table 3B shows the continuation of the socioeconomic characteristics of the respondents. From the table, the main occupation of the farmers is farming (31%), 16.8% are Artisans, 15.2% are Artisans, 16.3% are civil servants and 20.7% others. This is also the gap in registration according to Uduji & Okolo-Obasi, (2018a) seems to be a function of cultural practices. Some of the cultural practices in the country compel women to function under their husbands especially in the farming business.

As shown in the table, about 50.5% of the respondents agreed that they only had contact with the Extension agent only on a yearly basis while 37.5% agreed they had contact on a quarterly basis and 12.0% agreed they had contact with extension agents on monthly basis. . Also slightly above average 52.2% agreed that there is no availability of extension service delivery with regards to Postharvest loss management technology of Millet and Sorghum in the study area. Umar *et al.*, (2015) findings that about 69.0% belongs to farmers' cooperatives and other social groups within the study area.

Sources of Postharvest Information

Table 4: Sources of Postharvest Information

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Variables	Frequency	Percentage
ADP/Extension agent	0	0
Radio/TV	22	12
Print media	44	24
Family and friends	118	64
Total	184	100

Source: Field Survey 2023

Table 4: shows the respondent's sources of information on Postharvest Loss management of Millet and Sorghum which are as follows: ADP/Extension agent (0%), Radio/TV (12%), Print media (24%), Family and friends (64%), this shows that average number of the respondents rely on Family and friends as major sources of their information on PHLM. This supports the research findings of Atoma and Akeni (2017) that lack of information can prevent innovation from adoption. And also a recent FAO report indicates that at global level, volumes of lost and wasted food in high income regions are higher in downstream phases of the food chain, but just the opposite in low-income regions where more food is lost and wasted in upstream phases (FAO, 2013).

Agricultural Extension Services available to the Farmers in the Study Area

Table 5: Agricultural Extension Services available to the Farmers in the Study Area

Variable	Yes	%	No	%
Field Meeting	23	12.5	161	87.5
Method and result Demonstration	37	20.1	147	79.9
Regular visit	26	14.1	158	85.9
Individual Farmer Training	71	38.6	113	61.4
Technical Services	39	21.2	145	78.8
Training/Advisory Services	51	27.7	133	72.3
Good Linkages (Institution and Farmers)	36	19.6	148	80.4
Climatic Change Information	44	23.9	140	76.1
None	103	56.0	81	44.0

Source: Field Survey 2023

Table 5: shows the Available AESs provided to farmers on post-harvest losses of Millet and Sorghum in the study area which are as follows; Field Meeting (12.5%), Method and result Demonstration (20.1%), Regular visit (14.1%), Individual Farmer Training (38.6%), Technical Services (21.2%), Training/Advisory Services (27.7%), Good Linkages (Institution and Farmers) (19.6%), Climatic Change Information (23.9%) and None (56.0%) this implies that, most of the agricultural extension services are not available to the farmers in the study area. According to Ajibola et al., (2015) the results finding that the only method demonstration in the group (mean=2.64) can be considered an effective method because it is close to the scale of 2 (effective). Other leading extension teaching methods and sources of information used by respondents in the study area such as 56 Ife Journal of Agriculture, 2022, Volume 34, Number 2 farm/home visits of individuals (mean=2.28), and telephone calls of individuals (mean=2.25) were falls within the scale of 1 (not effective). The least utilized sources and means of acquiring information by farmers were information contact and newspaper.

Causes of Postharvest losses among millet and sorghum farmers in the study area

Table 6: Causes of Postharvest losses

Causes	VE	%	E	%	NE	%	Mean Scores
Insect/Pest/Diseases	127	69.0	57	57.0	0	0	61.33
Under/Over Maturity	38	20.7	45	24.5	101	54.9	
Mechanical Damages	42	22.8	103	56.0	39	21.2	
Transportation	31	16.9	83	45.1	70	38.0	
Theft	82	44.6	56	30.4	46	25.0	
Storage	82	44.6	64	34.8	38	20.7	
Climatic Conditions	48	26.1	78	42.4	58	31.5	
Others	78	42.4	82	44.6	24	13.0	

Source: Field Survey 2023

Table 6 shows that the causes of postharvest losses of Millet and Sorghum are multiple in nature, and sometimes work together to inflict a serious damage on the crops. According to the result, the major causes of postharvest loss of Millet and Sorghum are insect pest and disease (69.0%), theft (44.6%) and storage (44.6%). This finding agree with that of Obse et al., (2021) that the causes of postharvest losses are diseases, insects, rodents, thefts, mechanical damage and storage techniques. This is also in line with Tor and Akpehe (2020) that pest and diseases causes 69.5% of postharvest losses of Fluted pumpkin.

Constraints of farmers in receiving Agricultural Extension Services Delivered

Table 7: Limitations of farmers in receiving Agricultural Extension Services Delivered

Limitations	Yes	Percentage %	No	Percentage
Limited number of Field Extension Officers/agents	142	77.2	42	22.8
Adoption of new harvesting technology	0	0	184	100
Poor communication skills by field extension workers	0	0	184	100
Irregular visit by extension workers/agents	184	100	0	0
Lack of updated information on PHL management of Millet and Sorghum	34	18.5	150	81.5
Lack of involvement of local leaders in activities	0	0	184	100
Lack of Infrastructural facilities	167	90.8	17	9.2
Lack of finance	106	57.6	78	42.4

Source: Field Survey 2023

Table 7: shows limitation of farmers in receiving agricultural extension services delivered in the study area which are; Irregular visit by extension workers/agents (100%), lack of infrastructural facilities (90.8%), limited number of field extension officers/agents (77.2%), lack of finance (57.6%) and lack of updated information on post-harvest loss management of Millet and Sorghum. According to a study by Mshenga et al. (2016), farmers in sub-Saharan Africa face various challenges in accessing and utilizing agricultural extension services, including limited extension coverage, low quality of services, lack of training for extension workers, and inadequate funding for extension programs. These limitations can hinder farmers' ability to adopt new technologies, improve their farming practices, and increase their productivity

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Conclusion and recommendations: The study identified the major causes of postharvest loss management of millet and sorghum in Dutse local government area of Jigawa state.; It is therefore recommended that farmers should imbibe the culture of timely harvesting and allow the grains to dry well before storage

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A Comparative Study of Biogas Production from Some Organic Wastes by Fungal Biodegradation at Room Temperature.

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Abstract

Society is today confronted with dwindling and depletion of fossil fuel, green house emission and the proliferation of wastes generated by municipalities, agriculture and industries. The conversion of these wastes to biogas will help in mitigating the above challenges. These challenges have necessitated research on the comparative study of the production of biogas from biodegradable organic wastes: elephant grass, maize cobs, maize chaff and saw dust in the presence of yeast at room temperature (25°C) and slurry condition of ratio 4g to 30cm³. Elephant grass, sawdust, maize cobs and maize chaff were dried in the sun for about two weeks and ground to fine particles separately in different mortars. 4g of each sample was weighed separately and placed in different digesters. 0.6g of yeast and 30cm³ of water was added to the samples in the four different digesters. The results showed that maize cobs produced 245 cm³ of biogas, elephant grass produced 235 cm³ of biogas, sawdust and maize chaff produced 116 cm³ and 670 cm³ of biogas respectively. Maize chaff was found to produce the highest yield of biogas. Therefore, for maximum production of biogas, maize chaff is preferable above others. The graphs plotted show a similar pattern. It increases gradually for the first few days and a sudden rise as the days progress and finally reach a plateau (constant).

KEY WORD: Comparative, biodegradable, Slurry, organic waste, Biogas, yeast and digester.

Introduction: Conventional fertilizers are prone to leaching, degradation, volatilization and poor absorbance by crops, contributing to economic decline and severe environmental pollution (groundwater contamination and air contamination), soil acidification, heavy metal contamination and eutrophication of freshwater bodies (Savci, 2012). On the other hand, the periodic dosing of fertilizer also results in increasing acidity and toxicity levels, which may affect the growth of certain agricultural species (Singh *et al.*, 2012). The use of Biocontrol agents will help in mitigating nutrient loss. Biocontrol agents are inorganic or organic substances that have the potential to mitigate loss of nutrient in fertilizer by slowing down its release and thereby making it to have long-lasting effect (Jianye *et al.*, 2020). They achieve this by forming a weak bond with the fertilizer and gradually release the nutrients to crops. This action helps to prevent leaching, volatilization and degradation of fertilizer applied to crops.

Biocontrol agents fulfill different functions, which include reducing, volatilization of fertilizer, prevention of leaching of nutrients and better distribution of fertilizer in soil or plants. (Swarcewicz *et al.*, 1998). The above functions are so vital in the prevention of air and water pollution which is caused by volatilization or leaching of fertilizer. Nutrient uptake and protection are paramount to food security. Control of leaching, degradation and volatilization by biocontrol agents has a way of sustaining food security since it boosts or enhances maximum crops production. The technology of using biocontrol agents in mitigating nutrients loss in conventional fertilizers will help in improving the efficiency of fertilizer and prolonging their efficacy in plants and on the long run revolutionizes agriculture and food system (Sanjeev *et al.*, 2016).

The Challenges in the use of conventional fertilizers: The world population growth rate is 1.05% and is expected to reach 9 billion people by the end of 2050. Food demand will increase with the increasing population and this will require about 60% more food demand than the existing food demand worldwide (Purnomo & Saputra, 2021). Fertilizers are essential source of nutrients for plants to meet the global food demand. Most growers use synthetic fertilizers such as urea, ammonium nitrate, sodium nitrate, potassium nitrate, and calcium ammonium nitrate. Among all fertilizers, urea is widely used in agriculture, and overfertilization can cause severe damage to crops. The quick release of traditional urea causes fertilizer burn to plants and severe damage to the environment by leaching nitrate into groundwater, ammonia volatilization and nitrous oxide emissions. To overcome conventional fertilizer issues, the application of slow release or controlled release fertilizers (CRFs) application is recommended (Azeem *et al.*, 2014). CRFs proved a safer, economical, and efficient way to provide nutrients to meet crop demand. CRFs also help to improve nutrient use efficiency (NUE) and reduce environmental damage through their controlled release actions (Chen *et al.*, 2018).

Classifications of Biocontrol Agents: Biocontrol agents used in some fertilizers can be classified as inorganic materials, Synthetic polymer materials and natural polymer materials. Inorganic materials are sulphur, gypsum (Ibrahim et al.,2014), Magnesium lime (Babadi, et al.,2014), zeolite (Dubey & Mailapalli,2019), formaldehyde(Wang, et al, 2022) and so on. Synthetic polymer materials include polyurethane (li et al.,2016), aliphatic polyesters (Ye et al.,2020) , polyvinyl alcohol (Sarkar &Sen, 2018) and others. The natural polymer materials are starch (Dubey &Mailapalli,2019) guar gum, alginate, gelatin, chitosan and carboxyl methyl cellulose (plant cell wall).

Technology of Biocontrol Agents in Fertilizers: Technology involves basically three major processes, which are the coating of the fertilizer with a suitable biocontrol agent (Yang et al.,2013) and the reaction of the required biocontrol agents with fertilizer (Wang et al., 2022) and binding of the fertilizer with the required biocontrol agents (Dubey &Mailapalli,2019). This technology can be classified as follows:

1 (physical method): Coating materials are typically made up of two categories, namely inorganic materials and organic polymers. Inorganic materials include sulphur, bentonite, and phosphor-gypsum while organic polymers can be either synthetic polymers, such as polyurethane, polyethylene, alkyl resin, etc., or natural polymers such as starch, chitosan, cellulose and others (Trenkel, 2010). Additionally, recent studies show that organic materials such as biochar, rosin and polyphenol are being utilized (Wang *et al.*, 2020). Different combinations of these materials were explored to examine the effect on the release rate of urea and to determine their possibility as coating materials for CRFs(control release fertilizers). Physical method also include the use of starch, molasses, corn, hydroxyl methyl cellulose as binders to bind the biocontrol agents and fertilizer. Hermida & Agustian (2019) formulated CRF by incorporating bentonite using starch and hydroxypropyl methylcellulose (HPMC) binders.

2 **Chemical method:** The involve the chemical reaction of biocontrol agents with the fertilizer. Examples include the used of nanotechnology to develop urea-hydroxyapatite (HA) nanohybrid as control release fertilizer (Kottogoda *et al.*,2017). Release studies in water showed that the Urea-HA nanohybrid CRF released urea slowly for up to a week. This was attributed to the moderately strong bond between the amine group of urea and carbonyl group of hydroxyapatites and the chemical reaction of urea and formaldehyde to produced urea formaldehyde (Wang et al.,2022).

Significance of Biocontrol Agents: With the exponential growth of global population, the agricultural sector is bound to use large quantities of fertilizers to produce food for the large population. Fertilizers applied to crops are vulnerable to losses from volatilization, leaching and poor absorbance by plant, which may affect growth of plant and result to contamination of ground water, soil acidification and eutrophication of water bodies. The used of these biocontrol agents in the formulation of biocontrol release fertilizers will go a long way in mitigating the loss of plant nutrients through leaching and volatilization of fertilizers and on the long run prevent groundwater contamination, soil acidification, heavy metal contamination and eutrophication of freshwater bodies (Savci, 2012). The use of biocontrol agents in conventional fertilizers will also help to improve the efficiency of fertilizer and there by boost maximum yield of crops.

Conclusion: The technology of the use of biocontrol agents which are also know as nanoparticles should be maximally harness in Nigeria so as to mitigate nutrients loss in fertilizer through volatilization, leaching and degradation. This will also ensure the efficiency of fertilizer and maximum yield of crops. Ground water pollution, soil acidification and eutrophication of water bodies will be reduced by this technology.

Recommendation: The following recommendations are made in the use of biocontrol agents in fertilizer;

Government should harness this technology extensively in Agriculture so as to boost food production; Government should ensure the right biocontrol agents are used for different fertilizers; Government should ensure the use of biocontrol agents that are less expensive in the formulation of control release fertilizer

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Determinants of Choice of Market Outlet and Marketing Strategies for Cassava Tubers in Ebonyi State, Nigeria

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ABSTRACT

The study investigates the determinants influencing the choice of market outlets and marketing strategies for cassava tubers in Ebonyi State, Nigeria. Using a multi-stage random sampling technique, data were collected from 120 marketers and analyzed through descriptive statistics and multinomial logit models. Findings show that cassava tuber marketing is predominantly carried out by youthful and female marketers, with an average age of 36 years and 72.5% of respondents being female. Farm gate sales were the most preferred marketing outlet, favored by 57.5% of marketers, followed by rural markets (30.83%) and urban markets (11.67%). Price adjustment emerged as the dominant marketing strategy, adopted by 48.33% of marketers, with improved product (27.50%) and promotion strategies (24.17%) trailing. Multinomial logit results reveal that education ($p < 0.10$), cooperative membership duration ($p < 0.01$), marketing experience ($p < 0.01$), and entrepreneurial training ($p < 0.01$) positively influence the likelihood of choosing rural and urban markets and adopting improved marketing strategies, while age ($p < 0.01$) and distance to market ($p < 0.01$) negatively affect these choices. Economic analysis indicates that cassava marketing is profitable, with marketers selling an average of 47 bags per month and earning a mean monthly profit of ₦166,442.05, but marketing efficiency is low (23.06%) due to high operational costs. The major constraints identified include high transportation costs (mean = 3.525), perishability (mean = 3.450), seasonal production fluctuations (mean = 3.325), and labor expenses (mean = 3.192). The study concludes that socio-economic factors such as education, cooperative membership, marketing experience, and entrepreneurial training significantly enhance marketers' participation in more profitable rural and urban outlets and adoption of advanced marketing strategies in Ebonyi State.

Key words: Determinants, Choice of Market Outlets, Marketing Strategies, Cassava Tubers

INTRODUCTION: Cassava (*Manihot esculenta*) is a crucial staple crop grown widely across Nigeria and Sub-Saharan Africa due to its adaptability and high resilience to adverse environmental conditions. It plays a significant role in food security, particularly among rural populations that rely on it for both consumption and income. Nigeria is recognized as the world's leading cassava producer, with an estimated output of 59.1 million metric tonnes as of 2020 (FAOSTAT, 2020). Cassava cultivation occurs in 24 of Nigeria's 36 states, largely managed by smallholder farmers with an average yield of 10.6 tonnes per hectare (Rahman & Awerije, 2016; Okebiyorun & Jatto, 2017).

Global trends reflect an upward trajectory in cassava production, with Africa contributing approximately 61% of the world's total—a figure expected to rise to 62% by 2025 (FAOSTAT, 2020). Nigeria alone accounts for 20% of global cassava output, surpassing major producers like Indonesia, Thailand, and Brazil (FAOSTAT, 2020). Between 2007 and 2017, Nigeria recorded a 37% increase in production, underscoring the growing domestic and international relevance of the crop as a cornerstone of food systems and agricultural output (FAOSTAT, 2020).

Cassava's widespread cultivation is attributed to its agronomic versatility. The crop is notably drought-tolerant and can grow in nutrient-poor soils, making it well-suited to regions with low-nutrient rich soil and erratic climatic conditions. It thrives in tropical environments between 30°N and 30°S latitude, at elevations ranging from sea level to 2,000 meters, and under varying rainfall conditions from 50 mm to 5,000 mm annually (Rahman & Awerije, 2016). These characteristics position cassava as a strategic crop for mitigating the impacts of climate change and land degradation in marginal farming areas. Beyond its agricultural benefits, cassava significantly contributes to rural livelihoods. The International Fund for Agricultural Development (IFAD) estimates that over 600 million people in Africa depend on cassava as a staple food source (IFAD, 2019). In Nigeria, cassava is processed into diverse consumables such as garri, fufu, and flour, which are integral to daily diets. Additionally, the crop has expanding industrial and export value, particularly in the production of starch, ethanol, and animal feed, enhancing its commercial significance (IFAD, 2019).

However, cassava farming in Nigeria is not without its constraints. Key challenges include limited access to improved planting materials, inadequate storage infrastructure leading to post-harvest losses, and weak market linkages. Furthermore, climate-related threats such as unpredictable rainfall patterns and flooding continue to disrupt production cycles (Rahman & Awerije, 2016). Addressing these barriers through targeted policy measures, scientific innovation, and extension services is critical for ensuring the sustainability and productivity of cassava farming in Nigeria (Okebiyorun and Jatto, 2017).

According to Angba *et al.*, (2020) agricultural development cannot occur without improved and efficient marketing. This is because marketing is one of the significant aspects of Nigerian agriculture. Agricultural marketing is the performance of all the activities involved in the flow of agricultural products and services from the initial points of production until they reach the hands of the ultimate consumers (Angba *et al.*, 2020). Poor trading systems of some crops and their products partly lead to the inherent inefficient agricultural commodity

marketing in Nigeria. It is interested in everything that happens to crops after they leave the farm gate; making decision, taking actions and bearing the responsibility of the action. Agricultural marketing also articulates all processes that take place from when the farmer plans to meet specified demands and market prospects to when the producer finally gets it to the consumers (Angba et al., 2020).

Agricultural marketing starts with the farmer's decision to produce saleable farm commodities involving all aspects of marketing structure or system both financial and institutional with economic considerations including products assembly, preparation for the market, distribution and use by the final consumer. It comprises of all the activities from production to consumption such as harvesting, grading, packaging, storing, price fixation, selling and buying (Angba and Iton, 2020).

The choice of market outlets for cassava tubers refers to the decision-making process involved in selecting the specific channels or locations through which cassava tubers are sold and distributed to customers (Angba et al., 2020). This decision may involve considerations such as whether to sell directly to consumers at local markets, supply to wholesalers, partner with food processing companies, export to international markets, or process the cassava tubers into value-added products for specific industries. The choice of market outlets is an important aspect of marketing and distribution strategy for cassava tubers, as it directly impacts on how the product reaches its intended customers and end-users. Moreover, better choices help to reduce post-harvest losses, ensure adequate returns to farmers' investment and expansion in food production (Angba and Iton, 2020). Therefore, marketing of cassava tubers requires relevant strategy that are reliable at the lowest cost.

Strategic marketing of cassava tubers involves developing a plan to effectively promote and sell cassava tubers in the market. This may include identifying target markets, understanding consumer preferences, creating a unique selling proposition, and implementing promotional strategies to differentiate the product from competitors. It also involves considering factors such as pricing, distribution channels, and branding to maximize the value of cassava tubers in the market. According to Angba et al., (2020), marketing strategy is a plan used by any enterprise in business to achieve its marketing goals by focusing on a particular market segment. Strategic marketing among the cassava tuber marketers is something inherent to their actual performance; as they must seek continuous growth with the aim of maintaining their sales and profit levels, for them to survive commercially. Commercialization then helps to alleviate poverty in their households (Lawal *et al.* 2014). An enterprise's product positioning and service delivery depend on the performance and implementation of intellectual and good strategic plans. Thus, marketing has strong connection with financial performance. Sales volume has direct effects on the performance of a microenterprise hence the key concern is how they can expand their value chain activities for profits. An enterprise must go for a continuous growth with an aim of increasing or simply maintaining their sales and profits to guarantee their survival in the market (Angba and Iton, 2020).

Marketing strategies that cassava tubers marketers use are not limited to pricing strategy, product (sales) promotions, improved products (commonly known as value addition) and formation of strategic marketing alliance (Jokotola et al., 2020). It also involves market penetration strategy, which refers to efforts to increase the sales of an enterprise (market share) through the application of ideal marketing strategies that include pricing, product promotion, value addition and marketing partnership. Market penetration strategy seeks to increase the sales of present products and services in present markets (Mwiti, 2009). In cassava marketing, market penetration is both a measure and a strategy. As a measure, it helps them quantify market percentage captured by their products. Moreover, as a strategy leads into capturing large market shares quickly relative to otherwise and it transforms into growth in the marketers having their main goal of making profits achieved (Jokotola et al., 2020).

Therefore, the marketers are expected to offer high-quality commodities fetching high prices for better farming returns. This however are faced with both strategic and choice market outlets decisions, which has resulted in an overlap between strategic farming and marketing. Thus the need of this study on determinants of choice market outlets and marketing strategies for cassava tubers.

Marketing is one of the key activities in any enterprising entity; thus, in making effective decisions to sell and outperform competitors, each enterprise requires good knowledge in strategic marketing. One of the challenges faced by cassava marketers while handling commodities is failure to use appropriate marketing strategies that would enhance positions and margins. According to Jokotola et al, (2020) appropriate marketing strategies helps to offset the poor positioning of cassava products in the markets while giving them comparative advantages through relatively higher returns for the sustainable livelihoods on cassava.

In many sub-Saharan African countries, like Nigeria smallholder farmers typically have a choice between selling their products to brokers, who travel back-and-forth between villages and markets or transporting their products themselves to the nearest market Kolawole *et al.*, (2017). The different market avenues affect the share of the benefit that goes to farmers. Brokers may take advantage of a farmer's ignorance of the market price, seeking to extract a rent from them by offering very low prices for their products (Kolawole *et al.*, 2017). Access to better-paying markets for agricultural products is vital in enhancing and diversifying the livelihoods of poor subsistence or semi-subsistence farmers (Khan *et al.*, 2017).

However, in Ebonyi State, Nigeria there are limited information about choice of market outlets and marketing strategies of cassava tubers, hence their economic significance not well known. There is need to identify and improve on potential and profitable marketing strategies and better outlets for improved performance of cassava marketers. Without such information, cassava tuber farming will remain unattractive to both present and future generations. This study sought to bridge the gaps through the establishment of the choice market outlets and marketing strategies of cassava tubers. These justifications are useful during the identification of investment niches towards sustainable growth among cassava enterprises in Ebonyi State.

More realistically researchers have not beamed their search light on seeking for empirical evidence on choice market outlets and marketing strategies of cassava tubers in Ebonyi State, Nigeria. Some of the scholars focus their research separately on profitability, choice of market outlet and marketing strategies in their studies; without key focus on market outlet and marketing strategies. Also, most of the studies were carried out outside the study location, Ebonyi State. For instance Ngenoh *et al.*, (2020) analyzed the factors that influence the choice of marketing strategies among tuber marketers in cassava microenterprises in Kenya; Manganyi *et al.*, (2023) assessed the factors influencing cassava sales and income generation among South African cassava farmers; Akubo *et al.*, (2023) examined economics of small-scale cassava processing in Adavi Local Government Area of Kogi State; Adejobi and Adeyemo (2020) examined the nature and determinants of marketing channel levels in the cassava tuber and cassava products markets in the study area; Nwokugha and Ikeokwu (2023) assessed the internet marketing of Cassava tubers and its implications to Nigeria cashless policy in Port Harcourt metropolis, Rivers State; Osakue *et al.*, (2023) studied the profitability of cassava marketing in rural and urban markets in Edo South Agro-Ecological Zone, Edo State, Nigeria; Eze *et al.*,

(2023) examine the efficiency of the marketing systems of cassava in Southeast, Nigeria. These empirical evidence has shown that research on choice market outlets and marketing strategies of cassava tubers in Ebonyi State, Nigerian is grossly insufficient, and has hitherto suffered lack of attention from researchers and food policy makers especially in the study area.

It is against this knowledge gap that this study was designed to analyse the determinants of choice market outlets and marketing strategies of cassava tubers in Ebonyi State, Nigeria.

Materials and Methods

Study Area and Sampling Technique: The study was conducted in Ebonyi State, Nigeria. A multi-stage random sampling technique was used in selecting 120 cassava tuber marketers from the three Agricultural Zones. Data for this study were collected from primary sources. A well-structured questionnaire and oral interview was used to illicit information from the cassava tuber marketers. To describe the socio-economic characteristics of cassava tuber marketers in the study area was achieved using simple descriptive statistics like frequency table, means and standard deviation, and cross tabulation and which is to identify the various cassava tuber marketing outlets and analyze the determinants of choice of the identified marketing outlets in the area was analyzed using descriptive statistics and multinomial logit model

Multinomial logit model for choice of market outlet: The Multinomial logit model was used for determinants of choice of the identified marketing outlets in the area. Let P_{ij} represent the probability of choice of any given market outlet by cassava farmers, then equation representing this was:

$$P_{ij} = \beta_0 + \beta_1 X_1 + \dots + \beta_k X_k + e \quad (3.1)$$

Where i takes values (1, 2, 3), each representing the choice of marketing outlet (farm gate =1, rural =2, urban =3). X_1 are factors affecting choice of a market outlet, β are parameters to be estimated and e is randomized error. With j alternative choices, the probability of choosing outlet j is given by,

$$\text{Prob}(Y_i = j) = \frac{e^{Z_{ij}}}{\sum_{k=0}^j e^{Z_{jk}}} \quad (3.2)$$

Where Z_{ij} is a choice and Z_{jk} is alternative choice that could be chosen (Greene, 2000). The model estimates were used to determine the probability of choice of a market outlet given j factors that affect the choice X_1 . With a number of alternative choices log odds ratio is computed as:

$$\ln \left(\frac{P_{ij}}{P_{ik}} \right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + e_i \dots \dots \dots (3.3)$$

P_{ij} and P_{ik} probabilities that a farmer chooses a given outlet and alternative outlet respectively. is a natural log of probability of choice j relative to probability choice k , α is a constant, is a matrix of parameters that reflect the impact of changes in X on probability of choosing a given outlet, e is the error term that is independent and normally distributed with a mean zero.

The multinomial Logit model is empirically given below as:

$$P_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \epsilon_i \dots \dots \dots (3.4)$$

Where,

P_{ij} = Choice market outlets

It takes values (1, 2, 3), each representing the choice of marketing outlet (farm gate =1, rural =2, urban =3).

- X_1 = Age of the cassava tuber marketers (Years)
- X_2 = Household sizes for cassava tuber marketers (Number of persons)
- X_3 = Education level for cassava tuber marketers (Years)
- X_4 = Cassava output (Kg)
- X_5 = Vehicle Ownership (1=yes; 0=otherwise)
- X_6 = Years of Cooperatives Experience (measured in year)
- X_7 = Gender of cassava tuber marketers (Male =1, female =0)

- X_8 = Distance to the preferred market (Km)
- X_9 = Experience (Years)
- X_{10} = Entrepreneurial trainings received by cassava tuber marketers (number)

ϵ_i = error term

Results and Discussion

SOCIO-ECONOMIC CHARACTERISTICS OF CASSAVA TUBER MARKETERS IN RELATION TO CHOICE OF MARKET OUTLET AND MARKETING STRATEGIES: The socio-economic characteristics of cassava tuber marketers in relation to choice of--the most preferred market outlet and marketing strategies are shown in Table1.

Table 1: Cross tabulation of socio-economic characteristics of cassava tuber marketers in relation to choice of market outlet and strategies

Market choice

Marketing strategies

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PROCEEDINGS

Variables	Frequency	Percentage	Farm gate	Rural	Urban	Price	Promotion	Improved
Age (years)								
19 – 28	39	32.50	12	11	2	4	0	0
29 – 38	27	22.50	14	7	1	9	6	0
39 – 48	40	33.33	23	5	6	10	6	4
49 – 58	13	10.83	12	8	3	14	11	18
59 – 68	1	0.83	8	6	2	21	6	11
Mean	36							
Sex								
Male	33	27.50	56	12	6	44	11	15
Female	87	72.50	13	25	8	14	18	18
Household size								
1 – 5	59	49.17	12	2	2	12	16	8
6 – 10	42	35.00	22	12	5	18	0	14
11 – 15	19	15.83	35	23	7	28	13	11
Mean	6							
Marital status								
Married	63	52.50	45	14	11	41	19	24
Otherwise	57	47.50	24	23	3	17	10	9
Education								
No formal education	4	3.33	18	6	1	5	2	9
Primary	27	22.50	16	11	3	9	9	5
Secondary	64	53.33	21	14	4	19	8	12
Tertiary	25	20.83	14	6	6	25	10	7
Experience								
1 – 5	16	13.33	11	4	0	8	4	2
6 – 10	62	51.67	15	7	4	12	5	8
11 – 15	15	12.50	16	14	3	15	7	11
16 – 20	27	22.50	27	12	7	23	13	12
Mean	10							
Cooperatives								
No	34	28.33	29	16	5	19	16	11
Yes	86	71.67	40	21	9	39	13	22
Total	120	100.0	69	37	14	58	29	33

Source: Field survey, 2025

The average age of cassava tuber marketers in Ebonyi State is 36 years, indicating that the industry is dominated by relatively young and economically active individuals. The most represented age group was 39–48 years, accounting for 33.33% of the respondents. This group showed a strong preference for farm gate sales, a trend that suggests minimal exposure to broader or more formal markets. This reflects a limited level of commercialization and innovation. According to Akubo et al. (2023), small-scale cassava processors in Kogi State similarly operated within constrained environments, favoring informal markets due to lack of capital, poor market access, and inadequate value-addition facilities. The average household size is 6 members, which is typical in agrarian communities. Households with 1–5 members made up the largest group (49.17%), yet they had low participation in rural and urban markets, focusing mainly on farm gate sales. However, they recorded the highest use of promotional strategies (16). These observations support findings by Asogwa and Okwoche (2018), who argue that household labor availability plays a significant role in determining the scale and strategic direction of smallholder marketing decisions. Cassava marketers in Ebonyi State had an average of 10 years of marketing experience. The majority had 6–10 years of experience (51.67%), and this group primarily sold at the farm gate (15) and to a lesser extent in rural and urban markets. Despite their years in the trade, they showed only limited use of advanced marketing strategies, with 12 adopting price mechanisms and 8 adopting improved product strategies. This suggests that experience, while important, may not directly lead to market innovation unless accompanied by training and support services. In a similar vein, Angba and Iton (2020), in their study of cassava producers in Cross River State, observed that even experienced farmers often failed to access modern marketing tools and channels, due to a lack of extension services and education. Marital status also significantly influenced market behavior. Married respondents (52.5%) participated more broadly across market outlets—45 sold at the farm gate, 14 in rural markets, and 11 in urban areas. They also dominated in the use of marketing strategies: 41 used pricing, 19 used promotion, and 24 engaged in product improvement. Amanze et al. (2020) noted similar findings in Imo State, where married farmers were more risk-averse yet more committed to adopting income-enhancing strategies, especially where household livelihood security was at stake.

Gender distribution revealed that females represent 72.5% of marketers. Interestingly, despite their dominance, they were underrepresented in farm gate sales (13) compared to men (56). However, they were more active in rural (25) and urban (8) market outlets and equally adopted promotion (18) and product improvement strategies (18) as compared to their male counterparts. Enimu et al. (2016) found similar patterns in Cross River State, where women were more engaged in cassava processing and market interactions despite limited access to credit, land, and formal training. Education level was another critical factor. The majority of marketers had secondary education (53.33%), while 20.83% attained tertiary education. Interestingly, those with tertiary education showed a greater tendency to use price-based strategies (25) and product innovation, indicating that higher education levels may empower marketers with the confidence and knowledge to engage in more strategic marketing practices. A total of 71.67% of respondents belonged to cooperatives. These members had broader engagement across all market outlets: 40 sold at the farm gate, 21 in rural areas, and 9 in urban markets. They were also significantly more involved in strategic marketing, particularly in pricing (39) and product improvement (22). This confirms findings by Asogwa and Okwoche (2018) and Enimu, Igiri, and Oduma (2015), who documented the positive role of cooperatives in increasing farmers' access to credit, information, extension services, and collective marketing platforms.

CHOICE OF MARKETING OUTLETS FOR CASSAVA TUBERS AND ESTIMATE THEIR DETERMINANTS

Distribution of the cassava farmers based on the most preferred marketing outlet and determinants of choice of marketing outlets for cassava tubers is summarize and presented in Table 2 and Table 3

Choice of Marketing Outlets for cassava tubers

Distribution of the cassava farmers based on the most preferred marketing outlet is summarize and presented in Table 2

Table 2: Distributions of Respondents according to most preferred marketing outlet

Variables	Frequency	Percentage

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Farm gate	69	57.50
Rural	37	30.83
Urban	14	11.67
Total	120	100.00

Source: field survey, 2025

The data presented in Table 4.2 highlights the distribution of cassava tuber marketers in Ebonyi State according to their most preferred marketing outlets. The results indicate that a significant proportion of respondents (57.50%) prefer to sell their produce at the farm gate, followed by 30.83% who sell in rural markets, while only 11.67% utilize urban markets.

The dominance of farm gate sales suggests that the majority of cassava marketers operate within localized and informal market structures. This preference is likely attributable to factors such as immediate cash transactions, absence of transportation costs, and reduced risks associated with post-harvest losses. However, while farm gate marketing offers convenience, it tends to expose marketers to unfavorable pricing conditions due to limited bargaining power and market competition. As highlighted by Nandi et al. (2021) in their economic analysis of cassava production in Obubra Local Government Area of Cross River State, farm gate sales are often characterized by asymmetrical power relations, where buyers dictate prices due to farmers' urgent need to dispose of perishable produce and lack of market alternatives. Rural markets, preferred by 30.83% of respondents, represent an intermediate option. They offer broader buyer participation than the farm gate and allow for slightly more competitive pricing. However, these markets are still affected by seasonal demand fluctuations, inadequate storage infrastructure, and limited consumer purchasing power. As the Nigerian Institute of Social and Economic Research (2017) observed, the absence of efficient post-harvest systems in rural areas contributes to significant produce losses, thereby reducing the overall profitability of agricultural marketing in such settings.

The relatively low preference for urban markets (11.67%) is indicative of deeper structural challenges in cassava marketing. Urban centers offer access to higher-value markets, better pricing, and opportunities for value addition, including peeling, packaging, and processing. However, entry into these markets is often constrained by high transportation costs, poor road network, and inadequate market information. This pattern supports the findings of Ngenoh et al. (2020), who emphasized that access to marketing information, capital, and logistics logical significantly influence smallholder marketers' ability to engage with distant or urban markets. The limited urban market participation in Ebonyi State suggests that most marketers lack the operational capacity or institutional support needed to reach such destinations. Furthermore, digital technology has been increasingly recognized as a critical enabler for market access. Ndubuisi (2017) noted that innovations in mobile platforms and digital communication tools have helped farmers in other parts of Africa bridge the gap between production and markets by providing real-time access to pricing, weather, and buyer information. The low engagement with urban markets in the current study suggests that such digital interventions are either unavailable or underutilized among cassava marketers in Ebonyi State, thus limiting their ability to plan strategically or access distant, higher-paying buyers. From a broader macroeconomic perspective, the findings reflect a prevailing trend in Nigeria's agricultural sector, where subsistence-based production and informal marketing channels dominate. According to the National Bureau of Statistics (2017), agriculture remains a major contributor to national GDP, yet the majority of produce is traded informally, with limited integration into structured value chains. The underutilization of formal or urban markets therefore represents a missed economic opportunity for rural marketers and calls for policy-driven investment in infrastructure, cooperative formation, and market access programs.

Determinants of choice of marketing outlets for cassava Tubers : Estimate of the Multinomial Logistic Regression Results on determinants of choice of marketing outlets for cassava tubers is summarize and presented in Table 4.3. Likelihood Ratio (LR) Chi-Square Test: The LR chi-square statistic is 55.71 with 20 degrees of freedom, and the associated p-value is highly significant ($p < 0.001$). This indicates that the model as a whole provides a significantly better fit to the data compared to a null model with no predictors. In other words, the included explanatory variables jointly have a meaningful impact on predicting marketers' outlet choices.

Table 3: Multinomial Logistic Regression Results on determinants of choice of marketing outlets for cassava Tubers

Variable	Rural Market		Urban Market		Marginal Effect	
	Coef.	z-value	Coef.	z-value	dy/dx	z-value
Age of cassava marketers	-0.042	-13.31 ***	-0.019	-5.22 ***	-0.0095	-11.22 ***
Household size	0.386	0.97	-0.969	-1.14	-0.0786	-0.04
Education level	0.155	1.81 *	0.217	2.10 **	0.0380	2.61 **
Cassava output	0.014	0.26	0.054	0.82	-0.0037	-0.05
Vehicle ownership	0.701	1.25	-0.051	-0.08	-0.1603	-0.17
Years in cooperatives	0.508	1.95 *	0.195	6.22 ***	0.1152	12.17 ***
Gender (1 = Male)	-0.533	-0.75	14.862	0.02	0.0089	0.05
Distance to market	-0.243	-2.88 ***	-0.0079	11.29 ***	-0.0561	-0.19
Marketing experience	5.11e-06	3.82 ***	1.96e-06	0.10	1.16e-06	-0.12
Entrepreneurial trainings	1.48e-05	2.99 ***	6.99e-06	0.97	-3.50e-06	-0.44
Constant	-0.57	3.30***	-14.77	-3.07***		
Number of Observations	117					
LR Chi ² (20)	55.71					
Prob > Chi ²	0.0000					
Log Likelihood	-90.585					
Pseudo R ²	0.8352					

Source: Field Survey, 2025. Significance Levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Base Outcome: Farm Gate (Choice = 1).

Age negatively and significantly influences the choice of both rural and urban markets, with coefficients of -0.042 and -0.019 respectively, both significant at 1%. This indicates that as cassava marketers grow older, they are less likely to sell their produce in rural or urban markets relative to the farm gate. Education continues to have a positive and significant effect on the choice of marketing outlets for both rural (significant at 10%) and urban markets (significant at 5%), with coefficients of 0.155 and 0.217 respectively. The marginal effect of nearly 3.8% indicates that each additional year of education increases the probability of choosing rural or urban markets. Cooperative membership positively influences market choice, significant at 10% for rural markets and at 1% for urban markets, with coefficients of 0.508 and 0.195 respectively. The marginal effect of approximately 11.5% shows that each additional year of cooperative membership increases the probability of choosing rural or urban markets significantly. Distance has a negative and significant effect on rural market choice (coefficient = -0.243, significant at 1%). The marginal effect indicates that each additional kilometer reduces the likelihood of choosing rural markets by about 5.6%. Increased distance raises transportation costs, time, and reduces the viability of market participation for many smallholders (Olusoji et al., 2020). Improving rural infrastructure and reducing travel time could encourage greater market integration and choice diversification (Omotayo & Oladejo, 2016). Marketing experience has a small but significant positive effect on rural market choice (coefficient = 0.00000511, significant at 1%). Though the marginal effect is very small (approximately 0.0001%), it implies that accumulated experience marginally increases the probability of choosing rural markets. Experienced marketers likely develop skills to negotiate better prices, identify reliable buyers, and manage logistics more efficiently (Olaifa & Oyeniyi, 2016). Entrepreneurial training positively affects rural market choice (significant at 1%), although the marginal effect is positive but not statistically significant. Training likely enhances marketers' skills in financial management, business planning, and innovation adoption, which empowers them to engage more confidently in broader market outlets (Olutunla & Obamuyi, 2018). This highlights the importance of capacity-building programs in improving cassava marketing outcomes (Okebiorun & Jatto, 2017).

Conclusion and Recommendations: This study concludes that the choice of market outlets and marketing strategies for cassava tubers in Ebonyi State is significantly influenced by socio-economic characteristics such as education level, cooperative membership, marketing experience, and entrepreneurial training. Younger, more educated marketers who are members of cooperatives and have received entrepreneurial training are more likely to engage in rural and urban markets and adopt improved marketing strategies. The multinomial logit analysis showed that education, cooperative years, marketing experience, and entrepreneurial training had statistically significant positive effects ($p < 0.10$, $p < 0.05$, and $p < 0.01$), while age and distance to market negatively affected outlet and strategy choices ($p < 0.01$). These findings emphasize the importance of capacity building and support systems in enhancing cassava marketing outcomes.

The study also concludes that although cassava tuber marketing is profitable, it is constrained by high transportation costs, perishability, seasonality, and labour expenses. Marketing efficiency is relatively low (23.06%), largely due to high operational costs, even though market integration across farm gate, rural, and urban outlets is strong and statistically significant ($p < 0.01$). Marketing strategies also show partial integration, with price adjustment moderately correlated with promotion ($r = 0.462$, $p < 0.01$), but weakly related to product improvement. Overall, improving infrastructure, reducing marketing costs, and encouraging strategy integration are essential steps toward making cassava tuber marketing more efficient and sustainable in the state.

Based on the findings of this study, the following recommendations are made to address the objectives of the research and improve the marketing of cassava tubers in Ebonyi State:

- i. Since education, entrepreneurial training, and cooperative membership significantly influenced the choice of market outlets and marketing strategies, government agencies, NGOs, and agricultural extension services should intensify capacity-building programs. These should include regular workshops, business skills development, and market literacy training tailored specifically for cassava tuber marketers, especially women and young entrepreneurs, to improve their ability to access better markets and adopt value-driven strategies.
- ii. Findings showed that distance to markets and age negatively impacted participation in rural and urban markets. Therefore, there is a need for improved rural infrastructure, especially in road development and transportation systems, to reduce transaction costs and facilitate easier access to profitable markets. Supporting aged marketers with logistic services or market information platforms can also enhance their participation and competitiveness.
- iii. Given the dominance of price-based marketing and weak integration between promotional and product improvement strategies, stakeholders should promote diversified marketing practices. Extension services and cooperative societies should encourage and support marketers to engage in active promotion and product differentiation, such as improved packaging, branding, and quality enhancement, which are likely to increase consumer demand and profitability.
- iv. Since cassava marketing is profitable but challenged by high costs and low efficiency, it is essential to increase marketers' access to affordable credit facilities, storage technologies, and input subsidies. Government and private financial institutions should work to reduce financial exclusion by offering tailored credit schemes through cooperatives and marketers' associations to cushion costs associated with transportation, perishability, and labour.
- v. The strong integration between farm gate and other markets shows potential for efficient price transmission. However, to strengthen this further, the government should invest in market information systems that provide real-time data on prices, demand, and supply across markets. This will help reduce information asymmetry and improve marketers' decision-making. Strengthening linkages between producers and end markets through organized cooperatives or value chain partnerships can also foster better coordination and reduce marketing inefficiencies.

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Comparative Analysis of Compost and Phosphorus Fertilizers in Enhancing Nutritional Content of Pigeon Pea

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Abstract

*Pigeon pea (*Cajanus cajan*) is important leguminous crop, especially in tropical and subtropical regions, based on its high protein content and contribution to soil fertility. A field experiment was conducted at the Oyo State College of Agriculture and Technology, Igboora, to assess the comparative effects of compost and phosphorus (P) fertilizers on the nutritional composition of four pigeon pea varieties (NSWCC29A, NSWCC24, NSWCC34D and Otili). A Randomized Complete Block Design (RCBD) with treatments comprising compost, phosphorus fertilizer, and a control, each applied at varying rates was used. Harvested seeds were analysed for major nutritional parameters, including crude protein (CP), crude fat (CFAT), crude fiber (C.Fibre), Total ash (T.Ash), moisture content (MC), dry matter (DM), and nitrogen-free extract (NFE). All the data collected were subjected to analysis of variance (ANOVA) and means separated using Duncan Multiple Range Test at 5% level of probability. Results showed that compost application significantly enhanced seed quality, with increases in CP (24.39%), CFAT (2.62%), and NFE (51.49%) compared to phosphorus fertilizer (23.31% CP, 2.50% CFAT) and the control (21.17% CP, 2.21% CFAT). Compost also improved MC (8.09%) and T.Ash (5.36%), contributing to better overall crop quality. Statistical analysis revealed significant interactions among variety, fertilizer type, and application rate, indicating the importance of context-specific nutrient management. Application of 15 t/ha compost significantly improved the nutrition composition of NSWCC24. Integrating organic and inorganic fertilizers is recommended to optimize crop performance and support food security, particularly in regions where legumes are a dietary staple.*

Key word: Compost, Nutritional composition, Pigeon pea (*Cajanus cajan*), Grain yield and Soil fertility

Introduction: Pigeon pea (*Cajanus cajan*) is an important leguminous crop cultivated extensively in tropical and subtropical regions, prized for its high protein content and ability to enhance soil fertility through nitrogen fixation. It serves as a staple food source for millions, providing essential nutrients and contributing to food security in many developing countries. The nutritional quality of pigeon pea is significantly influenced by soil fertility management practices, particularly the application of fertilizers. Effective nutrient management is vital for optimizing crop yields and improving the nutritional profile of legumes. Among the various fertilizers used, compost and phosphorus (P) fertilizers are widely recognized for their potential to enhance soil nutrient availability and improve crop performance. Compost, derived from organic waste materials, not only supplies essential nutrients but also improves soil structure, increases water retention, and promotes beneficial microbial activity. This organic amendment plays a significant role in sustainable agriculture by reducing dependency on chemical fertilizers and enhancing soil health.

Phosphorus, on the other hand, is a critical macronutrient that influences various physiological processes in plants, including energy transfer, photosynthesis, and root development. Phosphorus deficiency is a common limitation in many soils, adversely affecting crop yield and nutritional quality. The application of phosphorus fertilizers can mitigate these deficiencies, leading to improved growth and higher nutritional content in crops, particularly in phosphorus-deficient soils.

The application of compost as an organic amendment has been shown to improve soil health and enhance the nutritional quality of crops. Compost enriches the soil with essential nutrients, such as nitrogen, phosphorus, potassium, and various micronutrients, which are critical for plant growth. Additionally, it improves soil structure by increasing organic matter content, leading to better aeration and water retention.

This enhanced soil environment increases microbial activity, which plays a crucial role in nutrient cycling and availability. Collectively, these factors contribute to better nutrient uptake by plants, resulting in healthier and more productive crops (Zhao *et al.*, 2022). Recent studies indicate that compost application can significantly increase the protein and micronutrient content in legumes, including pigeon pea, by enhancing the bioavailability of nutrients in the soil. This is particularly important in regions where soil fertility is declining due to intensive agricultural practices, as compost serves as a sustainable solution for improving soil health and crop quality (Singh *et al.*, 2023).

Phosphorus is a vital macronutrient that plays a critical role in various physiological processes in plants, including energy transfer, photosynthesis, and root development. It is essential for the formation of ATP (adenosine triphosphate), which is necessary for energy transfer in biochemical reactions (Ali *et al.*, 2023). The application of phosphorus fertilizers has been found to improve the yield and nutritional quality of pigeon pea, particularly in phosphorus-deficient soils where natural availability is low. Research has shown that appropriate phosphorus fertilization can lead to increased root biomass and enhanced flower and pod development, ultimately resulting in higher seed yields and improved nutritional content (Kumar *et al.*, 2023). However, the effectiveness of phosphorus fertilizers can vary based on factors such as soil type, pigeon pea variety, and environmental conditions, necessitating a tailored approach to fertilization practices (Babu *et al.*, 2023). Several studies have explored the combined effects of compost and phosphorus fertilizers on crop performance. For instance, Verma *et al.*, (2023) demonstrated that the integrated application of compost and phosphorus not only enhanced the yield of pigeon pea but also improved its nutritional profile, suggesting that such practices could be beneficial for sustainable agriculture. The synergistic effects of these amendments can lead to improved nutrient cycling and enhanced soil fertility, ultimately benefiting crop production. By combining organic and inorganic fertilizers, farmers can optimize their nutrient management strategies, promoting both environmental sustainability and agricultural productivity (Kumar *et al.*, 2023).

MATERIALS AND METHODS: A field experiment was conducted at Experimental field and Central Laboratory of Oyo state College of Agriculture, Igboora, This was located on latitude 72612.57"N and 317°18.77"E, attitude of 140m above the sea level. It has an average annual rainfall of 1,278mm with average annual temperature of 27°C to 32°C. The experiment was arranged in a randomized complete block design (RCBD) with three replications. The treatments consisted of different pigeon pea varieties, amendments (compost and phosphorus), and varying rates of compost application 5 t/ha, 10 t/ha and 15 t/ha and Phosphorus 18 kg/ha, 36 kg/ha, and 72 kg/ha and control to assess the comparative effects of compost and phosphorus (P) fertilizers on the nutritional composition of four pigeon pea varieties (NSWCC29A, NSWCC24, NSWCC34D and Otili). At maturity, the pigeon pea seed were harvested, and samples were collected from each treatment for nutritional analysis. The following parameters were measured:

Crude Protein (CP): Determined using the Kjeldahl method.

Crude Fat (CFAT): Measured through the Soxhlet extraction method.

Crude Fiber (CFibre): Analyzed using the Van Soest method.

Total Ash (T.Ash): Measured by incinerating the samples at high temperatures.

Moisture Content (MC): Determined by drying the samples to a constant weight.

Dry Matter (DM): Calculated as the difference between the fresh weight and moisture content.

Nitrogen-Free Extract (NFE): Calculated using the formula: $NFE = 100 - (CP + CFAT + CFibre + T.Ash + MC)$.

Data collected from the experiment were subjected to analysis of variance (ANOVA) using statistical software. Mean comparisons were performed using the least significant difference (LSD) test at a significance level of 0.05. The interaction effects of variety, amendment, and rate were also analyzed to determine their influence on the nutritional composition of pigeon pea.

RESULTS AND DISCUSSION

Nutritional composition of the Pigeon pea varieties: NSWCC29A, NSWCC24, NSWCC34D, and Otili shows a significant differences across most parameters ($p < 0.05$), as shown in the table.

The crude protein content ranged from 23.11% to 23.30%, with no significant differences among the varieties. Significant differences were observed in crude fat content ($p < 0.05$). NSWCC34D had the highest fat content (2.73%), followed by NSWCC24 (2.57%), NSWCC29A (2.53%), and Otili (2.47%), which recorded the lowest. NSWCC29A, NSWCC24, and NSWCC34D had significantly higher crude fibre content compared to Otili, which had the lowest (4.81%). Ash content, representing total mineral content, also varied significantly ($p < 0.05$), with NSWCC29A (5.37%) and NSWCC24 (5.31%) showing higher values compared to NSWCC34D and Otili. Moisture content did not vary significantly among the improved varieties (ranging from 5.04% to 5.18%), except for Otili, which had a significantly lower moisture level (4.81%). Dry matter content was relatively consistent across all varieties, with values ranging between 91.60% and 91.70%, NFE, which includes digestible carbohydrates, varied significantly among varieties. NSWCC24 recorded the highest NFE (65.21%), followed by NSWCC34D (63.53%) and NSWCC29A (60.21%), while Otili had the lowest (41.78%).

Effects of Fertilizer Nutritional composition of the Pigeon pea varieties

Crude Protein (CP): The data indicate that compost significantly enhances the CP content of pigeon pea, with the highest value recorded at 24.39% in the compost treatment. This improvement can be attributed to the higher nitrogen content typically found in compost, which contributes to protein synthesis in plants.

Crude Fat (CFAT): The CFAT content was highest in the variety NSWCC34D (2.73%), with the compost treatment yielding a CFAT of 2.62%.

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Crude Fiber (CFibre): All pigeon pea varieties exhibited similar fiber levels, reinforcing the idea that compost can maintain or slightly enhance fiber content.

Total Ash (T.Ash): The T.Ash content, which reflects the mineral content of the crop, was highest in the compost treatment (5.36%).

Moisture Content (MC): The compost treatment showed a significantly higher moisture content (8.09%) compared to the control.

Dry Matter (DM): The DM content remained consistent across treatments, indicating that neither compost nor phosphorus adversely affected the overall biomass of the pigeon pea.

Nitrogen-Free Extract (NFE): The NFE, representing the carbohydrate content, was significantly higher in the compost treatment (51.49%) compared to the control (34.56%).

COMPARATIVE ANALYSIS OF COMPOST AND PHOSPHORUS FERTILIZERS IN ENHANCING NUTRITIONAL CONTENT OF PIGEON PEA

Variety	CP	CFAT	CFibre	T.Ash	MC	DM	NFE
NSWCC29A	23.13a	2.53bc	5.07a	5.37a	5.04a	91.60a	60.21a
NSWCC24	23.30a	2.57b	5.18a	5.31ab	5.18a	91.70a	65.21a
NSWCC34D	23.11a	2.73a	5.04a	5.17b	5.07a	91.65a	63.53a
Otili	23.19a	2.47c	4.81b	5.15b	4.81b	91.60a	41.78b
LSD	0.16	1.97	0.17	1.98	0.16	0.32	5.45
<u>Amendments</u>							
Compost	24.39a	2.62b	5.22a	5.36a	8.09a	88.13a	51.49a
Phosphorous	23.31b	2.50a	4.93b	5.25a	7.68a	88.12a	48.94a
Control	21.17c	2.21b	4.87b	5.04b	5.78b	56.76b	34.56b
LSD	0.84	0.52	0.14	0.17	0.79	7.42	3.96
<u>Rates</u>							
Compost 5 t/ha	22.78bc	2.58a	5.23a	5.25ab	8.56b	91.64a	56.83a
Compost 10 t/ha	23.05abc	2.57ab	5.27a	5.38ab	9.12b	91.59a	56.90a
Compost 15 t/ha	24.11ab	2.62a	5.16ab	5.45a	10.28a	91.72a	56.68a
Phosphorous 18 kg/ha	24.40ab	2.61a	4.87b	5.25ab	8.50b	91.64a	56.69a
Phosphorous 36 kg/ha	24.89a	2.61a	4.95ab	5.25ab	9.01b	91.69a	56.55a
Phosphorous 72kg/ha	23.89a	2.61a	4.99ab	5.25ab	9.56ab	91.66a	56.60a
Control	21.17c	2.51b	4.87b	5.04b	6.03c	91.58a	56.57
SE	1.41	0.06	0.22	0.21	1.31	0.15	0.15
<u>Interaction</u>							
V	*	*	*	*	*	*	*
F	**	**	*	**	*	*	*
R	**	*	*	*	*	**	*
V*F*R	*	*	*	*	*	*	*

Means followed by the same letter within a column are not significantly different

Significant 0.05 = *; 0.01 = **

NS: Non-Significant

Conclusion and Recommendation

Crude Protein (CP): The results align with previous studies of (Zhang *et al.*, 2014). That have shown organic amendments can improve nitrogen availability in soils, leading to better protein content in crops (Reichel *et al.*, 2018). The ability of compost to enhance protein levels is especially important in regions where dietary protein intake is crucial for addressing malnutrition. The ability of compost to increase fat content, albeit modestly, indicates its role in improving the overall energy density of pigeon pea. Higher fat content can enhance the nutritional value of legumes, making them more suitable as a staple food in energy-deficient diets (Thomas *et al.*, 2019). This is particularly

relevant in developing countries where energy intake from food sources is a critical concern. All pigeon pea varieties exhibited similar fiber levels, reinforcing the idea that compost can maintain or slightly enhance fiber content. The importance of fiber in human diets cannot be overstated, as it plays a crucial role in digestive health and aids in preventing chronic diseases (Li *et al.*, 2017). The fiber content observed in this study aligns with expectations, as legumes are generally known for their high fiber levels, which are beneficial for gut health. The T.Ash content, which reflects the mineral content of the crop, was highest in the compost treatment. This finding suggests that compost not only improves the organic matter of the soil but also contributes to a higher mineral content in the harvested produce. Minerals are essential for various physiological functions in humans, and their presence in adequate amounts in food crops is vital for nutritional adequacy (White and Brown, 2010). The compost treatment showed a significantly higher moisture content compared to the control. This improvement in moisture retention is crucial for crop sustainability, especially in regions facing water scarcity. Compost can enhance soil structure and porosity, leading to better water retention and reduced irrigation needs (Alvarenga *et al.*, 2017). The ability to retain moisture is particularly beneficial for pigeon pea, which is often grown in dryland farming systems. The DM content remained consistent across treatments, indicating that neither compost nor phosphorus adversely affected the overall biomass of the pigeon pea. This stability in dry matter is essential for yield assessments and suggests that nutritional enhancements do not come at the expense of crop productivity. The NFE, representing the carbohydrate content, was significantly higher in the compost treatment compared to the control. This increase in carbohydrates is vital for energy provision in diets, especially in regions where legumes serve as a primary food source. The findings reflect the role of compost in enhancing the overall caloric density of pigeon pea, which can be beneficial for populations relying heavily on plant-based diet. The improved varieties (NSWCC29A, NSWCC24, NSWCC34D) generally outperformed the local check (Otili) in most nutritional parameters, particularly in NFE, crude fibre, and ash content. Among them, NSWCC24 stood out for its balanced nutritional content, especially high NFE and moderate values in other traits. These findings support the potential adoption of improved cowpea varieties for enhanced nutritional quality.

Recommendation: Based on the findings of the comparative analysis of compost and phosphorus fertilizers on the nutritional content of pigeon pea (*Cajanus cajan*), it is recommended that farmers prioritize the use of compost as a primary amendment. The significant enhancement in nutritional parameters such as crude protein, fat, and nitrogen-free extract with compost application underscores its importance in improving both crop quality and soil health. Selection of pigeon pea varieties should focus on those that exhibit superior nutritional performance, such as NSWCC24, which demonstrated high protein and carbohydrate content.

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Analysis of a Combined Effect of Socio-Economics and Agribusiness Factors on Soybeans Production as an Opportunity Crop for Food Security in Mubi North LGA, Adamawa State, Nigeria.

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ABSTRACT

The paper investigated the combined effects of socioeconomic characteristics and agribusiness factors on soybean as an opportunity crops for food security in Mubi north Local government area, Adamawa state, Nigeria. With the aid of questionnaires, Primary data were collected from 150 respondents using simple random sampling. Data were analysed using descriptive statistics and multiple linear regressions. The results revealed that 76% of the respondents were male, 40% attended secondary education, 60% has no formal access to credit facilities, 70% had no extension contact. Regression analysis indicated that both socio-economic factors such as income, education, age, gender and access to credit facilities and agribusiness factors such as market access, value addition and extension services significantly affect soybeans profitability. The study recommends improvement in respondents' access to credit facilities, enhances market access and value addition for soybeans and promoting soybeans production and marketing in Mubi north local government area.

Key words: Socio-economics, Agribusiness, Soybeans, Opportunity crop, Mubi north LGA.

INTRODUCTION: Nigeria is the largest producer of soybeans in West Africa. Its major producing states are Kaduna, Niger, Kebbi, Nasarawa, Kwara, Oyo, Jigawa, Taraba, Borno, Benue, Bauchi, Lagos, Sokoto, Plateau, Zamfara, and Abuja FCT. Soybean is also called Glycine max, it's among the species of legume and widely grown for its edible bean with numerous uses. In Nigeria, it grows majorly in the middle belt accounting for 65-75% of the production in Nigeria. Soybeans are grown from seeds planted in rows in the field and can grow well on various soils and climates. It takes about 4-7 days after planting to start growing and about 90-150 days after sowing to mature. The pod of soya beans is usually green but turns yellowish brown when mature with the beans being hard and dry. Also, there are other varieties of soya beans that are black, brown, or green colored, although these varieties are rare. After the soybeans are harvested, it is separated into pods and stems and can either be further processed or sold. The pod contains the soya beans, from which soya bean oil can be gotten, and is done by cracking the soybeans and subjecting it to heat at about 60°C- 88°C. Soybean is among the world's healthiest foods and has numerous health benefits including provision of vitamins and minerals like vitamin B and is a good protein, iron, and calcium source. It helps in cancer prevention due to the presence of isoflavone, which can increase the activity of a tumor suppressor which can send signals to cell death (apoptosis) in cancer cells stopping the growth of cancer and its activities and the formation of tumors too. The nutritional content of soybean include molybdenum, copper, manganese, phosphorus, iron, omega-3 fatty acids, dietary fiber, vitamin B2, magnesium, vitamin K and potassium, proteins, peptides, and phytonutrients.

PROBLEM STATEMENT: Despite the potential benefits of soybeans, Jigawa state soybeans producers and marketers encounter obstacles in maximizing revenue and competitiveness from producing soybeans as an opportunity crop. The traditional soybean production and marketing as well as distribution channels, characterized by manual transactions, limited market access, and inadequate supply needed inputs, impede the growth and returns of soybeans as an opportunity crop. The study aims to fill this research gap by investigating the combined effect of socio economic factors and agribusiness factors towards influencing the production of soybeans as an opportunity crop. Thus, the Key research questions include; what are the socio-economic characteristics of soybean producers?; what are

the costs incurred and revenues earned by these farmers?; What are the gross margin of soybean as an opportunity crop in the study area?; Are socio-demographic and agribusiness factors have effect of soybeans production as an opportunity crop?; What are the constraints impacting their operations.

OBJECTIVES OF THE STUDY: The broad objective of the study was to Analysis of a Combined Effect of Socio-Economics and Agribusiness Factors on Soybeans Production as an Opportunity Crop in Dutse LGA, Jigawa State, Nigeria., While the specific objectives include the following: to describe the socio-economics characteristics of soybeans production in the study area.; To determine the various costs and returns of soybeans as an opportunity crop in he study area; To examine the gross margin soybeans production as an opportunity crop in the study area; To investigate the combined effect or influence of socio-economic and agribusiness factors on soybeans crop as an opportunity crop in the study area; To describe the constraint faced by soybean production in the study area.

METHODOLOGY

The Study Area: Dutse Local government area of Jigawa State, Nigeria is located on 11°15N latitude and 8°24E longitude; covering a total area of 1,204km² (465 sq. mi) with a population of 376,100 as projected by City Population, 2022 census. The area experiences a tropical climate having rainy and dry seasons. Rainy season begins in April/May and ends mostly in October while dry season prevails for the rest of the year. The mean annual rainfall is 690mm with a relative humidity ranges from 20-70% and the mean annual temperature varies from 21°C to 27°C (Sha'Ato 2007). Dutse Local government is one of the 27 Local government areas of Jigawa state bounded by Kiyawa local government area to the west, Birnin kudu local government area to the south and Gaya local government area of Kano state to the north. The major ethnic groups predominantly found in the area are hausa Fulani ethnics group The hamattan is well pronounced. the Vegetation of the area is Sudan savannah types and the soil conditions of the area are suitable for growing different classification of crops like cereal crops such as maize, rice, guinea corn, millet and legume crops such as Soybean, cowpea, ground nut etc. the domestics livestock found in the area are cattle, sheep and goat. And the major economic activities of the people are farming, trading, civil service, business and marketing.

Method of Data Collection: The data was obtained from primary source. The primary data were collected with the aid of structured questionnaires that was administered to the respondents. Data was collected based on the socio-economic variables such as gender, age, farming experiences, educational status, household size and income level of the respondent, as well as profitability variables and factors influencing soybeans production in the study area.

Sampling procedure and Sample size: Multistage sampling technique was used to collect the data from soybeans farmers in Dutse Local Government Area of jigawa State

1st Stage Kafin Hausa local government was purposively selected due to its high intensity in soybeans production. 2nd stage Ten (10) communities were drawn from the Local government area and list of registered soybeans farmer for each community was obtained from Jigawa state Agricultural and rural Development Authority (JARDA). 3rd stage the soybean farmers from each community were proportionately selected using Cochran formulae as adopted by Joseph, 2018 with slight modifications as displayed below:

$$N = (Q \cdot h) / R$$

Where: N = number of soybeans farmers obtained from each community

Q (Nh) = number of registered soybeans farmers for each community as obtained from JARDA.

R(N) = Total Number of soybeans farmers in all the 10 sampled communities

h = total number of questionnaires distributed. The sample size was found to be 150 respondents The selected wards for the study are; Yelwawa, Fagoji, Garun malam, Takur Adua, kude, sabalari, laraba and Huguma

Tools for Analysis

The analytical tools employed to achieve the various objectives included; descriptive statistics, which was used to achieve i and iv, multiple regression analysis was used to achieve objective iv (Input-output relationship) and farm budgeting technique (Net-farm income) was used to achieve objective iii for the study.

Descriptive statistics: Descriptive statistics such as percentages, frequency distribution was used to describe the socio-economic characteristics of soybeans farmers, the inputs and outputs level in soybeans production and the constraints associated with soybeans production.

Farm budgeting techniques: The farm budget analysis such as Gross ratio (GR), operating ratio, Return on investment, and Net- farm income was used to achieve objective iii.

The net-farm income measures the returns to unpaid family labour and some few fixed costs that soybeans production has such as cost of land rent and depreciation of assets. The variable cost for maize production includes: seed, fertilizer, chemicals, organic manure, labour cost. Etc.

The general model for farm budget is as displayed below

$$NFI = GI - TC \dots \dots \dots (1)$$

Where:

NFI = Net farm income (N)

GI = Gross Farm Income (N) this is gross income for soybeans production, is the total output (kg) multiplied by the unit price of the product.

TC = Total cost for soybeans production (N) is the Total Variable Cost (TVC+TFC).....(2)

Multiple regression analysis (Input-Output Relationship): Multiple regression analysis was used to determine the input-

output relationship in soybeans Production.

Model Specification

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + U_i \text{ (Linear)}$$

Y = Yield

B₀ = Intercept

B¹ = B⁶ = Regression Coefficients

X₁=Income

X₂=Education (kg)

X₃=Age (litre)

X₄= Gender

X₅= Access to credit facilities

X₆= value addition

X₇= Market access

X₈= Extension services

X₁ – X₈ = Independent Variables

Uⁱ (e^{ui}) = Error Term

Table 1: Socio-economic Characteristics of the Respondents

Variable	Frequency	Percentage (%)
Age (years)		
20-30	51	34
31-40	30	20
41-50	25	16.7
51-60	10	6.6
>60	34	
Mean	30	
Family size		
2-11	80	53
12-21	40	26.7
22-31	30	20
Mean	50	
Years of Experience		
1-10	95	85
11-20	23	13
21-30	22	12
Mean	50	
Gender		
Male	138	76
Female	12	24
Educational level		
Primary	74	49.1

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Secondary	32	21.3
Tertiary	11	7.3
No formal education	35	23.3
Access to Credit facilities		
Had Access	60	40
Had No Access member	90	60
Access to Extension Agents		
Access	45	30
No Access	105	70

Source: field survey, 2022.

Average cost and return per hectare of Soybeans production.

Variable input	Quantity	Unit cost(₦)	Total cost	%TVC	%TC
Seed cost/kg	9.135	570.06	5207.5	2.50	2.24
NPK/bag	3.31	26347.4	87209.8	41.85	37.53
Organic fertilizer/kg	3694.36	6.08	22461.7	10.78	9.67
Agrochemicals	3.4	4559.7	15502.10	7.44	6.67
Labour					
Land			13200.5	6.33	5.68
Preparation					
Harrowing			9511.5	4.56	4.09
Ridging			9798.5	4.70	4.22
Planting			6228	2.99	2.68
Fertilizer Application			5032	2.41	2.17
Harvesting			8129	3.90	3.50
Bagging			7545.5	3.62	3.25
Threshing			9018	4.33	3.88
Transport			9551.5	4.58	4.11
Total variable cost			208,395.6		
Fixed cost					
Land rent			20000	83.33	8.61

verage yield kg/ha = 2650.00kg

Average price (N/Kg) = ₦500/ kg

Gross Revenue= ₦ 527,200

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Gross margin (GR-TVC)/ha= 207,868

Net farm income NFI= (GR-TC)= ₦294,805

Gross Ratio (GR) = TC/TR = 0.44

Operating ratio= (TVC/TR) = 0.39

Return per naira invested (ROI) = NFI/TC= 1.26

The variable cost components considered in the analysis included seeds, fertilizers, agrochemicals, organic fertilizer, land preparation, fertilizer application, harvesting and transportation. The costs and returns analysis in the Table, showed that labour and fertilizer inputs accounted for greater part of the total variable costs incurred in soybeans production. Labour and fertilizers constitutes were 33.58% and 37.5% respectively. The farm gate price of soybean (₦500/kg) was used in the estimating the revenue and comparing with the total variable costs to obtain the gross margin which measured the economic performance of the soybean production. The gross margin analysis as indicated in the table showed that from hectare of land cultivated, the total cost of soybean production was ₦232, 395.6 and gross revenue of ₦527, 200 thus making a gross margin of ₦207, 868. In terms of gross margin per Naira invested indicates that for every one Naira invested on soy bean production 126 kobo were the net gain, this agree with the finding of Ibrahim et al, (2012).

Combined effect of Socio-economic and agribusiness factors on of Soybean Production as an opportunity crop

Combined variables of both the socio-economic and agribusiness factors on Soybean production was analyzed using multiple regression models. The variables were the quantity of soybean output while the independent variables were income, education, age, gender and access to credit facilities and agribusiness factors such as market access, value addition and extension services. The Table below presents the effect of the socio-economic and agribusiness factors on Soy beans production as an opportunity crop.

Regression Result For the combined effect of socio-economic and agribusiness factors on of Soybeans Production as an opportunity crops..

VARIABLE	COEFFICIENT(β)	Standard error	T- value
Income	0.014	64.367	0.167
Age	0.422	3.314	3.113**
Gender	0.323	138.780	4.305**
Access to credit	0.234	0.015	1.992***
Market access	0.14	141.159	0.222ns
Value addition	0.245	0.016	1.996***
Extension services	0.236	0.018	1.998***
Education	0.341	0.020	2.134***
Constant	547.783	547.783	-1.449ns
R ²	84.8%		
R ² Adjusted	83.5%		
F- Value	66.945***		

Source: field survey 2022 **= 5% significant, ***= 1% significant, ns= not significant

The variables included in multiple regression analysis for combined effect of socio-economics and agribusiness factors on soybeans production as an opportunity crops include; income, education, age, gender and access to credit facilities and agribusiness factors such as market access, value addition and extension services. The table revealed that R² of 84.8% for Soybean production, the coefficient of age, gender, access to credit, value addition, extension services and education were positive and significant at 1% and 5% level of significance. This result is similar to the work of Adeola, (2009). This means increase in in the aforementioned variables result to an increase in soybeans output.

Constraints Faced by the Farmers

The major problem faces by the farmers were price instability (37%), storage facility (19%), transportation (21%), problem of pests and diseases (36%), high cost of input (39%), inadequate capital (27%). And the major among them were inadequate capital and price instability as lack of capital to purchase input and fertilizer may result as having a negative effect on the performance of the Soybeans.

The table presented the constraints associated with soybeans production in the study area as

Constraints	Response	Frequency	Percentage
1. Storage facility	YES	25	19%
	NO	125	81%
2. transportation	YES	41	27.3 %
	NO	109	72.7%
3. marketing	YES	30	20.0%
	NO	120	80.0%
4. Price instability	YES	57	38,0
	NO	93	62,0
5. Cost of input	YES	59	39,0
	NO	91	61,0
6. Lack of Capital	YES	41	27.3
	NO	109	72.7
7. Fertilizer	YES	35	20,0
	NO	115	80,0
8. Pest and diseases	YES	56	36,0
	NO	94	64,0

Source: field survey 2022

CONCLUSION AND RECOMMENDATION: The study was carried out with the broad objective of determining the A combined effect of socio-economics characteristics and agribusiness factors in soybeans production in Dutse, Jigawa State. Nigeria. The study specifically examined the combined effects of socioeconomic and agribusiness factors on soybean production in Dutse LGA, Jigawa State. The research revealed that socio-economic factors (education, farm size, and household income) and agribusiness factors (access to credit, market information, and extension services) significantly influence soybean production. The study recommends strategies to enhance soybean production, including capacity building

for farmers, improved access to credit, and market linkages.

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Comparative Evaluation of Physicochemical and Carcass Yield of Pork as Influenced by Post-Mortem Processing Methods

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ABSTRACT

To meet the quantity as well as the nutritional needs of consumers in Nigeria, there's need to adopt high meat yielding animals such as pig whose meat(pork) is a delicacy and cost effective in southern Nigeria. A study was therefore conducted to evaluate the Physicochemical and organoleptic properties of pork as influenced by post mortem processing methods at the piggery unit of department of Animal science, Akwa Ibom State University. A total of six pigs were allotted to three post mortem dressing treatment methods namely -: skinning, scalding and singeing. The experiment model was 3x2 factorial. Parameters measured were Physicochemical weights and measurements, nutritional composition and sensory evaluation. The results showed that nutritional composition was higher ($p < 0.05$) in skinned carcass than in singed and scalded carcass. Thermal and cold shortening were not affected ($p > 0.05$) by the dressing method, skinning imposed a higher degree of toughness on pork while in a similar way the cooking and cold loss was highest ($p < 0.05$) in skinned carcass with the least value recorded in singed carcass. Flavour, juiciness and tenderness were significantly improved for singed and scalded carcasses however tenderness was reduced for singed carcass. Colour was highest ($p < 0.05$) in skinned carcass with the least value recorded for singeing in both cooking and grilling methods. From this study it could be concluded that pork processed through skinning had a desirable nutritional composition since crude protein was increased while fat and total cholesterol levels were reduced however singeing and scalding processing methods gave better sensory properties.

INTRODUCTION: Meat is defined as the edible part of the skeletal muscle of an animal that was healthy at the time of slaughter. The most common sources of meat are sheep and poultry and to a lesser extent cattle, buffaloes and pigs. In some regions, other animal species such as camels, yaks, horses, ostriches and game animals are also eaten as meat. To a limited extent, meat is also derived from exotic animals such as crocodiles, snakes and lizards (Geleta and Diribe, 2020). Efforts has been made to control the pre-slaughter conditions that affect these parameters by livestock producers but the control of post-slaughter conditions that affect the same parameters are aspect in techniques and expertise of meat handlers. The well-known post-slaughter conditions that affect meat generally are the dressing techniques employed to process carcass (omojola and Adesehinwa, 2006). The demand for quality pork is on the rise among consumers today especially since there's a shift from poultry meat demand due to it's price increase, it is noted that lack of tailored post-mortem processing methods can reduce pork quality leading to inconsistency in the quality of pork, reduced consumer satisfaction and potential food safety issues (Simmons *et al.*, 2018; Honikel *et al.*, 2017). The relationship between post-mortem processing and pork quality is complex and not fully understood. This knowledge gap makes it difficult to develop optimal processing methods which will better improve pork quality hence a comprehensive investigation into the effects of post-mortem processing methods on the carcass yield and physicochemical characteristics of pork is essential to address these challenges and ensure the production of high-quality, safe, and consistent pork products. This study is carried out to assess the influence of post-mortem processing methods on the physicochemical characteristics of pork.

MATERIALS AND METHODS

3.1: The Experiment Site: The study was carried out at the piggery unit of the teaching and research farm, department of Animal science, Akwa Ibom State University, Obio Akpa Campus, Nigeria. The farm is located on latitude 5°17'N and 5°27'N and longitude 7°21'E and 7°58'E with a monthly temperature range between 24 to 26°C depending on the season, while the relative humidity varies between 60 to 90 % and the annual rainfall from 3500 to 5000 mm (AKSU-MET 2024).

3.2: Experimental Animal: A total of six large white X landrace pigs were obtained from the piggery unit of the department of Animal science Akwa Ibom State University, Obio Akpa campus for this experiment. The experimental animals were slaughtered and processed using three different methods- scalding, Skinning and singeing with each method representing a treatment

3.3: Slaughtering Procedure and Preparation: Pork used for this study were the muscles harvested from the carcass of fattened grower pigs slaughtered at the slaughterhouse of the Department of Animal science, Akwa Ibom State University. Prior to slaughtering, the animals were fasted for twelve hours, weighed before stunned mechanically and bled by severing both the carotid arteries and jugular veins. The slaughtered animals were conventionally skinned, singed, scalded and eviscerated. The dress weight obtained was used to calculate dressing percentage as the ratio of dressed weight to live weight multiply by hundred.

Scalding: Carcass was scalded by pouring hot water on the carcass for the hair to loosen and scraped off with a hand metal scrapper designed for the purpose until the carcass is clean as described by Omojola and Adesehinwa, (2006); Fasae *et al.*, (2011) and Apata (2014).

Skinning: The pelts of the carcass in this group were removed with a sharp scalpel and knife. A ring was made around one of the hind legs and the knife was inserted under the skin of the leg to open it up, the same was done on the second leg. Another incision was made right from the pelvic up to the neck. The pelt were gradually pulled until it is removed as the procedure described by Omojola and Adesehinwa, (2006) and Apata (2014).

Singeing: Hairs of the carcass in this group was flamed off over burning fire made with firewood, dry grasses and some few papers until all the hairs have been carefully burnt off with minimal damage to the skin as described by Omojola and Adesehinwa, (2006) and Apata (2014)). The carcass was thoroughly washed and scrapped.

3.4: Data Collection

Cooking loss: Each meat sample was put in an airtight transparent polythene bag to prevent moisture exchange. Initial weight of treatment samples was recorded (using a sensitive scale) before Cooking in a water bath at a temperature of 70°C for 20 minutes, final weights of the samples were taken after allowing cooked samples to cool at room temperature for 20minutes for the determination of cooking weight loss (Marlgorzata, 2005).

Thus:

$$\text{Cooking loss} = \frac{\text{initial weight of meat} - \text{final length of meal} \times 100}{\text{Initial weight of meat}}$$

Thermal shortening: Initial measurement was determined with the same meat samples used for measuring cooking loss. The lengths of meat samples were remeasured after cooking for 20 minutes and cooling to room temperature, the difference in length was expressed as thermal shortening.

Thus:

$$\text{Thermal shortening} = \frac{\text{initial length of meat} - \text{final length of meal} \times 100}{\text{Initial length of meat}}$$

Cold loss: Each meat sample was placed in an airtight transparent polythene bag to prevent moisture exchange. Initial weights of treatment samples were recorded (using a sensitive scale) before refrigeration. Samples were then refrigerated at a temperature of 4°C for 24 hours. Final weights of the samples were taken after removal from refrigeration, excess moisture was removed using a paper towel. The difference between the initial and final weights was calculated to determine the cold loss of the meat, as described by Marlgorzata (2005). Thus:

$$\text{Cold loss} = \frac{\text{initial weight of meat} - \text{final length of meal} \times 100}{\text{Initial weight of meat}}$$

Cold shortening: Initial measurement was determined with the same meat samples used for measuring cold loss. The lengths of meat samples were remeasured after placing on a tray and chilled at - 4°C for 24 hours, the difference in length was expressed as cold shortening following. Thus:

$$\text{Cold shortening} = \frac{\text{initial length of meat} - \text{final length of meal} \times 100}{\text{Initial length of meat}}$$

RESULTS AND DISCUSSION: The result of post mortem processing on dressing percent of pig is presented in table 4.1

Table 1: Effect of post mortem processing on carcass yield

Parameters	T ₁ (Skinning)	T ₂ (Scalding)	T ₃ (Singeing)	SEM
Pre-slaughter weight	33.38 ^b	34.04 ^b	38.00 ^a	1.66
Dressed weight	19.40 ^c	24.00 ^b	26.00 ^a	1.08

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Dressing percentage	58.11 ^b	70.50 ^a	68.40 ^a	2.60

^{abc} Means bearing different letters of superscript within the same row differ significantly (P<0.05)

The results of pre-slaughter weight as stated in table 4.1 indicated that T3 (38.00kg) had the highest compared to T2 (34.04kg) and T1 (33.38kg). T3 and T2 however were not significantly (p>0.05) different. The result of dressed weight showed T3 significant increase in ascending order as T3 recorded the highest value of 26.00kg while T1 recorded the lowest value (19.40kg). Dressing percentage did not follow any particular order as the highest value (70.50kg) was obtained from T2 followed by T3 (68.40kg) while T1 recorded the least value (58.11kg). The Pre-slaughter weight result obtained in this study followed a similar trend reported by Adeniji *et al.* (2019) and Okoh (2019). However, for dressing percentage (carcass yield) in which T2 recorded highest value followed by T3 though statistically similar (p>0.05) were superior (p<0.05) compared to T1. The increasing carcass yield value in T2 (scalding) suggest that during scalding which involved the application of hot water on the skin, the hot water might have hydrated the meat by opening the pores and allowing moisture to penetrate (Baranda *et al.*, 2002) thereby resulting in the slight increase in value obtained. Unlike T2 and T3, the significant reduction in dressing percentage value obtained for T1 is a reflection of the hide (skin) weight removed. This is in line with earlier report by Aduku and Olukosi (2000) who reported significant reduction in carcass yield of skinned meat animals compared to roaste

Result of post mortem processing on physicochemical properties of pork is presented in table 4.2 below:

Table 2: Effect of post mortem processing on physicochemical properties of pork

Parameters	T1(skinning)	T2(scalding)	T3(singeing)	SEM
Cooking loss	31.00 ^a	24.00 ^b	15.00 ^c	2.35
Cooking yield	69.00 ^c	76.00 ^b	85.00 ^a	2.33
Cold loss	20.00 ^a	16.00 ^b	9.00 ^c	1.68
Cold yield	80.00 ^c	84.00 ^b	91.00 ^a	1.63
Thermal shortening	10.00	9.00	8.00	0.50
Cold shortening	5.00	4.00	3.00	0.41

^{abc} Means bearing different letters of superscript within the same row differ significantly (P<0.05)

The results in table 2 indicated that cooking loss (moisture loss) and cold loss was significantly (p<0.05) higher in T1 followed by T2 and then T3. This indicates poor water holding capacity of pork processed by skinning methods. The absence of skin in T1(skinning) may have contributed to the increased cooking loss which led to reduced cooking yield earlier observed, this invariably showed that meat yield improved in T3(singeing) and T2(scalding) as compared to T1 (skinning), this findings is in Contrast to Adeniji *et al.*, (2019) who had cooking loss greatest for singed carcass and considerably low in scalded and skinned carcass of west African dwarf (WAD) sheep, this difference in result may be attributed to the varied specie of animal under study. There were no significant differences (p>0.05) in the thermal and cold shortening parameters of the meat. Ayanwale and Aye (2006) had earlier reported that low rate of cooking loss is considered an advantage in meat production because it leads to improved tenderness, juiciness and more flavourable meat compared to meat of high cooking loss. Generally, Fluid losses from meat leads to losses in water soluble vitamins and nutrient which can affect juiciness and flavour.

Conclusion; The study has revealed that singeing and scalding increased dressing percentage, cooking yield, Based on the result obtained from the study it can be recommended that skinning, scalding and singeing processing methods can be employed depending on consumers preferences for improved carcass yield and other qualities.

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Agro-Biodiversity and Climate Resilience: Strengthening Food Systems through Ecological Diversity – A Review

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Abstract

Agro-biodiversity, encompassing the diversity of crops, livestock, and associated ecosystems, is fundamental to enhancing the resilience of food systems amidst the increasing challenges posed by climate change. This review explores the role of agro-biodiversity in strengthening climate resilience by improving ecosystem functionality, promoting sustainable agricultural practices, and supporting adaptive capacity. The paper discusses how diversified farming systems contribute to ecosystem services, genetic resource conservation, and socio-economic stability for farming communities. Challenges to conserving agro-biodiversity, including agricultural intensification and socio-economic pressures, are highlighted, alongside policy recommendations to foster ecological diversity for sustainable food security. Emerging research and practical frameworks underpin the central role of agro-biodiversity as a cornerstone for resilient and equitable food systems in a changing climate.

Keywords: Agro-biodiversity, Climate resilience, Food systems, Ecological diversity, Sustainable agriculture and Genetic resources

INTRODUCTION: The global food system is increasingly threatened by climate change, with rising temperatures, irregular rainfall, and extreme weather events undermining agricultural productivity and food security worldwide (FAO, 2022). In this context, agro-biodiversity the diversity of species and genetic resources in agricultural landscapes has emerged as a critical factor for enhancing climate resilience. Agro-biodiversity not only supports productivity but also sustains ecosystem services that buffer against environmental stress, contributing to the stability and sustainability of food production systems (IPBES, 2019). Agro-biodiversity contributes ecosystem services such as pollination, pest regulation, soil health, and genetic resources that buffer yields against climatic variability (Aguilera, 2020). It also supports diversified diets, which enhance nutritional security (Bravo-Peña et al., 2024). Despite this consensus, empirical relationships between agro-biodiversity and resilience remain context-dependent, mediated by governance, market access, and socio-ecological dynamics (Panero et al., 2024). This review synthesizes current knowledge on the role of agro-biodiversity in strengthening climate resilience. It evaluates how ecological diversity within agricultural systems can mitigate climate risks, improve resource use efficiency, and empower farming communities. The review also addresses challenges to maintaining agro-biodiversity in the face of modernization and market forces, proposing integrative policy and research approaches to promote resilient, sustainable food systems.

AGRO-BIODIVERSITY: CONCEPTS AND COMPONENTS: Agro-biodiversity encompasses the variety and variability of animals, plants, and microorganisms used directly or indirectly for food and agriculture, as well as the diversity within species (genetic diversity), between species, and of ecosystems (FAO, 2019). Key components include:

- **Crop diversity:** Different species and varieties, including landraces and modern cultivars.
- **Livestock diversity:** Multiple breeds adapted to local conditions.
- **Soil biodiversity:** Microbial communities vital for nutrient cycling and soil health.
- **Associated wild biodiversity:** Pollinators, natural pest predators, and other beneficial organisms.

Diverse agroecosystems maintain ecological balance, reduce vulnerability to pests and diseases, and improve resilience to abiotic stresses such as drought, salinity, and temperature extremes (Tschamtké et al., 2021).

IMPORTANCE OF AGRO-BIODIVERSITY: Agro-biodiversity encompasses genetic, species, and ecosystem diversity within agricultural landscapes, directly influencing productivity, resilience, and sustainability. Genetic diversity within crops and livestock underpins breeding programs that develop climate-resilient varieties adapted to diverse agro-climatic conditions—from drought-resistant millet varieties in sub-Saharan Africa to flood-tolerant rice cultivars in Southeast Asia (Jarzebski et al., 2022; Smith et al., 2023). Beyond genetic traits, agro-biodiversity supports vital ecosystem services such as pollination, soil nutrient cycling, pest and disease regulation, and water retention, all of which contribute to sustainable land management and reduce reliance on chemical inputs (Jones & Thornton, 2021).

Globally, traditional farming systems—such as the milpa system in Mesoamerica, mixed crop-livestock systems in East Africa, and agroforestry practices in South Asia—demonstrate the value of biodiversity in maintaining productivity under variable climate conditions. These systems also preserve cultural heritage and indigenous knowledge, fostering community resilience and socio-economic stability.

AGRO-BIODIVERSITY AND CLIMATE RESILIENCE: Agro-biodiversity enhances adaptive capacity across multiple spatial and temporal scales. Diverse cropping systems, including intercropping, agroforestry, and diversified rotations, spread risks and increase system stability against extreme weather events (Jones & Thornton, 2021). Conservation of crop wild relatives and underutilized species—often rich in stress tolerance genes—is critical for future breeding efforts to address emerging climatic challenges (FAO, 2023). Livestock genetic diversity is equally crucial, offering traits such as heat tolerance, disease resistance, and efficient feed utilization that sustain production under changing environmental conditions. Globally coordinated efforts, such as the Global Plan of Action for Animal Genetic Resources, promote the conservation and sustainable use of livestock diversity in climate adaptation strategies. Innovative participatory breeding and seed exchange programs enable farmers to adapt varieties to local microclimates while preserving genetic diversity. Integrating indigenous knowledge systems with scientific research fosters context-specific solutions that enhance resilience and empower vulnerable communities (IPBES, 2022). Agroecological practices that foster biodiversity—such as intercropping, agroforestry, crop rotation, and integrated pest management—have been shown to improve resilience and productivity (Gliessman, 2015).

Table 1: Key Agro-biodiversity Components and Their Climate Adaptation Functions

Component	Description	Climate Role	Adaptation	Example Species/Varieties	References
Crop genetic diversity	Varieties and landraces of crops	Enhances tolerance to drought, heat, pests		Drought-tolerant millet (Africa), flood-tolerant rice (Asia)	Jarzebski et al., 2022; FAO, 2023
Livestock diversity	Breeds adapted to diverse climates	Disease resistance, heat tolerance		N'Dama cattle (West Africa), Yak (Himalayas)	IPBES, 2022; Smith et al., 2023
Pollinators	Bees, butterflies, other insects	Pollination services for crop productivity		Honeybees, native bee species	Jones & Thornton, 2021
Soil microbiota	Microorganisms in soil	Nutrient cycling, soil health		Mycorrhizal fungi, nitrogen-fixing bacteria	FAO, 2023

CHALLENGES TO AGRO-BIODIVERSITY CONSERVATION: Despite its recognized value, agro-biodiversity is declining at alarming rates due to several interconnected factors. Agricultural intensification, monoculture expansion, and market-driven preferences for uniform high-yielding varieties have led to extensive genetic erosion, with estimates suggesting that over 75% of crop genetic diversity has been lost globally in the past century (FAO, 2023; Smith et al., 2023). Climate change compounds these threats by altering habitats and exacerbating pest and disease pressures, often beyond the adaptive capacity of existing genetic resources (IPCC, 2022). Socio-economic barriers—including limited access to resources, intellectual property issues, and lack of supportive policies—further constrain farmers' ability to conserve and utilize agro-biodiversity. The loss of traditional knowledge is emphasized whereby younger generations may abandon traditional farming practices, leading to erosion of cultural and biological diversity (Ceccarelli et al., 2020). Gender disparities and marginalization of indigenous peoples also limit equitable participation in biodiversity stewardship. There is also pressures from market for uniform high-yielding varieties which can marginalize traditional crops and breeds (Khoury et al., 2020).

POLICY AND RESEARCH RECOMMENDATIONS: Internationally, the conservation and sustainable use of agro-biodiversity are embedded in key policy instruments such as the CBD, the Nagoya Protocol on Access and Benefit-Sharing, and the Global Biodiversity Framework. The FAO's Commission on Genetic Resources for Food and Agriculture (CGRFA) coordinates global efforts to monitor, conserve, and sustainably use plant, animal, and microbial genetic resources.

Practical approaches that have gained international traction include community seed banks, participatory plant breeding, and agroecological intensification. These strategies promote farmer empowerment, local innovation, and on-farm conservation, exemplified by projects in Latin America, Africa, and Asia that have enhanced food security and climate resilience (Jones & Thornton, 2021; IPBES, 2022). Capacity-building initiatives and knowledge-sharing platforms are critical for scaling these approaches globally, ensuring that diverse stakeholders—from smallholder farmers to policymakers—can contribute to and benefit from agro-biodiversity conservation.

To harness agro-biodiversity for climate resilience, the following are recommended:

- **Conservation and utilization:** Support in situ and ex situ conservation of genetic resources; promote the use of locally adapted varieties (FAO, 2019).
- **Support for diversified farming systems:** Incentivize agroecological practices through subsidies, extension services, and market access (Altieri & Nicholls, 2020).
- **Participatory approaches:** Engage farmers, especially indigenous and local communities, in breeding and management decisions to integrate traditional knowledge with scientific research (Ceccarelli et al., 2020).
- **Policy integration:** Incorporate agro-biodiversity conservation into national climate adaptation and food security strategies (IPBES, 2019).

Table 2: International Agreements Supporting Agro-biodiversity Conservation

Agreement/Framework	Year	Key Provisions Relevant to Agro-biodiversity	Participating Countries
Convention on Biological Diversity (CBD)	1992	Conservation and sustainable use of biodiversity; genetic resource access and benefit-sharing	196+ countries
Nagoya Protocol	2014	Access to genetic resources and fair sharing of benefits	130+ countries
FAO Global Plan of Action	2011	Strategies for conservation and sustainable use of plant and animal genetic resources	FAO member states
UNFCCC and Paris Agreement	2015	Integration of biodiversity in climate adaptation strategies	190+ countries

CONCLUSION: Agro-biodiversity is a foundational element for building resilient food systems capable of withstanding climate change impacts. By fostering ecological diversity, food systems not only enhance productivity and sustainability but also empower communities to adapt to ongoing environmental changes. Protecting and promoting agro-biodiversity through integrated policies, research, and community engagement is essential to ensure food and nutrition security for future generations.

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Determinants of Food Expenditure among Urban Households in Bayelsa State, Nigeria

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ABSTRACT

Globally, lack of access to food, hunger and poverty are major challenges, particularly in a developing economy such as Nigeria. This study sets out to examine the factors influencing food expenditure among urban households. It provides a quantitative assessment of the socio-economic determinants of urban households' food expenditure. Primary data was collected from 400 households through a structured questionnaire. A multi-stage sampling procedure was employed to select respondents across four local government areas of Bayelsa State. Data was analysed using descriptive statistics and multiple linear regression. The findings revealed that the average age of respondents was 41 years, with men accounting for 57% and women 43% of the sample. On average, respondents had an average of 11 years of formal education and lived in households of four members. On average, households spent about 81% of their total income on food. More than half (52%) of the respondents were categorised as low-income earners; 29% and 20% were grouped as middle-income and high-income earners respectively. Further results showed that households' food expenditure was influenced by their family size, home ownership status and income. The study suggests the need to implement policies aimed at improving income and asset accumulation to enhance households' wellbeing.

Keywords: Bayelsa, food expenditure, food security, households, urban

Introduction: Lack of access to food, hunger and poverty continues to challenge the global community including Nigeria where majority of the population are classified as poor. The poor spend more than 70% of their disposable income on food consumption (Muhammad & Sidique, 2019). A household's food expenditure is influenced by varying factors such as household size, education, income, food prices, unemployment status, marital status and age among others (Rashid et al., 2024; Antelo et al., 2017). Research has shown that food consumption is a major driver for health, social insertion, productivity growth and family and social stability (Antelo et al., 2017). As opined in Regmi and Meade (2013), higher food prices affect food intake and budget allocation to other activities such as medical care thereby impacting negatively on consumer's health. Thus, a negatively impacted food expenditure pattern would have significant implications for individuals' wellbeing and public policy. Fiedler (2013) noted that households' consumption and expenditures surveys have been increasingly used to address food and nutrition information gap because they contain a great deal of information about food acquisition and consumption. More so, food consumption is a key component of welfare measure (Backiny-Yetna et al., 2017) as it is used as an indicator of monetary poverty in many countries. However, there is limited study on determinants of households' food expenditure in Nigerian urban areas as most studies have been focused on rural households and food security (Muhammad & Sidique, 2019). Consequently, this study sets out to examine the factors influencing food expenditure among urban households in Bayelsa state. The study is premised on Engel's law that the proportion of expenditure spent on food is inversely proportional to total income although the total amount spent on food increases due to increase spending on more quantities and varieties of food for diet diversification (Babalola & Isitor, 2014). Hence, the type or quality of food consumed by an individual or household is a manifestation of their wealth or poverty status. Amao et al. (2013) noted that poverty is manifested in the kind of food the poor eat. According to Rosalina et al. (2007), food insecurity and poor nutritional status are almost inevitably the result of poverty.

Methodology: The study was undertaken in Bayelsa State, having a geographical location within latitude 4°15' to latitude 5°23' North and longitudes 5°22' to 6°45' East (Anugwa & Agwu, 2018). Bayelsa state has eight local government areas making up three senatorial districts, and its capital is Yenagoa. The State has an estimated population of 2,386,468 million people (National Bureau of Statistics, 2018). The people of Bayelsa state are mostly engaged in farming and fishing. The State is home to oil exploration and exploitation activities (Elum & Snijder, 2023). The study area is represented in Figure 1.

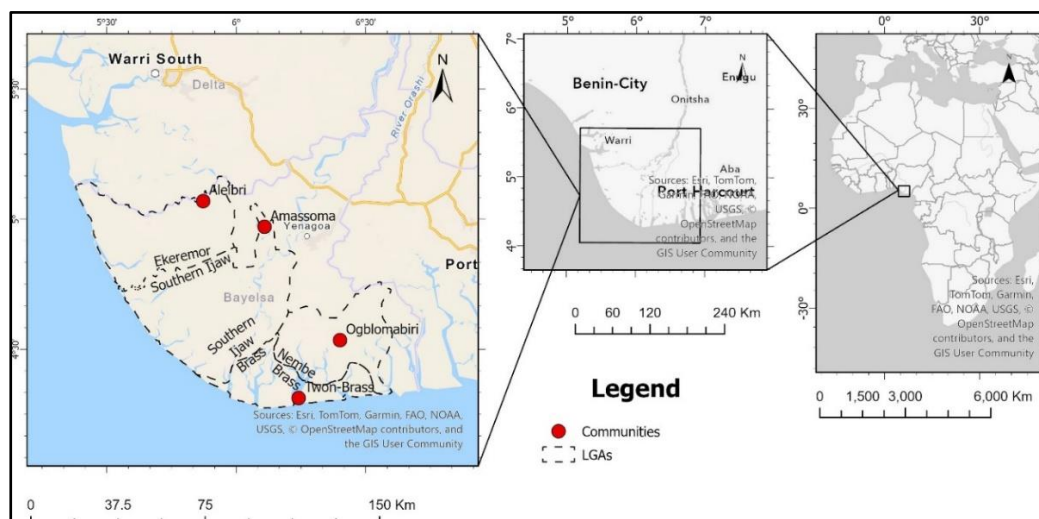


Figure 1. Study area. Source: Authors' illustration

The Yamane sample size formula as in Coker et al. (2017) was used to determine the study sample size as seen below.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where n is the sample size, N is the sample frame (population) and e is the precision level or error of the sample (taken as 0.05).

Data was collected from four hundred households, through a multi-stage sampling procedure with a structured questionnaire. In the first stage, four local government areas (LGAs) were randomly selected using the list of LGAs as sampling frame and these were Southern Ijaw, Brass, Nembe and Ekeremor LGAs. In the second stage, four communities were purposively chosen based on their urban status; one community was chosen for their urban status from each of the LGAs making a total of 4 communities. The third and final stage was the systematic random sampling of urban residents across the communities in a door-to-door survey in the absence of a sampling frame. A starting point was randomly chosen and after which a household was randomly chosen from every 20th house in a neighbourhood within the communities given time and resource constraints. This process of using a randomly selected starting point and the absence of any known cyclical or periodic pattern among the population reduces bias (Maduekwe & de Vries, 2019). Multiple regression in the form of a log-linear form was used in analysing the data.

$$\ln y = \alpha + \beta x_i$$

Where y is food expenditure and x_i s are the explanatory variables which included age, gender, education, household size, income and home ownership. The dependent variable was log-transformed while the independent variables were in their original scale. Therefore, in interpreting the results, it would be taken that a one-unit change in x will lead to a percentage change in y that is equal to the coefficient of beta. The log-transformation was made to eliminate heteroskedasticity problem, that is, stabilizing the variance and improving the model.

Results and Discussion

Descriptive statistics of socioeconomic characteristics of urban households in Bayelsa state.

Table 1 Descriptive statistics of the urban households

Variable	Mean	Frequency (%)
Age (years)		
≤ 35	40.67	140 (35.0)
36 – 50		189 (47.0)
51 – 65		61 (15.0)
≥ 66		10 (3.0)
Gender		
Male		228 (57.0)
Female		172 (43.0)
Education	11.38	
Non- formal		24 (6.0)
Primary		55 (13.8)
Secondary		186 (46.5)
Tertiary		135 (33.8)
Household size (nos.)	4.84	

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≤ 6		313 (78.3)
> 6		87 (22.0)
Income (₦)	168438	
≤ 100000		208 (52.0)
100000 – 200000		114 (28.5)
> 200000		78 (19.5)
Food expenditure (₦)	77610	
≤ 100000		296 (74.0)
100000 – 200000		73 (18.0)
> 200000		31 (8.0)
Food expenditure share of household income (%)	81.88	
Low-income group	115.64	208(52.0)
Middle income	51.07	114(28.5)
High income group	36.87	78(19.5)
Home ownership		
Yes		73 (18.3)

Source: Field survey, 2024.

The average age of the respondents is 41 years, and majority (82%) were in their young and middle age. A higher share of the household representatives were men (57%). Most had one form of education, an average family size of 4, an average income and food expenditure of ₦168,438 and ₦77,610 respectively. On average, households spent about 82% of the income on food, although those categorized as low income spent 116% implying that such households spending above their monthly income depended on savings and borrowings and probably financial gifts to meet their food expenditure needs. However, middle and high-income groups spend 51% and 37% of their income on food. Low income implies that households may not adequately afford consumption of good food and other basic amenities such as medical care, education and energy (Amao et al., 2013). Only a few (18.3%) owned their houses. The result supports the literature (Rashid et al., 2024; Arene & Anyaeji, 2010) that the share of money spent on food decreases as income increases and more so, metropolitan/urban poor spend 60 – 80% of the income on food.

Socioeconomic determinants of urban households' food expenditure in Bayelsa State.

Table 2 Estimates of multiple regression model

Variables	Coefficients	Standard error	P > t
Constant	10.495	0.164	0.000**
Age	0.00004	0.003	0.989
Gender (Male=1)	0.080	0.053	0.131
Household size	0.054	0.012	0.000**
Home ownership (Yes =1)	0.196	0.077	0.011*
Income group (Low)			
Middle income	0.301	0.064	0.000**
High income	0.683	0.078	0.000**
Education group (non-formal)			
Primary	-0.118	0.127	0.351
Secondary	-0.051	0.116	0.657
Tertiary	0.069	0.120	0.564
Adjusted R-squared	0.369 (0.000)		
Breusch-Pagan/cook-Weisberg test for heteroskedasticity- chi²	1.98 (0.160)		

Source: Field survey, 2024. ** and *, significant at 1%, and 5% respectively.

The result presented in Table 2 indicates that a unit increase in household size would result in higher food expenditure by 0.05%. This is expected as more food is required to feed more persons. Also, households who owned their homes spent more on food consumption than those who did not own theirs by 0.2%. This implies that homeowners were richer and could afford more expenditure from the purchase of more quantity or higher quality of foods. Similarly, middle- and high-income earners had higher food expenditure than low-income earners by 0.3% and 0.7% respectively. The result conforms with Rashid et al. (2024) that food expenditure increases with household size, asset ownership and income. Antelo et al. (2017) reported that unemployment (as indication of lack of income) had negative impact on food consumption among Spanish households. Furthermore, larger households experience more incidences of food insecurity (Ogunniyi et al., 2021). More so, inability of individuals or households to acquire adequate food may result in inadequate nutrition and poor calorie intake

(Ogunniyi et al., 2021), such households may experience hunger and the attendant health challenges. The adjusted R^2 value indicate 37% of the variation in the observed food expenditure is explained by the independent variables included in the model. The Breusch-Pagan/cook-Weisberg test for heteroskedasticity shows a test statistic that is insignificant, indicating that the transformed data is suitable for a linear regression.

Conclusion and Recommendations: This study examined the socioeconomic determinants of food expenditure among urban households in Bayelsa State. Results showed majority of the households are low-medium income earners and their food expenditure was influenced by their household size, home ownership status and income. Therefore, to increase household food expenditure for improved food security, it is important that policies aimed at improving income and asset accumulation are initiated to enhance households' wellbeing. The study also recommends adoption of policies to increase urban employment creation by government and private sector in the study area as well as implementing policies on affordable housing for low-income earners.

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Effect of Inflation on Food Security in Nigeria (1970-2023)

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Abstract

The study examined the effect of inflation on food security in Nigeria from 1970-2023. An autoregressive distributed lag (ARDL) bound test approach was employed to establish co-integration between series. The estimated short and long-run model parameters demonstrated stability, best quality, efficiency, and unbiased results. The findings showed that in the short run, the exchange rate significantly undermines food security by raising the cost of imported inputs. The interest rate has a positive and statistically significant coefficient thus increasing food security by resulting in improved capital accumulation for agricultural investments while lagged food price inflation reduces current household purchasing power. However, the lagged value of the money supply was positive and statistically significant, indicating that past increases in money supply positively influenced food security over time. This suggests that liquidity expansion might take time to translate into improved food production through increased investment in agriculture while higher agricultural input costs may signal investments in modern farming practices by enhancing food security. The error correction terms were negative and significant showing that 7.3% of any short-run disequilibrium was corrected each period. This gradual adjustment process underscores the importance of stabilizing inflation and exchange rate fluctuations to ensure sustainable food security. In the long run, there was the absence of a strong long-term relationship between these variables and food security. The implications of the findings justify the need to focus on stabilizing the exchange rate and supporting agricultural investment. Implementing policies that stabilize critical inputs and safeguard household food security against inflationary shock.

Keywords: Inflation, Food Security, Food prices, Exchange rate, Nigeria

INTRODUCTION: Food security has remained one of Nigeria's most pressing developmental challenges even globally despite the country's abundant agricultural endowments and economic potential. It is defined by the Food and Agriculture Organization (FAO, 2008) as a condition in which "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". However, Nigeria's progress towards this goal has been constrained by persistent macroeconomic instability, structural weaknesses in agricultural production and distribution systems, particularly high and volatile inflation which undermines both the supply and sides of food systems.

Over the past five decades, Nigeria has experienced repeated inflationary episodes caused by structural bottlenecks, fiscal imbalances, currency depreciation, and supply shocks. Between 1970 and 2023, inflation which is the persistent increase in the general price level of goods and services as averaged above 15% in Nigeria, with several peaks reaching over 70% in 1995, 18.6% in 2005, 16.5% in 2017, and more than 25% in 2023 (Central Bank of Nigeria [CBN], 2024; National Bureau of Statistics [NBS], 2023). Food inflation has been consistently higher than headline inflation, eroding the power of households and raising the cost of living, particularly among the poor who spend over 60% of their income on food (World Bank, 2022). The nexus between inflation and food security is complex and multifaceted. Rising prices reduce the purchasing power of consumers, making it difficult for households especially those in low-income groups - to afford adequate and nutritious food. At the same time, inflation increases production costs for farmers by raising prices of agricultural inputs such as fertilizer, fuel, seeds, and transportation (Janet, 2024). These dynamics undermine both the supply and demand sides of the food system, aggravating poverty and threatening the stability of food markets (Katuka et al., 2025). According to Jolliffe et. al. (2018), a consistent rise in price due to inflation brings about unbearable deprivation to the poor, increases prices of food, create food scarcity. All of these, decrease world's economic status and increase the price of the global agricultural system. Also, inflation on the price of food commodities may result

to application of certain survival mechanism by people in order to remain food secure. This makes food securities among families rely solely on accessibility and availability of food, in terms of financial, physical and social aspects.

Despite Nigeria's vast arable land, favourable agro-climate conditions, and large labour force, food insecurity has remained widespread and persistent. The FAO (2023) estimated that about 26.5 million Nigerians faced food insecurity in 2022-2023, compared to fewer than 12 million in 2010. The paradox of rising food insecurity in an agriculturally endowed nation has drawn attention to inflation as a critical determinant of declining food availability, accessibility and stability. Inflationary pressures erode real household incomes, widen inequality, and disincentivize investment in the agricultural sector. Episodes of high inflation such as during the 1980s, the 1990s' economic turmoil, the post-2020 COVID-19, currency depreciation (Akpaeti et al., 2023; 2024), and fuel subsidy removal era have been consistently accompanied by rising food prices and declining food availability. Numerous studies and empirical evidence across developing such as Aye et. al. (2025), Udochukwu et. al. (2024), Umar and Umar (2022) highlights a consistent negative association between inflation and food security. Others have explored determinants of inflation or agricultural output separately (Akpaeti et al., 2018, Mbah et al., 2022 & Elrasheed et al., 2024). These studies collectively demonstrate that inflation distorts both macroeconomic and microeconomics incentives affecting food production and consumption. However, empirical work often stops at specific periods or partial linkages; few analyses capture the long-run dynamic relationship between inflation and comprehensive food security indicators from 1970-2023. This gap justifies the present study, which aims to deepen understanding of how inflationary trends have shaped food security outcomes in Nigeria using Autoregressive Distributive Lag (ARDL) model regression.

RESEARCH METHODOLOGY

Study Area: The study area is Nigeria. The Federal Republic of Nigeria is in West Africa between Latitude 40° to 140° North of the equator and between Longitude 30° and 40° East of the Greenwich meridian. To the north the country is bounded by the Cameroon Republic and to the South by the Atlantic Ocean. Nigeria has a land area of about 923769Km² (Federal office of statistics (FOS), 1989); it is made up of 36 states and 744 L.G.As. Abuja is the capital while Lagos is the largest city in terms of population and the main commercial center. Nigeria has a total land area of 923,768. 622 squared kilometers and a population of over 140 million (National Population Census (NPC), 2006). The average annual growth rate According to the 2006 estimate was 2.38%. Cleaver and Schreiber (1994) put the surface area of Nigeria as 91.07 million hectares, 57% of which is believed to be either under crops or pastures while the remaining 43% is divided amongst forest, water bodies and other uses. It is estimated that about 25 million hectares are cultivated each year which implies a high cropping intensity with respect to Arable land. Forestry constitutes about 26 million hectares while crops contributes some 27% of GDPM, livestock another 3.3% and forestry and fisheries 1.5%. Some of the country's Agricultural exports include cocoa, vegetables, fruits and cotton and these exports only represent less than 5% of export earnings (African Development Bank [ADB], 2004)

Method of Data Collection : The data for this study was obtained from secondary sources. These data was obtained from the; Food and Agricultural Organization (FAO) statistical database, National Bureau of statistics (NBS) and the Central Bank of Nigeria (CBN) statistical bulletin, World Bank, USDA (United States Department of Agriculture)- Foreign Agricultural Service, OECD-FAO (Organization for Economic Cooperation and Development. Time series data from macroeconomic variables were collected from these sources spanning from 1970-2023.

Analytical Technique: The study utilized the Augmented Dicker-Fuller (ADF) regressions to perform the unit root tests for the variables. The unit root test was carried out using the following equation

$$\Delta X_t = \alpha_0 + \sigma X_{t-1} + \sum \beta \Delta X_{t-1} + e_t \quad (1)$$

where:

X_t = current values of variables;

X_{t-1} = immediate past values of variables;

Δ = difference operator

α, σ, and β = parameters to be estimated

e = error term which was assumed to be normally and identically distributed.

After achieving variables stationarity, the study used Autoregressive distributed lag (ARDL) model based on the result of the unit root test to accommodate variables with different order of integration. The ARDL model was selected to confirm cointegration among specified series as stated by Pesaran et. al. (2001). The short- and long-run models of the study were estimated. According to Harris and Sollis (2003) as cited by Akpan et. al. (2024), the ARDL model offers several advantages over other techniques (Engle and Granger (1987) two-stage technique and Johansen and Juselius (1990) cointegration method), including handling series with mixed unit root problems, applicability to stationary series at levels or first differences, efficient for small and finite sample data, and provision of unbiased long run estimates. The ARDL bound test was used to affirm the presence of co-integration among series. If the ARDL bound F-statistic exceeds the upper critical limit at the conventional probability levels (1%, 5%, or 10%), it indicates cointegration, rejecting the null hypothesis of no cointegration. If the ARDL bound F-statistic falls below the lower critical limits, the null hypothesis cannot be rejected, indicating the absence of co-integration among series. However, if the ARDL bound F-statistic falls between the lower and upper critical limits, the test is interpreted as inconclusive (Pesaran et al., 2001). After confirming the presence of co-integration, then the long and short-run (ECM) models are specified as follows:

Following Pesaran et al. (2001), the ARDL bounds test for cointegration is expressed as:

$$\begin{aligned} \Delta LNFPI_t = & \varphi_0 + \alpha_1 \sum_{i=1}^{n_1} \Delta LNFPI_{t-i} + \alpha_2 \sum_{i=1}^{n_2} \Delta CIPF_{t-i} + \alpha_3 \sum_{i=1}^{n_3} \Delta CIP_{t-i} + \alpha_4 \sum_{i=1}^{n_4} \Delta EXR_{t-i} + \alpha_5 \sum_{i=1}^{n_5} \Delta LNAIC_{t-i} + \\ & \alpha_6 \sum_{i=1}^{n_6} \Delta LNGAE_{t-i} + \alpha_7 \sum_{i=1}^{n_7} \Delta INTR_{t-i} + \alpha_8 \sum_{i=1}^{n_8} \Delta LNTOT_{t-i} + \alpha_9 \sum_{i=1}^{n_9} \Delta LNPG_{t-i} + \alpha_{10} \sum_{i=1}^{n_{10}} \Delta LNTA_{t-i} + \alpha_{11} \sum_{i=1}^{n_{11}} \Delta LNMSP_{t-i} + \\ & \alpha_{12} \sum_{i=1}^{n_{12}} \Delta INF_{t-i} + \vartheta_1 LNFPI_{t-1} + \vartheta_2 INFLA_{t-1} + \vartheta_3 INR_{t-1} + \vartheta_4 EXR_{t-1} + \vartheta_5 LNAIC_{t-1} + \vartheta_6 LNGAE_{t-1} + \vartheta_7 INTR_{t-1} + \\ & \vartheta_8 LNTOT_{t-1} + \vartheta_9 LNPG_{t-1} + \vartheta_{10} LNTA_{t-1} + \vartheta_{11} LNGAE_{t-1} + \vartheta_{12} LNMSP_{t-1} + \mu_t \end{aligned} \quad (2)$$

Where:

LNFPI _t	=	Log of Food Production Index
CPIF _t	=	Consumer Price Index for Food
CPI _t	=	Overall Consumer Price Index
EXR _t	=	Exchange Rate (between naira and dollar)
LNAIC _t	=	Log of Agricultural Input Cost
LNGAE _t	=	Log of Government Agricultural Expenditure
INTR _t	=	Interest Rate (percent)
LNATOT	=	Log of Agricultural Terms of Trade
LNPG _t	=	Log of Population Growth
LNTA _t	=	Log of Technological Advancement
LNMSPI _t	=	Log of Money Supply
INF _t	=	Inflation
U _t	=	Error term
$\alpha_1 - \alpha_{12}$	=	Short-run estimates of ARDL
$\vartheta_1 - \vartheta_{12}$	=	Long-run estimates of ARDL
φ_0	=	Drift or constant element and “n” denotes the maximum lag length

It is worthy to note that the Food Production Index was selected as the best variable to serve as a single proxy variable is needed to represent all components of food security in time series analysis. This was because it measures the total volume of food production in a country, covering various agricultural products. It encapsulates several key aspects which are critical components of food security particularly availability and stability and has data readily available for the period under review. It also provides a solid foundation for understanding overall food security in relation to inflation.

The long run model is given as:

$$LNFPI_t = \vartheta_0 + \vartheta_1 LNFPI_{t-1} + \vartheta_2 INFLA_{t-1} + \vartheta_3 INR_{t-1} + \vartheta_4 EXR_{t-1} + \vartheta_5 LNAIC_{t-1} + \vartheta_6 LNGAE_{t-1} + \vartheta_7 INTR_{t-1} + \vartheta_8 LNTOT_{t-1} + \vartheta_9 LNPG_{t-1} + \vartheta_{10} LNTA_{t-1} + \vartheta_{11} LNGAE_{t-1} + \vartheta_{12} LNMSPI_{t-1} + \varepsilon_t \quad (3)$$

The short run model (ECM model) is as stated:

$$\Delta LNFPI_t = \varphi_0 + \alpha_1 \sum_{i=1}^{n_1} \Delta LNFPI_{t-i} + \alpha_2 \sum_{i=1}^{n_2} \Delta CPIF_{t-i} + \alpha_3 \sum_{i=1}^{n_3} \Delta CPI_{t-i} + \alpha_4 \sum_{i=1}^{n_4} \Delta EXR_{t-i} + \alpha_5 \sum_{i=1}^{n_5} \Delta LNAIC_{t-i} + \alpha_6 \sum_{i=1}^{n_6} \Delta LNGAE_{t-i} + \alpha_7 \sum_{i=1}^{n_7} \Delta INTR_{t-i} + \alpha_8 \sum_{i=1}^{n_8} \Delta LNTOT_{t-i} + \alpha_9 \sum_{i=1}^{n_9} \Delta LNPG_{t-i} + \alpha_{10} \sum_{i=1}^{n_{10}} \Delta LNTA_{t-i} + \alpha_{11} \sum_{i=1}^{n_{11}} \Delta LNMSPI_{t-i} + \alpha_{12} \sum_{i=1}^{n_{12}} \Delta INF_{t-i} + \delta ECM_{t-i} + \mu_t \quad (4)$$

Where variables were as earlier defined in equations (2) and δ is the error correction term which represents the speed of adjustment towards the long-run equilibrium, and the remaining coefficients provide the short-run dynamics. The performance of the estimated model, RESET test, Serial correlation, normality and Heteroscedasticity tests were conducted whereas the cumulative sum (CUSUM) and cumulative sum of square (CUSUMSQ) test were conducted to verify the stability nature of the model.

RESULTS AND DISCUSSION

Determine the Effect of Inflation on Food Security.

Stationarity Test

Table 1 indicates the stationarity test carried out for all the variables used for the study using Augmented Dickey-Fuller (ADF) test technique at 0.05% critical value. The result in Table 1 shows that the series are integrated in mixed order: stationarity at level I (0) and stationarity at first difference I (1). Inflation, Money supply and consumer price index became stationary at level while other series are in the first difference. This result justifies the use of Autoregressive Distributed Lag (ARDL) model on the specified series.

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Table1: Stationarity Test

		<u>At Level</u>											
		<i>FPI</i>	<i>EXR</i>	<i>INF</i>	<i>INTR</i>	<i>GAE</i>	<i>ATOT</i>	<i>LNTA</i>	<i>MSP</i>	<i>CPI</i>	<i>PGR</i>	<i>CPIF</i>	<i>AIC</i>
With Constant	<i>t</i> -Statistic	0.5429	-1.2241	-6.1057	0.0982	-1.6815	-1.3109	-1.1583	-1.1031	-1.8664	-1.7886	-0.4502	-2.0577
	<i>Prob.</i>	0.9867	0.6575	0.0000	0.9626	0.4340	0.6179	0.6777	0.7082	0.3447	0.3821	0.8913	0.2622
		<i>n0</i>	<i>n0</i>	***	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>
With Constant and Trend	<i>t</i> -Statistic	-1.5865	-2.8567	-6.0886	-0.7993	-3.0394	-1.7178	-0.8927	-4.6771	-3.3575	-2.7269	1.1572	-1.8250
	<i>Prob.</i>	0.7849	0.1847	0.0000	0.9589	0.1326	0.7292	0.9429	0.0027	0.0699	0.2312	0.9999	0.6755
		<i>n0</i>	<i>n0</i>	***	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	***	*	<i>n0</i>	<i>n0</i>	<i>n0</i>
Without Constant and Trend	<i>t</i> -Statistic	1.2854	0.9735	-1.5334	0.4413	-0.5631	0.6007	0.2867	3.5443	-0.0417	0.3030	-1.3471	0.5594
	<i>Prob.</i>	0.9479	0.9105	0.1163	0.8058	0.4676	0.8430	0.7618	0.9998	0.6633	0.7697	0.1624	0.8333
		<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>	<i>n0</i>
		<u>At First Difference</u>											
		<i>d(LNFPI)</i>	<i>d(EXR)</i>	<i>d(INF)</i>	<i>d(INTR)</i>	<i>d(GAE)</i>	<i>d(ATOT)</i>	<i>d(TA)</i>	<i>d(MSP)</i>	<i>d(CPI)</i>	<i>d(PGR)</i>	<i>d(CPIF)</i>	<i>d(AIC)</i>
With Constant	<i>t</i> -Statistic	-4.1287	-5.8325	-9.0324	-7.2542	-2.2302	-4.9416	-2.9830	-10.2159	-0.7258	-6.5928	7.0570	-3.6227
	<i>Prob.</i>	0.0020	0.0000	0.0000	0.0000	0.1989	0.0002	0.0488	0.0000	0.8293	0.0000	1.0000	0.0090
		***	***	***	***	<i>n0</i>	***	**	***	<i>n0</i>	***	<i>n0</i>	***
With Constant and Trend	<i>t</i> -Statistic	-4.7654	-5.8119	-8.9648	-7.5475	-2.1830	-4.9741	-3.5569	-10.0794	1.8064	-7.0012	1.5447	-3.7696
	<i>Prob.</i>	0.0017	0.0001	0.0000	0.0000	0.4869	0.0009	0.0539	0.0000	1.0000	0.0000	1.0000	0.0276
		***	***	***	***	<i>n0</i>	***	*	***	<i>n0</i>	***	<i>n0</i>	**
Without Constant and Trend	<i>t</i> -Statistic	-3.9205	-6.6677	-9.1219	-7.1568	-2.1929	-4.9396	-3.0764	-2.6495	-1.3976	-6.5648	9.0509	-3.6037
	<i>Prob.</i>	0.0002	0.0000	0.0000	0.0000	0.0288	0.0000	0.0034	0.0091	0.1486	0.0000	1.0000	0.0006
		***	***	***	***	**	***	***	***	<i>n0</i>	***	<i>n0</i>	***

Source: Computed by the author, 2025 from E-view 10.

Cointegration Test : This study proceeds to estimate the long-run cointegration relationship among the variables using the ARDL Bound test approach. The result in Table 2 shows that the F-statistic value of 8.013491 and the number of explanatory variables in the model (K) is 11. Given that the F-statistic value is greater than the lower bound value of 1.98 and the upper bound value of 3.04 at 0.05 percent critical bound. The bound test results indicate stability or equilibrium of the long run food security in the study. It also shows that the model is cointegrated in the long-run, which implies that, there is a long run relationship between the dependent and the independent variables employed for the study.

Table 2: ARDL bound Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	8.013491	10%	1.76	2.77
K	11	5%	1.98	3.04
		2.5%	2.18	3.28
		1%	2.41	3.61

Source: Computed by the author, 2025 from E-view 10.

Long-Run ARDL Result: The results of the ARDL bound test confirm the existence of a long-run equilibrium relationship between inflation and food security in Nigeria, suggesting that the variables move together over time. However, the insignificance of the long-run coefficients implies that inflation and other included macroeconomic factors do not exert any meaningful long-run influence on food security as proxied by food production index as presented in table 3. This suggests that although food security and inflation are linked (move together), the magnitude and direction of their relationship are not strong enough to produce a stable or significant long-term effect because it is weak or uncertain. This affirms that inflation alone is not the main driver of food security in the long-run. The outcome of this study reveals common situation in agricultural economies like Nigeria, where structural factors (poor infrastructure, low technology adoption, post-harvest losses, exchange rate volatility, and climatic shocks) play a larger long-term role than inflation alone. This finding may reflect the role of structural rigidities, adaptive policy responses, and external shocks that weaken the transmission of inflationary pressures to agricultural output in the long-run.

Table 3: Long run Regression Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EXR	-0.175599	0.153506	-1.143921	0.2617
INF	-8.18E-05	0.002591	-0.031555	0.9750
INTR	0.003489	0.004458	0.782656	0.4400
GAE	-0.228178	0.325047	-0.701986	0.4881

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ATOT	-1.543992	1.724447	-0.895355	0.3777
TA	-0.085279	0.109188	-0.781032	0.4409
MSP	-0.161003	0.276896	-0.581457	0.5653
CPI	-0.000691	0.001963	-0.352096	0.7272
PG	0.015544	0.016257	0.956146	0.3466
CPIF	0.006261	0.004949	1.264925	0.2156
AIC	0.421816	0.504466	0.836162	0.4097
C	10.09058	6.355979	1.587573	0.1229

EC = FPI - (-0.1756*EXR -0.0001*INF + 0.0035*INTR -0.2282*GAE

-1.5440*ATOT -0.0853*TA -0.1610*MS -0.0007*CPI + 0.0155

*PG + 0.0063*CPIF + 0.4218*AIC + 10.0906)

Source: Computed by the author, 2025 from E-view 10.

Short-run ECM Result: The Error Correction Model (ECM) provides insight into the short-run dynamics and speed of adjustment of inflation-related variables affecting food security in Nigeria. The results reveal significant relationships among the explanatory variables, with key implications for food security. The coefficient of the exchange rate (D(EXR)) is negative and statistically significant at the 1% level (-0.028161, $p = 0.0000$). This suggests that an increase in the exchange rate, implying a depreciation of the Naira, negatively impacts food security in the short run. A weaker Naira raises the cost of imported agricultural inputs such as fertilizers, machinery, and food products, thereby reducing domestic food production and availability. This finding is consistent with the work of Falana et. al. (2024), who found that exchange rate depreciation in Nigeria lead to increase food prices and reduce household access to essential food items due to higher import costs. Similarly, Umar and Umar (2022) argue that exchange rate fluctuations increase inflationary pressures in food markets, further exacerbating food insecurity. However, some studies present conflicting findings. Isaac et. al. (2022) found that exchange rate depreciation, when accompany by strong local agricultural production policies, can enhance food security by making locally produced food more competitive against imported alternatives. Similarly, Aye et. al. (2024) argue that a depreciating exchange rate could incentivize local farmers to increase production, reducing reliance on food imports and ultimately improving food availability. These contrasting findings suggest that the impact of exchange rate fluctuations on food security depends on the structure of agricultural production and government intervention strategies.

The interest rate (D(INTR)) has a positive and statistically significant coefficient (0.000117, $p = 0.0392$), indicating that rising interest rates slightly increase food security in the short run. While this result may appear counterintuitive, it suggests that higher interest rates could incentivize savings, leading to improved capital accumulation for agricultural investments. Ajibade et. al. (2020) found a similar positive relationship, arguing that moderate increases in interest rates encourage financial institutions to offer higher savings rates, which can provide more funds for agricultural lending. Additionally, Nzeh et. al. (2024) suggests that higher interest rates could attract foreign capital inflows, stabilizing inflation and indirectly supporting food security. Conversely, Muhammed (2024) found that rising interest rates reduce farmers' access to credit, thereby hindering agricultural investments and food production. These opposing views highlight the complex interaction between monetary policy and food security, emphasizing the need for balanced interest rate policies that support both investment and price stability. Money supply (D(MSP)) has an insignificant coefficient (0.000195, $p = 0.9843$), meaning that changes in money supply do not have a direct impact on food security in the short run. However, the lagged value of money supply (D (MSP (-1))) is positive and statistically significant (0.025438, $p = 0.0017$), indicating that past increases in money supply positively influence food security over time. This result suggests that liquidity expansion might take time to translate into improved food production through increased investment in agriculture. Ojo et al. (2022) found similar evidence, concluding that while short-term increases in money supply have minimal direct effects, long-term increases in liquidity facilitate agricultural investments and productivity growth.

In contrast, Danlami et. al. (2017) argues that excessive money supply growth fuels inflation, leading to higher food prices and reduced purchasing power for households. Similarly, Amejì et. al. (2024) found that uncontrolled liquidity expansion contributes to food price instability, exacerbating food insecurity rather than improving it. These findings suggest that the effectiveness of monetary expansion depends on complementary policies that ensure investment in productive agricultural activities rather than speculative inflationary pressures. The short-run effect of food price inflation (D(CPIF)) is negative but statistically insignificant (-0.000130, $p = 0.1788$), indicating that immediate changes in food prices do not significantly impact food security. However, the lagged effect of food price inflation (D (CPIF (-1))) is negative and highly significant (-0.000692, $p = 0.0000$), meaning past increases in food prices negatively affect food security in the present period. This finding aligns with Lartey (2024), who found that food inflation in Nigeria has a delayed but persistent impact on household food consumption, reducing affordability and access to adequate nutrition. Additionally, Mbah et. al. (2022) emphasize that food inflation disproportionately affects low-income households, worsening food insecurity over time. On the other hand, Headey and Hirvonen (2023) found that in some cases, food price inflation can temporarily benefit food producers by increasing their earnings, allowing for reinvestment in production. Similarly, Anthony and Tijjani (2022) suggest that moderate food inflation could stimulate investment in agriculture, ultimately boosting food production and stabilizing food security in the long run. These contrasting perspectives highlight the nuanced effects of food inflation on different segments of the population and the economy.

Agricultural input cost (D(AIC)) has a strong positive and statistically significant impact on food security in the short run (0.018003, $p = 0.0000$). This suggests that increases in agricultural input costs, possibly driven by higher investments in modern farming technologies, contribute to improved food production and availability. Sanchi et. al. (2022) support this finding, stating that rising agricultural input costs often reflect increased adoption of high-yield seeds, fertilizers, and mechanized farming techniques, leading to enhanced food production. Similarly, Osabohien et. al. (2020) argue that investments in agricultural inputs improve productivity, offsetting initial cost increases and ultimately benefiting food security. Contrarily, Adekunle et. al. (2023) found that rising agricultural input costs can negatively impact

smallholder farmers, who may struggle to afford necessary inputs, thereby reducing overall food production. Amaechi (2018) also argue that high input costs, particularly in the absence of government subsidies, increase production expenses and food prices, leading to food insecurity for low-income households. These contrasting findings suggest that the impact of agricultural input costs on food security depends on accessibility, affordability, and government support mechanisms. The error correction term (CointEq (-1)) is negative and highly significant (-0.073170, $p = 0.0000$), confirming the existence of a long-run equilibrium relationship among the variables. The coefficient of -0.073170 indicates that approximately 7.3% of the short-run disequilibrium is corrected each period, suggesting a slow but steady adjustment process towards long-run stability. This finding aligns with Kutor et. al. (2024), who found that food security in Nigeria gradually, adjusts to macroeconomic shocks, stabilizing in the long run. Similarly, Aye et. al. (2025) argued that while inflationary pressures and exchange rate fluctuations create short-term food insecurity, long-term policy interventions help restore stability. However, Adesomoju et. al.(2024) contend that structural weaknesses in Nigeria's agricultural sector limit the speed of adjustment, prolonging food insecurity even after economic shocks subside. These opposing findings emphasize the importance of structural reforms and policy consistency in achieving long-term food security.

Table 4: Error Correction Model Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(EXR)	-0.028161	0.004362	-6.455657***	0.0000
D(INTR)	0.000117	5.41E-05	2.156122**	0.0392
D(MSP)	0.000195	0.009834	0.019788	0.9843
D(MSP(-1))	0.025438	0.007394	3.440143***	0.0017
D(CPIF)	-0.000130	9.47E-05	-1.376733	0.1788
D(CPIF(-1))	-0.000692	0.000114	-6.090202***	0.0000
D(AIC)	0.018003	0.002693	6.685876***	0.0000
CointEq(-1)*	-0.073170	0.006059	-12.07665***	0.0000
R-squared	0.803411	Mean dependent var		0.006589
Adjusted R-squared	0.770646	S.D. dependent var		0.021455
Durbin-Watson stat	2.105416			

Source: Computed by the author, 2025 from E-view 10.

Diagnostic Tests

Table 5 presents the results of diagnostic tests conducted to assess the validity of the model. The serial correlation test, with an F-statistic of 1.893737 and a p-value of 0.1693, indicates that there is no significant autocorrelation in the residuals. This suggests that the model's errors are not correlated over time, a crucial assumption for the reliability of the regression results. The heteroskedasticity test, with an F-statistic of 0.954168 and a p-value of 0.5321, shows no evidence of heteroskedasticity, meaning the variance of the errors is constant across observations. Finally, the normality test, with a statistic of 1.638356 and a p-value of 0.4407, suggests that the residuals are normally distributed. These results imply that the model does not violate key assumptions, and the regression findings can be considered reliable and valid for drawing conclusions. The Ramsey RESET test assesses the functional form of the model by checking for omitted variable bias. The F-statistic (0.303788) and a high p-values (0.5860), indicating that the null hypothesis of correct model specification cannot be rejected. This suggests that the model does not suffer from significant misspecification errors due to omitted nonlinear relationships.

Table 5: Diagnostics Tests

	F-Statistic	P-Value
Ramsey Reset Test	0.303788	0.5860
Serial Correlation	1.893737	0.1693
Heteroskedasticity Test	0.954168	0.5321
Normality Test	1.638356	0.4407

Source: Computed by the author, 2025 from E-view 10.

Table 6: CUSUM and CUSUM Square Stability Test

The CUSUM test confirms the stability of the model's parameters over time. The test results indicate that the variables remain within the critical bounds, suggesting no significant structural breaks. This stability ensures the reliability of the estimated coefficients and supports the consistency of the model for policy analysis and forecasting. Similarly, the CUSUM of squares test shows no structural instability, as the red lines move parallel upwards while the blue line stays within them. This suggests consistent variance in residuals and overall model reliability.

CUSUM STABILITY TEST

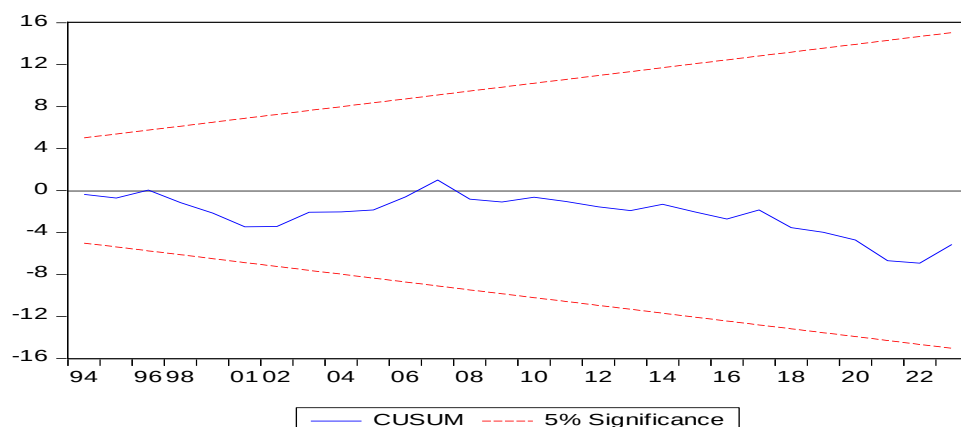


Figure 1: CUSUM STABILITY TEST

CUSUM OF SQUARE TEST

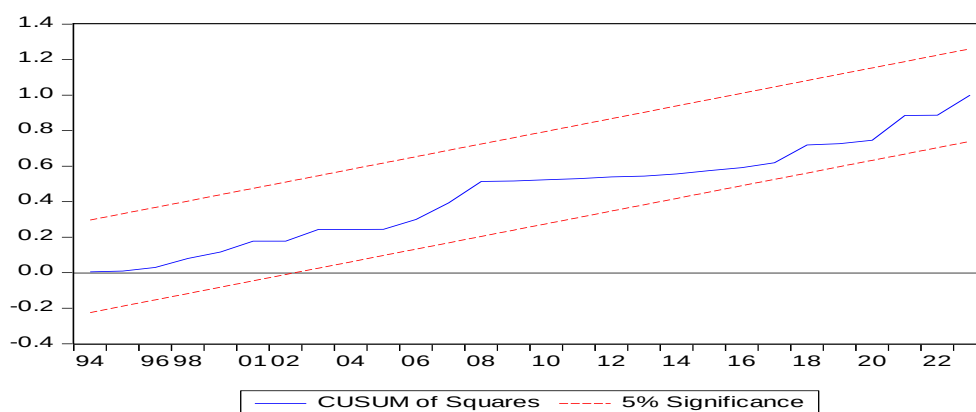


Figure 2: CUSUM OF SQUARE TEST

Source: Computed by the author, 2024 from E-view 10.

CONCLUSION AND RECOMMENDATIONS: In conclusion, the study demonstrates that inflation in Nigeria exerts a complex influence on food security. The findings reveal that high inflation erodes household purchasing power and indirectly worsens food security by increasing the cost of imported inputs, especially amid exchange rate depreciation. Although certain monetary factors, like increased agricultural investment prompted by higher interest rates or input costs, can slightly buffer food security, the overall effect of inflation remains destabilizing. These dynamics underscore that inflation contributes to heightened price volatility in food markets, ultimately challenging food affordability and accessibility. Addressing these issues requires comprehensive policy interventions to stabilize inflation and support sustainable agricultural production. Since rapid currency depreciation and lagged food price inflation undermine food security while better agricultural input costs appear beneficial, efforts must focus on stabilizing the exchange rate and supporting agricultural investments. Implementing policies that subsidize critical inputs, improve access to credit for farmers, and expand social safety nets will help safeguard household food security against inflationary shocks. The study also discovers that food security in Nigeria is more strongly determined by short-term price fluctuations than by persistent inflation trends. Therefore, short-term stabilization policies targeting price control and cost management are essential while long-term strategies should focus on addressing structural bottlenecks in the agricultural sector, improving productivity, and enhancing resilience to inflationary shocks.

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Climate Information: A Panacea for Climate Related Risks in Smallholder Farming Communities in the Kano Region, Nigeria

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Abstract

Weather monitoring is one of the most important aspects of climate science that is aimed at generating weather data from credible meteorological stations which if well interpreted and translated can assist in decision making in different sectors, especially in Natural resources management. This study is conducted in the Kano region (Kano and Jigawa) with the aim of assessing Meteorological stations, their fitness to provide the required Climate information which is very important in useful decisions in Agriculture for the benefit of smallholder farmers to combat weather uncertainty. The study adopted qualitative and quantitative research approach where primary data were generated through direct observation using checklist, Focus group discussions with smallholder farmers in five (5) agroecological zones and key informant interviews with major stakeholders such as staff of ICRISAT, IITA, AIR, KNARDA, JARDA, NiMet and extension service workers across the study area. Qualitative data was used analysed using Nvivo 12.00v software and results were shown as word clouds. Results reveal that climate data generation is not too good due to the condition of local stations which makes it difficult for extension workers to disseminate the required information to farmers. 50% to 60% of FGD respondents in all the study area reported that the major meteorological challenge they have is dry spell exceeding 14 days. They also reported that onset and cessation of rainfall has changed (late onset and early cessation) in the last twenty (20) years which seriously affect the length of growing season and ultimately decline in crop yield. The study also through small farmers' engagement identified radio as the main source of climate related information which in most cases does not address local issues. It was also found through KII that extension workers lack proper training on CIS, their work also is dominated by genetically modified organism propagation at the detriment of crop-weather relationship. The study recommend bringing on more more synoptic, hydrometeorological and Agrometeorological stations, advocate for more synergy among smallholders and better strengthening of CIS disseminations with the requisite expertise to promote smallholder farmers education of climate information that could help in curbing weather uncertainties and mitigating the effects of climate change there by achieving food security.

Introduction: Weather and climate monitoring plays a crucial role in various sectors, it is important in providing accurate and timely data that are essential for decision-making and planning. The stakeholders in charge of the monitoring, including government agencies, educational institutions, and research organizations are the ones responsible for collecting and disseminating the data and climate information services to various end users. The coordination and synergy among these stakeholders is necessary for ensuring the quality and reliability of the climate data through compliance with guidelines set by the World Meteorological Organization. It is however very important to acknowledge that to effectively utilize the data for various applications, it is essential to assess the spatial distribution, representativeness, instrumentation, and measurement intervals of weather stations. One important aspect of climate data generation is to provide the required Climate Information service (CIS) which is the backbone of supporting decision-making in critical sectors such as agriculture and water resource management. The production, translation, interpretation, dissemination, and use of climate information is essential in ensuring effective utilization of the valuable data for sustainable development, especially in weather uncertainty. As highlighted by Vaughan and Dessai (2014 in Kumar et al. (2021), the ability of CIS to serve as the foundation for providing accurate and reliable data which can be used for decision making depends largely on its credibility and its ability to be interpreted in an unambiguous language to ensure clarity and understanding among end users especially smallholder farmers who in most cases can't read or write. The translation of climate information into local languages is essential in ensuring that it reaches a wider audience and can be effectively utilized by smallholder farming communities and water resource managers (WMO, 2017). One of the core importance of weather stations is to produce credible climate data and climate information aimed at decision making, however, despite the immense potential of CIS in addressing issues such as climate change, climate variability, and declining crop yields, there are still some obstacles that hinder their effectiveness, particularly in developing countries. A study by Kumar, Saskia, Spyridon, Dilip, and Fulco in 2021 pointed out a number of shortcomings in CIS, including lack of awareness, understanding, and location-specificity at farm level are among these obstacles. This lack of tailored information and communication strategies can prevent farmers from utilizing climate information effectively to mitigate risks and improve productivity. It is pointed out further that many national hydro-meteorological organizations often employ a top-down approach, which fails to capture the specific needs and requirements of farmers at the grassroots level.

Another key issues raised in the study by Kumar, Saskia, Spyridon, Dilip, and Fulco in 2021 is the limited scope and complexity of meteorological information and forecasts, which are often presented in a technical and numeric format that is difficult for smallholder farmers to interpret and apply to their daily farming practices. This gap in knowledge and communication can lead to suboptimal decision-making and hinder the adoption of climate related practices linked to agriculture which are serious issues. In order to address these challenges and maximize the potential benefits of CIS, it is important to promote more inclusive and participatory approaches that empower farmers to engage with and utilize climate information effectively. Another hurdle identified by Antiri-Agyei et al. (2021) is the absence or insufficient training of extension service officers who are tasked with interpreting data and information for farmers. This lack of expertise can result in miscommunication or misinterpretation of important data, leading to ineffective decision-making by farmers. Moreover, the absence of these officers can leave farmers without the necessary support and guidance to make informed choices for their agricultural practices. The inaccessibility of data in a readily available form for local farmers exacerbates the challenges especially in local communities where farmers are facing difficulty in feeding themselves and their immediate families.

Without access to relevant and comprehensible (in local languages) information, farmers may struggle to implement sustainable practices, improve productivity, and adapt to changing environmental conditions. This can hinder their ability to optimize yields, reduce costs, and mitigate risks in their farming activities. From the foregoing, it become imperative to investigate how CIS is generated and disseminated in the Kano region.

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Study Area: The Kano region is located on Lat 12° 07'22"N and 12° 13'40"N and Longitude 8° 35'31"E and 8° 33'41.76"E. The region is the current Kano and Jigawa states, which used to be an entity before its split in 1991. It has a total land area of 43, 285sq. Km. The region is composed of two states namely; Kano and Jigawa (Figure 1). Jigawa State shares the same border with the Niger republic to the North, Yobe State to the East, Bauchi to the North. and Kano/Katsina to the West. On the other hand, Kano is bordered by Jigawa to the east and northeast, Katsina to the west and northwest Jigawa to the Southeast and Kaduna state to Northeast. Kano and Jigawa are referred to as part the Drylands of Northwestern Nigeria by virtue of their rainfall regime (Waziri 2016).

Table 1: Summary of study area description

Climate	Vegetation	Soils	Geology and land forms	Hydrology
✓ Aw(tropical wet and dry ✓ Clear wet and dry season ✓ cT (NE) and mT (SW) air masses ✓ Dryness: Sept – March/April ✓ Wetness: April-August/sept ✓ Rf range: 486.1mm - 1281.2mm with average of 811.9mm ✓ Tmax:April/May (40.6°C) ✓ Tmix:Dec/Jan (12.8°C)	✓ Sudan Savana ✓ Trees, shrubs and expanse of grasses ✓ Indigenous and exotic tree spp ✓ Numerous parks and game reserve with animals ✓ Falgore game reserve	✓ Soils formed from aeolian parent materials ✓ Soils mostly Entisols and Inceptisols ✓ low carbon , poor nutrient, fragile, low WHC and shallow depth	✓ Basement complex of the pre-cambian origin ✓ igneous, metamorphic and granite rocks (less porous, permeable) ✓ Gravels, clay sands, shales, gypsum and ferruginous sand stones ✓ Relief ranges from 300m to 750m and 1,600m	✓ Two major river system Niger flows into Atlantic Ocean and Haejia-Jama'are river which drains to Lake Chad. ✓ Several Dams

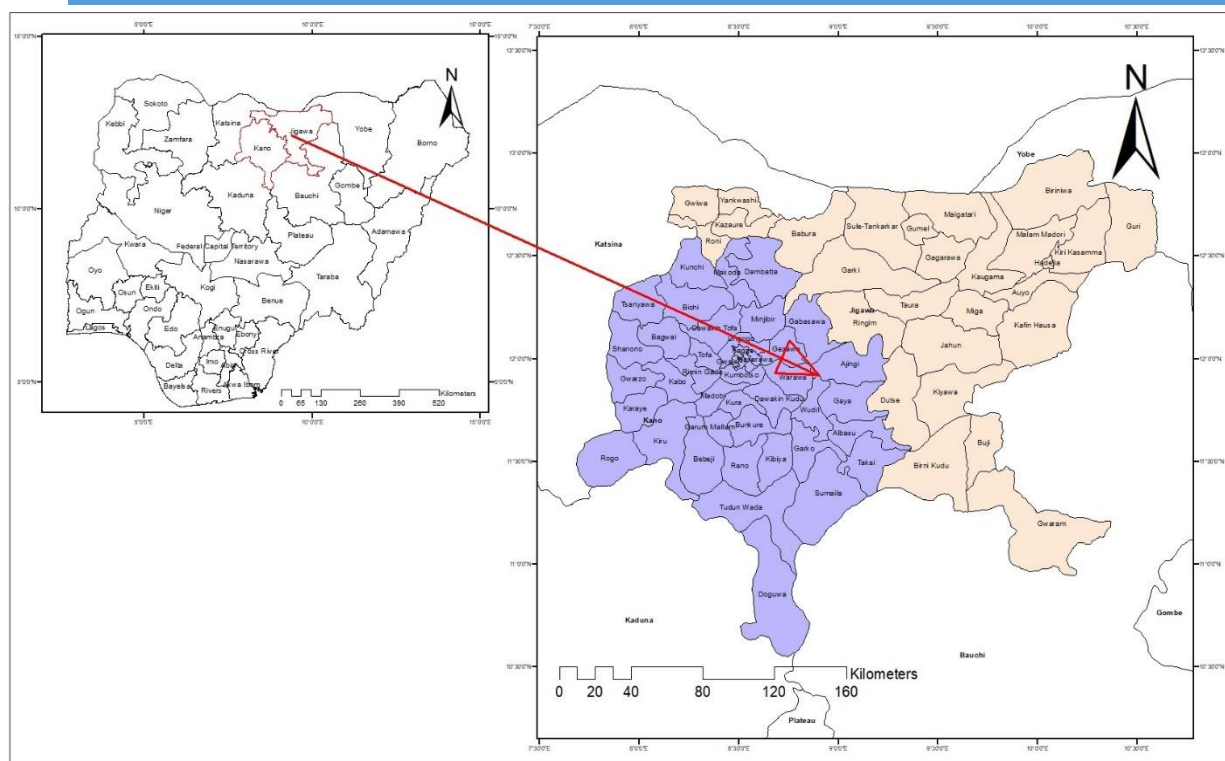


Fig 1: Study area

Climate Information Services and its importance: Climate information is defined as any data, knowledge or explanation that is related to the earth climate system which may include paleo (past) present and future climate conditions. It involves collecting, translating, analysing, and interpreting climate aimed at assisting scientists and policymakers assess current climate conditions, monitor climate trends over short or long term, and project future climate scenarios (Olofunfemi, Olofunfemi, & Oladele, 2020; Asule, et al., 2024) Climate information services (CIS) therefore refers to functions and supports provided by climate for individuals, businesses, and governments to make informed decisions in the face of a changing climate. These services provide valuable data on past, present, and future climate conditions, helping users understand and adapt to the impacts of climate change. CIS is getting more recognition because of its importance to decision makers in managing climate risks (Hilda, Oyedele, & Ginini, 2022). Mbiaferu, Molua, Setamenou, & Ndip (2024) assert that Climate services involve the collection, interpretation, organization, tailoring, and dissemination of weather and climate information. It therefore means that, climate services can be seen as a decision-making support tool developed based on a process of transforming climate information into relevant advisory services that assist decision-making by individuals such as farmers and social organizations. In agriculture, climate services can enable farmers to optimize many aspects of their production systems, including the timing of sowing, planting, fertilizer application, irrigation, harvesting, and spraying of pesticides and herbicides, and improve cropping pattern selection.

Factors that influence the utilization of Climate Information services by farmers: Olofunfemi, and Oladele (2020) and Nyoni, Bruelle, Chikowo, and Andrew (2024) put forward the following as the factors that influences the adoption and utilization of climate information services: Education: farmer's education level determines how they perceive and understand the information thereby improving their ability to seek information and participate in extension activities. This also means that farmers that are more literate have more chances of using CIS than those that are not, for example the literates among them can use weather and climate tools such as phone applications to get first-hand information without the help of extension workers.

Farm size: the size of farm in some cases tend to have positive influence on the access to CIS. It is argued that large farms have more positive influence to access CIS than smaller ones due to the magnitude of loss if the two are to be compared. Larger farms also have an increased capacity to adjust farm activities according to the climate information that is they are more likely to adopt climate change mitigation practices.

Agro-ecological zones: Agro-ecological zone play an important role in determining the use and adoption of CIS. Farmer located in arid and semi-arid regions are more aware and likely to use CIS than farmers that cultivate in humid regions due to increase in risk of crop failure in the former than in the later.

Extension services: availability of extension service staff in a region is one of the factors that motivate farmers to be aware, access and utilize CIS. Sometimes farmers are not able to combat climate related risks due to unavailability of extension service staff to talk to them.

Benefits of CIS for smallholder farmers: Climate Information Services (CIS) has a potential for smallholder farmers and it is important and timely subject in the field of climate change adaptation and agriculture. The concept of transforming climate and weather data into user-friendly information and knowledge to support decision-making is essential for building resilience and sustainability in agricultural practices. By enabling smallholder farmers to make informed decisions based on reliable forecasts, projections, and advisories, CIS can help mitigate risks and enhance productivity in agricultural activities especially in developing countries where adaptation strategies are always costly. However, one unique feature about is that engagement of diverse stakeholders in the production, translation, and dissemination of CIS products makes it key to ensuring that the information provided is relevant and responsive to the specific needs of users. This participatory

approach not only enhances the quality and usability of CIS but also fosters collaboration and knowledge exchange among different actors in the climate information ecosystem (Sarku, Gordana, & Troger, 2024)

The need for agricultural extension workers for CIS dissemination: Agricultural extension service is a system that delivers research findings in agriculture, and innovative technologies to farmers, rural communities, and stakeholders to improve farming practices thereby increasing agricultural productivity and promoting sustainable agricultural development aimed at food security attainment. The main aim is to increase farmers' knowledge and skills, promote the adoption of modern agricultural practices, enhance productivity and profitability, improve food security and nutrition, and promote sustainable and environmentally friendly farming practices (Mishra, Padhy, Mishra, Chakraborty, & Sai, 2024) Agricultural extension services are important for disseminating weather information that has direct implications for crop and livestock production to smallholder farmers, especially in rural areas where access to reliable weather forecasts may be limited. Extension workers can provide farmers with timely updates on weather patterns, helping them forecast what to anticipate and mitigate potential climate risks. Agricultural extension service workers employ a variety of methods to disseminate weather information to farmers, including radio and television broadcasts, text messages, use of mobile applications, and community meetings through farmers or religious associations. The benefits of receiving timely weather information from extension services are numerous. Farmers are better equipped to plan their planting and harvesting schedules, manage crop diseases and pests, and mitigate the impacts of extreme weather events such as droughts and floods. By incorporating weather information into their decision-making processes, farmers can increase their crop yields, reduce their risks, and ultimately improve their livelihoods. (Hilda, Oyediji, & Ginini, 2022, Mishra, Padhy, Mishra, Chakraborty, & Sai, 2024)

Water Resource management and Challenges in Nigeria: Water is an integral part of man's needs for survival. The management of a country's water resources is essential for sustainable development. It is clear that while Nigeria is endowed with abundant water resources, there are significant gaps in meeting the water needs of its population. The challenges faced by Nigeria in water management are a result of both natural and anthropogenic factors, including climate change, pollution of water bodies, and unsustainable groundwater exploitation. The reliance on private for-profit water ventures indicates a failure of policy and highlights the need for stronger government intervention and regulation in the water sector. Furthermore, the inadequate funding of water resource development in Nigeria is a significant barrier to achieving sustainable water management goals. The current budgetary allocation falls far short of the investment required to meet the Sustainable Development Goals by 2030, and consistent commitment to water resource development has been lacking in recent years (Onuh & Bassey, 2021).

To efficiently manage Nigeria's water resource, Integrated Water Resources Management (IWRM) which aims to address water scarcity and ensure sustainable water use for the benefit of both people and the environment is highly needed. Through the integration of various water sources and management strategies, IWRM seeks to improve economic development, enhance quality of life, and safeguard natural ecosystems Yunusa, Serah, Nouban, Aminu, & Madaki, (2020); Ibrahim, Sanyaolu, Alkali, & Usman (2022); Dike & Nwachukwu (2003)

However, the importance of IWRM lies in its emphasis on the coordinated use of surface and groundwater resources. By managing these two interconnected systems together, countries can optimize water supply reliability, enhance water security, and promote environmental sustainability. Efforts to implement IWRM have been seen in projects like the South Chad Irrigation Project and initiatives by organizations such as the Orange-Senqu River Commission and the Southern African Development Community. However, challenges still exist in the implementation of IWRM, particularly in transboundary water management. Failure to adopt conjunctive approaches can lead to issues like groundwater pollution, depletion of surface water resources, and land salinization. These challenges highlight the need for greater cooperation and coordination among countries sharing water resources (Yunusa, Serah, Nouban, Aminu, & Madaki, (2020); Ibrahim, Sanyaolu, Alkali, & Usman (2022); Dike & Nwachukwu (2003)

Methodology

Reconnaissance survey: A reconnaissance survey was conducted to get insight and make inquiries on what to prepare ahead of data collection, major stakeholders availability of resource persons and end users of CIS were identified at this stage. At this stage, also, resource persons for KII and potential FGD participants were also identified. Also, contacts with key stakeholders paved the way for fruitful collaboration and partnership with the help of friends and associates in those communities.

Types and sources of data: This research used primary data

Primary data: Primary data for this study were directly collected from FGD with farmers and KII with extension service workers.

Sampling frame: The sampling frame for this work include major stakeholders, and experienced farmers within the Kano region. Therefore samples were drawn from respondents for FGD and KII

Sampling of FGD respondents and Location: Systematic random sampling was used to come up with the configuration of the FGD respondents. First, respondents must be between age 25 and 65 (for experience sake), secondly, males or females ought to have form part of the discussion but unfortunately all the respondents were males for religious and cultural reasons only males participated. Lastly, the locations were chosen based on agroecology of the area and on basis of farming intensification. As such one town each was selected randomly from Northern Guinea Savanna (Bebeji), Southern Guinea Savanna (Doguwa), Sudan Savanna (Maigatari), Sahel Savanna (Babura) and the Kano river irrigation project (Kura)

Key Informant Interviews (KII): Key Informant Interviews were conducted with experts who have experience in their various fields. This is because their information is vital for making comparison with other sources of data such as FGD. Key Informant Interviews were conducted with major stakeholders of Climate Information Services (CIS) in order to bridge the gap between expert opinions and end user perspectives. The KII was conducted with the staff of KNARDA, JARDA, ICRISAT, IITA, NiMet, and HJRBDA to gather diverse viewpoints from individuals involved in climate information dissemination and utilization. It can be observed that most of the stakeholders chosen for KII have the requisite knowledge and have spent appreciable amount of time to talk on the subject matter. Their experiences in their roles ranges from 5-18 years which is commendable.

Focus Group Discussion (FGD): In order to gather data from its root, from the supposed beneficiaries of climate data and information, FGDs were conducted with farmers. Five FGDs were conducted in the seven agroecological zones, with one town from each zone strategically selected for participation. Also, the participants in each FGD are all males due to cultural and religious believe that limit mingling of male and females. Adults between 25-65 years were chosen for their expertise and knowledge of agricultural practices in the area. A cluster of 8-12 participants were included in each FGD group, ensuring a diverse range of perspectives. The discussions were structured into two sections: demographic characteristics of the participants and their knowledge of the climate-agriculture relationship, importance and sources of Climate Information Services (CIS), as well as the relevance of extension service workers and optimization strategies of CIS. By engaging directly with smallholder farmers through FGDs, the researchers were able to tap into valuable local knowledge and experiences, shedding light on the complex dynamics of climate and agriculture in the study area.

Table 1 FGD locations by Agroecology

S/N	Agroecology	Location	Age (Yrs)	No. of participants	Gender
1.	Northern Guinea savanna	Bebeji	26-65	9	Males
2.	Southern Guinea savanna	Doguwa (Maraku)	25-65	10	Males
3.	KRIP	Kura	30-65	12	Males
4.	Sahel Savanna	Babura	31-55	8	Males
5.	Sudan Savanna	Maigatari	27-67	12	Males

Author's Compilation, 2024

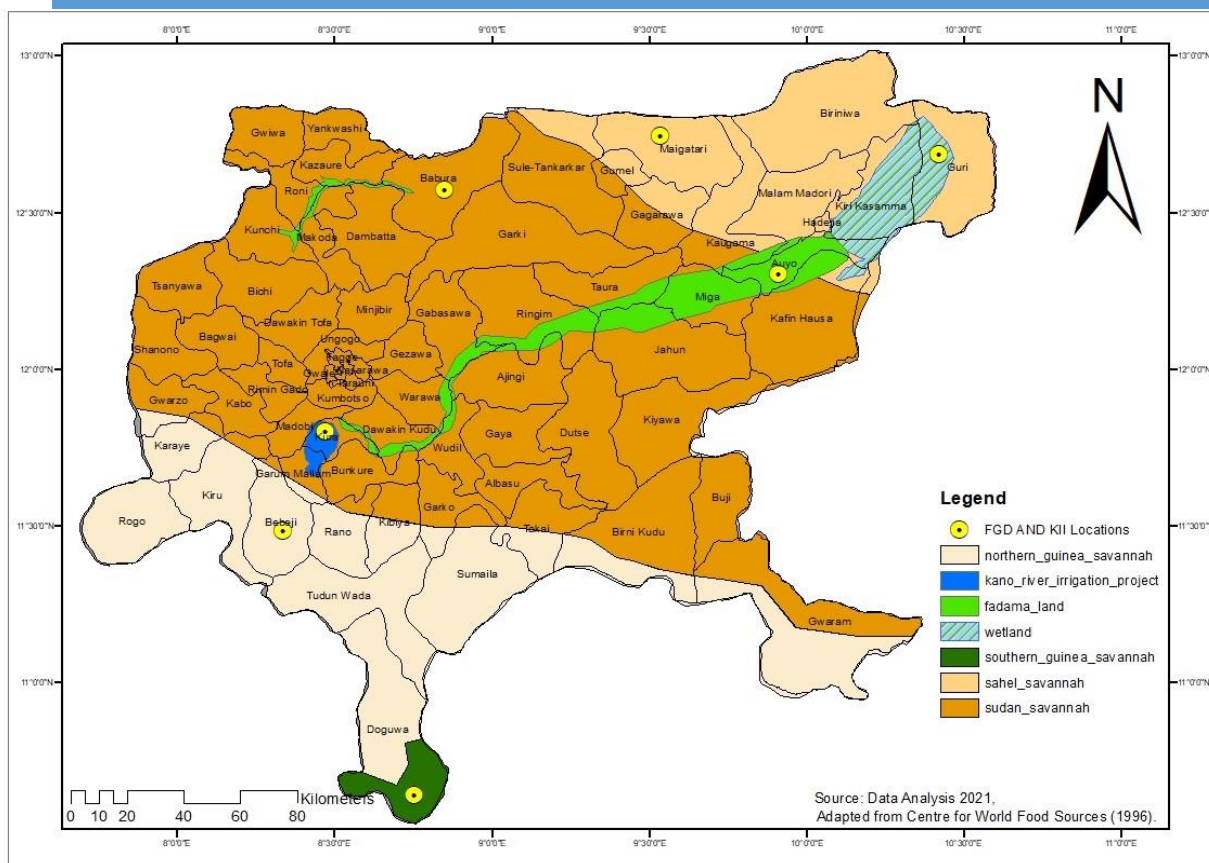


Fig 5:

Focus Group Discussion (FGD) Locations

FGD ethical considerations: FGD participants were educated on the purpose of the FGD and assured of the confidentiality of their responses. They were educated that the discussion is for academic purpose stressing that their input is very important for their practical knowledge. The discussion was conducted in Hausa language, as understood by the majority of the participants. They were also informed about the presence of research assistants for note-taking and recording, as well as the involvement of community friends as links between the researchers and participants.

Methods of Data Analysis: The qualitative data collected through in-depth interview and FGD from respondents were analyzed using NVivo, version 11.0 software. The software was able to condense large qualitative data from the KII and FGD. The data was transcribed and coded, and presented in word cloud, giving information on voluminous qualitative data base on people's opinions, perception into few lines.

Results and Discussion

Farmers knowledge and perception of the role of climate information service and meteorological parameters to farming

From the result on figure 1, all the five FGD groups agreed that climate information service and meteorological parameters are very important to farming system. Based on the responses, it is clear that meteorological elements are perceived as highly significant or very important in relation to farming activities in all the listed communities. This indicates that farmers in these communities understand the importance of monitoring and adapting to weather conditions in order to optimize their agricultural practices. This perception suggests that meteorological data and forecasts play a crucial role in decision-making processes for farmers, helping them to plan their planting, irrigation, and harvesting activities effectively.

significant
important
highly significant
very important

Fig. 1: Perception of the significance of meteorological parameters for all locations

Also from figure 1 of word cloud, it was gathered that meteorological parameters are highly significant to farming as attested by FGD respondents. Even though the view may vary for individual locations but the overall (for all FGD locations) is that they are highly significant, the reason it appeared in bigger font style (and in red) to show dominant opinion.

To dig more as to why FGD participants have that opinion, they were asked to shed more light on how significant these parameters are to farming, they were able to mention each of the metrological parameters and state how crops are affected when extremely exposed to them as shown (Table 13)

Table 2: Farmers identification of meteorological parameters

Temperature	Tomatoes are affected by high temperature Maize, rice, Okro and sohghum prefers more warm temperature
Rainfall	17 days of dry spell is not good for most field crops, especially in july when rice is about full maturity
Drought	Groundnut and soy beans can however withstand little drought
Wind	It's good when it is low to moderate but detrimental when it is high. It is important for "Numfashi" (soil aeration)

Author's Compilation, 2024

Results from table 1 reveals that farmers in all the FGD locations have basic knowledge of how meteorological parameters work in relation to farming activities. Farmer's in-depth knowledge of how much temperature, rainfall and drought may affect their farming activities is really amazing. This finding corroborate with that of Hilda et al (2002) where they found that smallholder farmers in his study location have indigenous knowledge of their farming activities including climate-crops relationship.

hightemperature
sunlight
rainfall humidity
lowtemperature
temperature

Figure 2: Overall response on most important meteorological parameter

Also to majority of the FGD respondents as depicted rainfall is considered the most important meteorological parameter for farming in the given areas, as it directly affects the availability of moisture for plant growth. Temperature, sunlight, and humidity are also important factors, but without adequate rainfall, crops may not be able to thrive. To further test the in-depth understanding of the farmers, a critical aspect of rainfall onset and cessation was discussed looking at the fact that most farming activities are rain fed. They attest that onset of rain is mostly between the month of April to May and cessation between the month of September to October in the last 20 years for most of the locations whereas 50% to 65% of the locations report it to be between June and others from April to May signifying that the onset is now late as compared to the past, an indication that farmers may not have double harvest in a year therefore they need techniques to optimize the length of the season through practices such as planting of drought resistant varieties and early maturing seeds, this is supported by Matere, Busienei, Ironjo, Nondokha, & Kweni, 2023 that smallholder farmers through long years of tilling the land have gathered so many experiences on the environment and farming system.

When the FGD participants were asked to identify major metrological hazards in relation to their environment, all the FGD groups identified drought and dry spell exceeding 14 to 21 days as the main hazard affecting their production except participants at Maraku in Doguwa and Maigatari who identified early cessation of rain and floods respectively which have adverse effects on farming system. This shows that they are knowledgeable of their means of livelihood which was gathered over decades as indicated by the work of Hilda et al (2002).

Farmer's knowledge of metrological parameters, measurement and availability of weather stations: FGD participants were asked if they know if the metrological parameters they identified earlier can be measured, 50% of participants are unsure if the parameters can be measured and 40% not sure, with only 10% of them having the knowledge of the measurement indicate a significant gap in knowledge. For example, a participant in Maigatari said:

"Yes I heard from someone that meteorological parameters are measured but in Niger Republic"

This indicates a common sentiment among smallholder farmers, with many mistakenly believing that weather data or weather stations are available only in countries other than theirs. This misconception underscores the importance of stakeholder engagement and education

initiatives aimed at bridging the gap between farmers and metrological services. This finding further confirms the work of Wamalwa et al (2016) who indicates that most farmers in rural African communities do not have the scientific backings for their indigenous knowledge.

Sources of climate information and dissemination among smallholder farmers: FGD participants in the five locations of the study area were asked to identify their sources of climate related information regarding their farming activities. They indicated the predominant reliance on radio (Figure 18) and limited access to television and farmers associations.



Fig. 3: Source of information on weather on crop/farming relationship in all locations

However very few mentioned farmers association. Further probing on what form of information they get from the radio, a participant at Maigatari said:

"They tell us that rainfall will be delayed this season, farmers should take measures regarding important days of planting and other cultural practices"

This is just one of the many kind of general nature of the information given to farmers and the call for location-specific information and best practices is particularly important. The lack of specificity in climate-related information can hinder farmers' ability to effectively respond to climate variability and change. As evidenced by the studies of Wamalwa, Mburu, & Gathuru, 2016, in which they identified newspaper, farmers group, internet and expert-community engagements in local vernacular as sources of information in the study area. Matere, Busienei, Ironjo, Nondokha, & Kwen, 2023 too identified mosques/church, farmer-farmer, seed stockers, SMS and pamphlets in addition to what was found in the Kano region.

What farmers need versus what extension service workers provides: Extension workers are very important in bridging the gap between farmers and the scientific community. Farmers in the locations acknowledged the existence of extension workers in various localities, but raises concerns about the nature and quality of the services they provide, particularly in relation to climate information dissemination and crop-related matters. This means there is disconnect between the services offered by extension workers and the needs of the farming community. Despite efforts to educate farmers on early maturing crop varieties and species/cultivar choices, it is disconcerting to learn that these initiatives may be driven more by economic incentives rather than genuine agricultural sustainability. Even though they interact with them on other agriculture related issues, the lack of emphasis on climate information dissemination is particularly concerning, given the increasing impact of climate change on agricultural productivity. It can also be observed that the promotion of Genetically Modified Organisms (Fig. 4) dominate the kind of information provided by extension workers which is linked to the highjack of extension work by seedling companies and promoters of GMOs.



Fig.4 : Type of information from extension workers

It was observed that there is resentment on the extension service workers in most of the location just like someone at Bebeji said

"We have no any relationship with them (extension workers), they are fraudsters who only come here to register us into different cooperative societies with the aim of facilitating loan for us. They collect registration fees from us, few people get the intervention and they vanish in thin air"

The level of mistrust between the farmers and extension service workers has reached a stage where a participant in Maraku village of Dogwa said

"Most of them are opportunists or children of elites whom studied agriculture in the four walls of classrooms, they don't live with us, they don't see us as them and they are not willing to assist that's even if they know".

This finding is similar to the results of Wamalwa, Mburu, & Gathuru, 2016 where they found that there is limited outreach of extension service workers to small holher farmers and if this is the trend where farmers do not have information on climate, they'll be predisposed to more climate related risks.

Extension Service Works and Climate information dissemination in the study area: Key Informant Interviews (KII) was conducted to complement to Focus Group Discussions (FGD) in the study area in order to gather a comprehensive understanding of the agricultural practices and challenges faced by farmers on one hand and what the extension workers provides to them on the other, doing so also help to balance and validate the information obtained from farmers. In order to balance the information supplied by farmers in the study area through FGD, a Key Informant Interview was conducted with extension service workers. Results from figure 20 indicates that only 30% of KII respondents received training within the past six years, with the majority lacking recent opportunities for knowledge and innovation transfer. Respondents from Babura and Bebeji, representing a significant portion of KII participants, reported not receiving any recent training in crop-climate relationship. Less than half of KII participants have received training on Subject Matter Specialist (SMS), a key aspect of their job, with little emphasis on crop-climate relationship. The lack of recent training on CIS and information dissemination to farmers poses a challenge for KII participants in effectively adding value to agricultural activities. Outdated training and workshops on crop-climate relationship may hinder KII participants' ability to provide up-to-date knowledge and innovation transfer to farmers.

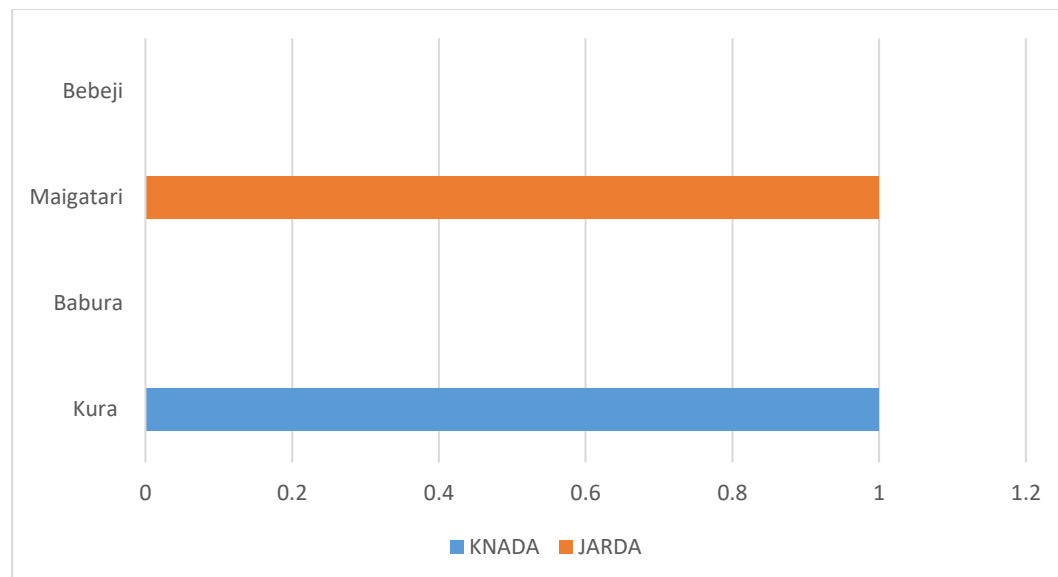


Fig 5: Trainings received by extension service workers from 2011-2021

It was found that most trainings received (if any) by extension workers are not directly linked to crop-weather relationship. For example, a respondent received training organized by JARDA in collaboration with SASAKAWA on dissemination of improved seed varieties. It also reveals that in other locations that extension service workers primarily attend trainings related to seed testing and acceptability, organized by seedling companies, rather than trainings on crop-climate relationship. The majority of interactions between extension service workers and farmers are centered on improved seed varieties, rather than discussions on uncertain weather patterns and technological solutions. The lack of communication on crop-climate relationship is actually undermining the ability of farmers in the study locations to optimize production which could also address climate-related crises in agriculture as indicated by Kumar *et al* (2021) for their study area

Location specific Climate Information Services for small holder farmers : Results from KII interactions with extension workers indicates that there are weather stations in their domain but they are not functional (Kura and Maigatari) and others denied having any even though they exist except they are not in full use. Participants at Babura said there is none and another participant at Bebeji said he is not sure whether there is or not, this is actually not a good story from the supposed information disseminators (extension workers). This finding corroborates that of Antwi-Agyei and Stringer (2021) who found that in most cases, extension service workers are not equipped with the requisite knowledge of the subject matter they sell to the farmers. If they as experts don't know the existence of agro meteorological stations in their area then it shows that there are either none or there is no much value addition in the job especially on CIS. However, all the interviewees acknowledged the importance of local stations for generating information that could help farmers in the study area rather than giving general information at national level. An extension worker in Bebeji said

“Even though we don't have them, we are not advanced it is the technique used in developed countries to achieve success in farming”

An informant at Babura in Babura responded that they sometimes receive a bulk information on weather pattern for the state irrespective of local peculiarities and wondered why large-scale weather predictions should be distributed to farmers without considering the specific peculiarities of different localities. This claim is valid, looking at the significant implications for agricultural practices because agronomic practices and crop yields are greatly influenced by local climate and weather conditions, therefore it is essential for farmers to receive accurate and localized weather information in order to make informed decisions regarding their farming activities. This is not in agreement with the findings of Ofogbu & New (2021) who opined the importance of organizations operating at a national level collaborating with local NGOs to disseminate weather information down to the community level. This decentralized approach allows for a more tailored and localized dissemination of weather predictions, taking into account the specific agro-ecologies and weather patterns of different regions.

By involving local stakeholders in the distribution of weather information, authorities can ensure that farmers receive accurate and context-specific predictions that are relevant to their specific agricultural practices. It is also worth noting for authorities to recognize the diversity of agro-ecologies and weather patterns across different localities and take these factors into consideration when disseminating weather predictions to farmers. Failure to do so could lead to ineffective agricultural practices, reduced crop yields, and ultimately economic losses for farmers.

When asked why there is need for local stations for informed climate smart farming rather than using remote decisions, three out of the informants affirmed the best practice is to issue weather information based on climate data generated at same level because weather is not static and so the locations are not the same. What is good for location A may probably not be good for location B. Because of this dynamism, information gathered from local stations will inform decisions such as planting harvesting the type of seeds to be sown, their duration on field and how they could be stored.

Conclusion: It can be concluded that the management of Meteorological stations in the Kano region is rather complex than it is thought. Generation and transmission of CIS is very important, which is highly linked to the conditions of the weather stations that generates them. It was found that there is a disconnect between the role of governmental, non-governmental, and private sector stakeholders in addressing climate-related issues and improving the availability and quality of climate data. It is evident that a collaborative approach among these stakeholders is essential for enhancing the effectiveness of CIS and ultimately addressing climate challenges.

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Assessment of Spatiotemporal Variation of Borehole Water Quality Parameters for Poultry Production in Maiduguri Metropolis, Borno State, Nigeria

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Being a paper submitted for presentation at the Annual National Conference of SAEREM/ABUJA 2025 to be held at the University of Abuja from 10th to 13th November, 2025.

ABSTRACT

Assessment of the spatio-temporal variation of borehole water quality for poultry production was undertaken. Water samples were collected in ten sample points (boreholes) in wet and dry seasons for the evaluation of seasonal fluctuations among water quality parameters for poultry production. The samples of water collected were subjected to laboratory analysis, using all the required materials, equipment, and procedures as practiced in a standard laboratory and WHO and FAO guidelines for poultry production. The study utilized T-test analysis to compute significant seasonal differences in these parameters. The study indicated that there was a significant difference ($p < 0.05$) in the mean concentration of temperatures, chloride, total hardness, nitrite, nitrate, and calcium. However, there is no significant difference ($p > 0.05$) among turbidity, TDS, colour, pH, magnesium, sodium, phosphate, sulphate, fluoride, calcium, cadmium, copper, iron, lead, manganese, and zinc during wet and dry seasons for borehole water. There was no significant difference ($p > 0.05$) in the concentration of total coliform count and colonies of *Clostridium perfringens* in borehole water during wet and dry seasons. It was also discovered that all the parameters are above the FAO standard for poultry production except for colour, pH and TDS. However, there was a statistically significant difference ($p < 0.05$) in the mean concentration of *E. coli*. The study concluded that there are significant fluctuations in key parameters such as temperature, chloride, total hardness, nitrite, nitrate, and calcium between wet and dry seasons which can significantly affect poultry production. The study recommended that regular monitoring should be conducted during both wet and dry seasons to capture seasonal variations accurately for effective poultry production.

INTRODUCTION: Water occupies a special place among natural resources. Water is the basis of life on earth, it is the main component of the environment and an essential constituent for life. It is a colorless, tasteless, and odorless chemical compound. Water is also fundamental for sustaining a high quality of life and for economic and social development. Just like other natural resources, water resources are limited at any location on earth at any time, and they should be used rationally for sustainable development.

Water makes up about 71% of the Earth's surface, while the other 29% consists of continents and islands. Earth's environment is relatively close to water's triple point, water exists on Earth as a solid, liquid, and gas. It forms precipitation in the form of rain and aerosols in the form of fog (Shiklomanov 2000). Water moves continually through water cycle of evaporation, transpiration (evapotranspiration), condensation, precipitation and runoff, usually percolating to reach groundwater and also reaching the sea. Water plays an important role in the world economy. Most of the freshwater used by humans goes to agriculture. Water is an excellent solvent for a wide variety of substances, both mineral and organic; as such, it is widely used in industrial processes and in cooking and washing. Water, ice, and snow are also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing, sport fishing and diving. Water differs from most liquids, it becomes less dense as it freezes. Natural water quality varies from place to place with the seasons, climate, and the types of soils and rocks through which water moves. When water from rain moves on the land, and through the ground, the water may dissolve minerals in rocks and soils, percolate through organic materials such as roots and leaves, and react with algae, bacteria, and other microscopic organisms. Water may also carry plants, debris, silt, and clay to rivers and streams making the water appear muddy or turbid.

HYPOTHESIS OF THE STUDY:

(H0): There is no significant difference among the mean values of physicochemical and bacteriological parameters of borehole water in wet and dry seasons at .05 alpha level.

(H1): There is a significant difference among the mean values of physicochemical and bacteriological parameters of borehole water in wet and dry seasons at .05 alpha level.

STUDY AREA: Maiduguri metropolis is the capital of Borno state located between latitude 10°00'00" and 14°00'00" North of the equator and longitude 11°00'30" and 14°45'00" east of the Greenwich Meridian (Figure 1). The area lies some 320m above sea level and it occupies a total area of 3000 sqkm (Ministry of Land and Survey Maiduguri, 2008). It lies on a vast open plain which is flat or gently undulating. The landscape is developed on the young sedimentary rocks of the Chad Formation. The River Ngadda and some short-course rivers drain the northern part of the plateau and flow northeast towards Lake Chad. River Yedsaram and its tributaries take their source from the Mandara Mountains and flow northeast toward Lake Chad (Daura, 2002; Nyanganji, 1994). Köppen-Geiger's climate classification system classifies Maiduguri's climate as hot semi-arid (BSh). It is characterized by a semi-arid and hot season, with a mean annual temperature of 25°C (Nigeria Meteorological Agency, 2008). The vegetation found in the Maiduguri metropolis is tropical Sahel Savannah consisting of mainly grasses with few droughts' resistant trees (Bukar *et al.*, 2021). The soil of the area is clay in nature which varies in colour, texture, structure, physico-chemical, and other essential characteristics from the hilly south to the northern dune landscape. Maiduguri Metropolis has an estimated population of 904,696 people out of which 473,125 were male while 431,571 were female (NPC, 2021).

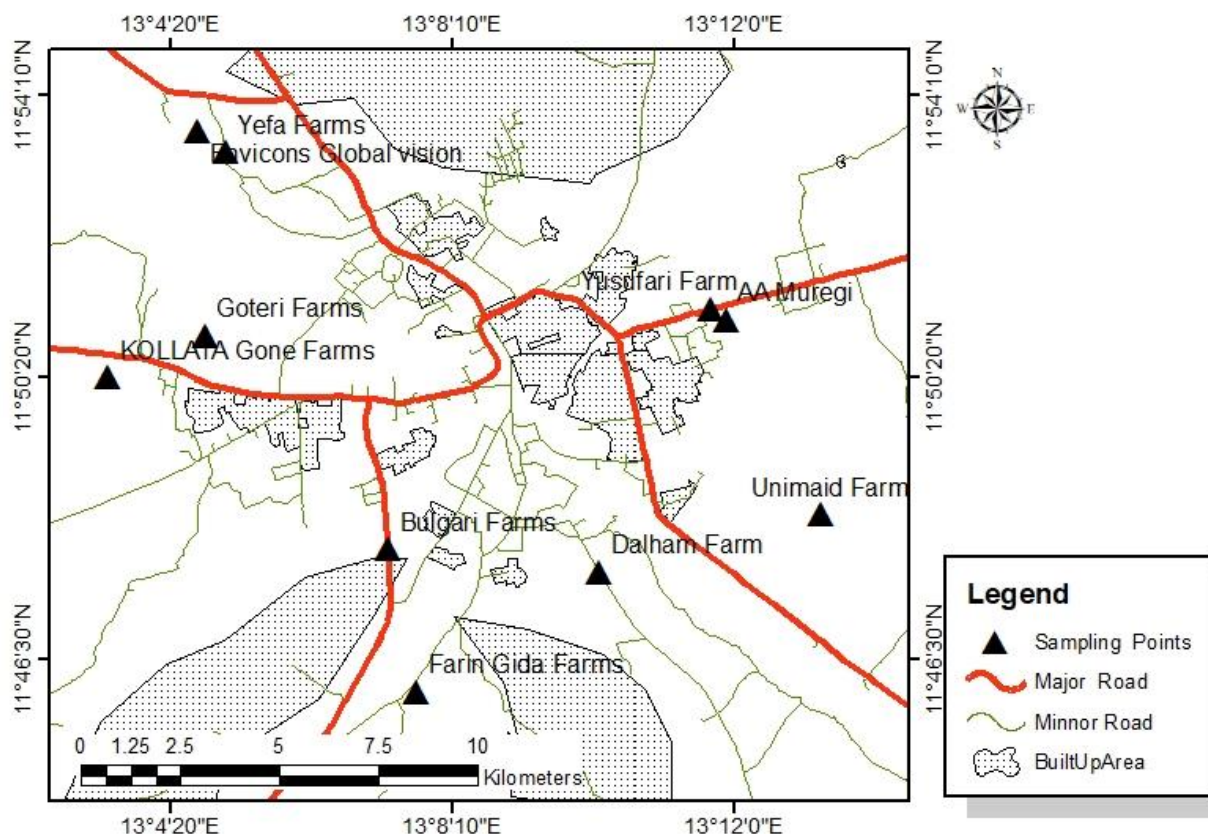


Fig. 1 Map of the study area showing the study locations
Source; Geospatial services 2021

METHODS: The target population for this study is the poultry farms within Maiduguri metropolis. All farms that house more than two thousand birds constituted the sample size for this study. Ten farms were randomly sampled for the analysis. Water samples were collected in clean and sterile plastic bottles with screw caps for the analysis. All the samples were labeled with appropriate codes (YSB) for proper identification. Y indicates the first letter of the farm's name, and B indicates borehole water respectively. The water samples were collected in both wet and dry seasons. A T-test was used to determine seasonal differences.

RESULTS AND DISCUSSION: This section presented and discussed the result of a comprehensive research study that utilized T-test analysis to compute significant seasonal differences in physicochemical and microbiological parameters for borehole water in wet and dry seasons. The physicochemical and microbiological parameters of ten poultry farms in Maiduguri below indicate the mean value, standard deviation, p-values, and t-values of the water samples.

Seasonal difference among physical parameters of borehole water: Results of the t-test for temperature indicated that the p-value at 0.05 significant levels in the wet and dry seasons is less than the t-value, therefore, we can now reject the null hypothesis, meaning that there is a significant difference in temperature variation between wet and dry seasons for borehole water. However, there was no significant difference ($p > 0.05$) in turbidity, colour and total dissolved solid in boreholes during wet and dry seasons, therefore, the null hypothesis is retained, meaning that there is no significant difference in the mean concentration of turbidity, colour and total dissolved solid (Table 1).

Table 1 Seasonal difference in mean among physical parameters of borehole water in wet and dry season

Parameter	Source	Wet season		Dry season		p-value	t-value
		Mean	SD	Mean	SD		
Temperature	Borehole	31.39	1.45	28.39	0.77	0.000331	13.9
Turbidity	Borehole	4.0	1.15	4.3	1.64	0.66	-0.44
Colour	Borehole	10.4	2.46	8.9	1.97	0.12	1.71
TDS	Borehole	344.1	99.4	469	186.3	0.1	-1.8
Odour	Borehole	-	-	-	-	-	-
Taste	Borehole	-	-	-	-	-	-

Field/laboratory work: 2022/23

Seasonal difference among chemical parameters of borehole water: The result of t-test in Table 2 indicated that there was no significant difference ($p > 0.05$) in pH, magnesium, phosphate, sulphate, calcium, cadmium, copper, iron, lead, manganese, and zinc in borehole water during wet and dry season, therefore, we retained the null hypothesis, meaning that there is no significant difference in mean concentration of pH, magnesium, phosphate, sulphate, fluoride, calcium, cadmium, copper, iron, lead, manganese and zinc. However, there is a statistically significant difference ($p < 0.05$) in the mean concentration of sodium, chloride, total hardness, nitrite, nitrate, calcium, and fluoride.

Table 2 Seasonal difference in mean among chemical parameters of borehole water in wet and

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PROCEEDINGS

dry season							
Parameter(mg/L)	Source	Wet season		Dry season			
		Mean	SD	Mean	SD	p-value	t-value
pH	Borehole	7.53	0.45	7.56	0.58	0.7	-0.39
Mg	Borehole	34.4	14.97	31.09	10.91	0.5	0.66
Na	Borehole	36.8	14.39	25.66	10.96	0.00005	7.21
PO ₄ ³	Borehole	0.022	0.009	0.032	0.015	0.06	-2.12
Cl ⁻	Borehole	136.7	27.51	196.5	50.13	0.006	-3.58
TH	Borehole	48.8	11.96	64.9	13.85	0.016	-2.92
NO ₂	Borehole	0.077	0.031	0.023	0.011	0.00086	4.88
NO ₃	Borehole	0.81	0.45	0.37	0.19	0.02	2.81
SO ₄	Borehole	32.1	7.37	34.9	11.78	0.39	-0.90
Ca	Borehole	28.7	10.22	41.8	14.88	0.017	-2.93
Fl	Borehole	0.82	0.55	1.158	0.36	0.05	-2.24
Cd	Borehole	0.0051	0.0019	0.0045	0.0010	0.34	1.00
Cu	Borehole	0.389	0.191	0.442	0.184	0.59	-0.56
Fe	Borehole	0.193	0.045	0.193	0.080	1.0	3.873E-16
Pb	Borehole	0.051	0.029	0.038	0.017	0.07	2.05
Mn	Borehole	0.018	0.009	0.022	0.011	0.15	-1.56
Zn	Borehole	0.557	0.282	0.93	0.272	0.009	-3.32

Field/laboratory work: 2022/23

The result of the t-test in Table 3 indicated that there was no significant difference ($p > 0.05$) in the concentration of total coliform count and colonies of *clostridium perfringens* in borehole water during wet and dry season, therefore, we retain the null hypothesis, meaning that there is no significant difference in mean concentration of total coliform count and colonies of *clostridium perfringens*. However, there is a statistically significant difference ($p < 0.05$) in the mean concentration of *E. coli*.

Table 3 Seasonal difference in mean among bacteriological parameters of borehole water in wet and dry season

Parameter	Source	Wet season		Dry season			
		Mean	SD	Mean	SD	p-value	t-value
Coliform bacteria	Borehole	4.6	2.63	1.8	0.63	0.08	3.38
<i>E. coli</i> count	Borehole	5.3	2.87	2.4	2.07	0.000016	8.33
<i>Clostridium</i> spores	Borehole	3.0	2.26	1.6	0.97	0.094	1.87

Field/laboratory work: 2022/23

Terebo *et al.*, (2019) at Ondo state, observed a significant ($p < 0.05$) difference in turbidity between the means and among the districts in the rainy season which is contrary to the finding of this study. Research conducted by Efe *et al.*, (2005) at the Niger-Delta region, supported the current finding, who stated that there was no significant difference ($P \leq 0.05$) found to exist in turbidity among the three water samples during dry and wet seasons (Efe *et al.*, 2005) at Niger-Delta region. Okoya & Elufowaju (2020) in south-western Nigeria, showed no significant difference among the mean of cadmium, copper, lead, manganese, and zinc concentration across the water bodies, the study is similar to the current study. This finding was, however, against the work of Adongo, *et al.*, (2022) at Kamiti-Marengeta Sub-catchment Kiambu, Kenya, who revealed that there is a statistically significant difference in the mean concentration of iron between samples collected in wet and dry seasons.

This finding was similar to the work of Frank, *et al.*, (2018) in Benin City, who stressed that the mean total coliform count of borehole water from metallic tanks was higher than that from plastic tanks yet there was no significant difference ($p > 0.05$) between the total coliform count value of metallic tank water and that of plastic tank water samples. This work is agreed with the work of Ali, (2020) at Aba River, Aba North, Abia state. The study of Frank, *et al.*, (2018) at Benin City, showed a significant difference in the mean of *clostridium perfringens* spore ($p < 0.05$) between treated and untreated water *clostridium perfringens* spore in drinking water which indicated faecal contamination and poor water treatment. The study is contrary to the current findings.

CONCLUSION AND RECOMMENDATIONS: The study concluded that there are significant fluctuations in key parameters such as temperature, chloride, total hardness, nitrite, nitrate, and calcium between wet and dry seasons. The study recommended that NAFDAC, NESREA, and State Water Treatment Plant should implement a robust monitoring programme for water quality parameters, particularly focusing on temperature, chloride, total hardness, nitrite, nitrate, sulfate, fluoride, and microbial contaminants such as *E. coli*. Regular monitoring should be conducted during both wet and dry seasons to capture seasonal variations accurately.

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Impact of Benin Republic Rice Importation on Nigeria's Rice Production: Evidence from Ardl Mordelling

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Abstract

This study examines the impact of Benin Republic rice importation on Nigeria's rice production using the Autoregressive Distributed Lag (ARDL) model. Secondary data from 1979–2022 were sourced from FAO, United Nations COMTRADE, journals and the Federal Ministry of Agriculture and Rural Development. Descriptive statistics were employed to determine the trends of local rice production in Nigeria and Nigeria's and Benin Republic rice importation. ARDL bound tests of cointegration were applied to determine short-run and long-run dynamics among rice production, Benin's rice importation, and other explanatory variables such as fertilizer use, tariff rate, and rainfall. Results reveal a long-run negative and statistically significant relationship between Benin's rice imports and Nigeria's rice production, implying that sustained rice inflows into Benin depress domestic rice production capacity. Conversely, rice area cultivated, fertilizer distribution, and domestic rice import positively influenced rice output. Short-run results, however, suggest that Benin's previous-year's rice imports may temporarily stimulate Nigeria's production before exerting adverse long-run effects. The study concludes that cross-border rice smuggling through Benin undermines Nigeria's self-sufficiency goals. It recommends moderating rice import tariffs, strengthening border surveillance through technology, and enforcing ECOWAS trade regulations to curb informal re-exports. Effective regional collaboration and consistent policy implementation are crucial to sustaining Nigeria's rice production growth.

Key words: ARDL, tariffs, fertilizer subsidy, rice importation.

BACKGROUND TO THE STUDY: Rice is one of the most consumed staples in Nigeria, with consumption per capita of 32kg. In the past decade, consumption has increased by 4.7%, almost four times the global consumption growth, and reached 6.4 million tonnes in 2017, accounting for 20% of Africa's consumption. Nigeria's rice production rose from 3.7 million metric tons in 2017 to 4.0 million metric tons in 2018. In spite of this, only 57 percent of the 6.7 million metric tons of rice consumed in Nigeria by 2018 is locally produced leading to a deficit of about 3 million metric tons, which is either imported or smuggled into the country illegally. To stimulate local production, the Government banned importation of rice across land borders in 2019, (FAO, 2020). Governments have also deployed policies to bridge the demand-supply gap since independence. These interventions have included the Presidential Initiative on Rice in 2007, National Rice Development Strategy I that was implemented from 2018-2018, National Rice Development Strategy II to be implemented from 2020-2030, and development programmes such as the Agricultural Transformation Agenda in 2011. Government actions and interventions were motivated by the facts that Nigeria is naturally endowed with viable ecologies that are suitable for massive cultivation of different rice varieties and should therefore not rely on importation of rice to feed its population (Adesina, 2012). Moreover, potential land area for rice cultivation of between 4.6 and 4.9 million hectares exists but fewer than 3.2 million hectares is under rice cultivation (FAO, 2015). Trade policies have been used to bridge the rice supply-demand gap since the country's independence in 1960. These policies included various measures ranging from tariff imposition or removal/reduction, quantitative restriction on imports through the use of quotas to outright ban on imported rice. The Nigerian government over the past few years has been promoting the concept of greater self-sufficiency in rice by supporting local production and aiming to curtail importation. Nigeria imposes a 10 percent tariff and a 60 percent levy (totaling 70 percent) on imported rice (arriving by sea). The official ban on rice imports through land borders remains, but is reportedly difficult to control (Thrive Agriculture, 2020). When Nigeria increased rice import duty and levy to 110% in 2013, Benin Republic, where parboiled rice was not consumed, crashed its rice import tariff from 35% to 7% in order to take advantage of the huge Nigerian market where parboiled rice is staple food, resulting in the diversion of virtually all vessels from Nigeria to Benin, Cameroun, Togo and Ghana, as only one rice ship berthed in the country in that year against the over 500 that berthed in the country in 2012 (Ships & Port, 2013). The following graph from Thai Rice Exporters Association (TREA) (2020) depicts the importation of parboiled rice from Thailand by Benin Republic and Nigeria.



Figure 1: Rice Import of Nigeria and Benin from Thailand
Source: Thai Rice Exporters' Association (TREA, 2020)

When Nigeria imported about 1.2 million MT of Thai rice in 2009, Benin's import of the commodity from the same country stood at 600,000 MT, but when Nigeria's import from Thailand moved up to 1.6 million MT in 2011, Benin's import of Thai rice dropped to 200,000 MT. However, when in 2013, Nigeria's import of Thailand rice dropped to 200,000 MT, the year Nigeria's rice import tariffs reached 110%, Benin's import from the country rose to more than 1.4 million MT. Then in 2015, Nigeria's Central Bank banned the use of its foreign exchange for rice importation, banned rice import across borders, and placed a 70% tariff on rice import, all of which reduced rice import from Thailand to 600,000 MT from 1.2 million MT in 2014, while Benin's import of Thai rice rose to 800,000 MT. Putting this trend in perspective, Hayley (2019), observed that most import into Nigeria were smuggled in from Benin, which despite a population of 11 million—barely 5 percent of Nigeria's population—had become the world biggest buyer of rice from Thailand, asserting that official shipments to Nigeria plummeted by more than 95 percent in the previous four years, while those of Benin had surged.

Nairametrics (2022) reported that the level of rice imported by Benin Republic from 2016 showed a sudden increase despite having a population of less than 6% of Nigeria's 216 million people, bringing up the questions about how a country with such a small population can consume so much rice, except it is a medium used in smuggling the item into Nigeria, where parboiled rice is consumed from Benin Republic where parboiled rice was hardly consumed.

Furthermore, World Bank (2020) reported that Benin's economy is heavily reliant on the informal re-export and transit trade with Nigeria, which accounts for about 20 per cent of its GDP, and that about 80 per cent of imports into Benin are destined for Nigeria. This is taking place against the backdrop of Article 3, Paragraph 2 of ECOWAS which states that the Community shall ensure the establishment of a common market through the removal of barriers between Member States of obstacles to the Free Movement of persons, goods, services and capital and the rights of Residence and Establishment (ECOWAS, 2014). When Nigeria closed its land borders in 2019 to curtail smuggling, Central Bank of Nigerian (CBN, 2019) reported Emezie, the former CBN Governor, urging the federal government to list out terms and conditions to be met by Nigerian neighbours before the borders are re-opened, stressing that there must be concrete engagements with countries that are involved in using their ports and countries as landing ports for bringing in goods that are smuggled into Nigeria. These "concrete engagement" with neighbours that Emezie canvassed for must be properly guided with studies of the effects of the neighbouring countries trading practices on Nigeria's local production among these guides. Accordingly, the main objective of this study was to determine the impact of Benin Republic rice importation on Nigeria's rice production. The specific objectives are to

- (i) describe the trend of Nigeria's rice production and rice importation of Nigeria and Benin Republic;
- (ii) determine the impacts of Benin Republic rice importation on Nigeria's rice production;
- (iii) make policy recommendations based on the findings.

MATERIALS AND METHODS

Study Area: This study was conducted in Nigeria, West Africa. The country is located on the Gulf of Guinea, occupying a geographical area of about 923,770 square kilometres with an estimated population of 223,804,632, going by the population growth rate of 2.41% (United Nations, 2022). It lies along latitudes 9° 04' 39.90" N and longitudes 8° 40' 38.84" E. It is bounded by the Atlantic Ocean to the south and by the Sahelian countries of Niger and Chad to the north. Nigeria operates a federal system of government with 36 states, the Federal Capital Territory, and 774 local government areas (LGAs).

Nigeria is characterized by three distinct climate zones, a tropical monsoon climate in the south, a tropical savannah climate for most of the central regions, and a Sahelian hot and semi-arid climate in the north of the country. The southern regions experience strong rainfall events during the rainy season from March to October with annual rainfall amounts, usually above 2,000 mm, and can reach 4,000 mm and more in the Niger Delta. The central regions are governed by a well-defined single rainy season (April to September) and dry season (December to March). Coastal areas experience a short drier season with most rain occurring over March to October. In the north, rain only falls from June to September in the range of 500 mm to 750 mm. Northern areas have a high degree of annual variation in its rainfall regime, which results in flooding and droughts (World Bank, 2022).

Nigeria has a total agricultural area of about 70 million hectares, which is distributed among arable land area of 34 million hectares, permanent crops area of 6.5 million hectares and 28.6 million hectares of meadows and pastures (Statista, 2022).

Nigeria has highly diversified agro-ecological conditions, which makes possible the production of wide range of agricultural products with maize, cassava, guinea corn, yam beans, millet and rice being the major crops. Potential land area for rice cultivation of between 4.6 and 4.9 million hectares exists but fewer than 3.2 million hectares is under rice cultivation (FAO, 2015).

Study Data:: Data for the study were sourced from secondary sources. Data on rice production and productivity were sourced from FAO web sites and the Federal Ministry of Agriculture and Rural Development. Data on rice importation were sources from FAO websites and United Nations COMTRADE.

Data Analysis: Descriptive statistics that include mean, standard deviation, skewness, and graph presentation were used to describe the trend of Nigeria rice importation, Benin Republic rice importation and Nigeria's rice production.

Stationarity Test: Unit roots test of stationarity was used to determine the stationarity of the data used, and afterwards ARDL Bound Test of integration was used to find long-run and short-run relationship among the integrated variables. In testing the series for stationary, Augmented Dickey Fuller (ADF) was employed together with the Phillip Peron test.

The unit root test is then conducted by investigating the following hypothesis test:

H_0 : = 0, unit root is present i.e. the time series is non-stationary

H_1 : < 0, no unit root is present i.e. the time series is stationary

H_0 is rejected if the t-statistic is negative and statistically significant when compared to appropriate critical values established for stationarity tests.

ARDL Model: The ARDL model capturing error correction term, adopted to determine co-integration among rice production and rice productivity variables, is explicitly specified as in Equation (3.9).

$$\Delta \ln Y_t = a_0 + \sum_{i=1}^p a_{1i} \Delta \ln Q_{t-i} + \sum_{i=1}^q a_{2i} \Delta \ln RAC_{t-i} + \sum_{i=1}^p a_{3i} \Delta \ln QFD_{t-i} + \sum_{i=1}^q a_{4i} \Delta \ln QFU_{t-i} + \sum_{i=1}^q a_{5i} \Delta \ln PFS_{t-i} + \sum_{i=1}^p a_{6i} \Delta \ln PFT_{t-i} + \sum_{i=1}^p a_{7i} \Delta \ln RF_{t-i} + \sum_{i=1}^p a_{8i} \Delta \ln ARP_{t-i} + \sum_{i=1}^p a_{9i} \Delta \ln ASP_{t-i} + \sum_{i=1}^p a_{10i} \Delta \ln AMP_{t-i} + \sum_{i=1}^p a_{11i} \Delta \ln NRI_{t-i} + \sum_{i=1}^p a_{12i} \Delta \ln BRI_{t-i} - \lambda ECT_{t-1} + e_{1t} \quad (3.9)$$

Where;

Y_{t-1} = Rice production in (tons) or rice productivity (yield) in year t-1 (tons/hectare)

Q_{t-1} = Rice Production in year t-1 (tonnes)

RAC_{t-1} = Rice Area cultivated in year t-1 (hectares)

QFD_{t-1} = Quantity of fertilizer distributed in year t-1 (tons)

QFU_{t-1} = Quantity of fertilizer used in year t-1 (tons)

PFS_{t-1} = Percentage fertilizer subsidy in year t-1 (%)

PRT_{t-1} = Percentage rice tariff in year t-1 (%)

RF_{t-1} = Rainfall in year t-1 (millimeters)

ARP_{t-1} = Average Rice Retail Price in year t-1 (₦/ton)

ASP_{t-1} = Average Sorghum Retail Price in year t-1 (₦/ton)

AMP_{t-1} = Average Maize Retail Price in year t-1 (₦/ton)

NRI_{t-1} = Nigeria Rice Import in year t-1 (ton)

BRI_{t-1} = Benin Republic Rice Import in year t-1 (ton)

Δ = the difference operator

e = error correction factor.

λ = speed of adjustment parameter with a negative sign

ECT = Error correction term.

Following ARDL model, the F-bounds test (pesaran et al., 2001) was conducted to check the long-run association among the variables considered in the model. If F-statistics exceeds the critical value of upper bound, I(1) at 1%, 5% and 10% level of significance, it can be concluded that there is cointegration, meaning there is a long-run relationship among the variables. We reject the null hypothesis and estimate the long-run model, the error correction model. If F-statistics is lower than I(0), the critical value of the lower bound, we conclude that there is no cointegration. There is no long-run relationship, and the null hypothesis is accepted.

RESULTS AND DISCUSSION

Trend of Nigeria and Benin Republic Rice Importation and Nigeria Rice Production

Figure 1 shows the trend of Nigeria and Benin Republic rice importation with Nigeria's rice production.

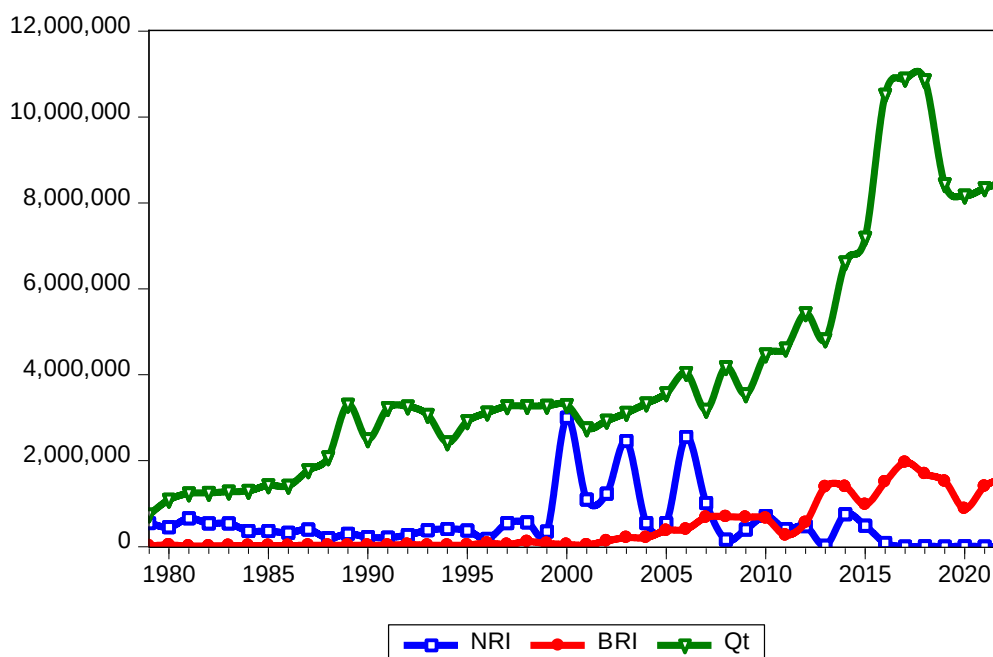


Figure 1: Trend of Rice Production, Nigeria Rice Import and Quantity of Fertilizer Distributed

Source: Computed from 1979 – 2022 Time Series Data The Nigerian Government banned rice import into the country in October 1978 till September 1979, after which the ban was reversed to issuance of general import licenses without quantitative restrictions in 1980. The Green Revolution was the agricultural policy in operation in this period, which, according to IRG (2020), had improvement of rice and fish production as the main focus. Nigeria's rice import rose from 450,000 tons in 1980 to 657,000 tons in 1981, but dropped to 365,000 tons by 1984. This was the period Obi-Egbedi *et al.* (2013) described as the import quota period when the global oil crises generated mounting debt servicing challenges forcing government to try and curb the influx of rice imports into the country. Rice production, on the other hand in this period, increased from 750,000 tons to 1,300,000 tons. During the outright ban period (1985-1995), no tariff was charged as importation was banned, and production rose from 1.43 million tons in 1985 to 2.92 million tons in 1995, however, the United Nation's COMTRADE (2022) still reported import into Nigeria for these years as 320,000 was reported to be imported into the country in 1985 while 374,000 tons was imported in 1995. In addition, Ugwuja and Chukwukere (2021), reported that during this period, illegal rice importation continually thrived due to the country's porous border thereby limiting the gains of the protectionist policies.

Importantly, Nigeria's rice import should not be discussed in isolation of its neighbours' rice import, especially the rice import of Benin Republic. As noted Golub *et al.* (2019), almost all of Benin's rice import are of parboiled rice, the preferred type of rice in Nigeria but not in Benin, providing further evidence that the large volume of rice imports in Benin is intended primarily for Nigerian markets. In 1995, at the beginning of post-ban period (1995-2011) a 100% rice import tariff was introduced, and Nigeria's rice import fell to 374,000 tons the following year from 411,000 tons in 1995, while Nigeria's rice production rose to 3.12 million tons in 1996 from 2.90 million tons in 1995. On the other hand, Benin Republic rice import rose to 80,000 tons in 1996 from 40,000 tons in 1995. From 2013 onward, Nigeria's Government shifted towards inputs substitution policies on several agricultural products, rice inclusive (Ugwuja and Chukwukere, 2021). Benin Republic rice import witnessed a huge spike in this period, jumping from 561,073 in 2012 to 1.93 million tons in 2013 and 2014 while Nigeria's import dropped to from 478,514 tons in 2012 to 19,618 tons in 2013. On the other hand, Nigeria's rice production initially dropped from 5.43 million tons in 2012 to 4.82 million tons in 2013 before rising to 6.61 million tons and 7.18 million tons in 2014 and 2015, respectively.

Although the period from 2016 to 2022 also recorded an upward and downward trend, it remains the period with the highest output in rice production. Building on the Agricultural Transformation Agenda of President Jonathan's government, President Buhari's Government put forward the Agricultural Promotion Policy, which among others had an objective of facilitating the government's capacity to meet its obligations to Nigerians on food security, food safety and quality nutrition. The Government also introduced Anchor Borrowers' Scheme as the Agricultural Transformation Agenda Support Program Phase 1 (ATASP-1), which had ensuring food and nutrition security as an objective, became operational in 2016.

In the late 2017, Nigeria introduced a ban again on rice import, and production rose to 10.89 million tons from 7.18 million in 2015, while importation fell to a meagre 4,144.57 tons the same year (2017) from 489,044 in 2015. However, Benin Republic rice import rose to 1.95 million in 2017 from 977,174 in 2015. By 2022, Nigeria's rice import had fallen to a mere 1,498.41 tons while the Benin Republic rice import that year was 1.59 million tons. It highly tempting to conclude from the trend of alternating fluctuations between Nigeria and Benin Republic rice importation that Benin Republic's rice imports could be a short-term supply stabilizer but harm Nigeria's production in the long term.

EFFECTS OF BENIN REPUBLIC RICE IMPORTATION ON NIGERIA RICE PRODUCTION

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Unit Roots Test of the Variables: The results of stationarity test in table 1 indicates that both quantity of fertilizer used (QFU) and rainfall (RF) were stationary at level 1(0) for both the ADF and PP test when their respective deterministic were both defined as constant and as constant with trend. The remaining variables did not return stationarity at level for both ADF and PP simultaneously. The remaining variables that were not stationary at level became stationary at first difference. Therefore, the variables have mixed stationarity of I(0) and I(1), which informs the choice of ARDL for the analysis.

Table 1: Result of the stationarity test of the variables in the model

Variable	Exogenous	ADF test (P-value)	Critical value at 5%	Phillip-Perron test (P-value)	Critical value at 5%	ADF Order	PP Order
ΔQ_t	Constant	-2.9369 (0.0003)	-4.8660	-2.9332 (0.0000)	-6.7105	1(1)	1(1)
	Constant and Trend	-3.5266 (0.0018)	-4.8476	-3.5208 (0.0000)	-6.6944	1(1)	1(1)
ΔBRI	Constant	-2.9350 (0.0000)	-7.241252	-2.9331 (0.0000)	-8.1231	1(1)	1(1)
	Constant and Trend	-3.5236 (0.0000)	-7.274314	-3.5208 (0.0000)	-12.2010	1(1)	1(1)
NRI	Constant	-2.9350 (0.0000)	-10.98792	-2.9314 (0.0002)	-4.9053	1(1)	1(0)
	Constant and Trend	-3.5236 (0.0000)	-10.91977	-3.5181 (0.0015)	-4.8824	1(1)	1(0)
ΔRAC	Constant	-2.9331 (0.0002)	-5.0462	-2.9332 (0.0002)	-5.0462	1(1)	1(1)
	Constant and Trend	-3.5208 (0.0013)	-4.9511	-3.5208 (0.0013)	-4.9511	1(1)	1(1)
ΔQFD	Constant	-2.9350 (0.000)	-7.1054	-2.9332 (0.0000)	-8.1879	1(1)	1(1)
QFU	Constant and Trend	-3.5236 (0.0000)	-7.0189	-3.5208 (0.0000)	-8.0770	1(1)	1(1)
	Constant	-2.9314 (0.0007)	-4.5221	-2.9314 (0.0007)	-4.5441	1(0)	1(0)
	Constant and Trend	-3.5181 (0.0039)	-4.5436	-3.5181 (0.0037)	-4.5638	1(0)	1(0)
ΔPFS	Constant	-2.9350 (0.0000)	-5.8742	-2.9332 (0.0000)	-6.8846	1(1)	1(1)
	Constant and Trend	-3.5236 (0.0001)	-5.8360	-3.5208 (0.0000)	-6.8207	1(1)	1(1)
PRT	Constant	-2.9314 (0.0252)	-3.2256	-2.9314 (0.0335)	-3.1063	1(0)	1(0)
	Constant and Trend	-3.5181 (0.0877)	-3.2547	-3.5208 (0.0000)	-9.0255	1(0)	1(1)
ΔARP	Constant	-2.9350 (0.0000)	-8.3071	-2.9331 (0.0000)	-6.1197	1(1)	1(1)
	Constant and Trend	-3.5266 (0.0001)	-5.9599	-3.5181 (0.0069)	-4.3266	1(1)	1(0)
ΔAMP	Constant	-2.9350 (0.0000)	-9.5623	-2.9332 (0.0000)	-6.1806	1(1)	1(1)
	Constant and Trend	-3.5236 (0.0000)	-9.6094	-3.5181 (0.0030)	-4.6372	1(1)	1(0)
ΔASP	Constant	-2.9350 (0.0000)	-8.1534	-2.9332 (0.0000)	-6.8805	1(1)	1(1)
	Constant and Trend	-3.5236 (0.0000)	-8.0072	-3.5180 (0.0230)	-3.8538	1(1)	1(0)
RF	Constant	-2.9331 (0.0003)	-4.8003	-2.9314 (0.0103)	-3.5810	1(0)	1(0)
	Constant and Trend	-3.5207 (0.0007)	-5.153939	-3.5180 (0.0330)	-3.7003	1(0)	1(0)

Source: Analyses of time series data from 1979-2022 using EViews 10

Note: Numbers in parenthesis are the probability value of the test statistics

The Bound test of co-integration among the variables

The result for the bound test of co-integration is presented in Table 2. It is observed that the rice production equation variables are co-integrated since its F-statistic value of 24.36771 is greater than the lower and upper bound of the critical values at 5% significant level, meaning there is a long run equilibrium relationship existing between rice production (Qt) with its various independent variables as captured in this study.

Table 2: Result of ARDL Bound Test of Co-integration

F-Statistics	Level of significance	Lower Bound	Upper Bound
24.36771	1%	2.54	3.86
	5%	2.06	3.24
	10%	1.83	2.94

Source: EViews 10 Output Result of Time Series data from 1979-2022

Long-run dynamics of rice production:

Table 3 shows the long-run results of the ARDL modelling of the effects of Benin Republic rice importation and other intervening variables on Nigeria's rice production. The result shows that Benin Republic rice importation (BRI) has a negative coefficient with a significant effect on Nigeria's rice production at 1% significant level during the long run period of production. This implies that as the Benin Republic rice import (BRI) increase by 1%, Nigeria's rice production will decrease by -0.942501 tons in the long run, suggesting that a sustained rice import flow into Benin Republic depressed Nigeria's production capacity.

Table 3: Long Run Elasticity of Rice Production

Variables	Coefficient	Std. Error	t-value	Pvalue
C	-9842576.	367629.2	-26.77311	0.0000
BRI	-0.942501	0.326348	-2.888023	0.0179
NRI	0.493720	0.107367	4.598440	0.0013
RAC	1.970118	0.175981	11.19506	0.0000
QFD	1.842629	0.279946	6.582087	0.0001
QFU	95679.80	19204.16	4.982244	0.0008
PFS	-10227.69	2042.863	-5.006544	0.0007
PRT	-6323.228	1903.538	-3.321829	0.0089

Selected Model: ARDL(1, 2, 2, 2, 2, 1, 2, 2, 2, 0, 0, 2, 2)
Source: EVIEWS 10 output result of time series data from 1979-2022

The negative effects of Benin Republic Rice importation on Nigeria's rice production conforms to the findings of Adefako (2017), who computed Parboil rice importation of Nigeria and three of its neighbouring countries of Benin, Cameroun and Niger from India and Thailand in 2017. From the author's computation of the imported parboil rice from India and Thailand into Benin, Cameroon, Niger and Nigeria in 2017, Benin Republic imported 1,675,608 tons representing 83.28%, followed by Cameroun with 186,527 tons representing 9.27%, and Niger with 117,968 tons representing 5.86% with Nigeria taking the rear with 31,918 tons representing 1.59%. According to the author, the shipments of parboiled rice from India and Thailand into Lome, Cotonou and Douala ports is a very fair estimate of smuggled rice into Nigeria as none of these countries have internal consumption of parboiled rice, reiterating that smuggling of parboiled rice from across the borders (mainly Benin Republic) is creating a major disaster for the rice industry in Nigeria. Hayley (2019), observed that most import into Nigeria were smuggled in from Benin, which despite a population of 11 million—barely 5 percent of Nigeria's population—was now the world biggest buyer of rice from Thailand, asserting that official shipments to Nigeria plummeted by more than 95 percent in the past four years, while those of Benin have surged. Most foreign rice imported from Benin Republic compete with Nigeria rice leading to a negative impact on rice production in Nigeria as seen from the negative long run relationship between Benin Republic rice importation (BRI) and Nigeria rice production (Qt).

Again, as noted by Golub *et al* (2019), imports per capita into Benin of certain products that are heavily protected in Nigeria are far too large to be explained by Benin's domestic consumption. The authors further submitted that almost all of Benin's rice import are of parboiled rice, the preferred type of rice in Nigeria but not in Benin, providing further evidence that the large volume of rice imports in Benin is intended primarily for Nigerian markets.

The result also shows that, in the long run, the coefficients of percentage fertilizer subsidy (PFS) provided to rice farmers was negative and significant at 1%. This implies that most subsidy on fertilizer provided by the government do not positively benefit rice farmers as an increase in PFS by 1% will only amount to a fall in rice production by 10227.69 metric tons rather than an increase. This finding also corroborated with Okoroanto *et al.* (2010), who reported that, in the long-run, the farmers would be more sensitive to use fertilizer by increasing the quantity of fertilizer distributed than increasing the fertilizer subsidy. A key finding by Liverpool-Tasie and Salau (2010) stipulated that the heavy emphasis on price subsidization to the detriment of other approaches, such as complementary actions to improve farmers fertilizer-use techniques, has hampered market development. This imply that it is more effective to raise fertilizer usage through an increase in the quantity of fertilizer distributed rather than reducing the price or through subsidy scheme that would hardly reach the target beneficiaries.

Further result from the study shows that percentage rice tariff (PRT) and Rainfall (RF) both have a negative coefficient with a significant effect on rice production at 1% significant level during the long run period of production. This implies that as the respective values of percentage rice tariffs (PRT) and rainfall (RF) increase by 1%, rice production will decrease by -6323.228 and -730.3307 tons in the long run and verse-versa.

The tariff results also conforms to the study of Obi-Egbedi *et al.* (2021) who found that if import were used to augment production with trade protection of high import tariff, farmers may not have motivation to increase their production. Ordinarily, tariff was meant to stimulate local production, but if it was not well calibrated, or if it keeps fluctuating rapidly, the desired result would remain elusive, partly because smuggling will increase thereby defeating the objectives of the high tariffs. In Nigeria, the interests of strong, politically connected importers influence the implementation of the national tariff policy. Customs duty waivers have often been abusively, indiscriminately granted to individual economic operators by government officials, under the authority of the Nigerian Presidency, in an opaque manner, outside the legal procedure, often without being gazetted (Modebe *et al.*, 2014). Tondel *et al.* (2020), submitted that those waivers have benefitted major economic operators and undermined the formal tariff protection. Reform to address this problem is, however, difficult, in the context of an oil rent economy like Nigeria. In Nigeria, as well as in other countries, electoral cycles appear to play an important role in driving the issuance of customs duty waivers, which allows public sector actors to obtain financial resources for the financing of campaigns. In short, the problem is not the total absence of regulation on rice imports, but the implementation of the existing regulation in an irregular manner and in favour of some sector incumbents.

The inverse relationship between rainfall (RF) and rice production (Qt) could be as a result of excessive rainfall and flood experience by rice farmers in most of the farming season within the observed period of production and which could be attributed to climate change.

On the other hand, the rice area cultivated, quantity of fertilizer distributed, quantity of fertilizer used and Nigeria rice import have a positive relationship with rice production at 1% significance levels. This means that 1% increase in rice area cultivated, quantity of fertilizer distributed, quantity of fertilizer used and Nigeria rice import will lead to a rice production increase of 1.9 tons, 1.8 tons, 95678.8 tons and 0,494 tons, respectively.

The result on rice area cultivated conforms to Nasrullah *et al.* (2021) who found that a 1% increase in rice area cultivated brought about a 0.73% increase in rice production in the long run. Also, Sadiq *et al.* (2020) found area effect to be the major source of production increase while yield or productivity showed minimal effect in increasing rice production level.

Short run dynamics of rice production: Table 4 shows the result of the short run coefficients of rice production (Qt). The empirical findings of the short run dynamics reveal that the adjusted coefficient of determination (R-squared) is 0.859902, implying that approximately 86% of the variations in rice production (Qt) can be attributed to changes in the explanatory variables. The remaining 14% can be attributed to other factors not explicitly incorporated into the model specification. The Error Correction Model (ECM) intends to validate the presence of long-run relationship and incorporate the short-run dynamics into the long-run equilibrium relationship. Evidence from the result presented indicates that the coefficient of ECM is negative (-0.854318) and significant at 1% suggesting the presence of a correction mechanism that adjusts deviations from the long-run equilibrium at a speed of approximately 85.43% per period. This implies that the equilibrium position is reached within a period of approximately one year and two months.

The result shows that, in the short-run, the coefficient of the lag value (-1) of Benin Republic rice importation (BRI) was statistically significant at 1% and positively influence rice production in the current year by 1.712043 tons. This means that as the Benin Republic's

previous year's rice importation increased by 1%, Nigeria's rice production changes directly by 1.712043 metric tons in the short run, suggesting that the import of Benin temporarily stimulate production.

Rice area cultivated (RAC) was significant at 1% and with a positive coefficient. This implies that a 1% increase in rice area cultivated (RAC) will increase rice production (Qt) by 2.929023 metric tons in the short run. The coefficient of both quantity of fertilizer distributed (QDF) and quantity of fertilizer used (QFU) were positively significant at 1%. This is an evidence that an increase in QFD and QFU in the short run will also increase current rice production by 1.154539 and 62408.60 tons.

The result of this findings showed that the coefficient of both quantity of fertilizer distributed (QFD) and quantity of fertilizer used (QFU) lag values (-1) are statistically significant at 1% and negatively influence rice production. Hence, when all the explained variables were held constant in the short run, a change in the previous year's quantity of fertilizer distributed (QFD) and quantity of fertilizer used (QFU) by 1%, will inversely affect rice production by -1.013479 and -26734.77 metric tons, respectively. This implies that rice farmers production decision may change based on the information gathered in the previous year than in the current year as they will have enough time to respond to previous changes. Other variables and the lag values of the variables with significant coefficients have been captured in the table.

Table 4: Error Correction Form and Short Run Elasticity of Rice Production

Variables	Coefficient	Std. Error	t-value	P-value
$\Delta(BRI(-1))$	1.712043	0.124055	13.80069	0.0000
$\Delta(NRI)$	0.187062	0.030354	6.162700	0.0002
$\Delta(NRI(-1))$	-0.434288	0.036313	-11.95972	0.0000
$\Delta(QFD)$	1.154539	0.073326	15.74524	0.0000
$\Delta(QFD(-1))$	-1.013479	0.075853	-13.36113	0.0000
$\Delta(QFU)$	62408.60	4985.453	12.51814	0.0000
$\Delta(QFU(-1))$	-26734.77	4810.556	-5.557521	0.0004
$\Delta(PFS)$	-9238.089	1429.831	-6.460966	0.0001
$\Delta(PRT(-1))$	7009.304	1094.971	6.401358	0.0001
$\Delta(ARP)$	7.800359	0.826728	-9.435222	0.0000
$\Delta(ARP(-1))$	-3.632139	0.690411	-5.260838	0.0005
$\Delta(AMP)$	-7.964386	1.324210	-6.014444	0.0002
$\Delta(AMP(-1))$	-7.805203	1.274330	-6.124944	0.0002
$\Delta(RAC)$	2.929023	0.110851	26.42295	0.0000
$\Delta(RAC(-1))$	0.676422	0.095616	7.074343	0.0001
ECM	-0.854318	0.070275	-12.15675	0.0000
R-squared	0.859902			
D-W stat	2.628103			
AIC	28.30349			

Selected Model: ARDL(1, 2, 2, 2, 2, 1, 2, 2, 2, 0, 0, 2, 2)

Source: Source: EVIEWS 10 output result of time series data from 1979-2022

CONCLUSION AND RECOMMENDATIONS: The graphical trend of Nigeria and Benin Republic rice importation with Nigeria rice production as well as the ARDL modelling suggest that Benin Republic rice importation harms Nigeria's rice production. It is recommended that rice import tariffs should be well moderated to minimize the tendency of rice importers from shifting to smuggling and to prevent erosion of welfare and food insecurity that very high tariff is likely to cause. While leveraging on ECOWAS common markets and AfCFTA, Nigerian Government should ensure effective regulation of cross-border flow of rice in the ECOWAS region. Nigeria should ensure enforcement of stringent rules with penalties on re-export of rice by the ECOWAS member states. Government should deploy modern technologies like drones, satellite, CCTVs and even border walls to safeguard the country's land border to checkmate smuggling and other forms of criminality that could constitute hindrance to rice production.

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Climate Change and Vulnerability of Crayfish Fishers in the Coastal Communities of Akwa Ibom State

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Abstract

Crayfish fishing is a major occupation of majority of the coastal population in Akwa Ibom State. Therefore, the vulnerability of crayfish fishers in the coastal communities of Akwa Ibom State to climate change impacts was estimated. The study used a multistage sampling method to choose fishers for the study, and information was gathered by using a questionnaire. An Integrated Vulnerability Analysis involving Principal Component Analysis was employed to determine the climate exposure, sensitivity, adaptive capacity and vulnerability of crayfish fishers. The results show that crayfish fishers were highly vulnerable to climate change impacts with a vulnerability index (VI) score of approximately 0.6. However, they were moderately exposed to (Exposure Index = 0.3722), weakly sensitive (sensitivity index = 0.1849) and had moderate adaptive capacity (Adaptive capacity index = 0.3953) It is recommended that crayfish fishers be equipped with climate-smart fishing techniques to lessen climate-induced challenges.

Key words: Climate change, Vulnerability Index, Principal Component Analysis, Crayfish Fishers, Livelihoods,

1.0: Introduction: Climate change is an increasingly urgent global challenge, particularly for vulnerable coastal communities whose livelihoods depend on natural resources. Rising sea levels, coastal erosion, increased rainfall variability, and extreme weather events are disrupting ecosystems, displacing populations, and undermining traditional livelihoods across the world (IPCC, 2023; FAO, 2022). In developing countries like Nigeria, these effects are magnified by poverty, limited infrastructure, and heavy dependence on climate-sensitive sectors such as agriculture and fisheries. Nigeria, with a coastline stretching over 850 kilometers, is highly susceptible to climate-related hazards. The southern coastal states—including Akwa Ibom, Cross River, Rivers, and Bayelsa—have witnessed recurrent flooding, shoreline retreat, saltwater intrusion, and declining fish productivity in recent years (UNFCCC, 2022; Climate Risk Profile: Nigeria, 2021). In 2022 alone, widespread flooding across the country affected over 1.4 million people, damaged 82,035 houses, and submerged more than 332,000 hectares of land (NEMA, 2022). These climate events directly threaten the livelihoods of artisanal fishers who rely on coastal access and marine ecosystems for survival. Akwa Ibom State, a maritime state in Nigeria, is endowed with the longest coastline in the country and abundant fish and aquatic resources. The state is well known for its highly valuable fish species, including crayfish. Historically, crayfish landings from the area constituting the present Akwa Ibom and Cross River States contributed 11% to Nigeria's national marine fish landings between 1980 and 1984 (Nsetip, 1985). Although more recent, disaggregated landing statistics are limited, the continued prominence of crayfish in local and regional markets, and the sustained involvement of fishing households in its harvest and trade, underscore its enduring importance to coastal livelihoods (Ahamefule et al., 2021; Esheya, 2023).

Crayfish fishing is a major occupation for many coastal dwellers in Akwa Ibom State, especially in communities like Mbo, Ibeno, and Eastern Obolo. The most recognized types—"Oron," "Ibeno," and "Obolo" crayfish—are indigenous to these local government areas, where fishing is conducted along the banks of the Atlantic Ocean using artisanal methods. According to Ahamefule (2021), crayfish fishing supports a significant share of the rural coastal population, with at least five out of the state's thirty-one local government areas actively engaged in the activity (Chinasa et al., 2017). In these communities, crayfish fisheries are not only economically vital but also culturally embedded and gender-inclusive, with women playing key roles in processing and marketing (Esheya, 2023). Unfortunately, this critical livelihood is increasingly vulnerable to both environmental and socio-economic threats. Coastal erosion, saltwater intrusion, flooding, and unpredictable rainfall patterns have intensified over the last decade, disrupting fishing activities and degrading natural habitats. In addition to climate stressors, fishers face challenges such as sea piracy, insecurity, and inter-community conflicts, all of which exacerbate their exposure and sensitivity. Nigeria's inclusion among the top 10 countries most vulnerable to climate change further highlights the urgency of assessing and strengthening adaptive responses in its coastal zones (USAID, 2021). This study aimed to investigate the vulnerability of crayfish fishers to the impacts of climate change. This study's objectives were to: (i) describe the socio-economic characteristics of crayfish fishers that influence their exposure to climate change impacts; (ii) assess the level of exposure of crayfish fishers to climate change; (iii) determine the sensitivity of fishers to climate-related stressors; and (iv) assess crayfish fishers' adaptive capacity to climate change. The study is structured as follows: Section 2 discusses conceptual frameworks and reviews relevant literature; Section 3 outlines the research methodology; Section 4 presents the findings and discussion; and Section 5 concludes with recommendations derived from the study's results.

2.0: Conceptual Literature: Vulnerability is a multifaceted concept that describes the susceptibility of physical and social systems to harm, powerlessness, and marginality (Adger, 2006). Various disciplines, including economics, anthropology, psychology, and engineering, employ the term vulnerability to guide normative analysis of actions aimed at enhancing well-being through risk reduction. Vulnerability is often conceptualized as comprising three components: exposure, sensitivity, and adaptive capacity (Makondo et al., 2014; Gallopin, 2006). Exposure refers to the nature and degree of environmental or socio-political stress, while sensitivity is the degree to which a system is affected by perturbations. Adaptive capacity is the ability of a system to evolve and accommodate environmental hazards or policy changes. Climate change is a global challenge characterized by diverse participants, multiple stressors, and effects that play out across different time periods (Adger, 2006). The existing evidence suggests that climate change impacts will disproportionately affect vulnerable populations, exacerbating existing burdens and challenges. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes"

(McCarthy et al., 2001). In the context of this study, vulnerability to climate change is defined as a characteristic of the crayfish system, influenced by exposure, sensitivity, and adaptive capacity. Marine ecosystems, including coastal areas, are vulnerable to climate change impacts, such as warming, sea level rise, and changes in ocean chemistry (Anon, 2007). Empirical studies confirm the reality of climate change impacts on aquatic resources, including changes in species distribution, productivity, and fisheries (Barange et al., 2018; Huang et al., 2021). The Nigerian coastal environment is also susceptible to climate change impacts, with potential consequences for aquatic resources and communities. Without effective intervention, climate change could result in significant economic losses, with estimates suggesting a potential loss of 6-30% of Nigeria's GDP by 2050 (BNRCC, 2011).

3.0: Analytical Framework and Estimation Techniques: This study employed an Integrated Vulnerability Assessment Approach, utilizing Principal Component Analysis (PCA), also known as Exploratory Factor Analysis (EFA). The primary objective of PCA is to identify underlying factors that explain the covariance relationships among variables, thereby reducing the dimensionality of complex datasets (Ashley, Amber, & Anthony, 2006; Tucker & MacCallum, 2012). By applying PCA, this study aimed to distill the multivariate data into a more manageable structure, revealing the underlying patterns and relationships between variables. This method was considered appropriate in explaining the vulnerability of crayfish fishers to the impact of climate change in the study area. The IVA involved a number of steps namely: (i) identification of indicator of vulnerability (See Table 1); (ii) generation of weights for each indicator. This was achieved through Principal Component Analysis (PCA); and (iii) computation of Vulnerability Index Based on the Intergovernmental Panel on Climate Change (IPCC, 2007) framework, this study conceptualized climate vulnerability as the susceptibility of the crayfish fishing ecosystem to adverse effects of climate variability and change, as well as its ability to cope with these impacts. Vulnerability was calculated as the difference between adaptive capacity and the combined effects of sensitivity and exposure to climate hazards. Adaptive capacity, in this context, refers to the potential to implement measures that mitigate potential impacts. The study utilized 17 indicators, categorized into four groups: wealth, technology, infrastructure, and institutional variables, to assess vulnerability.

A total of 6 wealth variables, 3 technology variables, 5 infrastructure variables and 3 institution variables were used. A higher positive value of adaptive capacity indicates reduced vulnerability to climate change among fishers, suggesting an inverse relationship between adaptive capacity and vulnerability (Adger et al., 2007). In other words, as adaptive capacity increases, vulnerability decreases. Exposure to climate change refers to the direct threat posed by changes in climate variables, such as temperature, precipitation, and extreme weather events. This study included four exposure variables, categorized into institutional (1) and climate change (3) variables. Sensitivity, on the other hand, describes the human-environmental conditions that can exacerbate or mitigate the impact of climate-related hazards. Four sensitivity variables were used, comprising one climate change variable and three climate extreme variables. To assess vulnerability, this study employed Principal Component Analysis (PCA) using SPSS version 19. The PCA generated component scores, which were used to weight the variables for constructing vulnerability indices. The vulnerability index was calculated as the difference between adaptive capacity and the sum of sensitivity and exposure, represented by the equation: $Vulnerability = Adaptive\ Capacity - (Sensitivity + Exposure)$. This was operationalized as: $[(wA1 + wA2 + \dots + wAn) - (wS1 + wS2 + \dots + wSn) - (wE1 + wE2 + \dots + wEn)]$, where w represents the weight obtained from the first principal component scores. Following UNDP (2006), climate vulnerability is assumed to range from 0 to 1, with value closer to 1 indicating greater vulnerability.

3.1 Study area: This study was conducted in Akwa Ibom State, situated in the coastal southeastern region of Nigeria. Geographically, the state lies between latitudes 4°32'N and 5°33'N, and longitudes 7°25'E and 8°25'E, with a projected population of approximately 5.5 million people (National Bureau of Statistics, 2016). Akwa Ibom State experiences a tropical climate, characterized by two distinct seasons: the rainy season (April to October) and the dry season (November to April). The state's mean annual temperature ranges from 26°C to 29°C, with an average annual sunshine duration of 1450 hours. Annual rainfall varies between 2000mm and 3000mm, depending on the location. The state's ecosystem is diverse, supporting a wide range of terrestrial and aquatic species, and is classified into three vegetation zones: saline water swamp forest, freshwater swamp forest, and rainforest. Notably, Akwa Ibom State has a significant coastline, with approximately 13.4% of Nigeria's 960 km Atlantic Ocean coastline passing through the state.

Akwa Ibom State's extensive coastline, which accounts for approximately 13.4% of Nigeria's 960 km Atlantic Ocean coastline, makes it a critical area for studying climate change impacts. This study focused on the Atlantic coast fishing settlements/communities, bounded by the Cross River estuary to the east, the Imo River to the west, and the Atlantic Ocean to the south. Three coastal Local Government Areas (LGAs) - Eastern Obolo, Ibeno, and Mbo - were selected for this study due to their vulnerability to climate-related impacts such as sea level rise, salt intrusion, and coastal erosion (Udoudo, Emenghini, & Igbokwe, 2018). A multi-stage sampling procedure was employed to select respondents. Firstly, these three LGAs, often referred to as the "crayfish corridor" (Enyenighi, 2020), were purposively selected from the eight coastal LGAs in Akwa Ibom State. Secondly, four fishing settlements were selected from each LGA based on their high concentration of large-scale crayfish fishing activities. Finally, 10 crayfish fishers were randomly selected from each settlement, resulting in a total of 120 respondents. After data collection, 108 questionnaires were retrieved, and 100 were deemed usable for analysis.

4.0: Result and Discussion

4.1 Fishers' Socioeconomic Characteristics: This study proceeds with the assumption that fishers' social and economic characteristics are capable of influencing their vulnerability or otherwise to climate change. This study investigated the socio-economic characteristics of crayfish fishers in the selected fishing settlements. The analysis focused on seven key characteristics: sex, age, marital status, educational level, income level, income from non-fishing activities, and membership of cooperative societies.

The findings are presented in Figure 1, providing insights into the demographic and economic profiles of the crayfish fishers.

Findings show that crayfish fishing is predominantly a male occupation as a total of 91% of the crayfish fishers were male while 9% were female. Discussion during the Focus Group Discussion session revealed that a large number of women used to participate in crayfish fishing when crayfish in time past, when, according to discussants, crayfish was abundant in nearby creeks and shores. This, according to them, is no more the case due to scarcity of crayfish in the nearby shores. They reported that to obtain reasonable catch, fishers have to go far ashore, sometimes spending a whole day for a single trip. This, they opined would be too much for women who now concentrate on picking periwinkle around the shores when the water ebbs. This change in gender-involvement in fishing activities was attributed by respondents to climate change.

The age distribution analysis of the crayfish fishers reveals that this occupation is dominated by men in their prime working years, with nearly 50% of the fishers falling within the 41-50 year age range. The mean age of the fisher was 48 years. The finding as found in this research is in agreement with the findings of Atairet & Umoh (2024) Shettima *et al.* (2014) and Ifeanyi-Obi & Iremesuk (2018). Their analyses of the socio-economic factors affecting artisanal fishers in their different study areas indicated that artisanal fishermen were aged 50 years and below. Arising from this they concluded that fishing activities is for the young age.

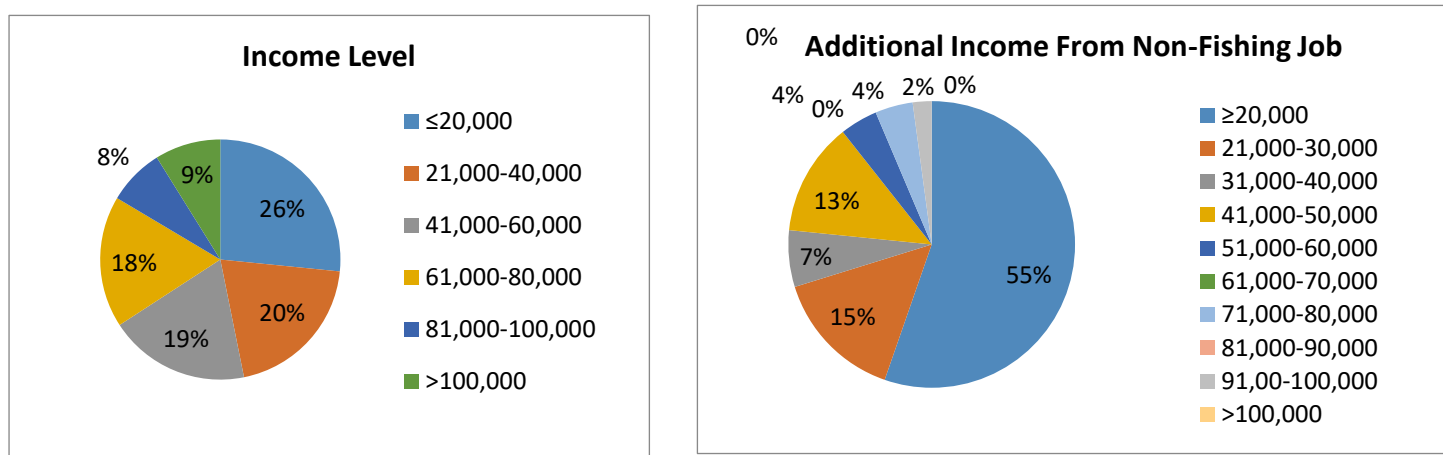
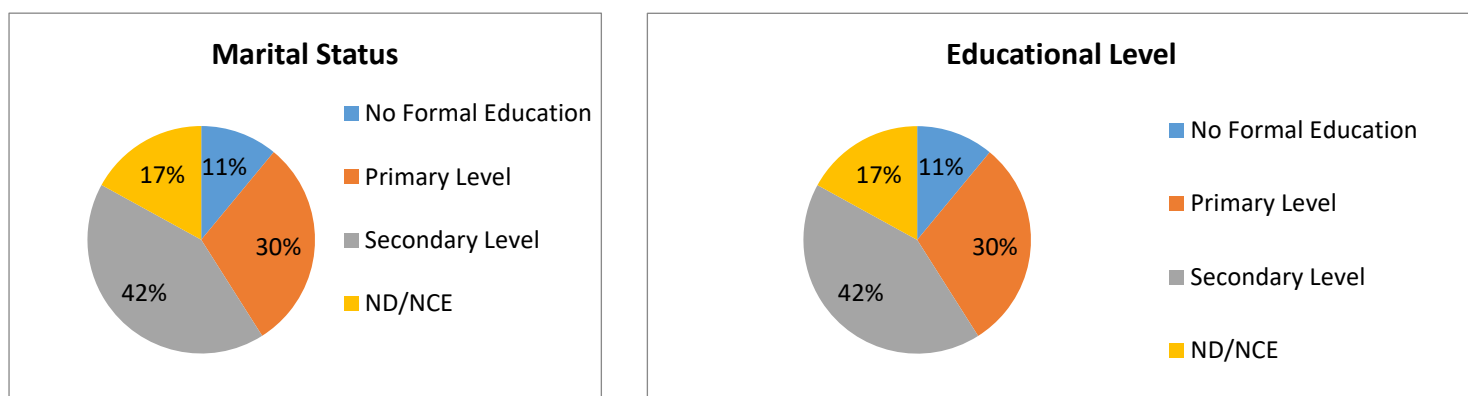
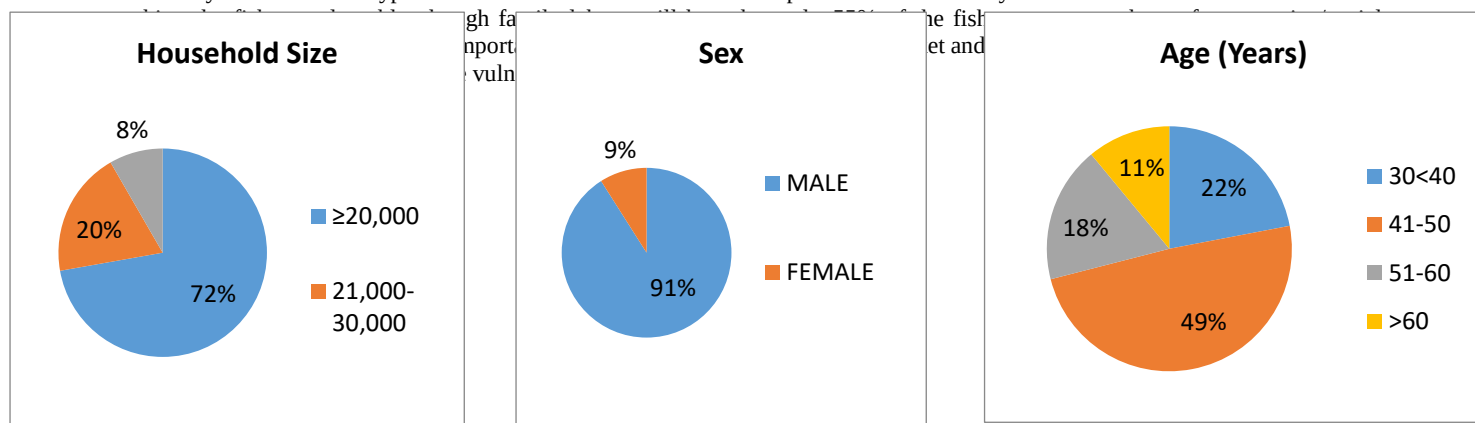
The study found that 72% of the crayfish fishers were married, indicating that many had significant family responsibilities. This suggests that losing their livelihood due to climate-related impacts would impose a substantial financial burden on their families. This finding is consistent with previous research by Okeowo *et al.* (2015), which reported that the majority of respondents in Epe and Badagry were married.

The educational level of fishers significantly impacts their vulnerability to climate change. Findings reveal that 72% of the fishers had only attempted primary and secondary school education, indicating limited formal education. The low literacy level may hinder their ability to adopt innovative strategies and adapt to changes that could enhance their fishing activities.

The result further revealed that the majority (16%) crayfish fishers, had income levels between the range of ₦21, 000 – 30,000. Additionally, the result of all other higher income classes showed one digit percentage. In a similar note to that of crayfish fisher income, the result revealed that the crayfish fishers had the majority (55.34%) earned below ₦20, 000 as additional income.

The Table again, shows the distribution of crayfish fishers in respect to the number of boats owned and reveals majority of the respondents (50%) had just one boat while distribution of the fishers based on the size of fishing crew revealed an average crew size of 3. Though crew size depends on the type and size of the boat, if it is a banana boat it normally consists of two to three persons. This could be attributed to the emergence of motorize boat; which require less energy to operate.

The study found that the typical household has 6 members. The implication is that family financial burden would be enormous further



4.2 Crayfish Fishers Vulnerability to Climate Change: Climate vulnerability is determined by the difference between fishers' adaptive capacity and the combined effects of exposure and sensitivity to climate impacts. This study assessed these components, including exposure, sensitivity, and adaptive capacity, to examine the vulnerability of crayfish fishers.

4.2.1 Crayfish Fishers' Exposure to Climate Change:: Exposure refers to the climate conditions and stimuli that affect fishers' operations, including changes in these conditions. According to Adger (2006), exposure encompasses not only the extent of climatic variations but also their degree and duration. Through Focus Group Discussions, fishers identified key climate exposure factors, including sea level rise, invasion of alien species, and conflict in fishing communities. These factors were used to compute the exposure index and climate vulnerability index. The Principal Component Analysis results are presented in Table 1. The computed Crayfish Fishers' Climate Change Exposure Index (CFCCEI) was approximately 0.4 (0.3722). Given that vulnerability values range from 0 to 1 (UNDP, 2006), a CFCCEI of 0.4 indicates a moderate level of exposure to climate-related factors that make fishers vulnerable to climate change impacts.

Table 1: Crayfish Fishers' Climate Change Exposure Index

Indicators	Variable	Conceptual Basis	1 st Principal Score
Incidence of sea level rise	Climate Change	Exposure	-0.1028
Invasion by alien species	Climate Change	Exposure	0.2386
Conflict	Climate Change	Exposure	0.2364
Climate Change Exposure Index			0.3722

Source: Computed by the Authors.

4.2.2 Crayfish Fishers' Sensitivity to Climate Change:: This study assessed the sensitivity of crayfish fishers to climate change, focusing on the impact of climate variability on their fishing environment. Four key indicators were used to compute sensitivity: extreme temperatures, intense sunlight, excessive rainfall, and stormy weather conditions. The principal component analysis results are presented in Table 2. The calculated Crayfish Fishers' Climate Change Sensitivity Index was approximately 0.2 (0.1849), indicating relatively low sensitivity. Despite documented changes in temperature and precipitation patterns (Umoh et al., 2013; Ataire, 2010), the crayfish sub-sector appears resilient to these fluctuations. Participants in the Focus Group Discussions attributed adverse effects on crayfish availability to non-climatic factors, such as sea piracy and extreme flooding events (2012 and 2022). Moreover, fishers demonstrated adaptability to seasonal weather changes, suggesting a level of familiarity and coping capacity.

Table 2: Crayfish Fishers' Climate Change Sensitivity Index

Indicators	Variable	Conceptual Basis	1 st Principal Score
Extremely high temperature	Climate extreme	Sensitivity	-0.0011
High intensity sunlight	Climate extreme	Sensitivity	0.0367
Too much rainfall	Climate extreme	Sensitivity	0.1569
Stormy rainfall	Climate extreme	Sensitivity	-0.0076
Climate Change Sensitivity Index			0.1849

Source: Computed by the Authors

4.2.3 Crayfish Fishers'

Climate Change Adaptive Capacity:: Index of crayfish fishers climate change adaptive capacity was approximately 0.4 (Table 3). This indicates a positive but weak correlation between the selected indicators and the fishers' climate change adaptive capacity. On individual indicator basis, having non fishing income and having many fishing boat have correlation values higher than other indicators. The former has positive though weak association with adaptive capacity while the latter is weakly and negatively correlated. Although most of the first Principal score for a number of indicators show weak relationship, the negative sign carried by a number of these indicators is worth noting. For instance, several wealth indicators have negative signs suggesting inverse relationship between them and adaptive capacity. Some of the results are actually contrary to a priori expectation. A case in point is ownership of many boats which is expected to fortify fishers against shocks of climate change, but the result is actually the opposite. Access to public transport and membership of social association also exhibits same behaviour. This can be interpreted to mean that these infrastructure and social safety net variables are incapable of protecting fishers against the vagaries of climate conditions. Compared with sensitivity index, the magnitude of adaptive capacity index is larger implying greater weight of adaptive capacity on climate vulnerability.

Adaptive indicators weights are = 0.4654 - 0.2684 + 0.3183 + 0.0530 - 0.1627 - 0.0651 - 0.4037 + 0.1807 + 0.0849 - 0.0946 + 0.1433 + 0.1739 - 0.0705 + 0.1260 + 0.0866 - 0.3216 + 0.1498
= 0.3953 (approx 0.4)

Table 3: Crayfish Fishers' Climate Change Adaptive Capacity

Indicators	Variable	Conceptual Basis	1 st Principal Score
Having Non fishing Income	Wealth	Adaptive	0.4654
Ownership of Radio	Wealth	Adaptive	-0.2684
Ownership of livestock	Wealth	Adaptive	0.3183
Quality of house	Wealth	Adaptive	0.0530
Ownership of crop farm	Wealth	Adaptive	-0.1627
Access to large farm	Wealth	Adaptive	-0.0651
Ownership of many boats	Wealth	Adaptive	-0.4037
Ownership of Motorize equipment	Technology	Adaptive	0.1807
Ownership different kinds of Nets	Technology	Adaptive	0.0849
Access to fishing input	Infrastructure	Adaptive	-0.0946
Access to fishing drying facility	Infrastructure	Adaptive	0.1433
Access to Market	Infrastructure	Adaptive	0.1739
Availability of public transport	Infrastructure	Adaptive	-0.0705
Storage Facilities	Infrastructure	Adaptive	0.1260
Credit	Institution	Adaptive	0.0866
Member Social Association	Institution	Adaptive	-0.3216

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Educational Level	Institution	Adaptive	0.1498
Climate Change Adaptive Index			0.3953

Source: Computed by the authors.

4.2.4 Crayfish Fishers Climate Change Vulnerability Index (CFCVI):

After examining the specific components of climate change vulnerability, attention was turned to estimating climate change vulnerability index for crayfish fishers. The result is as presented in the equation below. Crayfish fishers climate change vulnerability index was 0.5826, approximately, 0.6. This value is closer to 1, implying that crayfish fishers are disproportionately affected by climate change. This may not be unrelated to the climate-induced hazards such as incessant flooding, coastal inundation, and so on which the fishers in the Atlantic coast and other coastal communities of Nigeria have been exposed to. Again, IPCC report had pointed out that climate vulnerability will be higher in developing countries due to their inability to mitigate climate change impacts.

$$CCVI = \text{Adaptive capacity} - \text{sensitivity} + \text{Exposure} = 0.3953 - 0.1849 + 0.3722 = 0.5826$$

Table 4: Principal Component Analysis for Crayfish

S/N.	Indicators	Variable	Conceptual basis	1 st principal scores
1	Having Non fishing Income	Wealth	Adaptive	0.4654
2	Ownership of Radio	Wealth	Adaptive	-0.2684
3	Ownership of livestock	Wealth	Adaptive	0.3183
4	Quality of house	Wealth	Adaptive	0.0530
5	Ownership of crop farm	Wealth	Adaptive	-0.1627
6	Access to large farm	Wealth	Adaptive	-0.0651
7	Ownership of many boats	Wealth	Adaptive	-0.4037
8	Ownership of Motorize equipment	Technology	Adaptive	0.1807
9	Ownership different kinds of Nets	Technology	Adaptive	0.0849
10	Access to fishing input SS	Infrastructure	Adaptive	-0.0946
11	Access to fishing drying facility	Infrastructure	Adaptive	0.1433
12	Access to Market	Infrastructure	Adaptive	0.1739
13	Availability of public transport	Infrastructure	Adaptive	-0.0705
14	Storage Facilities	Infrastructure	Adaptive	0.1260
15	Credit	Institution	Adaptive	0.0866
16	Member Social Association	Institution	Adaptive	-0.3216
17	Educational Level	Institution	Adaptive	0.1498
18	Incidence of Sea rise	Climate change	Exposure	-0.1028
19	Invasion of Alien Spp.	Climate change	Exposure	0.2386
20	Conflict	Climate change	Exposure	0.2364
21	High Intensity Sunlight	Climate change	Sensitivity	-0.0011
22	Extreme High Temperature	Weather extreme	Sensitivity	0.0367
23	Too Much rainfall	Weather extreme	Sensitivity	0.1569
24	Stormy Rainfall	Weather extreme	Sensitivity	-0.0076

Source: Computed by the authors.

5.0: Conclusion and Recommendations: This study's key finding is that crayfish fishers in Akwa Ibom State's coastal communities are vulnerable to climate change impacts. Given the crucial role of aquatic resources like crayfish in human nutrition, health, and the economy, sustained vulnerability of these fishers to increased flooding and other climate-related stressors can have far-reaching consequences, including decreased primary productivity and altered resilience of aquatic systems.

This will not only be a threat to fisheries sector and the economy of Akwa Ibom State and beyond as investment can be discourage in that sector. Efforts will, therefore, be called upon to mitigate the climate change impacts on crayfish fishers. Given the vulnerability of these operators in this key livelihood sector and great contributor to the country's food, employment and gross domestic product, it is imperative that actions be taken to mitigate climate impact in this sector. Such actions could include building the capacity of fishers to not only cope but mitigate climate impacts. In addition, actions that would help reduce the quantum of greenhouse gases in order to protect the ozone layer could limit climate related hazards. New technologies for climate smart fishing could be advanced to fishers in developing countries may reduce their vulnerability to climate change.

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Big Data and Artificial Intelligence in Ecosystem Monitoring in the Mangrove Zone of Nigeria: Prospects and Challenges

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Abstract:

Mangrove ecosystems are vital coastal buffers that support biodiversity, sequester carbon, and sustain local livelihoods. However, they are increasingly threatened by climate change, urban encroachment, and unsustainable exploitation. Traditional monitoring methods are inadequate to address these complex and rapidly evolving challenges. This paper explores the integration of Big Data and Artificial Intelligence (AI) as transformative tools for ecosystem monitoring in the mangrove zone of Nigeria. It highlights how AI-powered analytics—applied to large-scale datasets from satellites, drones, and field sensors—can enhance real-time surveillance, pattern recognition, and predictive modeling. The study also discusses current applications, technological challenges, and future opportunities for AI–Big Data integration in Nigerian mangrove conservation. Emphasis is placed on the role of digital innovation in supporting climate resilience, sustainable resource management, and inclusive participation in environmental governance. By aligning with the broader goals of the digital economy, the paper underscores the potential of these technologies to revolutionize ecological intelligence and livelihood diversification in Nigeria's coastal regions.

Keywords: Big Data, Artificial Intelligence, Mangrove Ecosystem, Environmental Monitoring, Remote Sensing

1. Introduction: Mangrove ecosystems are among the planet's most productive and ecologically varied environments, and they are crucial for carbon sequestration, nutrient cycling, biodiversity preservation, and coastline protection (Alongi, 2012). Mangroves are found throughout Nigeria's coastal states, including Lagos, Ondo, Delta, Bayelsa, Rivers, Akwa Ibom, and Cross River. In addition to offering vital benefits to human populations, these ecosystems are intricately linked to regional livelihoods, such as fishing, fuelwood gathering, and traditional medicine (Numbere, 2018). However, unchecked urban growth, oil development, deforestation, pollution, and sea level rise brought on by climate change are posing a growing threat to Nigeria's mangrove zones. In these regions, traditional ecosystem monitoring techniques—which frequently depend on sporadic field trips and visual evaluations—are time-consuming, labor-intensive, and inadequate for capturing the spatiotemporal dynamics of rapidly deteriorating ecosystems (Ndukwu et al., 2020). To address these issues, the use of artificial intelligence (AI) and big data technology presents a viable avenue for effective, fast, and scalable environmental monitoring. Large, varied datasets produced by a variety of sources, including drones, Internet of Things (IoT) sensors, citizen science platforms, and remote sensing satellites, are referred to as "big data." In order to obtain significant ecological insights, AI—specifically machine learning and deep learning algorithms—makes it easier to process, classify, and analyze these datasets predictively (Reichstein et al., 2019). This paper aims to explore the current and potential applications of Big Data and AI in monitoring the mangrove ecosystems in Nigeria. It provides an overview of technological tools used, showcases real-world examples, identifies associated challenges, and proposes recommendations to harness these innovations for sustainable environmental management.

2. Big Data in Ecosystem Monitoring: The term "Big Data" describes extraordinarily large, complex, high-volume datasets that are produced quickly from a variety of sources (Laney, 2001). Big Data has revolutionized environmental science by providing high-resolution, real-time insights into ecological systems that were previously unattainable using traditional techniques. Better knowledge, prediction, and management of natural resources, especially mangrove ecosystems, are made possible by the use of big data in ecosystem monitoring. Satellite images, drone (UAV) surveys, ground-based sensors, weather stations, GPS-tracked wildlife, and social media inputs are the main sources of Big Data used in mangrove monitoring (Wulder et al., 2012; Buytaert et al., 2014). Across regional and temporal scales, these varied data sources provide multifaceted insights on everything from water quality and land use changes to vegetation health and soil salinity. Every day, gigabytes of data are produced by remote sensing technologies, particularly those offered by platforms such as Landsat, Sentinel-2, and MODIS. These technologies can be used to identify changes in mangrove cover, coastal erosion, or habitat fragmentation (Giri et al., 2011). These records can be used for monitoring carbon sequestration capacity, mapping susceptible areas, and estimating biomass when properly processed and integrated. According to Duffy et al. (2018), UAVs or drones fitted with multispectral and hyperspectral cameras can also offer comprehensive local-level photography, which is useful for fine-scale ecological evaluations, particularly in degraded or inaccessible mangrove zones.

Furthermore, the continuous collection of environmental data (such as pH, temperature, salinity, and dissolved oxygen) via Internet of Things (IoT) devices, like soil probes and water quality sensors, is essential for evaluating the resilience and health of mangrove ecosystems (Hardin et al., 2019). These gadgets produce feedback loops in real time, which when connected to a network, support an infrastructure for dynamic environmental observation. Big Data's frequency and volume of information, which allow for longitudinal analysis and historical trend comparisons, is one of its primary benefits in this regard. But it's not just the data that counts; it's also the capacity to evaluate and comprehend it. This is where artificial intelligence (AI), as discussed in the next section, comes in handy.

3. Artificial Intelligence in Environmental Monitoring: Artificial Intelligence (AI), particularly in the form of Machine Learning (ML) and Deep Learning (DL), has revolutionized environmental monitoring by enabling systems to analyze complex datasets, detect patterns, and make intelligent predictions without explicit programming (Jordan & Mitchell, 2015). In the context of mangrove ecosystems, AI offers robust, scalable tools for analyzing massive and multidimensional datasets generated through Big Data technologies, thereby enhancing the accuracy, speed, and automation of ecological assessments. Remote sensing imagery can be processed by AI-based systems to identify deforestation, categorize land cover, and evaluate the health of the vegetation. Mangrove species, canopy density, and land-water borders can be accurately identified from satellite or unmanned aerial vehicle (UAV) photos using methods like Convolutional Neural Networks

(CNNs) (Ma et al., 2019). These algorithms require little human oversight to define ecological zones because they can learn features from raw input photos.

Furthermore, the use of AI algorithms in time-series forecasting to anticipate ecological patterns like coastal erosion, the effects of sea level rise, or shifts in biomass and biodiversity is growing (Reichstein et al., 2019). Long Short-Term Memory (LSTM) models and Recurrent Neural Networks (RNNs), for instance, can estimate future environmental conditions by analyzing historical sensor data. These aids resource managers in anticipating dangers and organizing actions. An additional function of AI is anomaly detection, which involves identifying sudden changes in environmental factors like temperature, salinity, or chlorophyll levels that could be signs of pollution or ecological stress. Furthermore, environmental datasets can reveal hidden associations through unsupervised learning techniques like Principal Component Analysis (PCA) and k-means clustering, opening up new ecological insights and decision-making approaches (Benedetti et al., 2021).

Depending on the availability of data, AI may function at several scales, including local, regional, and global. This is one of its main advantages. While locally trained models can track micro-level changes unique to particular river deltas or coastal communities, global AI models, for instance, can offer insights for mangrove conservation across continents. The integration of AI into Decision Support Systems (DSS) is a significant step in helping policymakers with evidence-based planning and scenario modelling. Although AI has the potential to revolutionize environmental monitoring, there are still obstacles to overcome, such as the requirement for substantial labeled datasets, computational power, and specialized knowledge. Nonetheless, environmental organizations and conservationists in developing nations, notably West Africa, are increasingly able to use these technologies as cloud computing and open-source AI frameworks become more widely accessible.

4. Integrating Big Data and AI for Mangrove Ecosystem Monitoring: The combination of artificial intelligence (AI) and big data offers a revolutionary chance to improve the accuracy, scope, and responsiveness of monitoring the mangrove zone of Nigeria. Big Data technologies make it possible to gather and store enormous environmental datasets, but artificial intelligence (AI) is the analytical tool that turns these data streams into useful insights. They work together to provide a potent synergy that facilitates predictive, adaptive, and real-time ecosystem management. Data collection, pre-processing, analysis, visualization, and decision-making are all common steps in a Big Data–AI integrated monitoring system's workflow (Zhu et al., 2019). For example, cloud-based geospatial platforms are used to initially collect and store drone footage and satellite data. After that, these datasets undergo labeling, alignment, and cleaning. These data layers are analyzed by AI algorithms, especially deep learning models, to identify changes in land cover, evaluate the health of the vegetation, or predict the likelihood of degradation. Decision Support Systems (DSS) can use the results, which are displayed on dashboards or GIS platforms, to guide conservation planning.

Google Earth Engine (GEE), a cloud-based platform that integrates Big Data and AI to analyze satellite data for environmental monitoring at scale, is a real-world example of this integration (Gorelick et al., 2017). GEE has been used to simulate coastal vulnerability, identify illicit logging, and map the global area of mangroves. across a similar vein, programs like Global Mangrove Watch (GMW) and Mangrove Restoration Tracking Tool help mangrove conservation across Southeast Asia, West Africa, and Latin America by using AI-driven satellite analytics (Bunting et al., 2018). Big Data and AI integration could provide real-time alerts on oil spills, illicit deforestation, or invasion in Nigeria, where the Niger Delta is lined with extensive mangroves. These kinds of systems could enable researchers, local authorities, and coastal communities to adopt prompt, evidence-based measures if the right investments are made in data infrastructure and capacity building.

Furthermore, abnormalities like abrupt changes in temperature or water quality that could be signs of pollution or ecological stress can be automatically detected by AI-enhanced sensor networks. Such technologies enable spatiotemporal monitoring and provide detailed information on the where, when, and how of changes in mangrove ecosystems when combined with GIS-based Big Data platforms (Kuenzer & Dech, 2013). All things considered, the combination of AI and Big Data improves monitoring precision while also opening up predictive possibilities, such predicting deforestation-prone areas or simulating the effects of sea level rise in different climatic scenarios. These understandings are crucial for creating proactive adaption plans and regulations that support conservation objectives that are digitally enabled and climate-smart.

5. Opportunities and Future Prospects: Despite the challenges discussed earlier, the integration of Big Data and Artificial Intelligence (AI) in mangrove ecosystem monitoring presents numerous opportunities to enhance environmental sustainability, livelihood diversification, and climate resilience—particularly in the context of the digital economy and smart agriculture.

5.1. Advancing Climate-Smart and Digital Conservation

Big Data and artificial intelligence (AI) can greatly aid climate-smart conservation by facilitating the early identification of environmental stresses including illicit logging, flooding, and salinity intrusion. Coastal stability and mangrove health can be affected by several climatic scenarios that can be simulated using predictive analytics (Brodrick et al., 2019). Adaptive management techniques that increase ecosystem resilience and decrease vulnerability in coastal communities can be developed with the use of these insights. Furthermore, by making environmental data more accessible, transparent, and responsive, digital technologies promote accountability and transparency. By enabling real-time data interaction between researchers, policymakers, and community stakeholders, platforms like Google Earth Engine and Global Mangrove Watch democratize environmental governance (Bunting et al., 2018).

5.2. Empowering Youth and Local Communities: There is a chance to educate and enable young people, students, and neighborhood conservation organizations to take part in ecosystem monitoring thanks to the expanding availability of inexpensive sensors, smartphones, open-source software, and online learning platforms. According to Buytaert et al. (2014), participatory mapping projects and citizen science projects can enhance the granularity of ecological datasets and complement conventional data sources. By providing local actors with fundamental knowledge of data gathering and AI-powered tools (such as field sensors, drones, and mobile apps), nations may create grassroots networks of environmental stewards who support ecological monitoring and economic diversification.

5.3. Supporting Livelihood Diversification and Blue Economy: The blue economy depends on fishing, aquaculture, and tourism, all of which are supported by the vital ecosystem services that mangroves provide. Communities can investigate carbon trading opportunities through initiatives like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) and open up new revenue streams with precise, data-driven assessments of mangrove health and biomass (Donato et al., 2011). Additionally, by identifying the best areas for sustainable aquaculture or mangrove ecotourism, big data and artificial intelligence techniques can increase the number of alternate sources of income.

5.4. Strengthening Institutional Collaboration and Innovation: The use of AI and big data encourages cross-sectoral cooperation between the commercial sector, government organizations, NGOs, and academic institutions. Information technology, forestry, marine science, and environmental policy institutions can work together on integrated platforms for data exchange, model building, and decision assistance (Silva et al., 2020). Cross-sectoral collaboration like this encourages creativity and the joint development of locally applicable solutions.

5.5. Future Research and Technological Advancement: In order to increase the interpretability and trustworthiness of machine learning models, there is increasing interest in creating explainable AI (XAI) for environmental monitoring (Reichstein et al., 2019). To provide a thorough, up-to-date view of mangrove ecosystems, future studies can also investigate fusion models that include data from social media, in-situ sensors, drones, and satellites. For the next stage of innovation, emerging technologies like edge computing, blockchain for environmental data integrity, and AI-powered drones will probably be important.

6. Challenges and Limitations: While the integration of Big Data and Artificial Intelligence (AI) offers immense potential for monitoring and managing the mangrove zone of Nigeria, several challenges and limitations hinder their effective deployment, particularly in resource-constrained regions such as West Africa.

6.1. Data Gaps and Quality Issues: The consistency, quality, and accessibility of data are among the main obstacles to the integration of artificial intelligence (AI) and big data. Environmental data are sometimes lacking, out-of-date, or dispersed amongst organizations in developing nations. Incomplete datasets can limit the dependability of ecological models and lower the accuracy of AI predictions (Silva et al., 2020). Furthermore, in tropical and coastal regions, continuous cloud cover may obstruct satellite data, necessitating the use of radar-based alternatives or specialized image correction techniques.

6.2. Technical and Computational Barriers: Significant computational infrastructure, such as processing power, cloud storage, and high-speed internet, is needed for big data analytics and artificial intelligence. Adoption and scalability may be restricted by these requirements, which may be beyond the scope of regional conservation organizations and research institutes (Reichstein et al., 2019). Furthermore, deep learning networks and other AI models are data-hungry and need a lot of annotated training data, which is frequently unavailable for specialized ecological applications like mangrove monitoring.

6.3. Limited Technical Expertise and Capacity: The effective deployment of Big Data–AI systems necessitates specific expertise in machine learning, remote sensing, programming, and geographic analysis. A shortage of skilled workers capable of creating, maintaining, and interpreting such systems exists in many African nations (Chib, van Velthoven, & Car, 2015). The urgent need for capacity building and academic-industry collaborations to share tools and information is highlighted by this skills gap.

6.4. Financial Constraints: The cost of acquiring high-resolution satellite data, drone technologies, and environmental sensors, as well as licensing proprietary software and maintaining data infrastructure, can be prohibitively high. This financial burden limits access, especially for local governments and community-based organizations that are closest to the mangrove ecosystems.

6.5. Ethical and Policy Concerns: Data privacy, consent (particularly when incorporating citizen science or indigenous knowledge), and algorithmic bias are some of the ethical issues that are brought up by the use of AI in environmental monitoring. Leslie (2019) notes that many nations are still developing the legal and policy frameworks required to control technology standards, data sharing, and cross-sector cooperation. Fragmented efforts and data silos are more likely to occur in the absence of clear governance.

7. Conclusion: The lives of millions of people, coastal protection, carbon sequestration, and biodiversity are all seriously threatened by the destruction of mangrove ecosystem, especially in tropical areas like Nigeria. The scale, frequency, and accessibility of traditional ecosystem monitoring techniques are frequently constrained. Nevertheless, by facilitating high-resolution, real-time, and predictive environmental evaluations, the combination of Big Data and Artificial Intelligence (AI) offers a prompt and potent remedy for these constraints.

While artificial intelligence (AI) methods like machine learning and deep learning uncover valuable patterns, forecast ecological changes, and facilitate automated decision-making, big data technologies—derived from satellites, drones, sensors, and open platforms—generate vast amounts of environmental data. When combined, these resources can greatly enhance the monitoring, management, and restoration of the mangrove zone of Nigeria. The opportunities outweigh the difficulties, which include a lack of data, technological limits, budgetary restrictions, and ethical dilemmas. Researchers, communities, and policymakers can be empowered by localizing these technologies through strategic infrastructure investment, capacity building, and institutional engagement. Additionally, the integration of Big Data and AI supports the conference's central topics of digital innovation, climate-smart agriculture, and the development of a sustainable blue economy. Future research must put inclusive policies, interdisciplinary studies, and scalable technical solutions that take into account local environmental conditions as top priorities if we are to fully take use of these potential. It is not just a scientific priority but also an ecological and societal necessity to develop digital tools for ecosystem intelligence as environmental challenges increase on a worldwide scale.

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Assessment of Indoor Air Quality in Cybercafés Used by Students of the University of Agriculture and Environmental Sciences, Umuagwo: Implications for Health and Academic Performance'

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Abstract

Indoor Air Quality (IAQ) plays a crucial role in promoting a healthy and productive environment, particularly in spaces frequently occupied by students, such as cybercafés. This study aims to assess the indoor air quality of selected cybercafés used by students of the University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria, focusing on key pollutants and environmental parameters that may affect students' health, comfort, and academic performance. Air quality measurements—including carbon dioxide (CO₂), particulate matter (PM_{2.5} and PM₁₀), temperature, and relative humidity—were conducted using portable air quality monitors during different periods of the day. Observational data regarding ventilation, occupancy, and equipment usage were also recorded. Preliminary findings show that during periods of high occupancy, CO₂ and PM concentrations in many cybercafés exceed World Health Organisation, WHO and American Society of Heating, Refrigeration and Air-Conditioning Engineers, ASHRAE recommended thresholds, indicating poor ventilation and potential exposure risks. These conditions may contribute to headaches, eye strain, reduced concentration, and respiratory discomfort among users. The study concludes that interventions such as improved airflow design, regular air quality monitoring, and user awareness campaigns are essential to enhance indoor environmental quality in student cybercafés. The research offers evidence-based recommendations for healthier digital learning spaces within the university campus.

Keywords: Indoor air quality, cybercafé, students, CO₂, particulate matter, health, ventilation, academic performance.

1.0: INTRODUCTION: A study was carried out to evaluate microbial air pollutants in enclosed digital workspaces present in University of Agriculture and Environmental Sciences, Umuagwo, Imo State. Enclosed digital workspaces are computer-based environments where individuals access internet and digital services in a closed setting with limited airflow. Such spaces include cybercafés, computer laboratories, and call centers (Zhang et al., 2021). Due to poor ventilation and high equipment density, these workspaces can accumulate both chemical and biological pollutants. Indoor air quality (IAQ) has become an increasingly important public health concern in modern times due to the growing prevalence of enclosed environments in which people spend the majority of their daily hours (Chao et al., 2022). Enclosed digital workspaces, such as cybercafés, university e-libraries, and computer laboratories, are characterized by poor ventilation, high occupant density, extended use of electronic devices, and limited natural air circulation. These factors contribute significantly to the accumulation of air pollutants, including particulate matter, volatile organic compounds (VOCs), carbon dioxide, and bioaerosols.

Microbial contaminants, particularly bacteria and fungi, are a major subset of poorly maintained air-conditioning systems, dust resuspension, and electronic devices that trap heat and dust. Studies have shown that *Staphylococcus* spp., *Bacillus* spp., *Aspergillus* spp., *Penicillium* spp., and *Mucor* spp. are commonly isolated in enclosed digital environments, posing risks of respiratory infections, allergic reactions, and opportunistic diseases (Nwankwo et al., 2022). Indoor air pollutants fall into three major categories: physical pollutants such as dust, particulate matter (PM_{2.5}, PM₁₀), chemical pollutants such as volatile organic compounds, ozone from photocopiers, carbon monoxide, carbon dioxide and biological pollutants such as bacteria, fungi, and viruses. These microorganisms can cause nosocomial and opportunistic infections, trigger asthma, allergic rhinitis, and hypersensitivity pneumonitis, contaminate equipment and computer systems, contributing to deterioration. Thus, evaluating microbial and chemical pollutants in university cybercafés is essential for ensuring both environmental hygiene and occupational health. Factors influencing microbial survival in indoor air include relative humidity, temperature, poor ventilation, human activity (respiration, sneezing, and skin shedding). Prolonged exposure to microbial contaminants can cause respiratory tract infections, asthma and allergies (triggered by *Aspergillus* and *Cladosporium* spores), also impairment of immune functions caused by mycotoxin exposure from fungal metabolites. The students who use the digital enclosed space are most often exposed to these health hazards.

MATERIALS AND METHODS: The study was carried out at the University of Agriculture and Environmental Science, Umuagwo (UAES) Cybercafé. It is housing 60 computers, constant human traffic, and centralized air-conditioning. Air samples were collected using the settle plate method. Petri plates of brainheart infusion agar, chromogenic universal agar and sabouraud dextrose agar (SDA) were exposed for 15 minutes at different sampling points (entrance, center, corners, CO). Thereafter they were transported to the laboratory for culture and treated according to standard method (Anderson and Palombo, 2009). A variety of selective and differential microscopic methods were used for presumptive identification of microorganisms. Gram staining, microscopic examination and confirmatory biochemical tests were performed to further identify bacteria and fungi.

RESULTS AND DISCUSSION: Triplicate plates of each sample were used to achieve a plate count of between 30 to 300 colony forming unit (cfu). This quantitative enumeration of bacterial population was carried out by Standard or variable plate method. Total plate count was

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obtained using the various agar. The characterization of the isolates were observed based on their pattern of growth, elevation, size, shape, colony and edge after incubation on the appropriate. Bacterial isolates were identified using Gram staining, catalase, coagulase, oxidase. Fungi were identified by macroscopic (colony morphology) and microscopic (Lactophenol cotton blue stain) characteristics. Common isolates identified were *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Aspergillus niger*, *Penicillium spp.*, *Mucor spp.* Higher bacterial and fungal counts are expected at the center of the cybercafé due to crowding. The result pattern shows a repetition of certain isolates indicating their common appearance within the cybercafés. Samples from corner(CO) has the least average total bacteria count 64 cfu, fungal count 36 cfu sample from the entrance has bacterial count of 48 cfu, fungal count of 32 cfu while samples from centre (CE) has the highest number of bacterial isolates, 269 cfu and fungal count of 178 cfu. Sample centre (CE) has the highest number of total bacteria and fungal count followed by sample E(entrance). This correlates to the work carried out by Uzochukwu et al ,2022, which also indicated that higher bacterial and fungal counts are expected at the center of the cybercafé due to crowding.

Table 1. Microbial isolates from enclosed digital workspace

Isolates	Bacteria	Fungi
CO	<i>Staphylococcus</i> , <i>Escherichia</i> , <i>Bacillus sp</i>	<i>Aspergillus sp</i> , <i>Penicillium spp.</i> , <i>Mucor spp.</i>
CE	<i>Staphylococcus</i> , <i>Escherichia</i> , <i>Bacillus sp</i> .	<i>Aspergillus sp</i> , <i>Penicillium spp.</i> , <i>Mucor spp.</i>
E	<i>Staphylococcus</i> , <i>Escherichia</i> , <i>Bacillus sp</i> .	<i>Aspergillus sp</i> , <i>Penicillium spp.</i> , <i>Mucor spp.</i>

CO (corner), CE (centre), E(entrance)

Table 2 shows total plate count (number of colonies) for bacterial and fungal isolates.

Isolates (cfu)	Bacteria	Fungi
CO	64	36
CE	269	178
E	48	32

Key words; CO (corner), CE (centre), E (entrance)

Table 4.4: Morphological characteristics of fungal genera Isolated from different sections of the university cybercafé using sabouraud dextrose agar (SDA), Brain heart infusion agar(BHA), chromogenic universal agar(CUA)

Plate	Colony Size	Texture	Margin	Top Colour	Presumptive Isolate
CUA	2-5cm	Powdery or cotton	White regular and well defined	Blue-green	<i>Penicillium sp</i>
BHA	3-5cm	Powdery	White, narrow and well defined	Black	<i>Aspergillus sp</i>
SDA	6-9 cm	Fluffy	Irregular	White	<i>Mucor</i>

This study highlights the microbiological risks associated with enclosed digital workspaces. The expected isolation of *Staphylococcus aureus* supports previous findings that human occupants, which include students, are major contributors to indoor bacteria. The prevalence of *Aspergillus* and *Penicillium* is consistent with fungal contamination patterns reported in similar university settings. Ventilation, CO₂ and risk amplification: CO₂ is a practical proxy for ventilation adequacy; concentrations above 1000 ppm are commonly used to signal suboptimal air exchange. In cybercafés, sustained elevations in CO₂ during peak hours indicate inadequate fresh air delivery and permit accumulation of both gaseous pollutants and bioaerosols. Engineering controls: Improve ventilation (increase air exchange rates, repair/maintain HVAC, use supply/exhaust balance). Where feasible, install filtration (portable HEPA units) and ensure regular cleaning/replacement of HVAC filters. Studies show that even modest ventilation upgrades reduce both PM and culturable bioaerosol loads substantially.

Administrative controls: Manage occupancy (limit simultaneous users during peak times), implement scheduled breaks to allow air flushing, and restrict printing in enclosed rooms where possible. Routine maintenance and documented cleaning schedules (with appropriate disinfectants) for high-touch surfaces should be standard (Uzochukwu & Nwafor, 2021). Personal behaviours: Encourage hand hygiene, discourage eating at computer stations, and post visible signage about cough etiquette and the importance of hygiene. User education campaigns are low cost yet effective in reducing fomite spread.

Monitoring, surveillance and research considerations: A practical cybercafé IAQ program balances feasibility and rigor: continuous logging of CO₂ and PM_{2.5} offers low-cost, real-time indicators of ventilation and particulate burden; these can trigger spot microbiological sampling (settle plates, active samplers) on a monthly or quarterly cadence. Culture-based assays are inexpensive and informative for CFU trends, but molecular methods (qPCR, 16S/ITS sequencing) provide deeper taxonomic resolution and ARG detection — important when investigating antibiotic resistance or viral threats. The enclosed digital workspaces are not merely inconveniently crowded rooms — they are dynamic microbiological environments shaped by human behavior, building systems, and particulate pollution. These workspaces such as university cybercafés serve as reservoirs of microbial contaminants, influenced by human activity and inadequate ventilation. Regular monitoring, improved ventilation, and periodic fumigation are necessary to reduce microbial loads. The presence of these microbes are likely to affect the health and academic performance of the students in the university.

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Climate Changes, Insecurity and Economic Development in Nigeria: A Review

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Abstract

The objective of this paper is to explore the nexus between climate change, insecurity, and economic development in Nigeria, focusing on how these factors influence on one another. A review approach was adopted in this paper. Findings from the review revealed that climate change has led to worsening economic disparities in Nigeria, a key factor in the country's rising insecurity. The cycle of flooding in the country which is a product of climate change has destroyed farmland and livelihoods and worsened already severe food insecurity. The increased vulnerability and conflict in northern Nigeria stem from the influence of climate change and drought, which has resulted in competition between farmers and pastoralists. This has consequently led to a variety of conflicts, including the proliferation of small arms and light weapons, loss of life and property, loss of livelihood, internal displacement of people, food insecurity, and economic stagnation, contributing to several security crises. The paper concluded that the interconnectedness of climate change, insecurity, and economic development in Nigeria presents significant challenges. Addressing these issues requires a comprehensive and integrated approach that considers the complex dynamics at play. It also recommended integrated environmental and security policies; investment in sustainable agriculture; and engaging communities and civil society's need and support them to secure environment across scales.

Keywords: Climate Changes; Development; Economic; Insecurity; Nigeria.

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Introduction: Nigeria, a West African nation, faces a complex and interconnected challenge where climate change acts as a significant stressor, exacerbating insecurity and undermining efforts toward economic development. The country is highly vulnerable to climate change impacts due to its geographical location, reliance on climate-sensitive economic sectors like agriculture, and limited adaptive capacity (Madu, 2012; Onuoha, 2009). General increases in average temperatures are observed across Nigeria. Rainfall patterns are becoming increasingly erratic, with increased intensity leading to flooding in the south and coastal areas, and decreasing amounts resulting in drought and desertification in the North (Direction Générale du Trésor, 2024; Madu, 2012).

Severe perennial flooding, particularly in the coastal regions and major river basins, results in loss of life, displacement, and massive damage to infrastructure and farmlands. The 2022 floods, for example, caused an estimated billion in direct economic damage (Direction Générale du Trésor, 2024). Moreover, the northern part of Nigeria is increasingly affected by arid conditions and the southward creep of the Sahara Desert, leading to the loss of arable land and pastures with the coastal cities, notably Lagos and the Niger Delta, are threatened by rising sea levels and coastal erosion, which endanger critical economic infrastructure. Climate change may not have direct cause of conflict but acts as a threat multiplier and a driver of human insecurity by intensifying competition for scarce natural resources and destabilizing livelihoods.

Nigeria being the Africa's most populous country and largest economy, is profoundly vulnerable to climate-related hazards, which exacerbate deep-seated socio-economic and political fragilities. Observed climate change indicators include: rising temperatures, erratic rainfall patterns, desertification in the North, and coastal erosion and flooding in the South (Intergovernmental Panel on Climate Change [IPCC], 2021; Ajibade et al., 2014; Ogbuabor & Egwuchukwu, 2017). These environmental stressors act as potent "threat multipliers" that intensify existing resource competition, primarily driving the country's most pervasive security challenges (Mshelia, 2013).

Climate-induced scarcity of renewable resources, particularly arable land and water, pushes pastoralists southward from the desertifying regions, leading to violent farmer-herder conflicts (Homer-Dixon, 1999; Sayne, 2011; Folami & Folami, 2013). This relationship is frequently analyzed through the Resource Scarcity and Conflict Theory (Gleditsch & Urdal, 2002).

The resulting violence, alongside other forms of insecurity (e.g., banditry and terrorism), severely constrains economic activity. Empirical studies consistently show that heightened conflict deters Foreign Direct Investment (FDI), increases the cost of doing business, and destroys critical infrastructure and farmlands, thus negatively affecting GDP growth and sustainable development goals (Muhammed, 2023).

Climate Economic Development: Independent of conflict, climate events directly impair key economic sectors. Droughts and floods lead to significant crop failures and reduced yields, impacting the livelihoods of Nigeria's largely agrarian rural population, spiking food price inflation, and exacerbating poverty (Ibrahim & Ibrahim, 2024; Kareem et al., 2023). This cycle is further explained by the Vulnerability and Resilience Theory, which highlights how poverty limits adaptive capacity to climatic shocks (Ismail et al., 2019).

Theoretical Frameworks: The relationship between climate change, insecurity, and economic development in Nigeria is often analyzed through several interconnected theoretical lenses, primarily focusing on resource management and societal vulnerability.

A. Resource Scarcity and Conflict Theory: This framework, notably derived from the work of Homer-Dixon (1999), posits that environmental degradation and climate change-induced scarcity of renewable resources (like arable land and water) act as "stressors" that contribute to conflict and insecurity.

Core Postulate: The decrease in the quality and quantity of vital resources, especially when coupled with factors like population growth and unequal resource access, leads to resource competition, which can in turn strengthen existing ethnic, religious, or social cleavages and escalate into violence and insecurity (Homer-Dixon, 1999; Gleditsch & Urdal, 2002).

Application in Nigeria: This theory is crucial for understanding the persistent farmer-herder conflicts in Nigeria's North-Central region. Desertification and the shrinking of Lake Chad due to climate change push pastoralists southward in search of grazing land and water, leading to clashes with host farming communities over dwindling resources, thereby undermining regional stability and economic activity (Sayne, 2011; Folami & Folami, 2013).

B. Vulnerability and Resilience Theory: This framework focuses on the inherent fragility of human existence and the capacity of socio-economic systems to cope with adverse climate change effects (Musa et al., 2024).

Core Postulate: Vulnerability theory highlights how existing socio-economic inequalities, institutional failures, and poverty disproportionately expose marginalized populations to climate risks, weakening their capacity to adapt and increasing their susceptibility to harm (Ismail et al., 2019). Conversely, resilience refers to the ability of a community or system to anticipate, cope with, and recover from climatic shocks. **Application in Nigeria:** It explains why the poorest households and subsistence farmers in Nigeria, particularly in the arid north, are the most impacted by crop failures, reduced yields, and increased health risks from climate change. This reduced adaptive capacity translates into economic insecurity and can fuel migration and social unrest (Ibrahim & Ibrahim, 2024).

C. Human Security Framework: Moving beyond state-centric and military definitions, the human security framework places the individual at the center of security concerns, encompassing threats to their livelihood, well-being, and dignity (Mshelia, 2013).

Core Postulate: Climate change is viewed as a threat multiplier that endangers all fundamental dimensions of human security: economic security (loss of income/livelihood), food security (crop failure, price hikes), health security (disease outbreaks), and personal/community security (conflict, displacement) (Mshelia, 2013; Onuoha & Ezirim, 2010). **Application in Nigeria:** Climate-induced displacement due to sea-level rise in the coastal areas or desertification in the North directly impacts human security, creating a pool of vulnerable, jobless, and internally displaced persons (IDPs), which further strains the state's capacity and exacerbates existing insecurity (USAID, 2012).

Conceptual Frameworks: The conceptual framework for this nexus integrates the core variables, highlighting the direct and indirect pathways of influence.

A. Core Concepts: **Climate Change (Independent Variable):** Defined as long-term shifts in temperature and precipitation patterns, including increased frequency of extreme weather events like floods, droughts, and heatwaves (IPCC, 2021; Ajibade et al., 2014). In Nigeria, key indicators are rising temperatures, erratic rainfall, and increased carbon emissions (Ogbuabor & Egwuchukwu, 2017).

Insecurity (Intervening Variable): Encompasses threats to human well-being and stability, ranging from resource-based conflicts (farmer-herder clashes) and criminal activity (kidnapping, banditry) to political instability and terrorism. Climate change is seen as an aggravating factor that intensifies existing security threats (Ezirim & Onuoha, 2008). **Economic Development (Dependent Variable):** Refers to the sustained improvement in the well-being and quality of life for citizens, measured by indicators such as Gross Domestic Product (GDP), Human Development Index (HDI), poverty levels, and employment stability (Chin-Yee, 2019).

B. The Nexus Model: The relationship can be conceptualized as a multi-directional feedback loop: **Pathway 1: Climate Change Economic Development:** Climate change directly impacts key economic sectors (agriculture, energy) through reduced crop yields, power generation shortfalls, and infrastructure damage from floods, leading to economic instability and reduced productivity (Ikehi et al., 2023).

Pathway 2: Climate Change Insecurity: Climate-induced resource scarcity drives competition, forced migration, and land-use conflicts, directly escalating insecurity, such as the violence between herders and farmers (Sayne, 2011; Folami & Folami, 2013).

Pathway 3: Insecurity Economic Development: Heightened insecurity (terrorism, banditry) disrupts economic activities, deters Foreign Direct Investment (FDI), increases government expenditure on defense, and destroys infrastructure and farmlands, severely constraining national economic growth and sustainable development (Muhammed, 2023). **Feedback Loop:** Poverty and underdevelopment (low adaptive capacity) make communities more vulnerable to climate change, perpetuating the cycle of environmental stress, conflict, and economic decline (Olayemi, 2014).

3. Empirical Frameworks and Findings: Empirical studies in Nigeria utilize various econometric models (e.g., ARDL, ECM) and qualitative methods to test the relationships, yielding consistent but sometimes nuanced findings.

A. Climate Change and Economic Development: **Agricultural Impact:** Studies consistently show a negative and significant impact of climate change (specifically erratic rainfall and rising temperatures) on agricultural productivity, leading to decreased yields, food shortages, and higher food price inflation (Ibrahim & Ibrahim, 2024; Kareem et al., 2023). This directly harms the livelihoods of the majority of rural Nigerians (Ajibade et al., 2014). **Macroeconomic Impact:** Empirical evidence suggests that climate variables, such as carbon emissions and changes in average temperature, negatively affect long-run economic growth (GDP) in Nigeria, with disruptions being more pronounced in the long run (Ucheje, Okolo & Chukwueloka, 2024; Zilberman & Millar, 2020). However, some studies find the impact on overall GDP to be insignificant in the short term, though the negative effects on inflation and specific sectors are clear (Kareem et al., 2023).

Poverty Linkage: Climate change exacerbates poverty. For instance, increased food inflation and unemployment, often triggered by climatic shocks, have a significant causal link with the poverty headcount ratio in Nigeria (World Data Lab, 2020; EIU, 2019).

B. Climate Change and Insecurity: **Resource Conflict Evidence:** The most robust empirical finding is the link between desertification/aridity in the North and the ensuing farmer-herder conflict across the Middle Belt. Sayne (2011) and subsequent studies establish this as a primary mechanism by which climate change fuels insecurity, noting that the scramble for increasingly scarce grazing land and water is a major trigger for violence (Folami & Folami, 2013; Uexkuell & Bulhaug, 2021).

Migration and Displacement: Empirical studies confirm that extreme weather events (flooding, sea-level rise) and slow-onset phenomena (desertification) lead to mass displacement and migration, straining urban infrastructure and social cohesion, which can then precipitate urban insecurity and crime (Cattaneo and Massetti, 2019).

C. Insecurity and Economic Development: Cost of Conflict: Empirical research highlights that high levels of insecurity significantly deter both domestic and foreign investment, increase the cost of doing business (through higher insurance, security, and logistics costs), and divert significant state resources from productive investments to security, thereby retarding economic development and sustainable growth goals (Muhammed, 2023; Fragile States Index, 2022). Sectoral Disruption: Insecurity, such as banditry and terrorism, directly affects the agricultural sector by forcing farmers off their land, leading to food scarcity, and disrupting supply chains, which compounds the negative impact of climate change on food security (Abdullahi, 2020).

The climate change crisis in Nigeria highly dependent on climate-sensitive sectors like agriculture and oil, profoundly vulnerable to climate change impacts, which manifest primarily as erratic rainfall patterns, rising temperatures, and sea-level rise (Ogbuabor & Egwuchukwu, 2017; Ikehi et al., 2023).

- i. Environmental Degradation: The North is plagued by desertification and severe droughts, leading to the shrinking of water bodies like Lake Chad (Madu, 2012). Conversely, the Southern coastal regions face increasing frequency and intensity of flooding due to excessive rainfall and rising sea levels (Jibrillah et al., 2018).
- ii. Sectoral Impact: The agricultural sector suffers from reduced crop yields and livestock productivity due to extreme weather, affecting millions whose livelihoods depend on rain-fed agriculture (Ibrahim & Ibrahim, 2024). The energy sector is also impacted, as erratic rainfall affects hydroelectric power generation, contributing to energy shortfalls (Ikehi et al., 2023).

Climate change as a driver of insecurity indicates that the environmental consequences of climate change act as a threat multiplier, exacerbating existing ethnic, religious, and socio-economic tensions, thus fueling insecurity across the country (Madu, 2012; Sule et al., 2024).

- i. Farmer-Herder Conflicts: The most direct link is the intensified farmer-herder conflict in Nigeria's Middle Belt and North. Desertification and drought in the Sahel region push pastoralists to migrate southwards in search of dwindling grazing land and water resources, leading to violent clashes with farming communities over scarce resources. This struggle for survival is a major source of widespread violence and loss of life (Sule et al., 2024; Madu, 2012).
- ii. Displacement and Resource Competition: Climate-induced crises, such as prolonged droughts and massive floods, lead to internal displacement and migration. This rapid demographic shift places additional strain on the resources and infrastructure of host communities, creating new lines of tension and conflict (Ismail et al., 2019).
- iii. Food Insecurity: The decline in agricultural productivity due to climate shocks translates directly into food insecurity and soaring food prices, leading to desperation and a greater risk of criminality and organized violence (Ibrahim & Ibrahim, 2024).

Economic Development and the Vicious Cycle

The twin challenges of climate change and insecurity severely undermine Nigeria's efforts towards sustained economic development, creating a vicious cycle of poverty and instability.

- i. Economic Disruption: Climate-related disasters (e.g., floods) damage critical infrastructure roads, bridges, and housing incurring significant repair costs and disrupting supply chains and market access, all of which constrain national economic growth (Ikehi et al., 2023).
- ii. Reduced Productivity and Investment: Insecurity, particularly in the agricultural heartlands, prevents farmers from accessing their lands, leading to a massive decline in agricultural output. The general atmosphere of instability also discourages domestic and foreign direct investment across all sectors (Kareem et al., 2023).
- iii. Fiscal Strain: The government is forced to divert already limited financial resources from essential services and development projects to fund military operations and humanitarian aid, further straining the national budget and impeding long-term development (Musa et al., 2024).

4. Conclusion: Climate change is not merely an environmental problem in Nigeria; it is a fundamental threat to national security and a major constraint on economic development. By intensifying resource scarcity and displacement, climate change acts as a primary catalyst for conflict and insecurity, which in turn destroys livelihoods, infrastructure, and investment. Breaking this destructive nexus is paramount for Nigeria to achieve its Sustainable Development Goals.

Recommendations

- i. Integrate Climate-Security Planning for the government to adopt an integrated, multi-sectoral approach that treats climate change as a core national security issue, not just an environmental one. Security policies should explicitly address climate-induced resource conflicts.
- ii. Invest in Climate-Resilient Infrastructure to prioritize investment in climate-smart infrastructure, such as efficient water harvesting systems for irrigation, erosion control projects, and improved flood defenses in vulnerable regions.
- iii. Support Climate-Smart Agriculture to promote and fund climate-resilient agricultural practices that can cope with droughts and floods, providing extension services, and financial incentives for farmers to adopt new technologies and crop varieties.
- iv. Strengthen Conflict Resolution Mechanisms to establish and empower local and traditional institutions for resource conflict resolution and mediation, especially between herders and farmers, to address disputes before they escalate into violence.

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Growth and Yield Response of Potato (*Solanum Tuberosum* L.) Varieties to Planting Bag Size under Dry Season Conditions in Nigeria

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Abstract

A field study was conducted during the 2025 dry season at the Teaching and Research Farm, Department of Agricultural Science, Federal University of Education, Pankshin, Plateau State, Nigeria, to assess the effects of planting bag size and potato variety on growth and yield performance. The experiment employed a 3 × 3 factorial arrangement involving three planting bag sizes (B₁ - 250 L capacity, B₂ - 190 L, and B₃ - 130 L) and three varieties (V₁ - Jelly, V₂ - Marabel, and V₃ - Connect). Treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on vegetative and yield parameters were subjected to ANOVA, and means separated using the Least Significant Difference (LSD) at the 5% level. Results showed that larger bags (B₁) significantly improved vegetative parameters and yield. The tallest plants (25.0 cm), highest leaf count (24), and thickest stem girth (5.8 cm) were recorded in V₂B₁ and V₃B₁. V₂B₁ also produced the highest seed tubers per plant (15), while ware tubers peaked in V₁B₁ and V₃B₁ (8). Total yield was highest in V₃B₁ (29.6 t/ha), exceeding Nigeria's national average by a significant margin. Correlation analysis showed strong positive associations between vegetative traits and yield components. The study concludes that large bag volume enhances both growth and yield. For seed tuber production, Marabel in large bags is recommended; for ware tubers and maximum yield, Connect in large bags is optimal. These results suggest the viability of containerized potato farming for yield enhancement, especially in land-limited settings. Further multi-season and multi-location trials are advised to validate these results under varied agroecological conditions.

Keywords: Containerized cultivation, Dry season farming, Growth and yield performance, Planting bag size, Potato varieties, Urban agriculture.

Introduction: In Nigeria, particularly on the Jos Plateau, potato farming plays a significant role in the livelihoods of rural communities. However, traditional cultivation methods face numerous constraints such as shrinking arable land, soil degradation, pest infestations, and unpredictable weather patterns, all exacerbated by the growing impact of climate change (Masvodzi & Mapuwei, 2015; Sakadzo *et al.*, 2019; Deshi *et al.*, 2021). These challenges threaten the sustainability of potato production and call for innovative agricultural strategies that optimize resource use while ensuring food and economic security (Nwosu & Onuoha, 2022; Eze & Uka, 2021; Nguyen & Tran, 2021).

One such strategy gaining attention is the cultivation of crops in containerized systems, particularly the use of large grow bags commonly referred to as "bag gardening." This method involves growing crops in reusable bags filled with soil or growing media and is especially suitable for locations with poor soil conditions or limited access to farmland (Adesina *et al.*, 2020; Bello & Mohammed, 2022; Mowers *et al.*, 2023). Bag gardening offers several agronomic and environmental benefits, including efficient space utilization, improved control of soil fertility and moisture, reduced weed pressure, and better pest and disease management (Oyewole & Obioha, 2020; Davis & Kumar, 2020; Jones & Cooper, 2018). Despite its growing adoption in urban and peri-urban agriculture, there is limited empirical data on the performance of potatoes cultivated using grow bags in Nigeria, especially with respect to different varieties and container sizes. Understanding the interaction between variety and container volume could provide insights for optimizing productivity in smallholder systems. There is, therefore, a need to evaluate the growth and yield performance of potato varieties cultivated in grow bags of different volumes under local conditions. This study aims to evaluate the agronomic performance of selected potato varieties grown in sack-based planting bags of varying soil-holding capacities, with a focus on plant growth, yield response, and practical suitability for container-based production systems. Specifically, the study seeks to assess the growth characteristics and yield quantity of potato (*Solanum tuberosum* L.) varieties cultivated in planting bags of different volumes under dry season conditions in Nigeria.

Research Methodology

Study Area and Soil Type: The experiment was conducted during the 2025 dry season at the Teaching and Research Farm of the Department of Agricultural Science, Federal University of Education, Pankshin, Plateau State, Nigeria. The area lies within the Jos Plateau, a major potato-producing region of Nigeria. Well-decomposed loamy Alfisols, which is predominant and known for good drainage and moderate fertility were collected from a nearby cultivated field and thoroughly homogenized prior to filling the bags.

Experimental Design and Treatment Structure: The study adopted a 3 × 3 factorial arrangement within a Randomized Complete Block Design (RCBD), replicated three times, yielding a total of 27 treatment plots. The two factors tested were planting bag size (B₁, with a 250 L soil volume, B₂, 190 L soil volume and B₃, 130 L soil volume) and potato varieties (V₁, Jelly, V₂, Marabel, and V₃, Connect). Each treatment combination was assigned to all grow bags and treated as a single experimental unit. Treatments were randomized within each block to control for spatial variability.

Field Layout, Bag Preparation and Agronomic Practices: Each planting bag was filled to full capacity with the prepared loamy soil. The bags were arranged with 0.5 m spacing between units, allowing uniform exposure to sunlight and ease of maintenance. One pre-sprouted

tuber was planted per bag at a depth of 10 cm. All experimental units were managed using identical agronomic practices throughout the cropping period. Weed control was conducted by hand-pulling emerging weeds as needed.

Data Collection: Growth parameters (plant height, stem girth, and number of leaves per plant) were measured at 4, 6 and 8 weeks after planting. At maturity, plants were carefully harvested and assessed for number of seed tubers (≤ 30 mm diameter), number of ware tubers (>30 mm diameter) and total tuber weight per plant

Yield Estimation and Data Analysis: Yield per hectare (t/ha) was estimated by scaling the average yield per bag to the equivalent of 1 hectare using a soil volume basis of 20,000 kg/ha. All data were subjected to Analysis of Variance (ANOVA) using standard statistical software. Treatment means were separated using the Least Significant Difference (LSD) test at a 5% significance level. The assumptions of normality and homoscedasticity were verified before analysis.

Results

Effect of Bag Size and Variety on Vegetative Growth of Potato: The effect of planting bag size and potato variety on plant height, number of leaves, and stem girth at 4, 6, and 8 weeks after planting (WAP) is presented in Table 1. Analysis of variance revealed that bag size and variety significantly influenced all vegetative parameters ($p \leq 0.05$) at every stage of data collection. At 4 WAP, the tallest plants were recorded in treatment V₂B₁ with a height of 19.3 cm, followed closely by V₃B₁ and V₁B₁, which both had plant heights of 18.0 cm. The shortest plants were observed in V₂B₃ (Marabel in small bag) at 13.3 cm. This pattern was consistent at 6 and 8 WAP, where the larger bag sizes (B₁) generally promoted greater plant height across all varieties.

Table 1: Effect of Bag Size and Variety on Plant Growth Parameters

Trts.	Plant Height (cm)			Number of Leaves			Stem Girth (cm)		
	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
V ₁ B ₁	18.0 ^{ab}	21.5 ^a	24.0 ^a	10 ^a	16 ^a	24 ^a	3.8 ^a	4.9 ^a	5.7 ^b
V ₁ B ₂	15.5 ^{bc}	19.5 ^c	22.0 ^{cd}	7 ^c	10 ^c	15 ^c	3.1 ^{bc}	4.3 ^b	5.7 ^b
V ₁ B ₃	14.2 ^c	15.1 ^e	28.0 ^a	8 ^{bc}	16 ^a	23 ^a	2.3 ^d	3.8 ^c	4.3 ^d
V ₂ B ₁	19.3 ^a	22.0 ^a	25.0 ^a	9 ^b	14 ^b	16 ^{bc}	3.5 ^{ab}	4.7 ^a	5.8 ^a
V ₂ B ₂	14.5 ^c	16.2 ^d	20.0 ^d	6 ^c	9.0 ^c	14 ^c	3.2 ^{bc}	4.3 ^b	5.5 ^c
V ₂ B ₃	13.3 ^d	14.5 ^e	17.6 ^e	7 ^c	11 ^c	14 ^c	2.4 ^d	3.9 ^c	4.6 ^b
V ₃ B ₁	18.0 ^{ab}	20.1 ^b	23.5 ^{ab}	10 ^a	15 ^b	20 ^{ab}	3.6 ^{ab}	4.9 ^a	5.8 ^a
V ₃ B ₂	10.8 ^e	12.6 ^f	14.0 ^f	6 ^c	9 ^c	14 ^c	3.1 ^{bc}	4.1 ^b	5.8 ^a
V ₃ B ₃	14.3 ^c	16.0 ^d	18.0 ^e	7 ^c	12 ^c	15 ^c	2.5 ^d	3.7 ^c	4.7 ^d
LSD (0.05)	0.321	0.397	0.321	0.321	2.99	5.2	0.01	0.012	0.014
p-value	0.029	0.045	0.029	0.029	0.029	0.018	0.045	0.025	0.028

Note: Means followed by the same letter within each column are not significantly different at $p \leq 0.05$ using LSD (Least Significant Difference) test. Trts: Treatments; Varieties: V₁ = Jelly, V₂ = Marabel, V₃ = Connect. Sack sizes: B₁ = 250, B₂ = 190 L, B₃ = 130 L.

The number of leaves followed a similar trend. At 4 WAP, V₁B₁ and V₃B₁ recorded the highest leaf count (10), followed by V₂B₁ (9 leaves). The lowest number of leaves (6) was observed in V₂B₂ and V₃B₂. The advantage of larger bags in enhancing leaf development persisted at later growth stages. In terms of stem girth, treatment V₁B₁ produced the thickest stems at 4 WAP (3.8 cm), followed by V₂B₁ (3.5 cm) and V₃B₁ (3.6 cm).

The smallest stem girth (2.3 cm) was recorded in V₁B₃ (Jelly in small bag). Similar trends were observed at 6 and 8 WAP, indicating that container volume substantially affected stem development. Overall, the data suggested that vegetative growth of potato is positively influenced by larger planting container size (B₁) irrespective of variety, with V₁B₁, V₂B₁, and V₃B₁ consistently outperforming other treatments across all parameters.

Effect of Bag Size and Variety on Yield Parameters of Potato

The effect of bag size and potato variety on yield parameters is presented in Table 2. The data show that planting container volume significantly influenced all yield components ($p \leq 0.05$), including number of seed and ware tubers per plant, weight of seed and ware tubers per plant, and total yield per hectare.

Among all treatments, the highest number of seed tubers per plant (15) was observed in V₂B₁, followed by V₁B₁ with 14. The lowest number of seed tubers (4) was recorded in V₃B₃ and V₃B₂, both significantly lower than other treatments. For ware tubers, V₃B₁ and V₁B₁ produced the highest counts (8 per plant), followed by V₂B₁ with 6. The least ware tubers per plant (2) were recorded in V₃B₂.

Table 2: Effect of Potato Variety and Bag Size on Yield Parameters

Treatment	Seed Tubers	Ware Tubers	Seed Tuber Wt. (kg)	Ware Tuber Wt (kg)	Total Yield (t/ha)
V ₁ B ₁	14 ^a	8 ^a	6.6 ^a	8.3 ^a	29.4 ^a
V ₁ B ₂	8 ^c	3 ^d	2.1 ^e	3.0 ^e	20.2 ^d
V ₁ B ₃	6 ^d	3 ^d	4.2 ^c	5.4 ^c	22.1 ^c
V ₂ B ₁	15 ^a	6 ^b	4.3 ^c	5.3 ^c	28.2 ^a
V ₂ B ₂	6 ^d	4 ^c	3.2 ^d	4.2 ^d	21.4 ^{cd}
V ₂ B ₃	5 ^{de}	4 ^c	5.3 ^b	7.4 ^b	23.3 ^{bc}
V ₃ B ₁	10 ^b	8 ^a	5.6 ^b	7.6 ^b	29.6 ^a
V ₃ B ₂	4 ^e	2 ^e	3.5 ^d	4.3 ^d	23.2 ^{bc}
V ₃ B ₃	4 ^e	3 ^d	3.3 ^d	4.2 ^d	21.6 ^{cd}
LSD (0.05)	1.24	1.01	0.47	0.52	2.36
p-value	0.017	0.009	0.003	0.005	0.001

Note: Means followed by the same letter within each column are not significantly different at $p \leq 0.05$ using LSD (Least Significant Difference) test. Varieties: V₁ = Jelly, V₂ = Marabel, V₃ = Connect. Sack sizes: B₁ = 250, B₂ = 190 L, B₃ = 130 L.

The weight of seed tubers per plant followed a similar trend, with V₁B₁ producing the heaviest seed tubers (6.6 kg/plant), followed by V₃B₁ (5.6 kg) and V₂B₁ (4.3 kg). The lightest seed tubers (2.1 kg) were recorded in V₁B₂. In terms of ware tuber weight, V₁B₁ again recorded the highest (8.3 kg), followed by V₃B₁ (7.6 kg) and V₂B₃ (7.4 kg). The smallest ware tuber weight (3.0 kg) was from V₁B₂. Total yield (t/ha) was highest in V₃B₁ (29.6 t/ha), closely followed by V₁B₁ (29.4 t/ha), while the lowest yield (20.2 t/ha) was observed in V₁B₂. These results clearly indicate that larger planting containers (B₁) promoted higher yield performance across all potato varieties.

Relationship between Growth and Yield Parameters: The correlation matrix of vegetative and yield parameters is presented in Figure 1. Results reveal several strong and statistically meaningful associations among the measured traits. Notably, plant height across all sampling weeks exhibited very strong positive correlations with total yield ($r = 0.88$ at 6 WAP; $r = 0.72$ at 4 WAP), suggesting that taller plants tended to produce higher tuber yields. Similarly, number of leaves and stem girth at all weeks also demonstrated high positive correlations with total yield, particularly at 6 WAP ($r = 0.82$ and $r = 0.82$ respectively), indicating their critical influence on productivity.

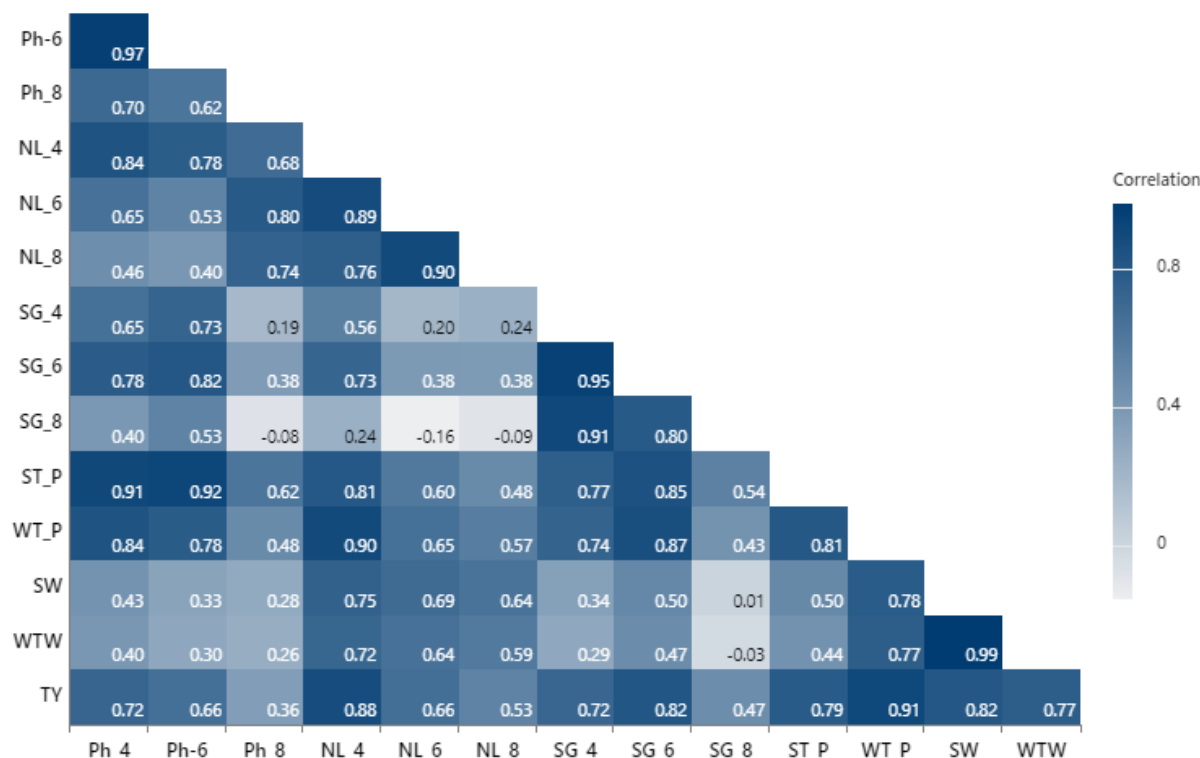


Figure 1: Correlation matrix showing Pearson's Correlation Coefficients Among Vegetative and Yield Parameters of Potato

Note: Ph = Plant Height, NL = Number of Leaves, SG = Stem Girth, ST_P = Number of Seed Tubers per Plant, WT_P = Number of Ware Tubers per Plant, SW = Seed Tuber Weight (kg), WTW = Ware Tuber Weight (kg), TY = Total Yield (t/ha). Subscripts 4, 6, and 8 denote Weeks After Planting (WAP).

Furthermore, strong inter-correlations were observed among the vegetative parameters themselves. For instance, plant height at 6 WAP correlated strongly with number of leaves at 4 WAP ($r = 0.84$) and stem girth at 6 WAP ($r = 0.82$), suggesting that these traits evolve together during the vegetative phase. Stem girth at 6 WAP also showed a very strong correlation with stem girth at 8 WAP ($r = 0.95$), affirming growth continuity and developmental consistency. Regarding yield components, seed tuber weight per plant (SW) and ware tuber weight per plant (WTW) were nearly perfectly correlated ($r = 0.99$), emphasizing a high likelihood that varieties producing heavier seed tubers will also yield higher ware tuber weights. Both SW and WTW showed strong correlations with total yield ($r = 0.82$ and $r = 0.77$, respectively). Likewise, weight of tubers per plant (WT_P) was also strongly correlated with total yield ($r = 0.91$), confirming it as a reliable predictor of yield outcome.

Discussion: This study reports preliminary findings on the effects of potato variety and growing container size on vegetative growth and yield performance. The results showed that plant height, number of leaves, and stem girth were significantly ($p \leq 0.05$) influenced by both the variety planted and the volume of the growing container. Consistently, plants grown in the largest containers (i.e. treatments V₁B₁, V₂B₁, and V₃B₁) exhibited superior vegetative growth. These treatments produced significantly taller plants, greater leaf numbers, and thicker stems than their counterparts in medium (190 L) and small (130 L) containers. This observation aligns with findings by Hossain (2005), Retana-Cordero *et al.* (2022), and Asnake *et al.* (2023); who emphasized that container volume directly affects root development, nutrient access, and water retention, all of which are critical to early vegetative vigor.

The superior performance in larger containers can be attributed to the greater rooting volume, which reduces root congestion and competition, enhances soil aeration, and supports efficient nutrient absorption. As Kanwal and Shoaib (2006) and Ibe and Aja (2021) also reported, plant morphology is strongly influenced by environmental and edaphic factors, including root zone size and nutrient availability, both of which are directly affected by container size.

In contrast, the smallest containers, especially treatments V₁B₂ and V₂B₂, demonstrated significantly lower performance in all vegetative parameters. This is likely due to root confinement, poor aeration, and limited nutrient mobility within the restricted soil volume. The medium-sized containers (V₂B₃ and V₃B₃) produced intermediate responses, suggesting a linear relationship between container size and vegetative

performance, in agreement with observations by Donnelly & Munger (2003) and Miller & Brown (2021). These vegetative differences translated into significant yield variations among treatments. Larger containers not only produced higher vegetative biomass but also yielded more seed and ware tubers per plant. Treatment V₂B₁ recorded the highest number of seed tubers per plant (15), while V₃B₁ and V₁B₁ produced the most ware tubers and also the highest total yields of 29.6 t/ha and 29.4 t/ha, respectively. This is a remarkable improvement over Nigeria's current national average potato yield of 3.1 – 3.8 t/ha as reported by FAOSTAT (2019). The yield levels observed in this study approach those reported from high-performing potato-producing countries such as Kenya (15 – 20 t/ha), Ethiopia (17 – 22 t/ha), and South Africa (30 – 35 t/ha) (Zework *et al.*, 2024). The strong correlations observed among vegetative and yield parameters further reinforce these findings. As shown in the correlogram (Figure 1), plant height at 6 WAP exhibited a very strong positive correlation with total yield ($r = 0.88$), suggesting that early vegetative vigor is a strong predictor of final yield. Similarly, stem girth at 6 WAP and number of leaves at the same stage were also positively correlated with total yield ($r = 0.82$ and $r = 0.82$ respectively), indicating that plants with robust stems and higher foliage are more likely to channel assimilates effectively toward tuber formation.

Moreover, the number and weight of seed and ware tubers per plant demonstrated near-perfect correlations with total yield. Seed tuber weight (SW) and ware tuber weight (WTW) had an inter-correlation of $r = 0.99$ and were both strongly associated with yield ($r = 0.82$ and $r = 0.77$ respectively), validating them as reliable yield components. These results align with the earlier tabular findings and confirm that treatments with superior vegetative traits, especially those in large containers, also performed better agronomically in terms of yield accumulation. The consistency of these correlations supports the physiological logic that optimal vegetative structure underpins carbohydrate production, translocation, and storage in tubers. As such, container volume, through its influence on early vegetative development, ultimately dictates yield potential. These findings are in agreement with previous studies such as that of Lahlou *et al.* (2003) and Khan *et al.* (2024), who demonstrated that plant vigor metrics like height and stem girth are positively correlated with tuber yield under both conventional and containerized systems.

Conclusion: This study demonstrated that potato yield and vegetative growth are significantly influenced by both variety and container volume. Larger bags, particularly with Connect and Jelly varieties, outperformed others in yield, while Marabel excelled in seed tuber production. Given the space-efficiency and high productivity, container cultivation offers a viable option for land-constrained farmers. Future studies may explore additional agronomic variables to further strengthen these insights and support broader adoption across diverse agro-ecological zone

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Isolation and Characterization of Root-Associated Microbes in the Rhizosphere of Bamboo in Cross River State, Nigeria

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ABSTRACT

Bamboo is a fast-growing plant of great ecological and economic value. Its remarkable adaptability is partly linked to its rhizosphere microbiome which consist of beneficial bacteria and fungi that support nutrient uptake, plant growth, pathogen suppression, amongst others. This study isolated, characterized and tentatively identified bacteria and fungi associated with the rhizosphere of bamboo, from three locations in Cross River State, Nigeria. Bamboo roots and adhering soils were obtained from Esuk Atu (Calabar Municipality Local Government Area), Bendeghe Ekeim (Etung Local Government Area) and Yahe (Yala Local Government Area), all in Cross River State. Twenty-five bacteria and six fungi were isolated and tentatively identified based on their morphology (such as shapes, spores, surface, peripheral & reverse color, hyphae septation, elevation, amongst others) and biochemical characteristics (such as ability to solubilize phosphate, sugar fermentation, gas production, etc.). The dominant tentative species among the twenty-five bacterial isolates identified from the three locations includes; *Pseudomonas fluorescens*, *Bacillus subtilis*, *Klebsiella pneumoniae*, *Enterobacter* spp., *Chromobacterium violaceum*, etc. Isolates such as *Bacillus polymyxa* and *Pseudomonas fluorescens* are said to be notable for nitrogen fixation, phosphate solubilization, and antibiotic production. Also, the six fungi isolates identified from the three locations in the study includes, *Penicillium*, *Aspergillus*, *Trichoderma*, *Rhizopus*, *Fusarium*, and *Phytophthora*. *Penicillium* and *Trichoderma* are said to support plant growth and pathogen suppression, while deleterious fungi such as *Fusarium* posed risks to plant health. The findings highlight the prevalence of different beneficial microbes with potential applications in agriculture and environmental management.

Keywords: Bamboo; Rhizosphere, Soil, Beneficial microbes, Microbial resource utilization.

INTRODUCTION: The rhizosphere refers to the narrow region of the soil or substrate that is directly influenced by plant roots secretion and associated soil microorganisms (Dais *et al.*, 2019). This region hosts a diverse array of microbes that can significantly enhance plant growth through various mechanisms, such as nitrogen fixation, phosphate solubilization, and production of growth-promoting hormones. Plants interact intimately with microbes in the rhizosphere, these rhizosphere microorganisms play a role in enhancing nutrient acquisition, promoting plant growth, and suppressing pathogens. Bamboo plants are a diverse group of mostly evergreen perennial flowering plants making up the subfamily *Bambusoideae* in the grass family *Poaceae* (McClure 2013; Canavan *et al.*, 2016). Bamboo is notable for its rapid growth and diverse uses in construction, food, and environmental conservation. Despite its importance, little is known about its root microbiome in Nigeria. This study aimed to isolate and characterize root-associated microbes from bamboo rhizospheres, with emphasis on identifying potential growth-promoting species, for future utilization.

MATERIALS AND METHODS

Experimental location: The research was carried out at the Department of Microbiology, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria.

Samples location/collection: Samples of the bamboo roots (washed and unwashed) and adhering soils were collected from Esuk Atu (Calabar Municipal L.G.A), Bendeghe Ekeim (Etung L.G.A), and Yahe (Yala L.G.A) of Cross River State. Collected samples were placed in sterile zipper bags according to Yanti *et al.* (2017), and transported to the laboratory for processing.

Preparation of the root sample: The roots were first placed on a sterile mortar and squashed completely using a sterile pestle, releasing their internal content into the mortar. A ten (10) fold serial dilution was done by measuring 9mls of sterile distilled water into ten (10) tubes labelled (10^{-1} – 10^{-10}) respectively. One gram of the squashed root samples was measured using a weighing balance, and transferred into a test tube labelled stock, it was properly mixed, then 1ml of the solution was then transferred into the tube labelled 10^{-1} and mixed properly, 1ml from the tube labelled 10^{-1} was again transferred into the tube labelled 10^{-2} and the process continued until the dilution was completed. At the end of the dilution process, 1ml of the diluent was removed from the tube labelled 10^{-10} into the Agar plate (Atlas and Bartha, 1992; Eja *et al.*, 2006).

Rhizosphere soil samples; Same procedure (as that of the roots) was applied to the rhizosphere soil samples.

Preparation of culture media

1. Nutrient Agar (NA) Composition and preparation

The NA used contained beef extract (3.0g), peptone (5.0g), Agar (20.0g), NaCl (0.5g), distilled water (1000ml).

Preparation: 28g of the powder was dissolved in 1000ml (1L) of distilled water, then autoclaved at 121°C for 15 minutes.

2. Potatoe Dextrose Agar composition: Potatoes infusion (200g), Dextrose (20.0g), Agar (15.0g), pH (at 25°C) 5.6 ± 0.2.

Preparation: 39g of the powder and was dissolved in 1000ml (1L) of distilled water. Then preheated to dissolve the medium completely before sterilizing in an autoclave at 15 lbs pressure (121°C) for 15 minutes.

Inoculation technique: The pour plate method of inoculation was employed for inoculating of sample into the culture medium.

Procedures for Bacteria inoculation: 1ml of the diluted sample was removed from serial diluted test tube of 10^{-5} and 10^{-6} respectively and transferred into two separate sterile petri dish plates. Already prepared nutrient agar (NA) at about 35°C, was poured directly to the petri dish containing 1ml of diluted samples. The petri dishes were mixed and sealed properly, then the plates were transferred to an incubator for incubation at 37°C within 24-48 hours to enhance bacterial growth. After incubation, macroscopic observation was carried out by visual recognition and identification of bacteria colonies via their appearances (shape, size, consistency, elevation, and pigmentation). Purification was carried out by sub-culturing different morphologically distinct colonies on freshly prepared Agar plates.

Procedure for Fungal inoculation: 1ml of the diluted sample was pipetted from serial diluted test tube of 10^{-4} and 10^{-5} respectively and transferred into two separate sterile petri dish plates. Already prepared PDA was added directly to the petri dishes containing 1ml of diluted samples. The petri dishes were mixed and sealed, then transferred to an incubator for incubation at 30°C within 48-72 hours to enhance fungal growth. After incubation, macroscopic observation was carried out by physical examination of the fungal to check their hyphae. Purification via sub-culturing different morphologically distinct fungi on freshly prepared Agar was carried out.

Colony Characterization: The colonies were characterized morphologically and biochemically, following Bergey's manual and Barnett & Hunter (1987) keys.

Morphological characterization of bacteria: The identification of different bacterial isolates was carried according to Bergey *et al.* (2010). The morphological characterization of the bacteria was first achieved by physically examining each colonies shape, size, pigmentation, and elevation (Swarupa *et al.*, 2014). For the identification of Phosphate Solubilizing Bacteria (PSB) and Nitrogen Fixing Bacteria (NFB) based on colony morphology, the isolates were grown on specific agars.

Biochemical characterization of bacteria: Several biochemical tests were carried out on all the bacteria, isolated from rhizosphere soil samples, and its associated root samples (washed and unwashed). Gram status was studied for all isolated bacteria using the gram staining kit, according to the manufacturer's recommendation. Other biochemical tests such as Oxidase test, citrate test, methyl red test, vogues Proskauer test, motility test, urease test, indole test, catalase test, and sugar fermentation tests such as Lactose fermentation test, Sucrose fermentation test, Glucose fermentation test, as well as gas production test and hydrogen sulfide test, was performed according to Gupta *et al.* (2019) for the identification of distinct bacteria colonies.

Identification of fungal structures: Fungi was characterized according to Barnett and Hunter 1987, through macroscopic and microscopic observation. Shapes, spores, surface, peripheral and reverse color, and hyphae septation, elevation, and margin was observed using a compound microscope. The Genus names of each fungal isolates were gotten after comparing spores against those found in Barnett and Hunter 1987 key.

RESULTS: A total of twenty-five (25) bacterial isolates were tentatively identified across the three locations. Dominant species included; *Pseudomonas fluorescens*, *Bacillus spp.*, *Klebsiella pneumoniae*, *Enterobacter spp.*, and *Chromobacterium violaceum*. Beneficial isolates such as *Bacillus polymyxa* and *Pseudomonas fluorescens* are notable for nitrogen fixation, phosphate solubilization, and antibiotic production. Six (6) fungi were also identified, these includes; *Penicillium*, *Aspergillus*, *Trichoderma*, *Fusarium*, *Phytophthora*, *Rhizopus*, *etc.* *Penicillium* and *Trichoderma* were observed to support plant growth and pathogen suppression, while deleterious fungi such as *Fusarium* posed risks to plant health.

Beneficial microbes dominated, but opportunistic pathogens such as *Staphylococcus aureus* and *Aeromonas hydrophila* were also present.

Table 1: Bacteria isolates obtained from Bamboo roots/rhizosphere in Calabar Municipal

S/N	Sample Type (Roots)	Treatment	Probable Isolates
1.	Root sample	Washed	<i>Enterobacter aerogenes</i>
2.	Root sample	Washed	<i>Pseudomonas fluorescence</i>
4.	Root sample	Washed	<i>Bacillus polymyxa</i>
5.	Root sample	Washed	<i>Bacillus licheniformis</i>
6.	Root sample	Washed	<i>Enterobacter agglomerans</i>
7.	Root sample	Washed	<i>Enterobacter faecalis</i>
9.	Root sample	Washed	<i>Klebsiella pneumonia</i>
10.	Root sample	Not washed	<i>Enterobacter cloacae</i>
S/N	Sample Type (Rhizosphere soil)	Treatment	Probable Isolates

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1.	Rhizosphere soil	Nil	<i>Bacillus subtilis</i>
2.	Rhizosphere soil	Nil	<i>Klebsiella pneumonia</i>
3.	Rhizosphere soil	Nil	<i>Pseudomonas fluorescense</i>
4.	Rhizosphere soil	Nil	<i>Chromobacterium violaceum</i>
5.	Rhizosphere soil	Nil	<i>Aeromonas hydrophyla</i>
6.	Rhizosphere soil	Nil	<i>Klebsiella oxytoca</i>

Table 2.: Bacteria isolates obtained from bamboo in Bendeghe Ekiem (Etung L.G.A)

S/N	Sample Type (Roots)	Treatment	Probable Isolates
1.	Root sample	Washed	<i>Proteus mirabilis</i>
2.	Root sample	Washed	<i>Klebsiella oxytoca</i>
3.	Root sample	Not washed	<i>Pseudomonas aeruginosa</i>
4.	Root sample	Not washed	<i>Chromobacterium violaceum</i>
5.	Root sample	Not washed	<i>Enterobacter cloacae</i>
6.	Root sample	Not washed	<i>Escherichia coli</i>
7.	Root sample	Not washed	<i>Staphylococcus aureus</i>
8.	Root sample	Not washed	<i>Klebsiella pneumonia</i>
9.	Root sample	Not washed	<i>Bacillus subtilis</i>
10.	Root sample	Not washed	<i>Staphylococcus saprophyticus</i>
S/N	Sample Type (Rhizosphere soil)	Treatment	Probable Isolates
1.	Rhizosphere soil	Nil	<i>Pseudomonas aeruginosa</i>
2.	Rhizosphere soil	Nil	<i>Escherichia coli</i>
3.	Rhizosphere soil	Nil	<i>Klebsiella pneumonia</i>
4.	Rhizosphere soil	Nil	<i>Staphylococcus saprophyticus</i>

Table 3. Table 1: Bacteria isolates obtained from bamboo rhizosphere in Yahe, Yala

S/N	Sample Type (soil)	Treatment	Probable Isolates
1.	Rhizosphere soil	Nil	<i>Streptococcus spp.</i>
2.	Rhizosphere soil	Nil	<i>Proteus vulgaris</i>
3.	Rhizosphere soil	Nil	<i>Enterobacter spp.</i>
4.	Rhizosphere soil	Nil	<i>Serratia marcescens</i>
5.	Rhizosphere soil	Nil	<i>Pseudomonas spp.</i>
6.	Rhizosphere soil	Nil	<i>Staphylococcus spp.</i>

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7.	Rhizosphere soil	Nil	<i>Escherichia coli</i>
8.	Rhizosphere soil	Nil	<i>Bacillus spp.</i>

Table 4. Some Fungi isolates obtained from Calabar Municipal, Etung, and Yala

S/N	Probable Fungi isolates	Appearance	Color	Margin	Surface	Location
1.	<i>Penicillium spp.</i>	Powdery, velvety	Blue-green, Green	Sharp, slightly irregular	Powdery, granular	Cal Mun, Etung, and Yala
2.	<i>Aspergillus spp.</i>	Powdery texture	Coffee brown, black	Sharp, irregular	Rough, granular	Cal Mun, Etung, and Yala
3.	<i>Rhizopus spp.</i>	Cottony, Woolly, fluffy	Grayish, black	Irregular, feathery edge	Cottony	Yala
4.	<i>Fusarium spp.</i>	Cottony, woolly	White, purple	Irregular, filamentous	Cottony, velvety	Cal. Mun, Etung
5.	<i>Trichoderma spp.</i>	Cottony/woolly	Dark-green	Irregular, feathery edge	Cottony, compact	Cal Mun, Etung, and Yala
6.	<i>Phytophthora spp.</i>	Rosette and chrysanthemum-like	Cream-colored	Irregular, faintly radiate pattern	Smooth, slightly fluffy	Cal. Mun, Etung

DSSCUSSON : The bamboo rhizosphere was found to be rich in microbial diversity, with bacteria outnumbering fungi. Many isolates have reported to exhibited traits beneficial for plant growth (Dais *et al.*, 2017), supporting the hypothesis that bamboo's resilience is linked to its root microbiome. The presence of deleterious microbes indicates that bamboo also faces potential pathogen threats, but these may be mitigated by the antagonistic effects of beneficial microbes. The identification of potential growth-promoting rhizobacteria (PGPR) suggests applications in sustainable agriculture, biocontrol, and soil fertility management. The bacteria and fungi play several roles which may include promoting plant growths via fixing nitrogen and solubilizing phosphorus, inhibiting various pathogenic and neutral microbes which may be harmful to the plant (Dais *et al.*, 2019). Also, other microbes (such as *Phytophthora* sp., *Chromobacterium violaceum*, *Klebsiella pneumoniae*, *Enterococcus faecalis*, *Staphylococcus aureus*, etc.) which are deleterious and neutral in nature (pathogenic and commensals), were seen in the rhizosphere of bamboo plant. Among all the microorganism found, bacteria were the most abundant microbe present in the rhizosphere of bamboo. Some probable bacteria such as *Pseudomonas fluorescens*, *Klebsiella pneumoniae*, *Bacillus subtilis*, *Klebsiella oxytoca*, *Chromobacterium violaceum*, among others were seen both on rhizosphere soil and roots, whereas others were seen only on either roots or soil samples. This indicates the endophytic and exophytic nature of the microorganisms, which have beneficial effects on plants.

Probable fungi such as *Penicillium* were present on both rhizosphere soil and root samples, while *Aspergillus*, *Fusarium*, *Trichoderma*, and *Phytophthora* were only present in the rhizosphere soil. Some bacterial such as *Bacillus subtilis*, *Klebsiella pneumoniae*, *Klebsiella oxytoca*, and *Enterobacter cloacae*, were seen to be present in samples (Roots and soil) from the three locations (Calabar municipal, Etung and Yala). Beneficial bacteria such as *Pseudomonas fluorescens*, produces antibiotics, solubilizes phosphorus, and suppresses plant pathogens. *Bacillus polymyxa* fixes nitrogen, solubilizes phosphorus, and produces antibiotics. *Bacillus licheniformis* and *Bacillus subtilis* decomposes organic matter, fixes nitrogen, and produces antibiotics (Umar *et al.*, 2020). *Enterobacter aerogenes* produces indole acetic acid (IAA), a plant growth promoter (Han *et al.*, 2019). These were all present within the rhizosphere and roots of bamboo plant in this study. Also, some fungi such as *Penicillium* spp. help in decomposition and nutrient cycling by breaking down organic matter, thereby releasing nutrients like nitrogen, phosphorus, and potassium making them available to plants (Umar *et al.*, 2020). It promotes plants growth by producing substances such as auxins, gibberellins, which can stimulate plant growth, and soil improvement. *Penicillium* also has the abilities to suppress and outcompete or inhibits plant pathogens thereby reducing disease incidence, plays a vital role in modifying the rhizosphere environment creating a more favorable niche for beneficial microorganism (Santoyo *et al.*, 2021).

The genus *Aspergillus* is another fungus that decomposes organic matter, solubilizes phosphate, promote plant growth by producing substances such as auxins and gibberellins, suppresses or inhibits plant pathogens, produces siderophores which helps plant acquire iron. Although, some species of *Aspergillus* such as *A. flavus*, *A. parasiticus*, and *A. terreus* have the potential to also cause detrimental effect on plant than others. The fungus *Trichoderma* also play a beneficial role in promoting plant growth, by producing substances such as auxins, gibberellins, and cytokinin, it is use for biocontrol as it suppresses plant pathogens, such as bacteria, fungi, and nematodes through mycoparasitism, antibiosis, and competition. It triggers plant defense mechanisms, increasing resistance to pathogens. It solubilizes phosphates, micronutrients, and other trace element, making them available to plants (Santoyo *et al.*, 2021).

Deleterious organism could include; *Chromobacterium violaceum*, *Klebsiella pneumoniae*, *Aeromonas hydrophyla*, *Klebsiella oxytoca*, *Enterococcus faecalis*, *Staphylococcus aureus* and a host of others. There are opportunistic microorganisms found to struggle and compete with plants for recycled nutrient, and have great potential to cause mild-severe harms on plant health and physiology (Mishra *et al.*, 2016). Neutral organisms such as *Enterobacter agglomerans*, *Escherichia coli*, *Staphylococcus saprophyticus* are less harmful and can either promote plant growth or be harmful to the plant. However, they also help in decomposing organic matter in the rhizosphere of bamboo plants, or serve as biocontrol agents (Gupta *et al.*, 2019).

CONCLUSION: The rhizosphere of bamboo in Cross River State harbors a diverse microbiome comprising beneficial, deleterious, and neutral organisms. Twenty-five bacteria and six fungi were isolated, with Gram-negative bacteria being dominant. Beneficial isolates such as *Pseudomonas*, *Bacillus*, and *Penicillium* highlight the potential of bamboo rhizospheres as reservoirs of plant growth-promoting microbes.

RECOMMENDATION

1. Future research should include molecular identification
2. Evaluation of plant growth-promoting activities in-vivo, and
3. Exploration of microbial inoculants for agricultural and ecological applications.

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Sustaining Vitamin-A Potato Production in the Face of Climate Change: Accessing Agricultural Adaptation Practices of Smallholder Farming in Kogi State, Nigeria

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ABSTRACT

The study examined the drivers of climate change and agricultural adaptation practices for the sustainable production of Vitamin A potatoes among smallholder farmers in Ankpa LGA of Kogi State, Nigeria. Specifically, it described the socio-economic characteristics of respondents, assessed their awareness of climate change, outlined adaptation practices, and estimated how these practices and institutional factors affect the adoption and use of Vitamin A potato production. A multi-stage sampling technique was used to select eighty (80) respondents. Data were collected through structured questionnaires and analyzed using descriptive statistics and inferential Statistics. Results of the socioeconomic characteristics showed that 46.3% of the respondents were aged between 36-50 years and dominated the production while 8.8% were between the active age group of 21-35 years. Male farmers accounted for 72.5%, and 87.5% were married. Most (87.5%) of the respondents had formal education. A small proportion (25.2%) had access to extension services and credit. Result of the awareness of climate change showed that not all the respondents were aware of adaptation practices. There was a significant difference ($p < 0.001$) in annual output between those who adopted adaptation practices and those who did not. Probit regression indicated that the use of adaptation practices influenced Vitamin A potato adoption. All adaptation methods positively and significantly ($p < 0.05$) affected the adoption and use of the crop. Credit and extension services were essential for effective farm production in the area.

INTRODUCTION: Eradication of chronic hunger and poverty are among Sustainable Development Goals of the United Nation's SDGs 1 and 2 (Food and Agriculture Organization of United Nations, FAO, 2015). Chronic hunger includes lack of protein (kwashiorkor), lack of protein and energy (marasmus), or lack of micronutrients such as vitamins and minerals (hidden hunger syndrome). Generally, there is wide spread hunger and poverty in developing regions like sub-Saharan Africa (SSA) with about 214 million people trapped in chronic hunger and poverty (Nazmul, et al., 2021). However, climate change effects are worsening the worlds poverty level especially the hidden hunger component. Rising temperature and altered precipitation pattern significantly impact crop yield and nutrient density (Thompson & Garcia, 2022). Crops are major sources of vitamin A in many developing countries and there has been a drop in beta-carotene content when grown under heat stress conditions (Anderson et al., 2021). Efficient irrigation systems and water conservation techniques have shown promising results in maintaining vitamin A levels in crops. Emerging techniques such as vitamin A potato bio-fortification and precision agriculture offer enhanced opportunity for maintaining nutrient levels. Such successes will require continued research and development of locally adapted solutions for rural households (Martinez et al., 2021). Climate change mitigation has not received much attention as climate change adaptation because mitigation requires much resources and technical skills which are limiting in developing countries like SSA (De Guisti et al., 2019). Though, adaptation practices are promising in SSA, resource constraints hinder their effective implementation (Roberts, 2022). As a result, the future of vitamin A supply in a changing climate will likely depend on integrated approach combining multiple adaptation approaches and continued research and development of locally adapted solutions

There is copious empirical literature on adoption of improved crop varieties in Nigeria which include the study by Oyinbo et al. (2019) on maize; Manda et al. (2020) on cowpea and Abdoulaye et al. (2014) on rice. However, there is insufficient empirical studies on how climate change adaptation practices affect the adoption and use of bio-fortified Vitamin A potato in the study area. This work is designed to fill this gap. The aim of the study was to assess the factors that influence the adoption and use of vitamin-A bio-fortified potato products by smallholder farmers in Nigeria. The result of the study was expected to provide information on level of resilience in Vitamin-A potato production in Nigeria. To achieve the aim of the study, the following questions were raised; what is the level of awareness of smallholder farmers on climate change phenomenon? What are the socio-economic characteristics of the farmers (that would enable them adopt climate change adaptation practices)? how do climate change adaptation practices affect the adoption of vitamin A potato product among smallholder farmers?

METHODOLOGY

Study area: The study was conducted in Ankpa Local Government Area (LGA), Kogi State. The state is in north-central Nigeria within latitudes $5^{\circ}30'N$ and $8^{\circ}50'N$ and longitudes $5^{\circ}51'E$ and $8^{\circ}00'E$. The state is referred to as "Confluence State" because it is the meeting point of river Niger and river Benue. The State covers an area of approximately 29,883 Km² and borders with nine states. The ethnic groups in the state are Igala, Ebira and Okun. The state's economy is primarily agrarian with majority of the population engaged in farming. Major crops include cassava, maize, yam, potato, rice, cashew and the rearing of goats, sheep, chicken etc.

Sampling techniques: The study adopted a survey design during the 2024 cropping. Multi-stage sampling technique was employed to sample respondents. On the first stage, five communities in Ankpa LGA were purposely selected because agriculture is intensive in these communities. The communities included Ojede, Ikamekpo, Ogoto, Ojokodo and Ojogobi. Simple random technique was used to select (16) sixteen respondents from each of the communities giving a total of (80) eighty respondents for the study.

Data collection and analysis: Data were generated using structured questionnaire. Data included socio-economic characteristics like household income, educational level, age of household head, years of farming experience, number of extension visits, climate change adaptation practices. Data were analyzed using descriptive for socio-economic characteristics, state of awareness of climate change adaptation practices using frequency and mean distribution and inferential statistics Logistic regression model and analysis of variance (ANOVA).

Logistic Regression: Logistic regression was used to examine how climate change adaptation practices and some socio-economic characteristics influenced the adoption and use of Vitamin-A potato in production activities. The adoption and use of Vitamin-A potato was indicated with a yes =1 or a no =0 otherwise. Therefore, logistic regression can predict how socio-economic and climate change adaptation practices drives adoption and use of vitamin-A potato production in the study area. It is explicitly represented as:

$$Y_i = \ln \left(\frac{P_i}{1-P_i} \right) = \beta_0 + \beta_i X_i + e$$

Where Y_i = respondents act of adopting and use of Vitamin-A potato

$\ln \left(\frac{P_i}{1-P_i} \right)$ = Ln of odds of adoption and use of Vitamin-A potato in production

β_0 = constant

β_i = coefficients of logistic estimates of covariates

X_i = covariates including, years of farming experience,

educational level (had formal education, yes=1, 0 otherwise),

diversified crop production? (Yes=1, no = 0),

do you grow drought resistant crops? (Yes=1, 0 otherwise),

Do you change planting dates? (yes=1, 0 otherwise),

Do you use water conservation practices? (yes=1, 0 otherwise),

Do you use soil conservation techniques? (yes=1, 0 otherwise),

Do you make use of weather forecasting information? (yes=1, 0 otherwise),

do you use insurance coverage? (yes=1, 0 otherwise),

do you have access to credit? (yes=1, 0 otherwise) and

do you access extension services in your area? (yes=1, 0 otherwise)

+e = error term

RESULTS AND DISCUSSION: The results and discussion covered socioeconomic characteristics of the potato farmers, level of awareness of climate change adaptation practices, number of adaptation practices adopted, effect of adaptation practices on the farmer's choice on adoption and use of vitamin A potato and effects of adaptation practices on the level of output.

Socioeconomic characteristics of the respondents: The socioeconomic characteristics of the respondents discussed include gender, marital status, educational background, number of years in formal education, major occupation, minor occupation, annual income, household size, farm size, years of growing potatoes, source of farm labor and capital, access to credit facilities and extension services. The socioeconomic characteristics of respondents is presented in appendix 1

Gender: The gender distribution presented in Table 1 showed that majority of the respondents were males with a percentage of 72.5, with females having a percentage of 27.5. This indicates that men constitute a significant proportion of farmers involved in potatoes production in Ankpa local government.

Educational background: The distribution of respondents according to educational level presented in Table 2 shows that majority (88.8%) of the respondents had received formal education while (11.3%) had no formal education. The prevalence of formal education among potatoes farmers shows a correlation between educational background and involvement in potatoes farming. Typically, education provides an individual the capacity to understand and apply technical skills and adopt innovations as well as maximize the potentials of available technology.

Credit facilities: It indicates that 26.3% of the respondents have access to credit facilities and a very high proportion (73.8%) of the respondents do not have access to credit facilities.

Extension services: Indicates that 33.8% of the respondents have access to extension services and the remaining percentage (66.3%) of the respondents do not have access to extension services. This implies that there would be low knowledge on technical skills and expertise on innovations that can improve production and output level of potatoes.

Source of farm labor: Shows that 25.0% of the respondents use just their family labor in their farms, 40.0% use hired labor and 35.0% of respondents employ both family and hired labor in their farms.

Source of farm capital: Shows that 3.8% of the respondents are funded or receive government supports in their farming activities, a high proportion (76.3%) of the respondents sponsor their activities from personal savings, 5.0% get their capital from banks and the last group is that of respondents (15.0%) who get their farm capitals from informal lenders.

Household size: Reveals that majority of the respondents (40.0%) had a household size ranging from 4 to about 6 persons, followed by 31.3% of respondents who reported a household size of 2 to about 4 persons and 28.8% of the respondents reported to have household size of 6 persons and above. The mean household size is 7.88 persons. This indicates a moderately high household size among potatoes farmers which can facilitate high supply of farm labor. Large household size is helpful as it provides family labor and reduces the cost of hired labor nevertheless.

Farm experience: The appendix 1 highlights the distribution of farming experience among respondents in the study area. The majority (47.7%) of respondents having potatoes farming experience of 1 to 5 years, which is in line with findings of Uche et al (2020) 26.4% respondents indicated 6 to 10 years of experience. 16.4% of the respondents have 11 to 15 years of experience and finally is the 10.1% of respondents with 16 years and above farming experience. The calculated mean for years of farming experience is 7.88 years, providing an average representation an average representation of the level of experience within the study area.

Annual income: The findings show that a proportion (16.3%) of respondent earn between ₦100,000 and ₦500,000 annually followed by the second group with the percentage 16.3. This group of the respondents earn between ₦501,000 and ₦1,000,000 annually then you have the highest proportion (50.0%) of respondents earning between ₦1,100,000 and ₦5,000,000 annually. Lastly, we have the smallest group (7.6%) who earn from ₦5,100,000 and above annually in the study area.

Major occupation: It shows that the largest proportion of respondents (58.8%) primarily are civil servants, a significant percentage of 22.5 engage majorly in farming, indicating that after civil service, agriculture is the main occupation for the individuals surveyed. Additionally 15.0% are traders and 3.8% are artisans.

Farm size: This reveals that 58.9% of the respondents have farm sizes of 0.1 to 0.5 hectares, 25.1% respondents have 0.6 to 1.0 hectares and finally, 16.4% of the respondents have farm sizes of 1.1 hectares and above.

Awareness on climate change adaptation practices: The level of awareness of the respondents on climate change adaptation practices. The result reveals that 100.0% of the respondents were aware of climate change. On the awareness of climate change adaptation practices, the following are the outcomes:

Adoption and use of climate change adaptation practices: The climate change adaptation practices adopted by the respondents in the study area. Almost all, (92.5%) of respondents indicated they adopted some climate change adaptation practices. A few (7.5%) did not adopt any practice. 68.3% indicated that they adopted crop diversification to mitigate climate change effects while 31.3% did not adopt crop diversification. 28.8% of the respondents indicated they adopted drought-resistant crops as a practice while 71.3% indicated they did not adopt as a result of poor awareness. 52.5% of the respondents adopted changing of planting dates as a climate change adaptation practice but 47.5% did not. 7.5% adopt water conservation technique but 92.5% did adopt the practice. 5.0% of the respondents adopted soil conservation technique to mitigate climate change and 95.0% have not adopted the practice. 27.5% of the respondents have adopted weather forecasting to reduce effects of climate change while 72.5% of the respondents have not adopted this practice. 2.5% of the respondents have their farms insured and this helped to reduce outcomes of risk and climate change effects but 97.5% of them have not adopted this practice and so any outcome they face from climate change effect may lead to food insecurity in the long run. The result shows that 7.5% were yet to adopt a practice from all climate change practices, 20.1% adopted just one of the many practices, 50.0% have adopted two climate change adaptation practices and the last percentage (22.5%) of the respondents have adopted 3 and above of the adaptation practices.

Effects of adaptation practices on the farmers' adoption and use of vitamin A potato: The results on Appendix 2 reveal that several climate change adaptation practices significantly influence farmers' decisions to adopt Vitamin A potatoes in Ankpa Local Government. Among the most influential factors, changing planting dates ($p < 0.01$) and soil conservation techniques ($p < 0.01$) had positive effects on adoption. This finding aligns with the study by Bryan et al. (2013), which emphasized that adjusting planting schedules helps farmers mitigate climate variability and improve yields. Similarly, soil conservation techniques, including mulching and contour farming, enhanced soil fertility and water retention, creating favourable conditions for Vitamin A potato cultivation. The significance of water conservation techniques ($p < 0.01$) also reinforces the importance of sustainable water management in promoting crop adoption under changing climatic conditions (Deressa et al., 2009).

Socioeconomic factors also played a critical role in the adoption decision. Educational level ($p < 0.01$), access to credit ($p < 0.01$), and access to extension services ($p < 0.01$) were all positively and significantly associated with the likelihood of adopting Vitamin A potatoes. These findings align with previous research by Feder et al. (1985), which highlighted that higher education levels improve farmers' ability to process agricultural innovations and make informed decisions. Furthermore, access to credit facilitates investment in improved seeds, fertilizers, and irrigation, all of which are necessary for successful adoption. Extension services, as reported by Mwangi & Kariuki (2015), bridge the knowledge gap by providing farmers with technical support and training on climate-smart agriculture, ultimately enhancing adoption rates. The significance of these institutional factors suggests that policies aimed at improving agricultural financing and extension outreach could be instrumental in scaling up Vitamin A potato adoption.

Drought-resistant crops ($p < 0.01$) and crop diversification ($p < 0.05$) also had a significant positive effect, indicating that farmers who engage in multiple adaptation strategies are more likely to adopt Vitamin A potatoes. This supports the findings of Asfaw et al. (2016), who argued

that diversified farming systems reduce risks associated with climate shocks and enhance food security. The positive influence of weather forecasting ($p < 0.05$) suggests that access to timely climate information enables farmers to make strategic decisions about when and how to plant, ultimately reducing climate-related risks (Hansen et al., 2011). Overall, these findings emphasize the need for an integrated approach that combines agronomic, financial, and institutional support to enhance the adoption of Vitamin A potatoes as a climate adaptation strategy.

Conclusion: Adoption and use of bio-fortified Vitamin A potato is dependent on the capacity of smallholder farmers to adapt climate change agricultural practices. This affects the level of production of Vitamin A potato especially in modern day environment with climate change effects as deterrent. The farmers were educated with males of middle age dominating the production. Many had no access to credit and extension services. Many also were aware of climate change phenomenon but not all used adaptation practices. The annual output level for those who adopted adaptation practices was higher than those who did not use them. The study recommends that the farmers form cooperative societies to enable them gain access to Bank loans and other economies of scale. Extension agents also should reach out to educate the farmers on the benefits of adopting adaptation practices that can lead to higher farm output.

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Machine Learning Evaluation of Irrigation Water Quality Indices Affecting Rice Performance in the Northern Guinea Savanna

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Abstract

Optimizing rice yields while sustaining soil health in tropical rainfed systems critically depends on irrigation water quality and the functional interpretation of its chemical indices. This study evaluates the effects of irrigation water quality on rice growth and yield over a two-year period under field conditions across five sites in Wukari Local Government Area, Nigeria. Water samples were analyzed for major cations (Na^+ , Ca^{2+} , Mg^{2+}), anions (HCO_3^- , CO_3^{2-} , Cl^-), and several derived indices, including Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Magnesium Hazard (MH), and adjusted calcium (Ca_{adj}). Rice performance traits, such as plant height, tiller number, leaf area index (LAI), 1000-grain weight, and grain yield, were also measured under uniform agronomic practices. Significant differences ($p < 0.05$) were recorded across sites in EC (1.40–2.07 dS m^{-1}), Ca^{2+} (13.44–22.53 cmol kg^{-1}), RSC (–25.6 to –17.3), MH (24.9–36.1%), and PI (34.6–42.1%), corresponding to variations in plant height (86.7–99.1 cm) and grain yield (7.6–8.2 t ha^{-1}). Water classification using the US Salinity Laboratory (USSL) diagram placed samples within C3-S1 class, indicating moderate salinity and low sodicity risk. Wilcox's chart also suggested generally safe irrigation suitability with potential concerns over prolonged usage. Random Forest regression explained over 90% of the variance in key crop performance traits, identifying RSC, Ca_{adj} , Na^+ , and MH as the most influential predictors associated with rice growth and yield parameters. These findings emphasize the importance of derived indices in routine water quality assessment and the use of site-specific irrigation strategies to support sustainable rice production in tropical environments.

Keywords: Irrigation suitability, Random Forest regression, Rice (*Oryza sativa* L.), Tropical rainfed agriculture, Water quality indices

Introduction: Rice (*Oryza sativa* L.) is a staple crop in sub-Saharan Africa, contributing greatly to the livelihood, food security, and economic resilience of millions. In Nigeria, its significance continues to grow in response to rapid population expansion and dietary shifts (FAOSTAT, 2023). To meet national production targets and reduce dependency on imports, both irrigated and rainfed rice systems have expanded into marginal ecologies, including the tropical savannas of the Middle Belt region. However, this intensification is increasingly threatened by **poor water quality**, particularly in regions where irrigation is sourced from local rivers, streams, or shallow aquifers with poorly understood hydrochemical dynamics (Prasad et al., 2017). In rainfed lowland ecologies of **Wukari Local Government Area (LGA)** in Taraba State, irrigation is often applied supplementally at key growth stages, especially during intermittent dry spells. While irrigation can stabilize yields under erratic rainfall, the **chemical composition of irrigation water plays a critical role in shaping plant nutrient uptake, soil structural health, and long-term sustainability** of rice production systems (Grattan & Grieve, 2019). Parameters such as **sodium adsorption ratio (SAR)**, **residual sodium carbonate (RSC)**, and **magnesium hazard (MH)** are known to influence soil permeability, cation exchange processes, and osmotic balance, with consequences for both plant physiology and field-scale productivity (Qadir et al., 2018; Lyu et al., 2020).

Previous research in Nigeria and elsewhere has documented the **deleterious effects of sodicity and salinity** on crop yield, particularly when water is rich in sodium or bicarbonates (Demo et al., 2025; Shahid et al., 2021). However, most such studies focus on arid or semi-arid zones and often rely on conventional water classification metrics such as EC and SAR alone. These metrics, though useful, may fail to capture complex **interactions between ionic ratios, nutrient antagonism, and biological responses** under tropical rainfed systems, where salinity is sub-critical but still influential (Ali et al., 2023). Moreover, few studies have directly **linked water quality indices to individual growth and yield components of rice**, especially using **machine learning models** that can capture nonlinear and interacting effects. This gap is particularly acute in the **northern Guinea savanna zone of Nigeria**, where **empirical data on irrigation water quality, its spatial variability, and agronomic consequences remain sparse**. In Wukari LGA, anecdotal evidence suggests that water quality varies across locations due to geogenic and anthropogenic influences, including weathering of basement complex rocks, land use practices, and seasonal runoff. Yet, **little effort has been made to quantify how such variation in water quality affects rice growth and productivity** at the field level. To address this gap, the present study combines classical statistical methods, agronomic field measurements, and advanced machine learning techniques to **diagnose the influence of multiple water quality indices on rice performance traits**. This work investigates how water chemistry shapes **specific growth parameters and yield components** under real-world, smallholder field conditions. This approach is justified by the **need for evidence-based guidance** to inform water management decisions in rainfed and semi-irrigated rice systems, as understanding the influence of water chemistry can improve recommendations on water use, soil amendment, and site

selection. **Therefore, the objective of this study** is to assess how variation in irrigation water quality indices across five field locations in Wukari LGA affects the growth and yield parameters of rice.

Materials and Methods

Study Area: The study was conducted during the 2023 and 2024 wet seasons in **Wukari Local Government Area (LGA)**, located in the southern part of **Taraba State, Nigeria**, within the **northern Guinea savanna agro-ecological zone**. Geographically, the study area lies between **latitude 7.85°N and 7.90°N** and **longitude 9.40°E and 9.50°E**, with an average elevation of approximately 178 meters above sea level.

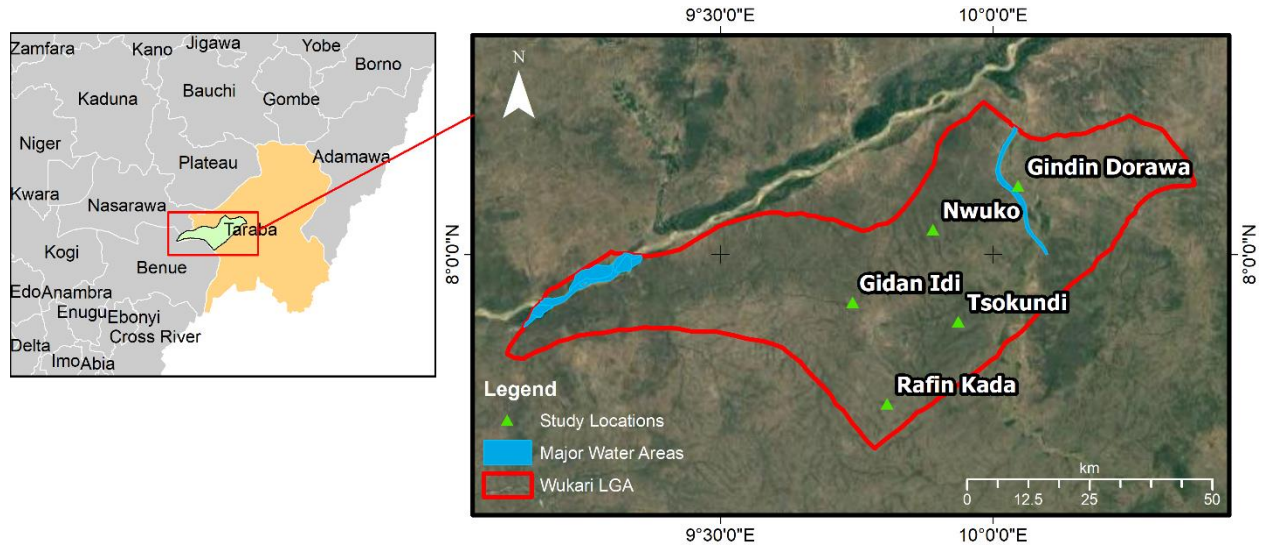


Figure 1: Google Earth Imagery of the Study Area Showing Study Area Locations

The climate of the area is tropical wet-and-dry, characterized by a distinct **rainy season from April to October** and a **dry season from November to March**. Average annual rainfall ranges between 1,100 – 1,300 mm, and the mean annual temperature is approximately 28 – 32°C (Awwal and David, 2023). Soils in the area are dominantly **alfisols and luvisols**, moderately fertile but prone to structural degradation under poor water quality.

2.2 Site Selection and Experimental Layout: Five rice fields were purposively selected based on observed spatial variation in **irrigation water sources**, soil texture uniformity, and farmer willingness to participate. The five sites were located in **Rafin Kada, Tsokundi, Nwuko, Gidan Idi** and **Gindin Dorawa (G/Dorawa) localities (Figure 1)**. Each site was treated as a **replicated experimental unit**, representing a unique irrigation water profile. The same rice variety (**FARO 44**, a popular lowland variety) was planted across all sites using **standard agronomic practices** to minimize confounding effects. Fields were prepared using local ploughing methods, and **transplanting was done at 21 days after sowing** with a spacing of **20 cm × 20 cm**. Uniform application of **NPK 20-10-10 fertilizer** (basal dose at 80 kg ha⁻¹) and **urea** (top dressing at 60 kg ha⁻¹) was maintained across sites.

2.3 Water Sampling and Quality Analysis: Irrigation water samples were collected during active irrigation periods between **late June and mid-September**. From each site, **three composite water samples** were collected using acid-washed 1 L polyethylene bottles, stored on ice, and transported to the laboratory within 6 hours of collection. Water samples were analyzed for parameters such as **pH and EC**, using standard pH and EC meters, cations extracted and analyzed using **flame photometry (Jenway PFP7)** for Na⁺ and **EDTA titration** for Ca²⁺ and Mg²⁺. **Anions such as HCO₃⁻, CO₃²⁻ were measured via acid-base titration**, while Cl⁻ was determined by the **Mohr's method**.

Derived water quality indices, such as HCO₃⁻: Ca²⁺ was computed, while sodium adsorption ratio (SAR), adjusted SAR (SAR_{adj}), residual sodium carbonate (RSC), Kelly's ratio (KR), magnesium hazard (MH), permeability index (PI), using the following formulas:

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \quad \text{Equation [1]}$$

For the SAR_{adj}, correction due to Ca precipitation due to HCO₃⁻ was calculated as

$$Ca^* = Ca^{2+} \times \left(1 - 0.35 \times \frac{HCO_3^-}{Mg^{2+}}\right) \quad \text{Equation [2]}$$

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \quad \text{Equation [3]}$$

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \quad \text{Equation [4]}$$

$$MH = \left(\frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}\right) \times 100 \quad \text{Equation [5]}$$

$$PI = \left(\frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Na^+ + Mg^{2+}}\right) \times 1000 \quad \text{Equation [6]}$$

Water Quality Classification

Water samples were classified based on the U.S. Salinity Laboratory (USSL) diagram and Wilcox chart, using origin-labelled scatter plots for visualization.

Plant Growth and Yield Data Collection: Growth and yield data were obtained from each site using five randomly selected 1 m² quadrats per field. Plant height (cm) was measured from the soil surface to the tip of the panicle using a standard meter rule. The leaf area index (LAI) was calculated following the method of Yoshida et al. (1972), based on the measured leaf area of sampled plants. Tilling was assessed by counting both total and productive tillers per plant, while 1000-grain weight (g) was determined using sun-dried, hand-threshed grains weighed with an electronic balance. Total grain yield (t ha⁻¹) was estimated by scaling up the quadrat yield to a per-hectare basis, with adjustments made for a standard grain moisture content of 14%.

Statistical and Machine Learning Analysis: To understand variations in water quality and rice performance across different sites, descriptive statistics and analysis of variance (ANOVA) were carried out. Where significant differences were observed ($p < 0.05$), Tukey's HSD test was used for pairwise comparisons. The strength and direction of relationships between water quality indices and rice parameters were examined using Pearson correlation analysis. To further explore the influence of individual water quality variables, Random Forest regression models were applied. Variable importance was ranked using the percentage increase in mean squared error (%IncMSE), focusing on key growth and yield traits and the model performance was cross-validated using R², root mean square error (RMSE), and mean absolute error (MAE). All statistical analyses were performed using R software (version 4.5.1).

Results and Discussion

Variability in Irrigation Water Quality Across Experimental Sites: The characteristics of irrigation water across the five study locations presented in Table 1 revealed significant heterogeneity in several key water quality indices, indicating the presence of distinct edaphic and hydrochemical regimes influencing rice growth. While the pH remained near-neutral to slightly alkaline and statistically uniform across sites ($p = 0.804$), parameters such as EC, Ca, HCO₃⁻, CO₃²⁻, RSC, and MH showed marked spatial variation ($p < 0.05$), with implications for both nutrient availability and potential toxicity.

Table 1. Water quality indices across experimental sites

Parameter	Rafin Kada	Tsokundi	Nwuko	Gidan Idi	G/Dorawa	p-value
pH	7.96 ± 0.03	7.89 ± 0.01	7.90 ± 0.11	7.95 ± 0.02	7.85 ± 0.11	0.804
EC (dS m ⁻¹)	1.96 ± 0.02 ^{ab}	1.79 ± 0.16 ^{ab}	1.57 ± 0.26 ^{ab}	1.40 ± 0.03 ^b	2.07 ± 0.03 ^a	0.018*
Na (cmol/kg)	13.71 ± 1.46 ^a	12.04 ± 0.12 ^{ab}	12.61 ± 1.72 ^{ab}	8.51 ± 0.31 ^b	11.82 ± 1.25 ^{ab}	0.048*
Ca (cmol/kg)	22.53 ± 1.90 ^a	16.82 ± 0.25 ^{ab}	15.16 ± 1.52 ^{ab}	13.44 ± 0.78 ^{ab}	16.30 ± 0.06 ^{ab}	0.000***
Mg (cmol/kg)	7.28 ± 0.10 ^{ab}	7.18 ± 0.17 ^{ab}	6.08 ± 0.64 ^{ab}	7.52 ± 0.11 ^a	7.80 ± 0.36 ^a	0.018*
HCO ₃ (meq/L)	3.29 ± 0.13 ^a	3.13 ± 0.04 ^{ab}	3.01 ± 0.20 ^{abc}	2.74 ± 0.09 ^{bc}	2.58 ± 0.03 ^c	0.001**
CO ₃ (meq/L)	0.67 ± 0.02 ^b	0.73 ± 0.02 ^b	0.71 ± 0.04 ^b	0.88 ± 0.02 ^a	0.86 ± 0.02 ^a	0.000***
Cl (meq/L)	12.81 ± 0.31 ^a	12.86 ± 0.07 ^a	12.80 ± 0.29 ^a	10.69 ± 0.41 ^b	10.37 ± 0.71 ^b	0.000***
RSC (meq/L)	-25.6 ± 1.79 ^b	-20.1 ± 0.22 ^a	-17.8 ± 1.87 ^a	-17.3 ± 0.78 ^a	-19.4 ± 0.89 ^a	0.001**
SAR	3.61 ± 0.26	3.43 ± 0.06	3.81 ± 0.35	2.65 ± 0.14	3.42 ± 0.38	0.056
HCO ₃ : Ca	0.15 ± 0.01 ^c	0.19 ± 0.00 ^{ab}	0.20 ± 0.01 ^a	0.21 ± 0.02 ^a	0.16 ± 0.00 ^{bc}	0.000***
Ca _{adj}	21.38 ± 1.85	15.72 ± 0.24	14.11 ± 1.45	12.48 ± 0.80	15.39 ± 0.05	0.000***
SAR _{adj}	3.59 ± 0.28	3.56 ± 0.04	3.91 ± 0.36	2.71 ± 0.15	3.49 ± 0.39	0.062
PI (%)	35.40 ± 0.92 ^b	38.33 ± 0.29 ^{ab}	42.07 ± 0.97 ^a	34.62 ± 1.65 ^b	37.06 ± 2.52 ^{ab}	0.013*
KR (%)	0.45 ± 0.02 ^{ab}	0.50 ± 0.01 ^{ab}	0.58 ± 0.03 ^a	0.41 ± 0.03 ^b	0.50 ± 0.06 ^{ab}	0.024*
MH (%)	24.93 ± 1.70 ^c	29.92 ± 0.73 ^b	28.58 ± 0.68 ^{bc}	36.11 ± 1.45 ^a	32.30 ± 0.92 ^{ab}	0.000***

Note: Values represent means ± standard error. Different letters within rows indicate significant differences at $p < 0.05$ using Tukey's HSD test.

EC varied significantly across the different sites ($p = 0.018$), ranging from 1.40 to 2.07 dS m⁻¹. These differences reflect varying salt levels and the potential for osmotic stress, especially in G/Dorawa where EC levels were highest (2.07 dS m⁻¹). Studies by Grattan and Grieve (2019) attributed higher EC levels in irrigation water to evaporative concentration or human activities and can limit water uptake by reducing the availability of water to plant roots. Shahid et al. (2021), similarly asserts that EC values close to 4 dS m⁻¹, can potentially impact yield, especially in moderately salt-sensitive rice varieties. Since elevated EC in soil water typically results from salt accumulation, these findings suggest the need for consistent monitoring to prevent salinity buildup and its adverse effects on rice productivity.

There were also significant differences ($p < 0.05$) in the concentrations of key cations. Rafin Kada recorded the highest sodium level (13.71 cmol kg⁻¹), which may lead to soil structural issues such as poor infiltration and aeration. Although SAR and SAR_{adj} were not statistically significant ($p > 0.05$), values above 3 were observed across all sites, indicating a moderate risk of sodicity build-up under low leaching conditions as postulated by Qadir et al. (2018).

The bicarbonate-to-calcium ratio (HCO₃⁻: Ca²⁺), an indicator of the risk of calcium precipitation, showed highly significant variation ($p < 0.001$). Higher values in Gidan Idi and Nwuko suggest a greater tendency for calcium to form insoluble compounds, which reduces its availability and can indirectly increase SAR (Ayers & Westcot, 1985). A similar pattern was observed in the adjusted calcium index (Ca_{adj}), which was lowest in Gidan Idi (12.48 cmol kg⁻¹). Notably, sites with lower Ca_{adj} values also had poorer crop performance, suggesting a possible link. This occurrence was further evidenced by the positive correlation between Ca_{adj} and key crop performance indicators like total grain yield ($r = 0.26$) and number of productive tillers ($r = 0.39$) (Figure 2).

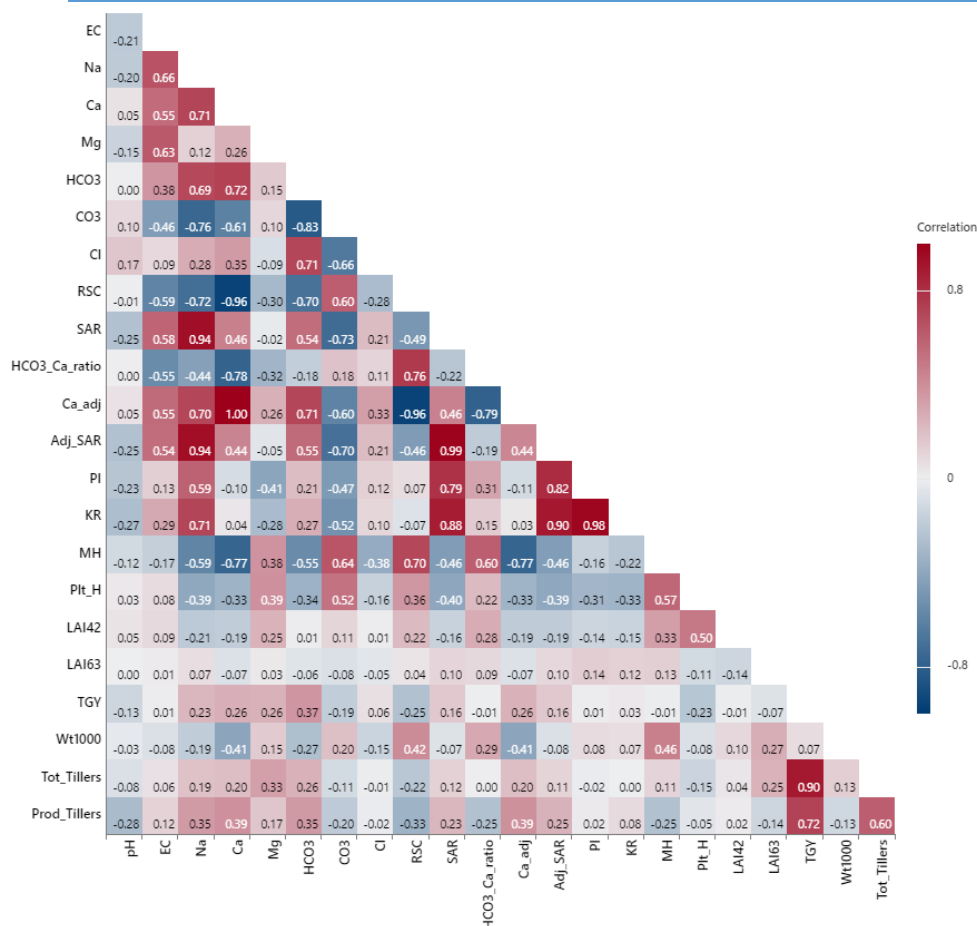


Figure 2: Correlogram of Water Quality Indices, Growth and Yield Parameters

Other water quality indicators such as PI, KR, and MH also showed notable trends. Nwuko had the highest PI (42.07%), while Gidan Idi had the lowest (34.62%). These values support the interpretation that water from Nwuko may be more suitable for maintaining soil permeability (Todd & Mays, 2005). MH values for all samples were notably below the 50% threshold, suggesting low risk of inhibited infiltration due to excess magnesium (Lyu et al., 2020).

Carbonate (CO_3^{2-}) and chloride (Cl^-) levels also varied significantly ($p < 0.001$). Elevated chloride levels in Rafin Kada and Tsokundi may pose toxicity risks, particularly in poorly drained soils. Chloride accumulation in rice has been linked to reduced chlorophyll content and impaired photosynthesis (Khan et al., 2020). This is further evidenced by the negative correlation between Cl and most plant indices (Figure 2).

Water Quality Classification

The US Salinity Laboratory (USSL) classification plot used to classify irrigation water suitability is presented in Figure 3. All five irrigation water samples from the study area cluster in the C3-S1 (medium salinity and low sodicity) zones. This suggests moderate limitations for irrigation, especially under poor drainage or in sensitive crop stages. According to Ayers and Westcot (1985), such water may be used safely on well-drained soils with salt-tolerant crops, but poses increasing risk under prolonged use. This is particularly relevant to rice systems, where ponded conditions may reduce leaching and amplify accumulation risks (Murtaza et al., 2019; Qadir et al., 2018; Ali et al., 2023).

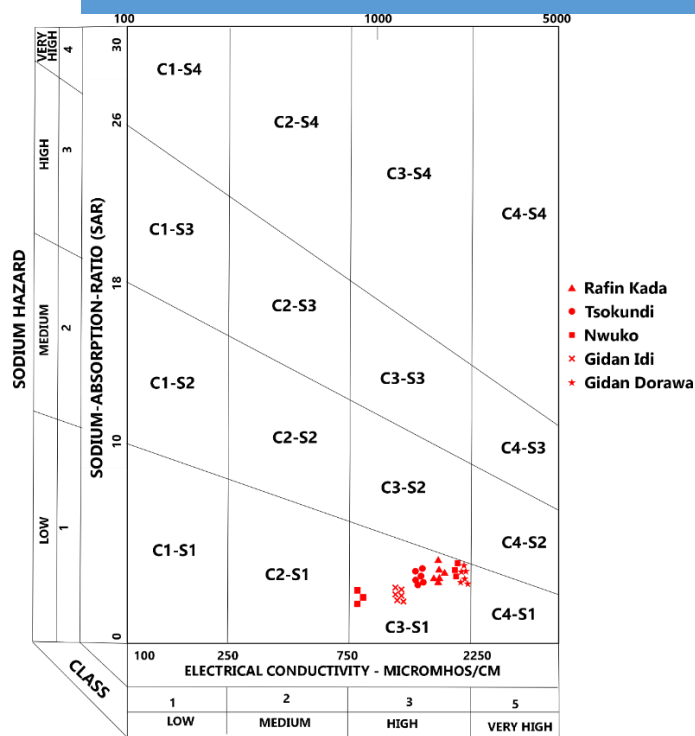


Figure 3: USSL Irrigation Water Quality Diagram Showing Irrigation Water Suitability Classes for the Study Sites

Similarly, the Wilcox diagram (Figure 4) shows that water samples fall within "Good to Permissible" and "Doubtful to Unsuitable" (Ayers & Westcot, 1985). This range is characterized by EC values approaching or exceeding 2000 $\mu\text{S}/\text{cm}$ and sodium percentage levels approaching 40%. This combination suggests potential challenges for irrigation, particularly for salt-sensitive crops like rice. Water in this category may lead to gradual soil degradation, especially under conditions of poor drainage or inadequate leaching, as excess sodium can replace calcium and magnesium on soil exchange sites, thereby reducing soil structure and permeability (Grattan & Grieve, 2019). Therefore, care must be taken to monitor changes over time, particularly under high evaporative demand or repeated irrigation cycles.

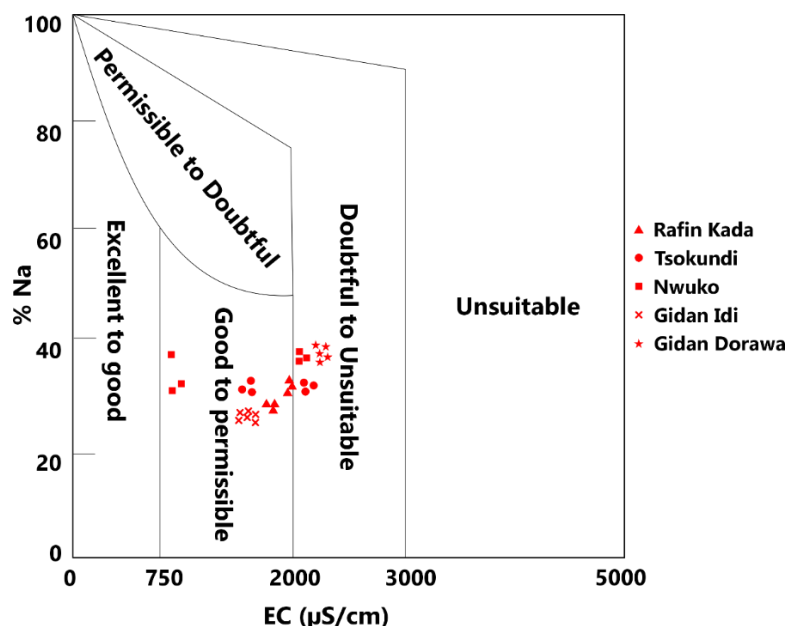


Figure 4: Wilcox Diagram Showing Irrigation Water Suitability Classes for the Study Sites

Rice Growth and Yield Response to Water Quality Differences

The growth and yield parameters of rice (Table 2) showed varying degrees of sensitivity to the spatial variation in irrigation water quality. Among the parameters evaluated, plant height and grain yield were significantly affected ($p < 0.05$), indicating a measurable agronomic response to the chemical constitution of water inputs. Plant height varied from 86.7 cm in Rafin Kada to 99.1 cm in G/Dorawa, exhibiting a positive trend with increasing magnesium (Mg^{2+}) concentrations in the applied water, as can be confirmed by positive correlations between these properties ($r = 0.39$) (Figure 2). As a nonessential microelement, Mg^{2+} plays a pivotal role in cell wall stability and enzymatic regulation during vegetative growth (Wang et al., 2020). For instance, G/Dorawa, which had the highest Mg^{2+} content ($7.80 \text{ cmol kg}^{-1}$), also recorded the tallest plants. This supports studies that report enhanced biomass accumulation in cereals under balanced Ca–Mg regimes (Fageria, 2014; Lyu et al., 2020).

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Table 2: Growth and Yield Parameter

Parameter	Rafin Kada	Tsokundi	Nwuko	Gidan Idi	G/Dorawa	p-value
Plt. H (cm)	86.7 ± 0.438 ^b	88.3 ± 1.023 ^b	89.4 ± 0.466 ^b	94.8 ± 3.498 ^{ab}	99.1 ± 3.632 ^a	0.004 [*]
LAI (cm ³)	10.5 ± 0.766	10.0 ± 0.369	11.4 ± 0.999	10.9 ± 0.923	10.7 ± 0.699	0.816
Tot_Tillers	22.0 ± 0.516	21.3 ± 0.667	19.3 ± 0.667	22.0 ± 0.894	20.3 ± 0.955	0.084
Prod_Tillers	18.3 ± 0.333	17.8 ± 0.601	17.3 ± 0.667	17.7 ± 0.615	17.7 ± 0.558	0.796
Wt1000 (g)	26.3 ± 0.251	26.7 ± 0.133	27.2 ± 0.196	27.2 ± 0.608	26.9 ± 0.315	0.321
TTY (t/ha)	8.2 ± 0.094 ^a	8.1 ± 0.211 ^a	7.6 ± 0.172 ^b	8.2 ± 0.134 ^a	7.7 ± 0.211 ^b	0.050 [*]

Note: Values represent means ± standard error. Different letters within rows indicate significant differences at $p < 0.05$ using Tukey's HSD test.

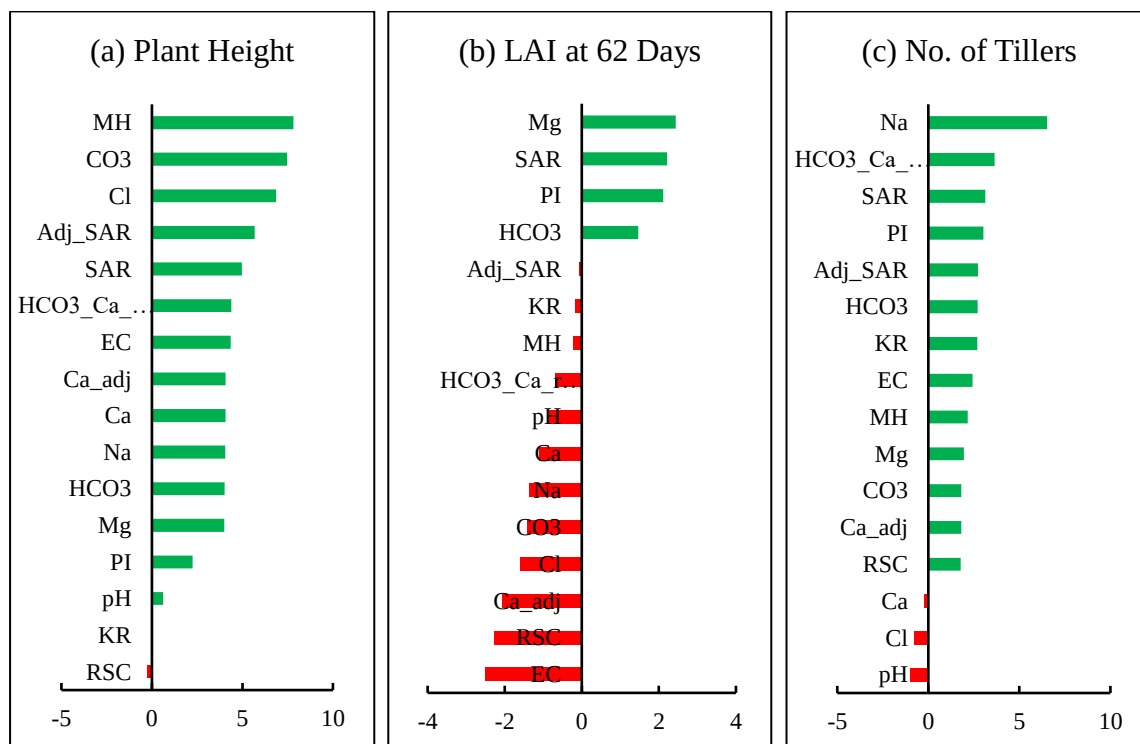
Although leaf area index (LAI), tillering, and 1000-grain weight did not differ significantly among sites, slight fluctuations mirrored subtler chemical variations, especially in sodium and chloride concentrations. For example, Nwuko exhibited a marginally higher LAI and grain weight, possibly due to moderate EC and favorable ionic balance conducive to stomatal function and photosynthetic activity (Ali et al., 2023).

Most notably, grain yield (TTY) differed significantly ($p = 0.049$), with Rafin Kada and Gidan Idi achieving the highest yield (8.2 t ha^{-1}), while Nwuko and G/Dorawa yielded lower ($7.6\text{--}7.7 \text{ t ha}^{-1}$). This variation cannot be attributed to salinity per se, as EC values were moderate across sites. Rather, it suggests the influence of bicarbonate toxicity and ionic ratios, such as HCO_3^- : Ca^{2+} and MH, which were elevated in lower-yielding sites. For example, Gidan Idi, despite a moderate EC, had a high bicarbonate-to-calcium ratio and the lowest Ca_{adj} , indicating potential Ca^{2+} unavailability and precipitation losses (Qadir et al., 2018). This would reduce cell wall elasticity and panicle initiation efficiency, ultimately suppressing yield (Shahid et al., 2021).

Variable Importance Analysis Using Random Forest Regression

The Random Forest (RF) model revealed the hierarchical influence of individual water quality indices on rice physiological and agronomic performance. Overall, the model validation statistics (Table 3) revealed high predictive reliability ($R^2 > 0.80$ for all traits), indicating that the selected water quality parameters captured substantial variance in the observed field data. Notably, grain yield and plant height emerged as the most predictable variables ($R^2 = 0.907$ and 0.903 , respectively), suggesting these are particularly sensitive to the ionic and osmotic profiles of irrigation water in this environment.

Among the predictor variables, RSC, Ca_{adj} , Na^+ , and MH ranked highest in importance across most traits, suggesting their mechanistic roles in modulating rice productivity. The elevated importance of RSC is consistent with its biochemical function: high residual alkalinity enhances bicarbonate and carbonate precipitation, leading to secondary calcium and magnesium deficiencies and soil dispersion (Qadir et al., 2018; Murtaza et al., 2019). This aligns with the observed negative associations between high RSC and both yield ($r = -0.25$) and tillering ($r = -0.33$) (Figure 2).



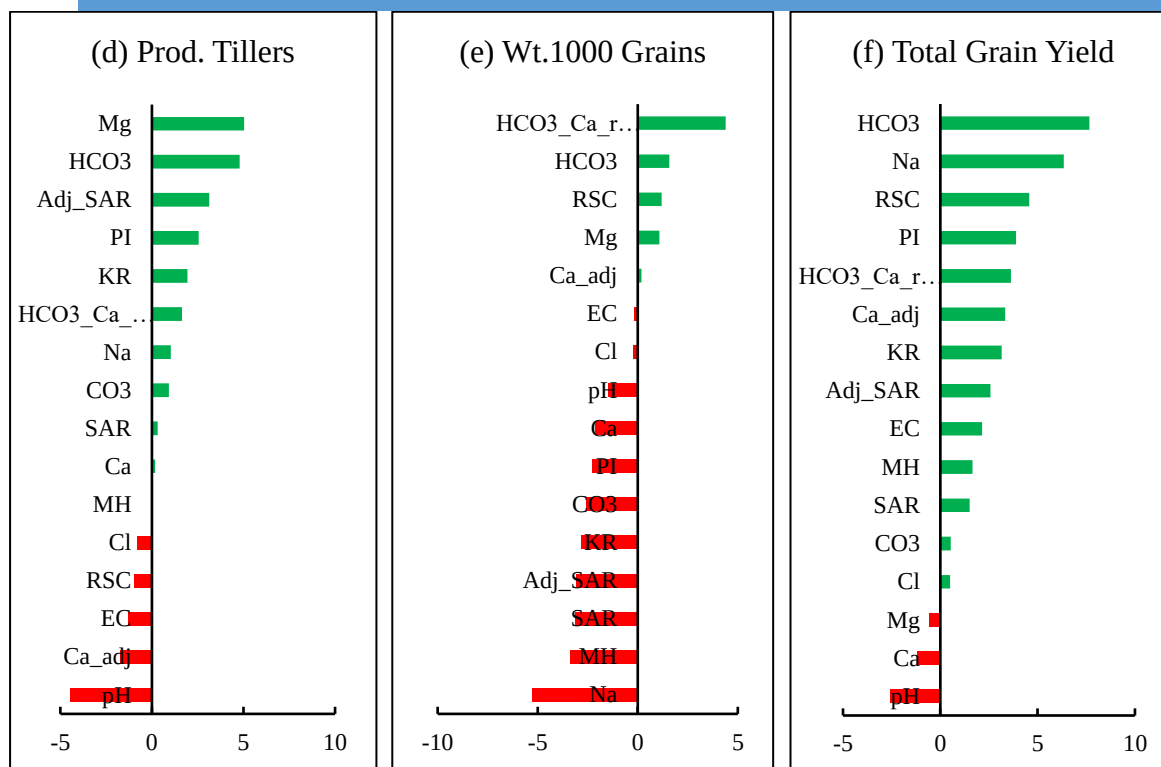


Figure 5(a-f): Mean percentage increase in mean squared error (%IncMSE) of rice growth and yield parameters when individual water quality variables were permuted in a Random Forest regression model. Note: Higher %IncMSE values indicate greater predictive importance of the respective variables.

Table 3: Validation Metrics

S/N	Parameters	R ²	RMSE	MAE
1	Plant Height	0.903	2.708	1.833
2	LAI at 63	0.862	0.964	0.724
3	No of Tillers	0.902	0.889	0.685
4	Productive Tillers	0.899	0.604	0.467
5	1000 Grain Weight	0.810	0.464	0.317
6	Grain Yield	0.907	0.196	0.141

The role of Ca_{adj} is equally critical. As a corrected metric for soluble calcium under bicarbonate-rich conditions, it functions as a proxy for plant-available Ca^{2+} . Sites with low Ca_{adj} , such as Gidan Idi, saw depressed LAI and grain yield despite favorable EC, further emphasizing the utility of this derived parameter in diagnosing hidden deficiencies not apparent from total Ca^{2+} alone. These results reinforce findings by Shahid et al. (2021), who noted that Ca_{adj} values correlate more strongly with grain development and panicle emergence than total ionic concentrations.

Surprisingly, Na^+ and MH were also dominant contributors, especially for vegetative growth parameters like tiller number and LAI (Figure 5b, 5c). High Na^+ interferes with potassium uptake and disturbs ionic homeostasis, while excessive Mg^{2+} (reflected in MH) is associated with deteriorated soil structure and competitive inhibition of calcium uptake (Lyu et al., 2020; Siyal et al., 2022). The model's emphasis on these parameters confirms that both absolute concentrations and ionic ratios significantly shape rice performance (Brahimi et al., 2023; Wang et al., 2021).

Contrastingly, variables traditionally emphasized in routine irrigation water evaluation, such as SAR and EC showed lower relative importance, despite being statistically significant in univariate analyses. This suggests that their predictive capacity may be limited when multicollinearity is accounted for, or that their effects are mediated through more nuanced interactions with other variables. This also suggests that when the values of these routine indicators fall within agronomically acceptable ranges, other less commonly assessed indices emerge as stronger predictors of yield outcomes.

Conclusion: The results show that variations in irrigation water quality across sites in Wukari Local Government Area have meaningful effects on rice growth and yield. Water samples differed significantly in key quality indicators such as Na^+ , RSC, and Ca_{adj} , which influence the chemical balance of the soil and the plant's ability to absorb nutrients. Classification based on established indices revealed that irrigation water samples from some sites, posed moderate to severe irrigation risks over long-term usage. These sites exhibited field symptoms of ionic stress, including poor tillering, reduced plant height, and lower grain yield.

SAR and EC values staying within acceptable ranges, derived indices such as HCO_3^- , Ca^{2+} , PI, and MH proved more reliable in explaining the observed variability in crop response. Among all parameters analyzed, RF models identified Na^+ , RSC, and Ca_{adj} as the strongest

predictors of yield performance, achieving high model accuracy ($R^2 > 0.80$). It is therefore recommended that irrigation planning in tropical rice systems incorporate derived indices to guide site-specific management. Further studies should explore long-term impacts on soil health, nutrient dynamics, and varietal responses under varying water quality regimes.

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Effects of NPK Fertilizer and Poultry Manure on Soil Macro-Nutrients and Yield of Pepper (*Capsicum Spp.*)

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Abstract

Experiment was carried out to evaluate the effects of NPK fertilizer and poultry manure on some soil macro-nutrients and yield of pepper (*Capsicum annum*). Field experiment was carried out at the Teaching and Research Farm, Emmanuel Alayande University of Education, Oyo, Oyo State, Nigeria. It consisted of four treatments; Control (no amendment), Poultry Manure (PM) at 5 t/ha, NPK 15:15:15 at 120 kg/ha, and combination of NPK 15:15:15 (60 kg/ha) + PM (2.5 t/ha). The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated four times. Data collected include yield (first and second harvesting t/ha) and Some soil properties after cropping (pH, organic matter, (OM)%, Available nitrogen (N), phosphorus (P) and potassium(K)). All the data collected were subjected to analysis of variance and means were separated using Duncan Multiple Range Test (DMRT) at ($p < 0.05$). The result showed that the application of NPK at 120 kg/ha gave the highest yield (13.96 and 14.56t/ha) followed by NPK + PM (11.86 and 12.68t/ha), while the control had the lowest (2.96 and 6.76t/ha) at first and second harvestings. Application of NPK and PM had significant effects on the soil properties considered after cropping with the PM plots given the highest soil pH (6.98), OM (3.38%), and N (0.84%), P (11.26mg/kg) and K. (4.55cmol/kg). The study conducted showed that pepper has the capacity to do well in the study area. Application rate of 120 kg/ha of NPK 15:15:15 and 60kg/ha NPK + 2.5PM were therefore recommended.

Key words: Pepper (*Capsicum spp*) NPK fertilizer, poultry manure, yield

Introduction: NPK fertilizers are the main sources of nitrogen (N) for vegetative growth, phosphorus (P) for root development and flowering, and potassium (K) for fruit development and disease resistance, are commonly applied due to their quick nutrient availability and ease of use (Olaniyet *et al.*, 2010). Although, long-term reliance on synthetic fertilizers alone can lead to undesirable outcomes, including soil structure degradation, decline in organic matter, increased soil acidity, and reduced microbial diversity, all of which compromise soil health and sustainability (Ayeni and Adetunji, 2017). Similarly findings so far had shown limitations of the use of mineral fertilizers to improve soil fertility and crop yield, consequently informed shift of attention to the use of organic fertilizers for soil fertility improvement, especially, the highly weathered tropical soils (Ame, 2012; Kader, 2012). Poultry manure contains considerable amounts of nitrogen, phosphorus, potassium, and secondary nutrients, making it an effective complement or alternative to inorganic fertilizers (Adeleye *et al.*, 2020). Conversely, poultry manure enriches the soil biologically but lacks the rapid response characteristic of inorganic fertilizers (Nweke *et al.*, 2021). Yet, research on the synergistic effect of combining these inputs remains limited in the Nigerian context. Also, findings have shown that the soil could be sustained with the addition of poultry manure, its application in the soil may contribute to combat soil organic matter decline and soil erosion (Adeleye *et al.*, 2010). Thus, Ewulo, (2005) reported that poultry manure contains high percentage of nitrogen and phosphorus for the healthy growth of plants. However, the use of organic fertilizers, too, has certain demerits of slow release and non – synchronization of nutrient release with period of growth for most short – season crops, as well as being required in large quantities to sustain crop production, which may not readily be available to the small – scale farmers (Keary, 2014). In view of the above limitations of sole application of organic or inorganic fertilizers in improving soil fertility and crop yield, there is a dire need to critically appraise the potential of combined application of organic and inorganic fertilizers as a nutrient source to improve soil fertility, and hence, ensure balanced crop nutrition. Hence, the present study was initiated at Oyo State College of Agriculture and Technology, Igboora to evaluate the effect of poultry manure and NPK fertilizer on some soil nutrients, immediate and residual yield of sweet pepper (*Capsicum annum*) in the northern derived savannah zone of Oyo State.

Materials and Method: Field trials were conducted at Emmanuel Alayande University of Education, Oyo, Oyo State spanning from 2023 - 2025 cropping seasons. Oyo is located between (latitude 7°51'N and longitude 3°57'E) in guinea savanna zone of Nigerian vegetation. The experimental location was characterized with mean annual temperature and rainfall of 27°C and 1165 mm respectively and between 300 and 600 m above the sea level (Iwena, 2012). Pepper seedlings were raised in a nursery with sterilized top soil. Seeds were planted 5cm apart, sowing depth was about 5mm. Nursery beds were made under shade to protect the seedlings from direct impact of rain drops and sunlight. Watering of the nursery was carried out regularly on daily basis. Emergency began a week after sowing in the nursery. Surface (0-15cm) soil samples were randomly collected and bulked to form a composite before planting and at the end of each cropping season another soil samples were collected. The soil samples and crop residues were air dried, crushed and allowed to pass through a 2mm sieve. Particle size distribution of the soil was carried out by the Hydrometer method, while the pH was evaluated in water (1:2, soil water ratio) using pH meter with glass electrode in distilled water. Routine chemical analysis were also carried out for organic carbon (C), total nitrogen (N), available P, exchangeable Ca, K, Na and Mg. Total nitrogen was determined using the Kjeldhal procedure method as described by Bremner and Mulvaney, (1982). The organic carbon content was determined using the Walkley-Black method (Nelson and Sommers, 1992), available P content was determined by Bray P -1 method (Bray and Kurtz, 1945), while exchangeable Ca, K, Na and Mg were determined using Flame photometry. Seed variety F1 306 was collected from National Horticultural Research Institute (NIRHORT), Ibadan. The seedlings were transplanted to the field after four weeks of planting. Transplanting was done with a hand fork with ball of earth around the roots. Each plot measured 2 m x 2 m with an inter plant space of 50 cm x 50 cm given a total of 16 plant stands per plot. The experiment was laid out in a Randomized Complete Block Design. The treatments were; control (no treatment, CO), 5t/ha Poultry manure (PM), 120kg/ha NPK 15:15:15 fertilizer (NPK), and the integration of 60kg/ha NPK 15:15:15 fertilizer and 2.5t/ha Poultry manure (NPK + PM) and replicated four times. The organics were applied two weeks before planting to enable proper decomposition and NPK fertilizer was applied three weeks after transplanting. Supplying was done five days after transplanting to replace the missing gaps. Data were taken on fruit yield at harvest and soil nutrient content (pH, OM, N,P and K,) in 2024 respectively. Data analysis was done using Analysis of Variance (ANOVA) while the

significant means were separated by Duncan Multiple Range Test (DMRT) at 5% level of significance. The experiment was repeated in the second year on the same plots without fertilizer application in order to assess the residual yields of sweet pepper

RESULTS AND DISCUSSION: The pre- soil analysis of the experiment is presented in Table 1. From the result, the soil was sandy loam in texture with high proportion of sand (74.4%). This indicated that the basic cations Ca, K, Na and Mg would be easily leached with the type of the textural nature of the soil (Sanni and Adenubi, 2015.). The soil was slightly acidic in pH (6.58) and low in organic carbon, total Nitrogen and available P content of the soil. The low organic carbon and organic matter in the soil could be as a result of high proportion of the sandy nature of the soil. Similarly, the low N levels noticed in the soil could be as a result of continuous cropping on the soil. With regards to the FAO, (1984) ratings, nutrient contents of the soil fell within the low rating scale (Mafongaya *et al.*, 2003). Thus, the low soil OC, N, P, K, Mg status and acidic nature of the soil justify the need for poultry manure addition (Table 1). Also, Table 1, revealed the chemical properties of the poultry manure, the result showed that poultry manure is richer in nutrients and this may definitely influence the result of the experiment.

Effect of NPK and Poultry manure on yield of pepper (t/ha): The effect of poultry manure and NPK on the yield of okra was significant. Application of 120kg/ha NPK gave the highest yield followed by application of 60kg/ha NPK + 2.5t/ha PM and 5 t/ha of PM while the control gave the least yield (Table 2). From the result, the use of NPK gave (13.96 and 14.56 t/ha), while NPK + PM gave (11.86 and 12.86 t/ha) followed by PM that gave 10.36 and 9.16 t/ha of yield in the first and second harvesting respectively. The lowest yield of 2.96 and 6.7 t/ha were recorded from the control in the first and second harvesting.

Effects of NPK Fertilizer and Poultry Manure on Soil Nutrient Status: The nutrient status as affected by PM and NPK fertilizer after cropping season is presented in Tables 3. Inorganic NPK fertilizer significantly reduced soil pH and increased N and P content of the soil. The decline in pH of plots treated with NPK fertilizer alone in this study could be attributed to their rapid rates of release of nutrient, which are immediately used up by plants, leading to poor accumulation of exchangeable bases that neutralizes soil acidity. While the sole poultry manure at 5t/ha application (6.98) and the combined application of 2.5t/ha Poultry manure + 60kg/ha NPK gave significantly ($p < 0.05$) higher pH values of (6.76) in 2024 compared to control. Similarly, sole poultry manure and combination of poultry manure and NPK significantly ($p < 0.05$) increase soil Organic carbon (SOC) with 5t/ha PM producing the highest value (3.38%) while 2.5t/ha PM + 60kg/ha NPK application caused a decreased (3.16 %) in SOC followed by NPK while the control had the lowest. Similar pattern was also shown by Soil N% with PM plot producing the highest % (0.84) followed by NPK + PM > NPK while control gave the least. Both P and K macro-nutrients also followed the same trend of performance. The treatments performance corroborated the work of Bello *et al.*, (2019) that the use of NPK fertilizer gave a better response in the first cropping season while the farmyard manures application produced higher pepper yield in the second cropping season. The residual response from the treatment corroborated with the work of Ajari *et al.*, (2003) who discovered that nutrients contained in poultry manure and other organic sources are released more slowly and are stored for longer period in the soil, thereby ensuring longer residual effects. The results of this study have demonstrated that the combined applications of poultry manure and inorganic fertilizer NPK had significant influence on okra plant production. The application of poultry manure alone and its combination with NPK fertilizer significantly ($p > 0.05$) increased soil pH, OM, N, P and K.

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Table 1: Physical and Chemical Properties of the Soil and Poultry manure used

Element	Soil	Poultry manure
pH CH ₂ O) 1.2	6.588.64	
Organic (%)	1.5412.95	
Total N (%)	0.19 1.83	
C/N ration	9.95	
Bray P (mg/kg ⁻¹)	17.6279.50	
Exchangeable cations (cmol/kg ⁻¹)		
Ca	3.3	mg/kg ⁻¹ 95.20
Mg	0.40 ^{ac}	9.69
K	0.31	“ 119.20
Na	0.37	“ 68.50
Acidity H ⁺	0.42	
Mn (cmol/kg ⁻¹)	0.2	“ 1.02
CEC (cmol/kg ⁻¹)	4.58	
Particle size – Analysis (g/kg)		
Sand	744	
Salt	136	
Clay	120	
Texture	Sandyloam	

Table 2: Effect of NPK and Poultry manure on yield of pepper (t/ha)

Treatment	First harvest	Second harvest
Control	2.96d	6.76d
PM	10.36c	9.16c
NPK	13.96a	14.56a
NPK + PM	11.86b	12.68b

Means followed by the same letter in a column are not (p>0.05) significantly different

PM: poultry manure WAT = weeks after transplanting, CO = Control, PM: poultry manure, NPK = NPK 15:15:15.

Table 3: Effect of NPK and poultry manure on some soil properties after cropping

Treatment	pH	OM (%)	N (%)	P (mg/kg)	K (cmol/kg)
Control	5.96d	2.36d	0.32d	7.32d	1.50d
PM	6.98a	3.38a	0.84a	11.26a	4.55a
NPK	6.34c	3.00c	0.52c	9.26c	3.21c
NPK + PM	6.76b	3.16b	0.72b	10.68b	3.89b

Means followed by the same letter in a column are not (p>0.05) significantly different

PM: poultry manure WAT = weeks after transplanting, CO = Control, PM: poultry manure, NPK = NPK 15:15:15.

Farmers Perception on Effectiveness of Participatory Extension Approach on Beans Production in Paikoro Local Government Area of Niger State.

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Abstract

The study evaluated farmer's perception on effectiveness of participatory extension approach on beans production in Paikoro Local Government Area of Niger State. A total of 213 respondents were selected from the Local Government Area as the sample size for the study. Primary data was used for the study, the data were collected by researchers and trained enumerators using structured questionnaire complimented with interview schedule. The findings showed that the mean age of the respondents in the study area was 35 years while the average family size was 9 person and 92% were married with almost 72.6% with non-formal education. The findings in table 3 indicate that farmers participated most actively during the implementation phase with (mean = 6.8) compared to planning (mean = 4.2) and M&E (mean = 1.8). Table 4 shows that the majority of respondents (70%) adopted improved seed varieties, and over 79% applied fertilizers correctly. However, the adoption rate for timely weeding and pest control, together with post-harvest practices was relatively lower with 61% and 59% respectively. This indicates that while farmers are responsive to innovations promoted through participatory extension, there is room for improvement in post-production and agronomic practices. The mean Effectiveness Index was **68**, showing a generally high level of effectiveness of the PEA. The positive correlation ($r = 0.53$, $p < 0.01$) shows a strong and statistically significant relationship between farmer participation and the effectiveness of the extension approach. It was therefore recommended that Efforts should be made to ensure that farmers are involved in all stages of the extension process, planning, implementation, monitoring & evaluation to foster ownership and sustainability. Government and development partners should increase funding and logistical support for agricultural extension services to enhance their efficiency and outreach.

Keywords: Perception, Effectiveness, Participatory, Approach and Extension.

INTRODUCTION: Agriculture plays a central role in the economic development of Nigeria, contributing significantly to employment, income generation, and food security (Yahaya and Hafsat, 2024). In Nigeria, beans *Phaseolus vulgaris* is one of the most important leguminous crops, both for local consumption and as an export product. Beans are a rich source of protein and are grown across various regions of Nigeria, including the middle-belt and northern areas such as Niger State (Kpotun and Abdullahi, 2025). Paikoro Local Government Area (LGA) in Niger State is one of the areas where beans production is a vital agricultural activity. Despite its importance, farmers in Paikoro LGA often face challenges such as inadequate access to improved agricultural practices, low yield, pest and disease infestations, and poor market access. These challenges often lead to suboptimal production levels and poor income generation for farmers (Kehinde, 2023). In response to these challenges, the participatory extension approach has been introduced as a method to enhance farmers' access to information and technology. This approach aims to involve farmers directly in decision-making processes and knowledge-sharing activities, making them active participants in agricultural extension programs (Micheal, 2025). The focus is on tailoring advice and interventions to local contexts, as well as ensuring that farmers' needs and perceptions are integrated into agricultural development strategies. Consequently, there is insufficient understanding of farmers' perceptions of the effectiveness of this approach in improving their production systems. It is unclear whether participatory extension programs are achieving their intended goals or whether they are meeting the real needs of farmers in this region (Ayodele and Musa, 2025). Therefore, this study seeks to evaluate the perceptions of farmers in Paikoro LGA regarding the effectiveness of participatory extension approaches in improving beans production. By exploring farmers' experiences and challenges with these programs, this study aims to contribute valuable insights to the development of more effective and context-specific extension services. The specific objectives are to:

- i. Describe the socio-economic characteristic of the respondents in the study area.
- ii. Ascertain farmers' perception of the participatory extension approach in beans production.
- iii. Assess the effects of the participatory extension approach on the adoption of improved agricultural practices for beans farming.

METHODOLOGY: Paikoro Local Government Area is one of the 25 Local Government Areas (LGAs) in Niger State with its headquarters in located in Paiko. It lies between latitude 9°26'N and longitude 6°38'E. It covers an area of 2,066km² with a total projected population of 158,086 as at 2022 Niger State Geographical Information System, (NIGIS) 2023. It is important to note that migration and natural population growth may have caused population estimates to change since that time. The dry and wet seasons are the two main ones in Paikoro LGA, it has an average humidity of 60% during the dry season and 80% during wet season with an average temperature of 34°C. Economic activities includes, Agriculture, fishing, and livestock farming, while crops mostly cultivated are beans, millet, sorghum, rice, maize and cassava. The research was carried out in six (6) different communities in Paikoro Local Government area of Niger State.. Multi-stage sampling technique was used for the study. The first stage involved random selection of Agricultural zone II (Paikoro) out of 25 LGS's in the state. The second stage involved random selection of six (6) communities from the Local Government Areas (LGA). At the third stage, 15% of the farmers were randomly selected from the sampling frame of each community. In all, a total of 213 respondents were selected from the LGA as the sample size for the study.

Table 1: Sample distribution of the respondents in the study area

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Communities	Sample frame	Sample size (15%)
Tungan Mallam	322	48
Kwakuti	290	42
Kafin koro	240	36
Gwam	218	33
Bakajiba	186	28
Kuka	170	26
Total	1426	213

Sources: Field survey, 2025

Primary data were used for the study, the data were collected by researchers and trained enumerators using structured questionnaire complimented with interview schedule. The data obtained from objective I and II was analyzed using descriptive statistics such as (frequency distribution, percentage mean), while objective III was measured using Logit Regression Model.

3.0 RESULTS AND DISCUSSIONS

3.1 Socio-economic Characteristics of the Respondents: The socio-economic characteristics of the respondents under consideration include age, marital status, household size, years of farming experience and level of education. Result in Table 2 indicates that the mean age of the respondents was 35 years. The finding suggests that the respondents belong to the middle age classes, who are agile and eager to participate in the effectiveness of participatory extension approach on Beans production which will directly or indirectly affect their means of livelihoods. This finding agreed with that of Abubakar and Umar, (2025) that middle aged farming families embraces extension approach on the production of beans for the betterment of their livelihoods. Finding in the Table 2 also shows that 92.0% of the respondents in the study area were married which is a strong indication of some kinds of family responsibilities that will compel them to seek for alternative means of livelihood. This result is in line with Aishat and Gogo, (2024) that married people participate more effectively on extension approaches in beans production to benefit their means of lives. Results in table 2 further shows that the mean household size of respondents in the study area was 9 persons. Large household size point to availability of more information on agricultural extension approach. This agreed with Lawal, *et al.* (2025) who stated that the large household size is a strong indication that farming families can embrace different extension approaches on beans production that will benefit them directly or indirectly to better their lives. In Table 2 the average years of experience in farming activities was between 11 and 20 years respectively, while the mean year of experience for the respondents was 16 years. The fact is that the majority of the respondents in the study area started seeking for participation in extension approaches long before now, which signifies that most beans farmers in the study area earned their living on farming activities to better their lives. This finding conforms with that of Idowu and Joseph, (2025) who stated that majority of farming household in the northern part of Nigeria had long years of experience in beans production which has gone a long way in the betterment of their lives. Table 2 shows that 72.6% of the respondents lack formal education. The implication of this is that those who are literate will be more informed about the extension approach in beans production because of their literacy ability to access information more quickly on agricultural activities. In a related study, Amaechi and Ugo, (2023) contended that education is an important factor that influence acceptance of innovations among farming families in Nigeria.

Table 2: Distribution of respondents according to socio-economic characteristics (n=213)

Variables	Frequency (%)
Age (year)	
<20	30 (16.2)
21-30	52 (19.0)
31-40	70 (33.7)
41-50	48 (18.0)
51-60	23 (13.1)
Mean	35
Marital status	
Single	48(6.5)
Married	156 (92.0)
Widow	9(1.5)
Separated	-
Household size (number)	
1-5	22 (6.7)
6-10	78 (47.0)
11-15	47 (26.3)
16-20	38 (13.2)
21-25	18 (4.4)
>25	10 (2.4)
Mean	9.0
Experience in farming (years)	
1-10	54 (22.0)
11-20	76 (45.2)
21-30	47 (17.6)
31-40	30 (12.0)
>40	6 (3.2)
Mean	16
Educational level (year)	
Non-formal education	152 (72.6)
Primary education	22 (10.2)

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Secondary education	10 (7.3)
Tertiary education	4 (0.9)
Adult education	15 (9.0)

Sources: Field survey, 2025

3.2 Farmers' Perception of the Participatory Extension Approach in Beans Production.

Farmers' participation in the participatory extension approach was measured across three major stages: planning, implementation, monitoring and evaluation (M&E). The results in Table 3 indicate that farmers participated most actively during the implementation phase with (mean = 6.8) compared to planning (mean = 4.2) and M&E (mean = 1.8). This suggests that farmers are primarily engaged as participants or trainees during field activities rather than being fully involved in decision-making or evaluation processes. The findings imply that while the participatory extension approach encourages active engagement, participation is still uneven across different stages. This study is in line with Edward & Yusra (2023) who suggested that all phase should be apply as an approaches to the end uses for effective and efficiency agricultural activities.

Table 3: Distribution of Respondents on Farmers' Level of Participation in Extension Activities

Participation Area	High Participation (%)	Moderate Participation (%)	Low Participation (%)	Mean Score (1–10)
Planning (problem identification, setting objectives)	50	30	20	6.8
Implementation (training, demonstration, field trials)	65	25	10	4.2
Monitoring and Evaluation (feedback and reporting)	55	30	15	1.2

Sources: Field survey, 2025

3.2.1 Adoption of Recommended Beans Production Practices

The table shows that the majority of respondents (70%) adopted improved seed varieties, and over 79% applied fertilizers correctly. However, the adoption rate for timely weeding and pest control, together with post-harvest practices was relatively lower with 61% and 59% respectively. This indicates that while farmers are responsive to innovations promoted through participatory extension, there is room for improvement in post-production and agronomic practices. This study is in line with Nurudeen, and Badmus, (2025) who stated that adoption of all recommended agronomical practices in grains production is effective for farmer's productivity for the betterment of their livelihoods.

Table 4 Distribution according to adoption of recommended Beans Production Practices

Practice	Adopted (%)	Not Adopted (%)
Use of improved seed varieties	70	30
Row planting	65	35
Recommended fertilizer application	79	21
Timely weeding and pest control	61	39
Proper storage and post-harvest handling	59	41

Sources: Field survey, 2025

3.3 Effectiveness of the Participatory Extension Approach

Effectiveness was assessed using a composite index that included knowledge gain, adoption rate, productivity (yield), income, and satisfaction. The mean Effectiveness Index was 68, showing a generally high level of effectiveness of the PEA. Farmers who participated more frequently in planning and implementation phases reported greater improvements in yields and profitability. The findings suggest that participatory methods have enhanced farmers' learning, adoption, and performance outcomes. The positive correlation ($r = 0.53$, $p < 0.01$) shows a strong and statistically significant relationship between farmer participation and the effectiveness of the extension approach. Regression results also indicate that participation has a significant positive effect on the Effectiveness Index, controlling for education, experience, and access to inputs. This implies that farmers who are more involved in planning, implementation, and evaluation of extension activities are more likely to achieve higher yields and satisfaction. This result concurs with that of Owolabi, (2024) who stated that planning, implementation, and evaluation of extension activities has a great impact on the means of livelihood of the end user (farmers).

Table 5: Distribution of respondents according to Effectiveness of the Participatory Extension Approach

Indicator	Mean Value	Effectiveness Category
Effectiveness index	68	High
Knowledge gain (self-rated, %)	65	High
Adoption rate (%)	50	Moderate
Average yield (kg/ha)	1,560	High
Gross margin (₦/ha)	₦162,000	High
Satisfaction with extension services (Likert mean)	5.2	High
Correlation (Participation vs. Effectiveness)	$r = 0.53$	0.000*
Chi-square (Participation × Adoption)	$\chi^2 = 16.40$	0.001**
Regression (β for participation)	0.51	0.000*

Sources: Field survey, 2025

4.0 Conclusion and Recommendations: It was concluded in the study that the participatory extension approach (PEA) has been effective in improving the productivity and livelihood of beans farmers in Paikoro Local Government Area of Niger State. The approach has enhanced farmers' knowledge, promoted the adoption of improved agricultural practices, and increased yields and incomes. Farmers who participated more actively in planning, implementation, and evaluation stages benefited more from the program than those who participated less. The study also concludes that the success of the participatory approach depends largely on the quality of farmer involvement, the capacity of extension agents, and the adequacy of institutional and financial support. Therefore the following recommendations were made to strengthen the participatory extension approach and enhance beans production in Paikoro LGA and beyond. Efforts should be made to ensure that farmers are involved in all stages of the extension process, planning, implementation, monitoring & evaluation to foster ownership and sustainability. Government and development partners should increase funding and logistical support for agricultural extension services to enhance their efficiency and outreach.

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Use of Information and Communication Technologies for Effective Extension Service Delivery among Extension Agents in Kano State, Nigeria

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Abstract

This study investigated the use of information and communication technologies (ICT's) for effective extension service delivery among extension agents in Kano State, Nigeria. A Multi-stage sampling procedure was used to select 74 extension agents as respondents from the study area who were used for the study. Primary data were collected using structured questionnaire. Both descriptive and inferential statistics were used to analyse the data. The result revealed that majority (86.5%) of the respondents were males, Married (66.2%) with mean age of 39 years. The result further revealed a mean household size of 6 person per household, with Farming (47.3%) as the major source of income, with tertiary education (43.2%) being the highest level of education. Majority (78.4%) of the extension agents had access ICT's through personal possession, about more than half of the respondents (56.8%) used ICT tools rarely and more than half respondents acquired knowledge on ICT through training (52.7%). The result further showed that most available, accessible and most utilized tools to the respondents were radio ($x=2.50$) and mobile phones ($x=2.58$) respectively. The result revealed that the main constraints to utilization of ICT materials were unstable power supply ($x=2.67$), cost of purchase ($x=2.59$) and cost of maintenance ($x=2.26$) among others. The study concluded that extent of usage of radio and mobile phones were high. The study further recommended that measures should be taken to mitigate the constraints hindering the use of ICT's as well as trainings to improve the utilization of other ICT tools such as computer and internet.

Keywords: Information and Communication Technology, Extension Service, Extension Agents

INTRODUCTION: Agricultural extension services can be defined as the entire set of organizations that facilitate and support people engaged in agricultural activities to solve problems and obtain information, skills, and technologies which will improve their livelihoods and wellbeing (Davis *et al.*, 2020). Extension service globally involves the dissemination of knowledge, agricultural information, and new technologies to farmers and rural dwellers. According to the International Food Policy Research Institute (IFPRI), agricultural extension plays a crucial role in promoting productivity, increasing food security, improving rural livelihoods and promoting agriculture as a pro-poor economic growth engine (IFPRI, 2020). Globally, the objective of agricultural extension service remains the development of rural populations and raising their standard of living through increased farm production and income. Digital agriculture can be defined as the process of digitizing the various components of the agricultural value chain. It can also be defined as targeted information services helping farmers to use new technology in order to increase productivity and profitability. In digital agriculture, mobile phones and internet are important resources for enabling poor farmers to make informed decisions regarding their farming activities, especially in the rural areas of developing countries (Olaniyi, 2018). Development in the field of agriculture has been made possible through the use of latest technology for communication which is known as information and communication technology (ICT). According to Anand *et al.*, (2020), ICT encompasses a diverse range of technologies including traditional methods such as radio, television, and telephone as well as modern advancements such as mobile devices, wireless, satellite technology, multimedia and the internet. ICTs can be broadly interpreted as technologies that facilitate communication and the processing of information by electronic means. ICT can be used as an effective communication tool, where time and distance is a barrier as well as cost effective alternative for some of the traditional technology dissemination. ICTs have the potentials of bridging the existing communication gap among the extension workers on one hand and between the extension workers and the farmers on the other. According to a study by Aker (2019), the adoption of ICTs in extension services has led to improved access to information, increased farmer knowledge, and higher adoption rates of modern agricultural practices. According to (Ayeni *et al.*, 2023), Internet communication technologies for agricultural extension possess the potential of energizing data collection, processing and transmission leading to a faster spread of high-quality information to more farmers through an upstream and interactive channel of communication. ICTs have the potentials to enhance farmers' ability to collate demands; interactive learning; exchange of time sensitive information, for example, market price and disease outbreaks; making extension system and structures more efficient; engage farmers in assessing own needs, solutions; facilitating access to markets and credits; training and demonstration; community learning; search, select and compile information for individual clients early warning for disasters, weather forecast and peer to peer sharing and exchange among extension according to (CTA 2003).

In Nigeria, there are various obstacles to the advancement of agricultural extension service delivery which are; inadequate funding or poor logistic support for staff, limited access to production facilities and ratio of extension agents to farm family is imbalanced (FAO, 2017). As expected, the level of extension contact with farmers has been poor which is quite noticeable in the activities of the Agricultural Development Programmes (ADPs). Despite efforts made during the ADPs initiatives to enhance the proportion of farm families reached, numerous farmers remain unreachable. This is due to the limited number of extension agents providing services given the large number of farmers. The effective delivery of extension services has faced two significant obstacles. Firstly, reduced government expenditure to support extension services gave rise to shortage of extension agents. Secondly, economic crisis that led to citizen with little or no knowledge on agriculture to go into the sector, which necessitated the increasing demand for the limited extension agents. Presently, the use of ICT in all sectors, such as health, education, finance, political as well as agriculture has increased. ICT applications have the potentials to identify and find solutions to some of the numerous problems faced in agriculture ranging from prolonged droughts, pest and diseases outbreaks, seasonality and spatial dispersion of farming; high transaction and information asymmetry (Anh *et al.*, 2019). Modern agricultural extension system encourages the development of positive attitude in the scientist to appreciate the knowledge, experience and capacities of the local people in research development process. It has therefore become necessary for all stakeholders to join hands in developing ICT world in Nigeria since it has the potential of transforming agriculture through agricultural extension in the country. An agricultural extension worker can learn new technologies, rainfall forecast, commodity prices etc and use that information to advise farmers in villages. The importance of ICTs in development process was long recognized and access to ICTs was even made one of the targets of the Millennium Development Goal No. 8 (MDG 8), which emphasizes the benefits of new technologies, especially ICTs in fight against poverty. The use of ICTs by extension agents

in Kano state has been increasingly important for improving agricultural practices and productivity. Extension agents in Kano plays a crucial role in the agricultural sector, providing essential services through the use of mobile phone to disseminate information and get direct contact with the farmers, Radio for interactive sessions and internet/ social media for detailed guide, sharing updates and tips for best practices. These methods demonstrate the significant impact of ICTs on enhancing the efficiency and effectiveness of agricultural extension services in Kano. Agricultural extension system has the responsibility to develop the country's agriculture. Such development is often measured through the extension agents, whose main responsibility is to communicate new ideas and technologies to farmers. However, there is no adequate information on whether the agricultural agents use the necessary ICTs in contacting the farmers, especially in Kano state.

Statement of the Problem: The current aspect of agricultural extension service delivery face challenges in effectively disseminating information and giving support to farmers. Extension plays a vital role in bridging the gap yet there is limitation in reach and efficiency of traditional method of communication. Bringing information and communication technology into extension service delivery has the potential to improve outreach efforts. However, there is still a gap in understanding the most effective ways for using ICTs among extension agents. Extension agents and farmers face several challenges in the effective use of ICTs in agriculture and those challenges may hinder the adoption and optimization of ICT based solutions. There may be limited access to reliable internet connectivity, electricity and mobile network coverage which limits the use of online platforms and mobile apps in Kano and ICT tools and content may not be available in local languages or may not address the specific needs and challenges in Kano state. Extension service delivery by extension agents is attributed to several factors such as; inadequate funding, poor training of staff, low level of education among the extension agents, low rate of adoption of technologies, low income, awareness and access. There is therefore the need for the development of ICTs infrastructure especially in rural areas to enable the extension agents have access to the key ICTs like telephone, computer and internet. This study aims to investigate the use of Information and Communication Technologies for effective extension service delivery among extension agents in Kano state, Nigeria.

Objectives of the Study: The broad objective of this study is to investigate the use of Information and Communication Technologies for effective extension service delivery among extension agents in Kano state, Nigeria. While the specific objectives of the study are to; describe the socio-economic characteristics of the extension agents in the study area; identify ICT available to the extension agents in the study area; ascertain the accessibility of the extension agents to ICT facilities in the study area; ascertain the degree of utilization of ICTs by the extension agents and to identify the constraints faced by extension agents in using ICTs for dissemination of information in the study area.

METHODOLOGY

The Study Area: The study was be conducted in Kano state, Nigeria. It was created in the year 1967. The state contains 44 local government areas, which lies between latitudes 10° 33' N and 12° 37' N and longitudes 7° 34' E and 9° 29' E. The total land area is estimated to be 20, 760 square kilometers with a population of 15,462,200. Most of its inhabitants are Hausa/Fulani and 80% of them are engaged in farming activities (NPC, 2006).Kano state lies within the semi- arid Sudan savannah zone of West Africa. Kano has a mean height of about 472.5m above sea level. The climate of Kano state is characterized by variability in rainfall between the 70s and 80s with drought and near drought conditions Buba(2010). Based on the report of the Nigerian Metrological Agency (NIMET), the amount of rainfall varied between years with a mean value of 899.7mm. Many large market exist within Kano today, such as Kurmi Market, SabonGari Market, Yankura Market, Galadima Market, Dawanau Market and Bata Market. Many of these markets specialize in a certain product, such as textiles or grain. Subsistence and commercial agriculture is mostly practiced in the outlying districts of Kano state. Some of the food crops cultivated are millet, cowpeas, sorghum, maize and rice for local consumption while groundnuts and cotton are produced for export and industrial service. During colonial period and several years after the country's independence, the groundnut produced in the state constituted one of the major sources of revenue of the country. Kano state is a major producer of hides and skins, sesame, soybean, cotton, garlic, gum Arabic and chili pepper. Kano state is the second largest industrial centre after Lagos state in Nigeria and the largest in Northern Nigeria with textile, tanning, footwear, cosmetics, plastics, enamelware, pharmaceuticals, ceramics, furniture and other industries. Kano is also the center of a growing Islamic bank industry in Nigeria. KNARDA divided Kano state into three administrative division called Agricultural Development Programme (ADP) zones namely, zone 1, zone 2 and zone 3 with their respective local government areas (LGAs) as follows:

Zone 1: Rano, Tudunwada, Doguwa, Bebeji, Kiru, Garun- malam, Kura, Kumbotso, Madobi, Gwarzo, Karaye, Rogo, Kibiya and Bunkure with Rano as ADP zone 1 Headquarter. Zone 2: Dambatta, Bichi, Bagwai, Shanono, Tsanyawa, Kunchi, Kobo, Rimi-Gada, Tofa, DawakinTofa, Makoda, Minjibir and Ungogo with Dambatta as ADP zone 2 Headquarter. Zone 3: Gaya, Ajingi, Wudil, Albasu, Garko, Takai, Sumaila, Dawakin Kudu, Warawa, Gezawa, Gabasawa, Kano Municipal, Tarauni, Dala, Gwale, Fagge and Nassarawa with Gaya as ADP zone 3 Headquarter.

Population of the Study: The population of the study comprised of all the extension agents in Kano State. The total population of the extension agents in Kano state is 1120 registered under the Kano State Agricultural and Rural Development Authority (KNARDA).

Sampling Procedure and Sample Size : A multi-stage sampling procedure was used in the study. It involved purposive selection of all ADP zones of Kano state. This was to ensure equal representation of the respondent in the study. In the first stage, four (4) LGA's were randomly selected from the LGA's in each of the zones of the state. The LGA's are: Dambatta (Zone I), Kura (Zone II) and Gaya & Wudil (Zone III), to give a total number of 4 LGA's. This is because of the high number of extension agents and extension activities in the LGA's selected. In the second stage, 8 communities were selected from each of the LGA's selected. The communities are: Danhassan & Butulawa from Kura, Kore & Ajumawa from Dambatta, Indaboand Bange from Wudil and Maimakawa & Kademi from Gaya. In the third stage, 104 extension agents were selected from the 8 communities to make sample size as obtained from KNARDA. In the final stage, 70% of the sample frame (104) which is 74 was used as the sample size.

LGA's	Sampling frame		Sample size(70%)
Dambatta	29	20	
Gaya	15		11
Kura	35		25
Wudil	25		18
Total	104		74

Source:

KNARDA, 2024

Method of Data Collection: Data for the study was collected from two sources; primary data which was obtained with the aid of a well-structured questionnaire. The questionnaire includes both open ended and close ended questions to obtain data on the socio-economic characteristics of the extension agents, degree of utilization, accessibility, the type of ICTs available and the constraints faced by the extension agents in using ICT's. While the secondary data was obtained from Kano State Agricultural Development Authority (KNARDA). A total of Seventy-Four (74) questionnaires were administered to the extension agents in the study area.

3.5 Method of Data Analysis: Descriptive statistics was used to analyze the data such as frequency counts, Mean, Percentage.

RESULT AND DISCUSSION

Socio-economic Characteristics of the Respondent: The first objective of the study was to describe the socio-economic characteristics of the respondents. These are: age, marital status, gender, household size, education qualification, work experience and source of income. The Table 1 shows the distribution of the respondents based on their socioeconomic characteristics.

Age of the Respondents: The result in table1 shows that most of the respondents have an average age of 39 years. This implies that most of the respondents are in their prime and active age of utilizing ICT's. This finding is in consonance with that of Samson *et al.*, (2023) that found out that extension agents in Abuja have an average age of 39. This is also in agreement with the findings of Listiana, (2019) in a research which discovered that extension workers who worked with administrations in Lampung Province have an average age of 39.

Marital Status of the Respondent: The results in table 1 shows that majority of the respondents were married with few single and one divorced. This implies that most of the extension agents were responsible and had families to take care of. This is in line with the findings of Ayotunde (2021) which states that clienteles are disposed to married extension agents as society places high level of respect on the status of married people who are expected to be responsible in carrying out their duties.

Gender of the Respondent : The result in table 1 shows that majority of the respondents were male. This implies that agricultural extension work is dominated by males. This corroborates with the findings of Nyarko and Kozari, (2021) which finds out that for every five (5) employees you encounter, one (1) is a female extension worker, agreeing to the fact that males predominate in agricultural extension operations. And also, because farming is seen as men domain and so extension professionals are mainly male to serve the male farmers who are in the majority.

Household Size of the Respondents: The result shows that majority of the respondent fell within the household size of 1-10 persons while the rest fell within the household of above 10 persons with an average of 6 persons per household.

Table 1 Distribution of the respondents based on their socioeconomic characteristics

Variables	Frequency	Percentage	Mean
Age			
21-30	18	24.3	
31-40	25	33.8	
41-50	20	27.0	
51-60	9	12.2	39
Above 60	2	2.7	
TOTAL	74	100	
Marital Status			
Single	24	32.4	
Married	49	66.2	
Divorced	1	1.4	
TOTAL	74	100	
Gender			
Male	64	86.5	
Female	10	13.5	
TOTAL	74	100	
Household Size			
1-10	67	90.5	6
Above 10	7	9.5	
TOTAL	74	100	

Source: Field Survey, 2024

Educational Qualification

The result in table 1 shows that over 74% of the respondents have secondary or tertiary education with only 1.35% lacking formal education. This implies that extension agents have foundational knowledge needed to grasp ICT concepts.

Source of Income

The results in table 1 shows that the respondents are into other occupations apart from extension work such as farming, fishing, trading, carpentry, rearing and driving with farming with the highest percentage. This implies that the extension agents are into farming due to the availability of land.

Working Experience

The results in table 1 shows that 58.11% of the respondents had work experience of 1-10 years while 41.89% of the respondents had more than 10 years of experience. The result is also supported by the findings of Agha et al (2018), who found out that majority of the extension agents had at least 10 years of professional experience.

Table 1 Continued: Distribution of the respondents based on their socioeconomic characteristics

Variables	Frequency	Percentage(%)
Educational qualification		
Primary	10	13.5
Formal	1	1.4
Secondary	23	31.1
Tertiary	32	43.2
Islamiyya	08	10.8
Total	74	100
Source of income		
Carpentry	07	9.5
Drivng	01	1.4
Farming	35	47.3
Fishing	05	6.8
Animal Rearing	10	13.5
Trading	16	21.6

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Total	74	100
Working Experience(years)		
1-10	43	58.1
Above 10	31	41.9
Total	74	100

Source: Field Survey, 2024

Available ICT Facilities to the Extension Agents.

The results in the table 2 below shows the type of ICT facilities available to the respondents in their area of coverage. Radio and mobile phones were the most available ICT facilities to the extension agents in their area of coverage. Their high availability maybe due to their affordability, portability and ease of use. Telephone is the least ICT available due to the shift towards mobile phone which offers more versatility and are generally more affordable and accessible. Akweta *et al.*, (2018) observed that radio, mobile phones were the most commonly used ICT's.

Table 2 Distribution of the Respondents based on Availability of ICT Facilities

Variables	Frequency	Percentage (%)
Radio	66	89.2
Mobile phone	66	89.2
Email	34	46
Internet	26	35.1
Telephone	9	12.2
Videos	40	54.1
Computer/laptop	19	25.7
Social media	44	59.5

Source: Field Survey, 2024

*Multiple responses exist

Accessibility of the Extension Agents to ICT Facilities

The accessibility of the extension agents to ICT facilities was examined under how ICTs are accessed, length of access to ICT's

Accessed to ICT, Frequency of ICT' usage and Length of access to ICT's

From the result in the table below it shows that a significant number of respondents have access to ICT's through personal possession. This implies that most extension agents rely on their own devices for extension work. The result in the table below shows that half of the respondents used ICT's rarely. This implies that the disparity maybe due to factors such as limited access to resources, network issues or the need for additional training. The result in the table below shows that the 39.19% of the respondents had access to ICT's for 4-6 years, 28.38% had access for 7-9 years, 28.38% had access for more than 9 years and 8.11% had access for 1-3years.

Table 3 Distribution of the respondents based on Accessibility of the Extension Agents to ICT Facilities

Category of Access	Frequency	Percentage(%)
Personal possession	58	78.4
Cafes	6	8.1
Borrowing	10	13.5
TOTAL	74	100
Frequency of Usage		
Always	32	43.2
Rarely	42	56.8
Never	-	-
Length of Usage		
1-3	6	8.1
4-6	29	39.2
7-9	18	24.4
Above 9	21	28.4
Total	74	100

Source: Field Survey, 2024

Level of Utilization of ICT's among Extension

Table 4 shows the distribution of the respondent based on extent of utilization of ICTs among extension agents. The respondent's degree of utilization of ICT's is shown in the table below. The variables were measured on a 3- point likert scale of always, rarely and never respectively. The mean value for reference was calculated as 2.00 which implies that any mean value of two (2)and below the threshold indicates low utilization, while any mean value of two(2) and above indicates high utilization. From the results obtained it shows that the respondents highly utilized radio($x=2.50$) and mobile phones ($x= 2.58$) with telephone ($x= 1.15$), videos ($x= 1.65$), computer/ laptop($x= 1.20$) and Social media ($x= 1.88$) indicates low utilization.

Table 4: Distribution of the Respondents based on the Extent of Utilization of ICT's among Extension Agents

ICT's/Platforms	Always	Rarely	Never	Mean ($\bar{x}$)
Radio	45	25	6	2.50
Mobile phone	48	21	5	2.58
Email	18	32	24	1.92
Internet	17	30	27	1.86
Telephone	-	11	63	1.15
Videos	7	34	33	1.65
Computer/laptop	-	15	59	1.20
Social media	18	29	27	1.88

Source: Field Survey, 2024. Mean threshold: Any mean value of 2 and below: low utilization. Any mean value of 2 and above indicates: high utilization. Adapted from Makinta, 2021.

Mean knowledge of Respondents on ICT's

From the results in the table 5 below, 52.7% of the respondents learned to use ICT's through training and rest either from friends, workshops and other farmers. This implies that training provides extension agents with a comprehensive understanding of ICT's and their applications in agricultural extension, contributing positively to the quality of extension services.

Table 5 Distribution of the respondents based on knowledge on ICT usage

Variables	Frequency	Percentage(%)
Training	39	52.7
Workshop	8	10.8

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Friends	20	27.0
Other farmers	7	9.5
TOTAL	74	100

Source: Field Survey, 2024

Constraints faced by Extension Agents in Using ICT's

From the result in the table 6 below, the major constraints to the use of ICT's by extension agents were unstable power supply ($\bar{x}=2.67$), cost of purchase ($\bar{x}=2.59$) and cost of maintenance ($\bar{x}=2.26$) respectively. These findings are in conformity with that of Adekun et al, (2020) and Mustapha et al, (2018) who found that the cost of digital tools, poor internet connectivity and poor electricity supply were the major constraints hindering the effective use of digital tools in Nigeria. Similarly, Ibe *et al.*, (2020), found out that the cost of acquiring digital tools was a major challenge in the utilization of digital tools among extension agents. There is also lack of training farmers on ICTs ($\bar{x}=2.23$) and Lack of training by ext. agents on ICT ($\bar{x}=2.09$).

Table 6 Distribution of the respondents based on constraints to the usage of ICTs

Variables	Serious Const.	Mild Const.	Not a Const.	Mean	Rank
Unstable power supply	50	24	5	2.67	1 st
Cost of purchasing ICT	49	20	14	2.59	2 nd
Cost of maintenance	33	27	5	2.26	3 rd
Lack of training ext. agents on ICT	22	47	9	2.23	4 th
Farmers attitude towards the use of ICT	16	49	15	2.09	5 th
Lack of training farmers on ICT	21	38	8	2.08	6 th

Source: Field Survey, 2024.

Conclusion and Recommendations : The study concludes that there are more males than female extension agents in Kano state with some middle aged with an average age of 39 years and majority married. Most had working experience of 10 years with farming as a major source of income. Most of the extension agents have 1-10 persons per household. Most of the extension agents had attained a higher level of education. The most available ICT tools to the extension agents in their area of coverage are radios and mobile phones. The results indicated low level of utilization of ICT's with radio and mobile phones as the most utilized. The results also indicated that most of the extension agents owned the ICT tools used and most of them acquired knowledge on how to use ICT through training followed by friends. Unstable power supply and cost of purchase were the major constraints faced by extension agents. Addressing these constraints is essential for enhancing the use of ICT's for extension services and improving agricultural communication and productivity in the region. Based on the findings of the study, the following recommendations were made;

1. Efforts should be made to provide reliable power supply and alternatives such as solar power to address the challenge of unstable power supply.
2. Investment should be made in other ICT tools such as computers and internet to make it more available and accessible to improve communication and dissemination of information.
3. Policies should be made to support the adoption of ICT's in extension services including funding, partnerships and programs that enhance rural ICT infrastructures.
4. Interventions should be done to improve the use of ICT's by increasing the salaries of extension workers or giving them incentives to enable them purchase ICT tools such as computers/laptops, video players etc. or providing them with ICT tools to support the use of ICT's in areas where needed.
5. Policies should be developed to promote the inclusion of women in agricultural extension work which can be achieved through offering scholarships, target recruited campaigns to attract and retain more women in the field.
6. Lastly trainings should be continuously provided to maximize the effective use of ICT tools available.

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Application of Semivariogram Analysis in Measuring Spatial Variability and Distribution of Selected Soil Properties in Umuagwo, Imo State.

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ABSTRACT:

This study investigates the application of Semivariogram analysis to evaluate the spatial variability and distribution of selected soil properties in Umuagwo, Imo State, Nigeria. By utilizing geostatistical techniques, the research analyzes five soil samples collected from a profile pit from the study area to map the spatial structure of selected soil properties such as Soil pH, organic matter content, and nutrient levels. The semivariogram serves as a critical tool in understanding the degree of variability and spatial dependence of these properties, enabling the identification of trends and patterns within the soil data. The results of the semivariogram analysis showed that all the selected soil properties exhibited spatial dependence within some distances. The spatial dependence for pH is 5.56; organic carbon is 8.59; Available Phosphorus is 17.14, which gave rise to strong spatial class, using exponential and Gaussian models. The findings aim to enhance soil management practices in the region, provide insights for agricultural planning and environmental conservation. Overall, this study contributes to a deeper understanding of soil dynamics in Umuagwo, supporting sustainable land use and resource management strategies. The study also highlights the relevance of semivariogram analysis in supporting site-specific nutrient management and sustainable land use planning.

Keywords: Geostatistics, Semivariogram, Spatial Variability, Kriging, Soil Properties.

Introduction: Soil properties vary spatially due to inherent factors such as parent material, topography, and climate, as well as extrinsic factors including management practices, land use, and fertilizer application (Okerefor et al., 2025). This variability has profound implications for sustainable agriculture, as ignoring it often results in mismanagement of soil resources, reduced crop yields, and environmental degradation. In Nigeria, studies have shown that land-use planning and soil management are often hindered by poor knowledge of variability patterns (Fabami, 1990). Traditional statistical approaches describe averages but fail to capture spatial dependence among soil properties. Geostatistics, however, provides a robust framework to quantify spatial relationships and model soil heterogeneity effectively. The semivariogram, a fundamental tool in geostatistics, describes how similarity between samples decreases with distance. When combined with kriging, it allows for the generation of continuous prediction maps from discrete sample data (McBratney et al., 2003). Previous research across different regions (Cambardella et al., 1994; Goovaerts, 1998) has demonstrated that soil properties commonly display strong to moderate spatial dependence. Despite progress globally, limited work has been conducted in southeastern Nigeria using semivariogram analysis. Umuagwo, Imo State, is an intensively cultivated area where soil degradation, nutrient depletion, and inefficient fertilizer use are pressing challenges. By applying semivariogram analysis to key soil properties; pH, organic carbon, and available phosphorus, the study provides insights into variability patterns that can guide site-specific nutrient management and sustainable land-use practices.

Materials and Methods

Study Area: The study was conducted in Umuagwo, Imo State, Southeastern Nigeria as shown in figure 1. The region lies within the humid tropical climate zone, characterized by an annual rainfall of 2000–2500 mm and mean annual temperatures of 25–30°C. Rainfall is bimodal, with a wet season extending from March to October and a dry season from November to February. The soils of the area are predominantly Ultisols, which are highly weathered, strongly acidic, and prone to nutrient leaching. Due to intensive cultivation, fertility is often low, necessitating frequent fertilizer and organic amendments (Okerefor et al., 2024).

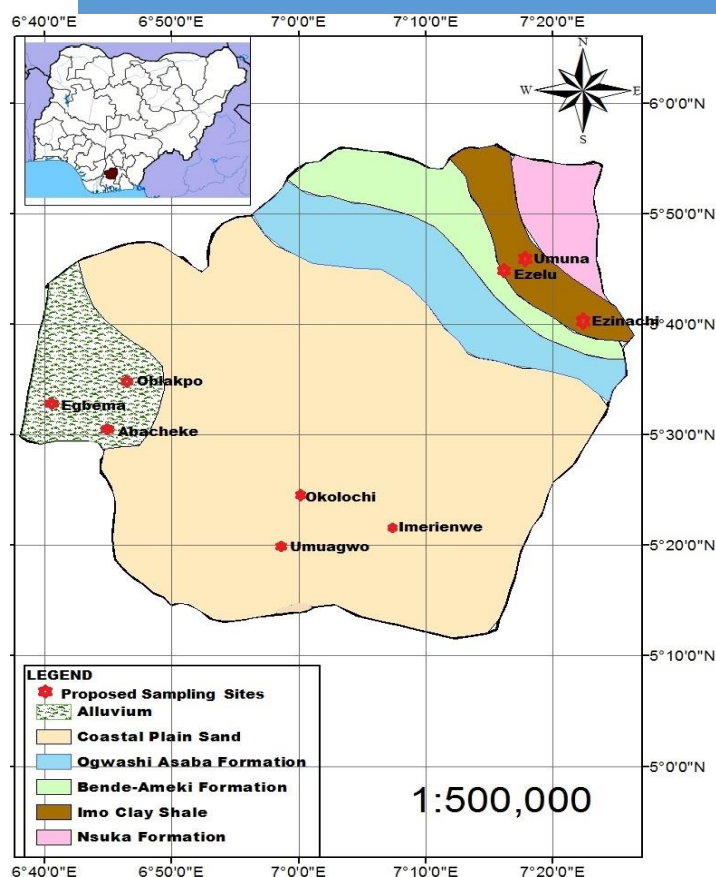


Fig. 1: Map of Imo State showing the study area

Soil Sampling: A reconnaissance field study was carried out with the help of geology map, through which mapping unit were delineated based on apparent soil variability, vegetation cover and land form. The soils are derived from coastal plain sand. A profile pit was excavated at the study location and described according to FAO guidelines for soil description (FAO, 2006), and sampled according to the genetic horizons from bottom layer to the topmost layer using free grid-base sample approach for more accurate spatial variable data. Five soil samples were collected using cor sampler and subjected to laboratory analysis.

Laboratory Analyses: Soil pH was measured in a 1:2.5 soil-to-water suspension using a pH meter (Hendershot et al., 1993). Soil Organic Carbon (SOC) was determined using the Walkley and Black dichromate oxidation method (Nelson & Sommers, 1982). Organic matter content was calculated using a factor of 1.724. Available Phosphorus (P) was extracted with Bray I solution and measured colorimetrically using the molybdenum blue method (Udo et al., 2009).

Data Analyses: Basic descriptive statistics (mean, standard deviation, coefficient of variation) were computed. The coefficient of variation (CV) was used to classify variability following Wilding et al. (1994): Low: <15%; Moderate: 16–35%; High: >35%. Semivariograms were constructed for each property using ArcGIS 10.2 software. Theoretical models (exponential and Gaussian) were fitted to experimental semivariograms. Key parameters included: Nugget (C0): representing measurement error or microscale variability. Sill (C0 + C): total variance. Range (a): distance beyond which spatial correlation disappears. Spatial dependence was classified according to Cambardella et al. (1994): Strong (<25%), Moderate (25–75%), Weak (>75%). Ordinary Kriging (OK) interpolation method was used for the prediction of the values of the un-sampled locations.

Results and Discussion

Descriptive Statistics: Descriptive statistics revealed variability in the studied properties. Soil pH was consistently acidic, ranging between 4.0 and 4.2, indicative of strong acidity across the study area. Organic carbon levels were low, reflecting continuous cropping and insufficient organic inputs. Available phosphorus showed wider variation, which may be attributed to uneven fertilizer application and soil chemical fixation (Table 1).

Semivariogram Models: Soil pH: The semivariogram showed strong spatial dependence with a short range of 5.56 m, suggesting localized variability due to fertilizer use and leaching. Organic Carbon: Range = 8.59 m, indicating moderate-scale variability influenced by crop residues and organic amendments. Available Phosphorus: Range = 17.14 m, the broadest, reflecting fertilizer placement and P fixation

dynamics (Table 2), (Figure 2-4).

Figure 2. Semivariogram of pH in 1N KCl

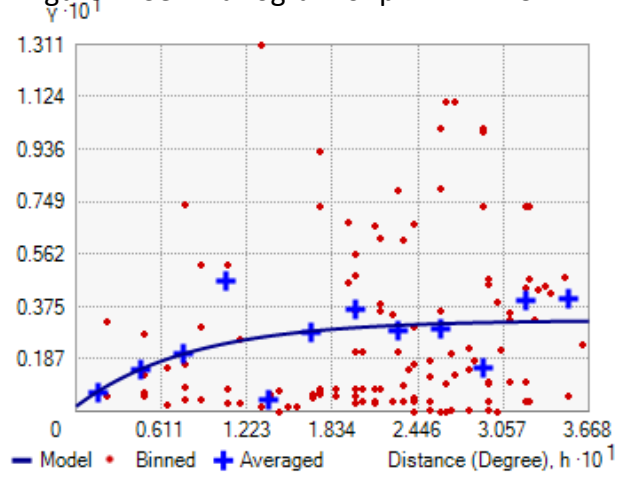
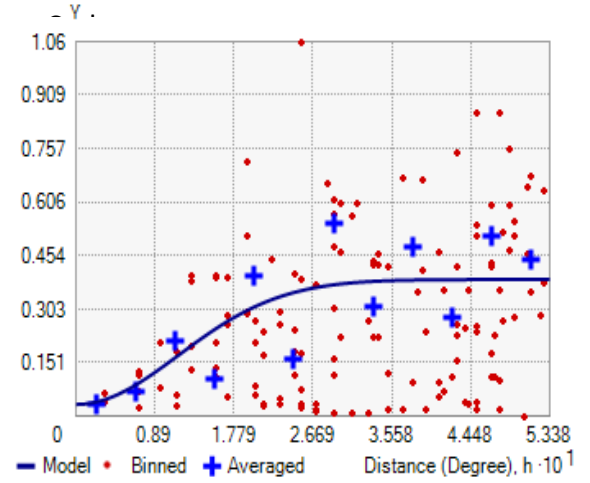
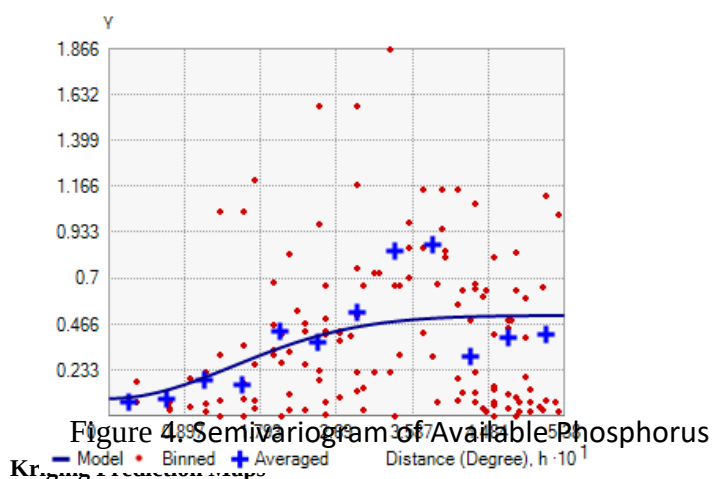


Figure 3. Semivariogram of Soil Organic





Kriging maps derived from semivariogram models displayed spatial gradients of soil properties: pH values clustered in small pockets, highlighting micro-scale variability. Organic carbon showed larger patches of variability, consistent with differences in land management. Available phosphorus exhibited distinct zones of enrichment and depletion (Figure 5-7).

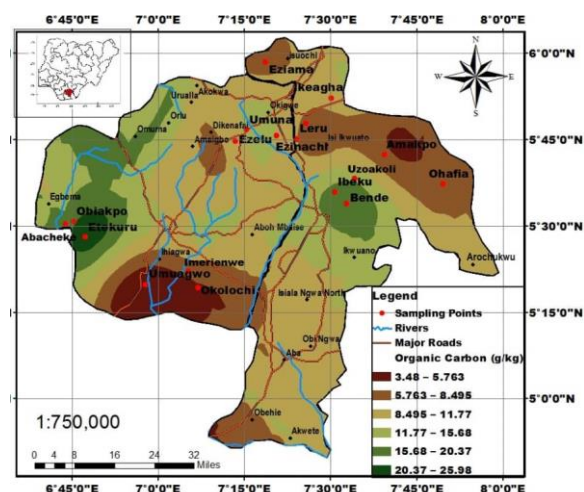


Figure 5. Kriged Map showing the spatial distribution of Organic Carbon in the study location.

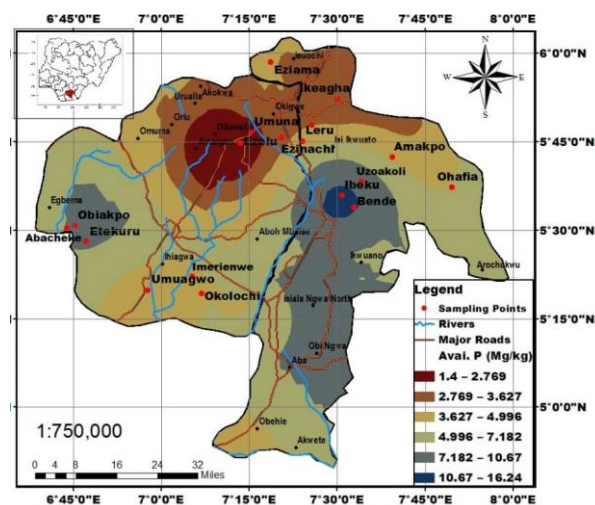


Figure 6. Kriged Map showing the spatial distribution of Available Phosphorus in the study location.

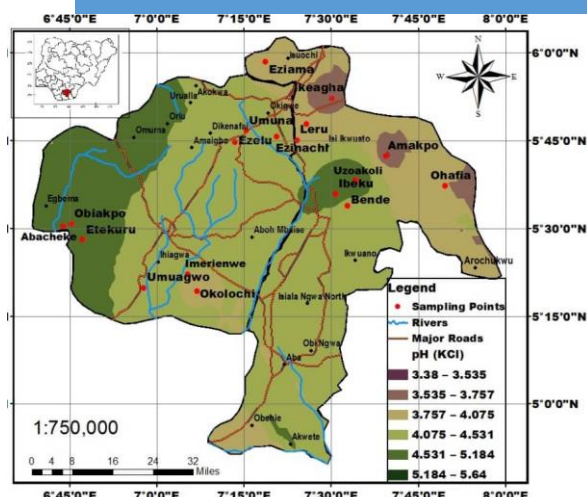


Figure 7. Kriged Map showing the spatial distribution of pH (KCl) in the study location.

Spatial Dependence Patterns:: The strong dependence of soil properties suggests that intrinsic factors (parent material, soil forming processes) and extrinsic factors (fertilizer, tillage, residue management) both play important roles in variability. The short range of pH reflects localized influences, while organic carbon and phosphorus variability spans broader distances, consistent with management practices.

Comparison with Previous Studies:: These findings align with Cambardella et al. (1994), who reported strong spatial dependence in Iowa soils, and Goovaerts (1998), who demonstrated similar patterns in European contexts. Locally, they corroborate studies in southeastern Nigeria that highlighted high variability in fertility indices under intensive cultivation.

Implications for Precision Agriculture:: Identifying ranges of variability provides practical guidance for fertilizer and lime application. Site-specific nutrient management (SSNM) could reduce wastage, improve input efficiency, and sustain yields. Spatial maps also provide tools for policymakers in land allocation and conservation planning.

Table 1. Mean physicochemical properties of soils of the study area.

Horizon	Depth (cm)	Sand	Silt	Clay	SCR	pH	Organic Carbon (%)	Avail. P.	Ca	Mg.	K	Na
								Cml/kg				
A	0-21	964	12.8	23.2	0.55	4.10	7.2	5.39	0.5	0.25	0.005	0.020
AB	21-50	964	12.8	43.2	0.3	4.12	3.4	2.94	0.7	0.30	0.005	0.021
Bt ₁	50-80	924	22.8	53.2	0.43	4.03	3.6	3.64	0.5	0.19	0.003	0.021
Bt ₂	80-131	914	42.8	43.2	0.99	4.17	1.8	3.43	0.6	0.23	0.003	0.022
Bt ₃	131-200	864	13	123.2	0.11	4.08	1.4	2.52	0.5	0.16	0.003	0.018
Mean		926	62.42	57.2	0.48	4.12	3.48	3.58	0.56	0.23	0.00	0.02
CV (%)		4.48	4.48	67.26	69.42	1.82	65.85	30.68	16.13	23.95	28.83	7.10

Table 2: Semi-variogram models and parameters of the selected soil properties in the study area.

Properties	Model	Partial Sill	Nugget	Sill	Range (m)	Spatial Dependence (%)	Spatial Class
Sand (g/kg)	Gaussian	0.2428	0.0324	0.2752	28633.3	11.77	Strong
Clay	Gaussian	0.5335	0.1632	0.6967	76977.8	23.43	Strong
SCR	Gaussian	0.9092	0.232	1.1412	28633.3	20.33	Strong
pH (KCl)	Exponential	0.0308	0.0018	0.0326	27300.0	5.56	Strong
Organic Carbon	Gaussian	0.3536	0.0333	0.3869	31377.8	8.59	Strong
Available Phosphorus	Gaussian	0.4225	0.0874	0.5099	40155.6	17.14	Strong
Calcium	Gaussian	0.2205	0.1989	0.4194	44322.2	47.43	Moderate
Magnesium	Exponential	0.7511	0.1125	0.8637	41544.4	13.03	Strong
Potassium	Gaussian	4.2282	0.121	4.3492	78177.8	2.78	Strong

Conclusion and Recommendations: This study demonstrates that semivariogram analysis is a powerful tool for quantifying soil variability. In Umuagwo soils, pH, organic carbon, and available phosphorus all exhibited strong spatial dependence, with distinct ranges of variability.

These results underscore the need for site-specific soil management to enhance input efficiency and sustain agricultural productivity. The study was limited by sampling density and focused only on three soil properties. Incorporating additional parameters (e.g., micronutrients, bulk density, CEC) and temporal monitoring could provide a more comprehensive understanding. Future work should link kriging maps directly with crop yield data for improved decision-making and as cross validate the data to select the best-fit model for each soil property.

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Hot Water Priming as a Pre-Treatment for Enhancing Germination and Sprouting in Carrot (*Daucus carota*)

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ABSTRACT

Seed priming mitigates environmental challenges, including water and salt stress, hence enhancing seed germination and subsequent growth. This research aimed to investigate the impact of hot water priming on the germination of Carrot (*Daucus carota*) in the Southern Guinea Savannah. The research was performed in the Crop Production Department Laboratory, Faculty of Agriculture, Ibrahim Badamasi Babangida University, Lapai (Latitude 9°06' and Longitude 6°57'). The experiment was structured using a Completely Randomized Design (CRD) and reproduced thrice. The treatments consist of T1 (control), T2 (25°C), and T3 (50°C). The assessed germination attributes include germination percentage, germination velocity, mean germination duration, mean daily germination rate, peak value, and germination value. The results indicated significant differences among treatments ($P < 0.05$) for germination %, peak value, mean daily germination (MDT), and plumule length. Furthermore, no significant variations were seen in germination speed, mean germination duration, or germination value ($P > 0.05$). The experimental results indicated that priming enhanced the majority of the assessed parameters of carrot seeds compared to the unprimed seeds. Priming carrot seeds at 50°C resulted in a substantially increased germination %, peak value, mean daily germination, and plumule length.

Keywords: Carrot, germination, priming, sprouting

Introduction: The carrot (*Daucus carota* L.) is a herbaceous plant that belongs to the Apiaceae family (Rubatzky, 1999). Carrots are botanically classified as biennial plants, meaning they exhibit vegetative growth in the first season and generate seeds in the second season. Nonetheless, the plant is mostly grown for root yield. Low temperatures and certain stressors may sometimes trigger flower formation, especially in certain types. Carrots are cultivated in tropical areas with high altitudes that provide cool nighttime temperatures, as well as in temperate locations globally (De Lannoy, 2021). Carrots thrive in chilly circumstances (10° to 25°C), and their seeds germinate well, if slowly, in such environments. Temperature and soil moisture affect the morphology, hue, and quality of carrots. Optimal grade carrots are produced under weather conditions that promote consistent, continuous development. Optimal plant growth occurs at temperatures ranging from 15° to 20°C, where roots also exhibit superior color and taste development. Seed priming entails pre-sowing treatment of seeds to augment physiological responses, increase germination rates, and ensure uniform sprouting (Farooq *et al.*, 2019). Hot water priming, including the immersion of seeds in warm water for a designated duration, facilitates the softening of the seed coat, enhances water absorption, and activates early metabolic processes inside the seed. Research indicates that this technique may alleviate seed dormancy and enhance the speed and uniformity of germination across many crops, such as carrots (Bradford, 2016). Swift and uniform field emergence is a crucial condition for enhancing yield and product quality, particularly for direct-seeded crops like carrots. The emergence and establishment of carrot seeds are often sluggish and inconsistent, especially under stressful circumstances. Seed priming has effectively enhanced seed vigor in several vegetable and agronomic crops, resulting in accelerated and uniform germination and seedling emergence. It may enhance vitality, particularly in challenging environments such as extreme temperatures, limited water supply, and salinity (McDonald, 2020). Inadequate crop stand establishment is a significant abiotic limitation in both tropical and temperate regions. Numerous factors contribute to this issue, including substandard seed quality, insufficient seedbed preparation, improper sowing timing, and ineffective sowing techniques, as well as abiotic challenges such as drought, extreme temperatures, salt, and unfavorable soil characteristics (e.g., crusting). Seed priming is an effective method for alleviating certain limitations. The goals of the research are to evaluate the optimal temperature in degrees for priming carrot seeds to enhance germination and to ascertain the impact of priming on germination, seedling emergence, and seedling vigor of carrot seeds.

Materials and Methods: The experiment was conducted in the Crop Production Laboratory, Faculty of Agriculture, IBB University, Lapai, Niger State. The experimental location is located at latitude 9°4'6"N and longitude 6°34'24"E in the Southern Guinea Savanna zone of Nigeria, with a mean annual temperature between 21°C to 36.5°C. The experiment used a Petri dish, tissue paper, a watering bottle, and a measuring tape. Carrot (*Daucus carota*) seeds were procured from a reputable seed merchant in Minna recognized for seed quality.

The experiment was conducted using a Completely Randomised Design (CRD). Each treatment in the experiment was performed three times. Each replication included 30 carrot seeds.

Priming with hot water: The carrot seeds underwent priming with hot water. The temperature factor had two values (25°C and 50°C), while the soaking period was set at 5 minutes. For each treatment, 30 seeds were immersed in 100 ml beakers containing water at a consistent, suitable temperature for a length of five minutes; these beakers were positioned in a water bath with regulated temperatures. The dishes were stored in obscurity. Subsequent to the designated duration, the seeds were extracted from the water and allowed to air dry. Seeds were air-dried for 5 hours and then stored before initiating the germination test.

Germination Test: Seeds from each treatment group were submitted to a standardized germination test under regulated circumstances of temperature and moisture. The germination percentage, germination rate, and vigor index will be documented.

Data Collection: Observations were made on number of days for germination required for the first count, germination percentage, germination speed, mean germination time, mean daily germination, peak value and germination value.

Daily and Cumulative germination count: the seeds with radicle growth were observed and counted as germinated seeds. The primary data on seed germination were collected on a daily basis. The final germination percentage was calculated from the total seeds that germinated. Daily germination percentages was summed up to obtain cumulative germination percentage for each treatment.

Germination speed was calculated using the formula described by Aldhous (1972) and Djavanshir and Pourbeik (1976):

$$\text{Germination Speed} = \frac{\text{Final germination percentage}}{\text{Days of completion of germination}}$$

Mean Germination Time (MGT) = Mean germination time was calculated by the formula given by Ellis and Roberts (1981)

$$\text{MGT} = \frac{(n_1 \times d_1) + (n_2 \times d_2) + (n_3 \times d_3) \dots}{\text{Total number of days}}$$

Where: n = number of germinated seed and d = number of days

(MDG): The Mean daily germination was calculated by the following formula given by Czabator (1962)

$$\text{MDG} = \frac{\text{Total number of germinated seeds}}{\text{Total number of days}}$$

Peak Value (PV): Peak value was calculated by the following formula given by Czabator (1962).

$$\text{PV} = \frac{\text{Highest seed germinated}}{\text{Number of days}}$$

Germination Value (GV): Germination value was calculated by the following formula given by Czabator (1962).

$$\text{GV} = \text{PV} \times \text{MDG}$$

Data Analysis: The acquired data was subjected to analysis of variance (ANOVA) to ascertain significant differences across treatments. Post-hoc comparison tests were done with Least Significant Difference (LSD) at a 5% probability level.

Results

Effect of hot water priming on the Germination speed of carrot: The germination speeds of carrot (*Daucus carota*) demonstrated that there is no significant ($p > 0.05$) variation in the germination speed of carrot as impacted by hot water priming. However, priming carrot seeds with hot water at 50°C had the best germination speed, followed by priming with hot water at 25°C and finally control, but were not statistically different as shown in Fig 1

Effect of hot water priming on the Mean Germination Time of carrot: In a manner analogous to germination velocity, the mean germination time of carrot (*Daucus carota*) seeds is displayed in the table. The findings indicated that hot water treatment does not exert a significant ($p > 0.05$) influence on the average germination time of carrot seeds. The results indicated that priming carrot seeds at 50°C resulted in the longest mean germination period, whereas the control exhibited the shortest, as shown in Fig 2.

Effect of hot water priming on Germination percentage of carrot: Figure 3 illustrates the cumulative germination percentage (GP) of *Daucus carota* seeds. The results indicated a substantial difference in germination percentage (GP) among the pretreatment seeds, with the highest GP (76.76%) achieved in seeds primed with hot water at 50°C, exhibiting fewer ungerminated seeds relative to the majority of other treatments. Hot water priming at 25°C resulted in a germination rate of 70%, in contrast to the control group, which exhibited a rate of 5.3%. Nonetheless, there was no substantial difference in germination percentage between seeds primed with hot water at 50°C and 25°C at a 5% probability level.

Effect of hot water priming on Peak value of carrot: Figure 4 illustrates the peak germination value of carrot seeds. The results indicated that the highest peak value (PV) was achieved in seeds primed with hot water at 50°C, surpassing other pre-sowing treatments. Untreated seeds (Control) exhibited a significant difference at the 5% probability level compared to treated seeds, however *Daucus carota* seeds primed with 25°C hot water showed no statistically significant difference ($P > 0.05$) when compared to seeds primed with hot water at 50°C; the control group recorded the lowest peak value.

Effect of hot water treatment on Mean Daily Germination of carrot: Figure 5 indicated that the maximum mean daily germination of *Daucus carota* seeds occurred with seeds primed in hot water at 50°C, followed by those immersed in 25°C hot water for 5 minutes, while the control exhibited the lowest mean daily germination. No significant differences ($P > 0.05$) were observed between the mean daily germination of seeds immersed in 25°C and 50°C hot water.

Effect of hot water treatment on Germination Value of carrot : Figure 6 presented the outcomes of the ultimate germination. The results demonstrated considerable diversity in seed GV across treatments. The germination value of *Daucus carota* was greatest for seeds immersed in 50°C hot water, followed by those soaking in 25°C, and then the control group. Nonetheless, there were no substantial ($P > 0.05$) differences across the therapies.

Effect of hot water treatment on the plumule length (cm) of *Daucus carota*

Figure 7 illustrates the plumule length of carrots as affected by hot water treatment. The results indicated considerable variations in the plumule length of carrots, with seeds soaked in 50°C hot water exhibiting the longest plumule, followed by those soaked in 25°C hot water, while the control group demonstrated the shortest plumule length.

Discussion: This study aims to evaluate the impact of hot water priming on the germination of carrot (*Daucus carota*) seeds. Figure 1 presents the average mean for germination speed, mean germination duration, peak germination percentage, mean daily germination, germination value, and plumule length. The results indicated a significant ($p < 0.05$) difference in germination percentage, peak value, mean daily germination, and plumule length; however, no significant differences were observed in germination speed, mean germination duration, and germination value. The maximum germination speed of 11.96 was seen in carrot seeds primed with hot water at 50°C for 5 minutes, while the minimum speed of 8.5 was noted for unprimed carrot seeds. Sung (2019) showed that seed priming led to an increase in antioxidants such as glutathione and ascorbate, which enhance germination speed by reducing lipid peroxidation activity. The likely cause for the premature emergence of primed seeds is the completion of pre-germination metabolic processes, which prepare the seed for radicle protrusion.

Priming methods enhance the germination percentage of carrot seeds, with hot water priming at 50°C yielding the most favorable mean germination time. The current finding aligns with Selvarani's (2011) previous research, which indicated that hydro-priming carrot seeds with 45°C hot water enhances radicle protrusion percentage, reduces days to 50% germination, decreases days to maximum germination, increases germination speed, and elevates germination percentage by 10, 22, 25, 11, and 12, respectively, compared to the control group. Nascimento *et al.* (2013) reported that at 35°C, the germination percentages for unprimed and primed carrot seeds were 35% and 65%, respectively. The elevated germination percentage of primed seeds may result from the alleviation of dormancy and the elimination of germination inhibitors. Hydro-priming influences DNA and RNA synthesis, ATP availability, alpha-amylase activity, and enhances embryonic growth. Consequently, enhanced germination rates, consistent growth, vigorous seeding, and development contribute to superior plant growth (Basra *et al.*, 2006; Harris *et al.*, 2019).

The average performance of seedling plumule length varied between 4.31 cm and 4.89 cm. The maximum value was seen in seeds subjected to 50°C hot water treatment. This outcome aligns with the findings of Eisvand *et al.* (2011), who indicated that hydro priming treatment enhanced both shoot and root length of seedlings in two carrot cultivars compared to hormonal treatments. Sanchez *et al.* (2021) also discovered that hydro-priming enhanced the root length of cucumber and carrot.

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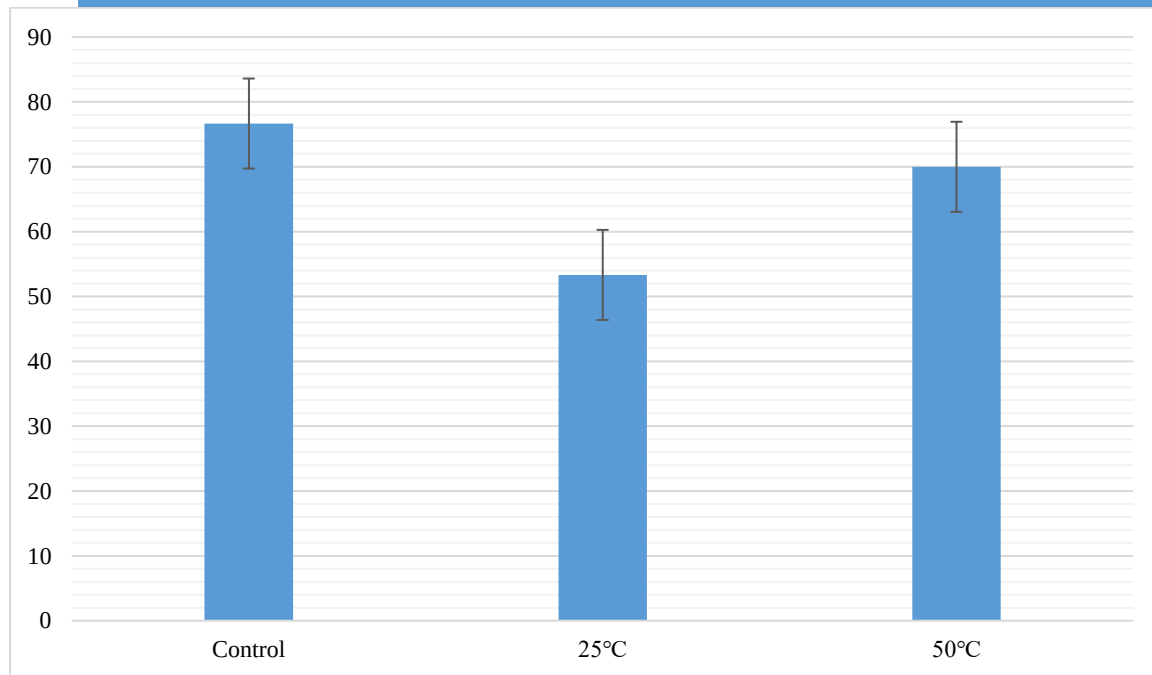


Figure 1: Effect of hot water priming on the Germination speed of carrot

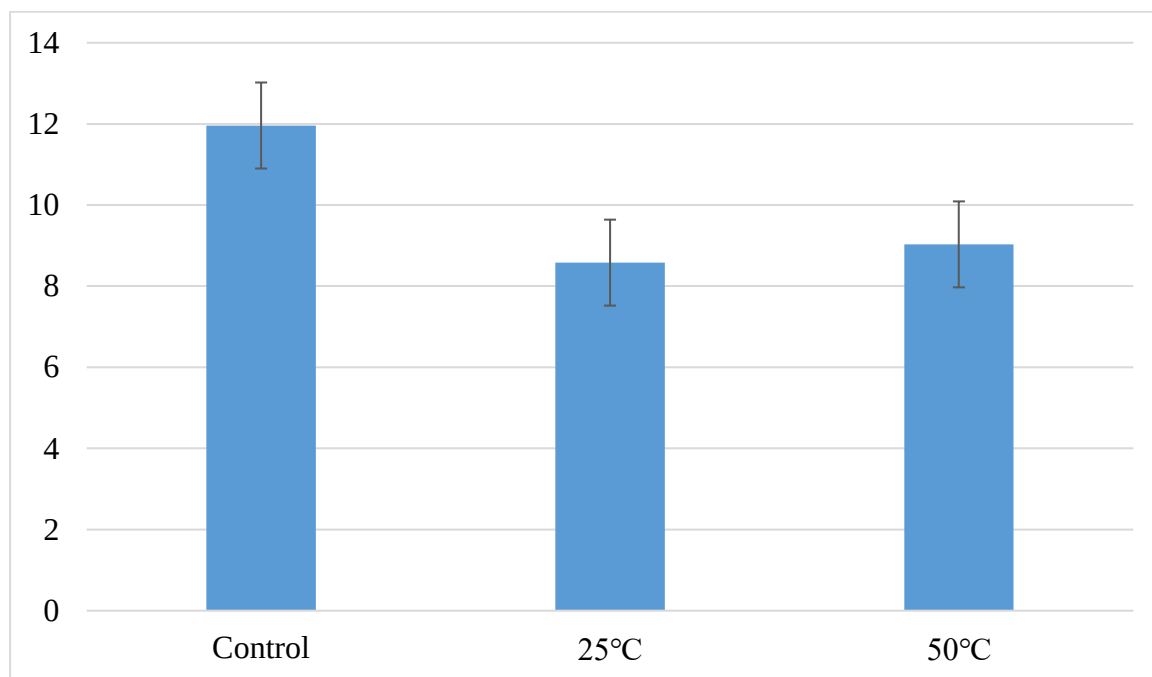


Figure 2: Effect of hot water priming on the Mean Germination time of carrot

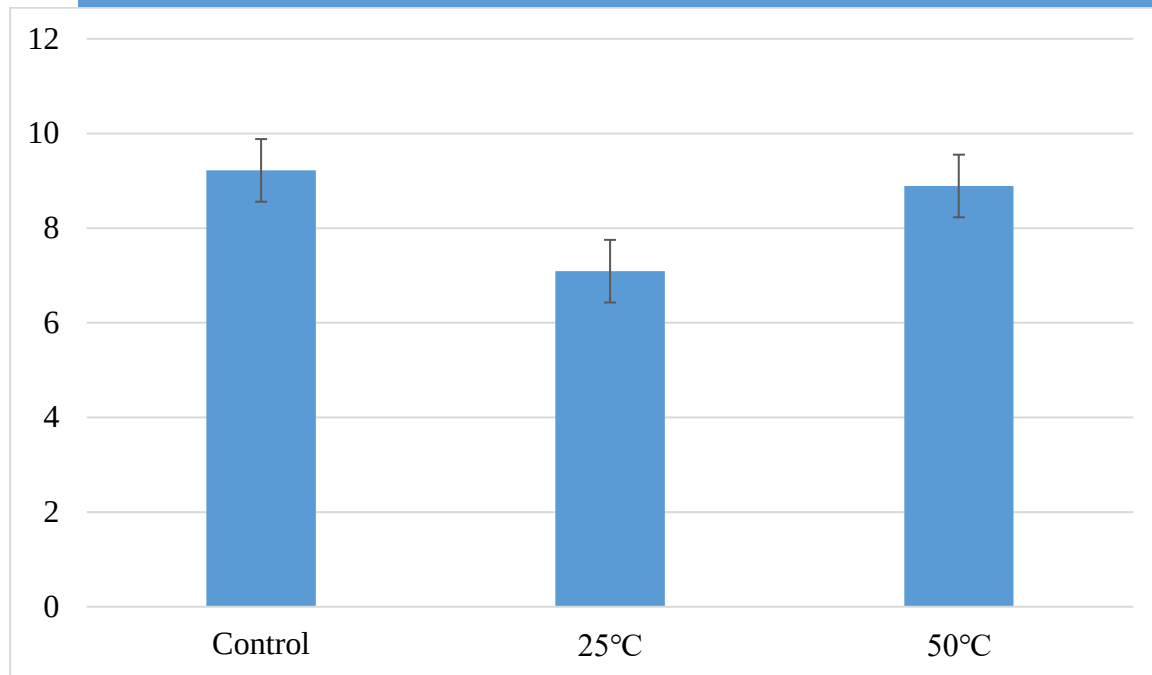


Figure 3: Effect of hot water priming on Germination percentage of carrot

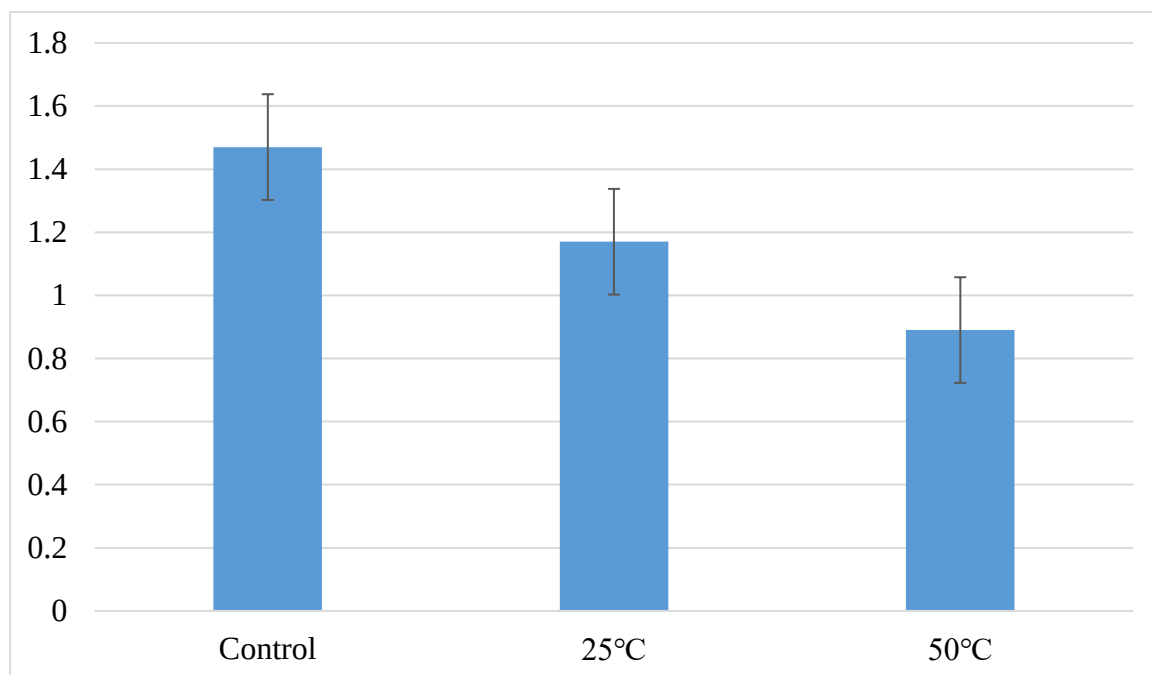


Figure 4: Effect of hot water priming on Peak value of carrot

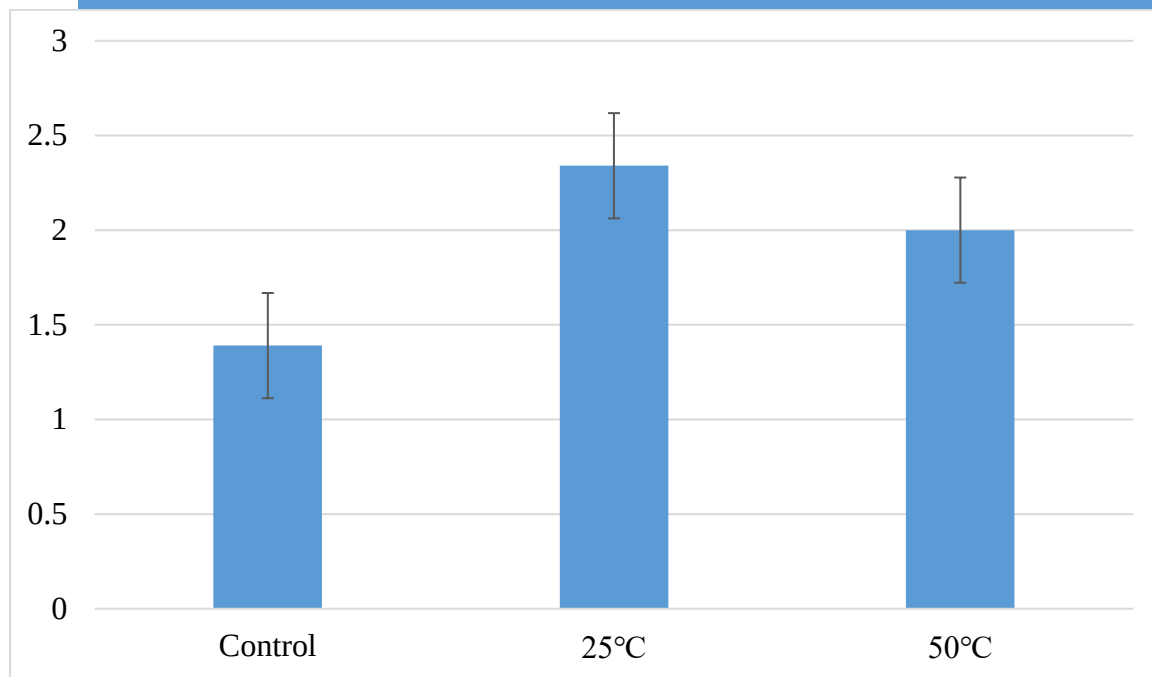


Figure 5: Effect of hot water treatment on Mean Daily Germination of carrot

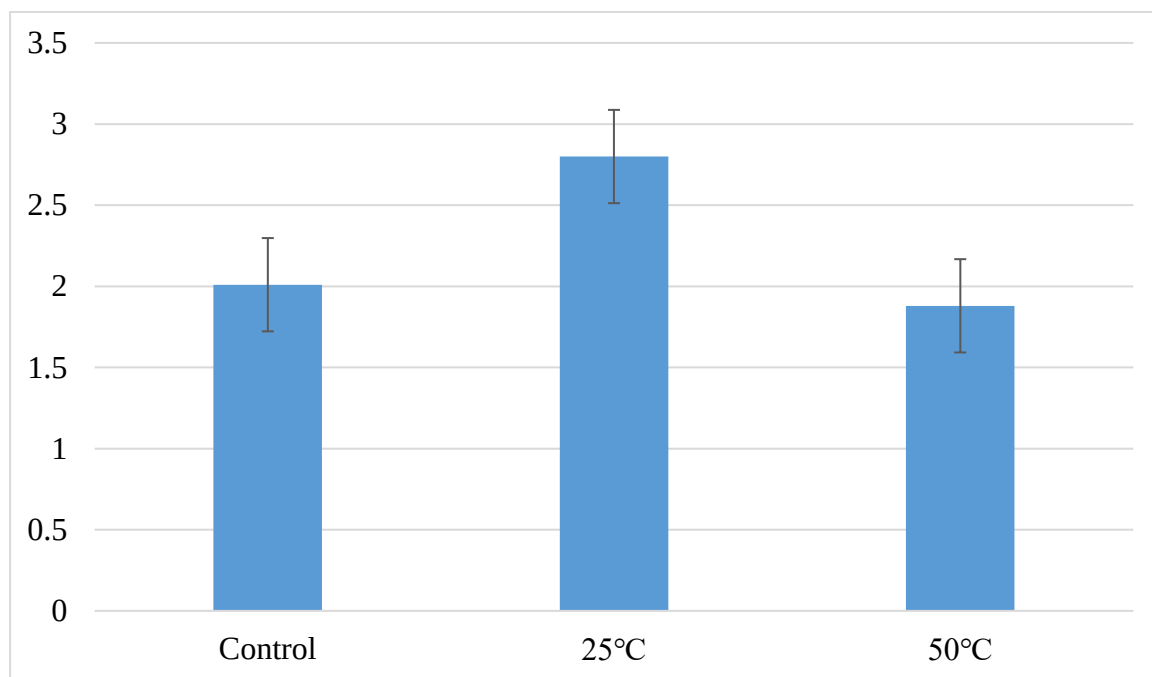


Figure 6: Effect of hot water treatment on Germination Value of carrot

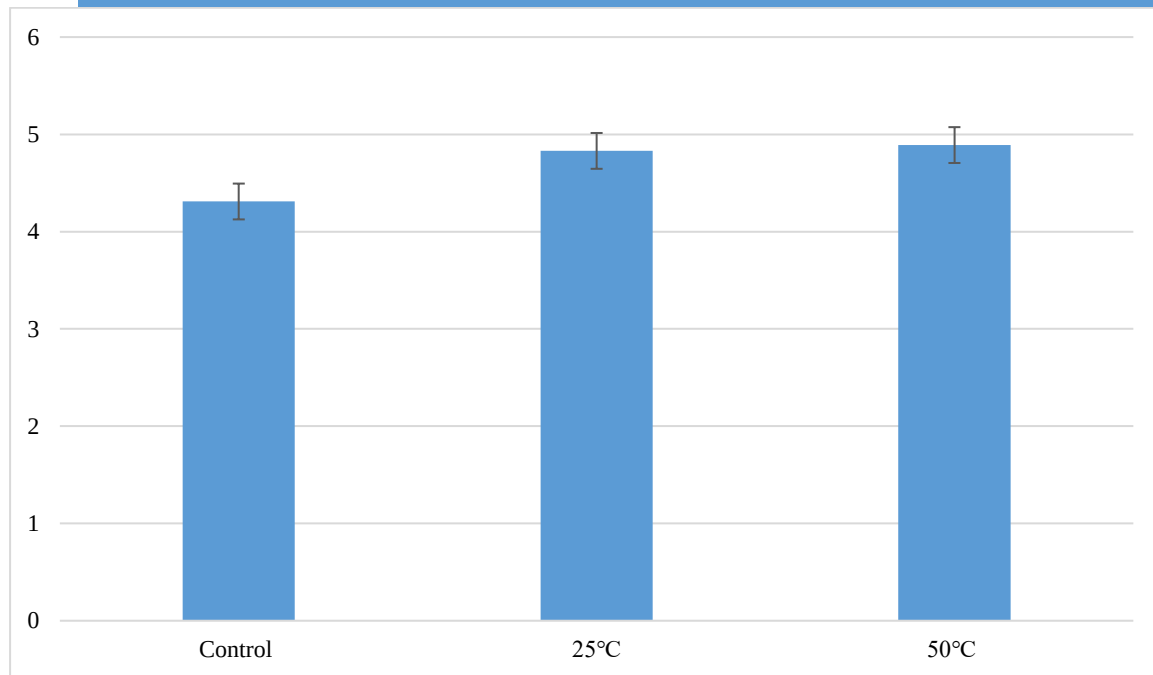


Figure 7: Effect of hot water treatment on Plumule length (cm) carrot

The Consumers' Preference on Consumption of Locally Produced Rice in Jigawa State, Nigeria

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Abstract

The huge rice importation negatively affected locally produced rice consumption as most consumers opted for imported rice. Major reason advanced for the preference of imported rice includes; the presence of stones and other impurities such as rice husks, rock pebbles and dirt in the locally produced rice. Conducting a study on consumers' willingness to consume local rice lies in its potential to provide insights and address several important issues. This research analysed the consumers' preference for local rice in Jigawa State, Nigeria were investigated. The general objective of the study was to evaluate the factors that influenced consumers' willingness for local rice consumption in Jigawa State, Nigeria. Data were collected from 400 respondents in four local government areas using structured questionnaire. Data collected were analysed using descriptive and inferential statistics. Majority of the respondents were male, with mean age of 28 years, mean household size of 6 persons, and had formal education. The factor analysis result revealed that the respondents' willingness to consume local rice was influenced by four factors (colour, good packaging, price, and quality) explaining 62.0% variance in consuming local rice. Thus, there was a positive correlation between rice attributes and the respondents' intention to consume it in the study area. Regression analysis results also showed that quality (0.528, $P < 0.000$), good packaging (0.263, $P < 0.000$), and colour (0.134, $P < 0.000$) influenced rice consumption among the respondents in the study area. However, price ($=\beta -0.006$, $P < 0.806$) did not. Moreover, it was concluded that rice consumption in the study area was affected mainly by presence of foreign matter irrespective of the brand and packaging, and the unevenness in the size of the grains). Recommendation made was to invest in local rice processing which should be centered on equipment that will eliminate stones and sand in local rice and also improve its cleanliness.

Keywords: Consumer, Preference, Consumption, Local Rice, Jigawa State, Nigeria

Introduction: Over the decades, rice has occupied a prominent position as a strategic crop for food security and economic development in many nations of the world. Rice is a crop that provides food for approximately half of the world's population (Mohidem et al., 2022). World rice consumption has been estimated at an annual growth rate of four percent; the estimated consumption rate is higher in Africa at about 27-28 million Mt (Arouna & Aminou, 2021). Rice production is projected to increase, on a global scale, 567 Mt by 2030 (Mohidem et al., 2022). Leading producers of rice include China (148.30 Mt), and India (120 Mt) while Nigeria ranked 12th country in rice production with an annual production of 5.04 Mt (United States Department of Agriculture, (USDA), 2022). Nigeria's rice consumption stood at 7.3 Mt of milled rice while supply is 4.98 Mt, leaving a huge gap of 2.32 Mt which is mainly filled through import (USDA, 2023). Projections reveal a significant increase in the demand for rice in Africa, driven primarily by population growth, dietary changes, and intensification [Organisation of Economic Cooperation and Development/Food and Agriculture Organisation (OECD/FAO), 2021]. OECD/FAO 2021 citation is incomplete (brackets not properly closed). Staple foods such as rice, are key priority commodity to the actualization of food security objective in Nigeria. This assertion justifies why billions were spent by various government regimes in importing rice to meet the shortfall of supply in the rice value chain. In recent times, investment in locally produced rice production has led to the reduction in food import bill by more than 64 percent (Oteh et al., 2019; Nwachukwu & Achike, 2020). Although Nigerians have seen improvement in rice production and its value chain activities, poor branding, communication strategy; and wide gaps in locally produced rice supply and demand have limit the nations' ability to achieve competitiveness and stimulate local economic opportunities thereby creating export opportunities, and employments for other nations. The consumption of rice in Nigeria has shown tremendous improvement. Hitherto, rice was considered as a festive food that was eaten during Christmas, Easter, Sallah, marriage, and burial ceremonies among other festivities. However, consumption of rice and preference for local rice by many households have increased considerably in recent times (Warda et al., 2022).

Rice is the most widely accepted and consumed staple food by both the urban and rural populace in Nigeria (Johnson, 2013). Some citations are outdated (e.g., Johnson 2013, Ogundele 2014) without linking to more recent improvements in local rice processing. Eighty-two percent of Nigerians eat rice at least once a day (Ogundele, 2014). The locally produced rice was of poor quality due to the presence of stones, husk, impurities, and large quantities of uneven and broken grain. In Nigeria, rice is a diet of an estimated population of 200 million consumers and it is cultivated widely across all states. Consumers are the ultimate and foremost deciders when it comes to selecting between different types of goods. The quality differential between local and imported rice thereby seems very important. Before 2010, about 71% of rice was processed by small- scale cottage mills with a capacity of 10–300 kg hr⁻¹ in Nigeria. However, with improvement in rice processing by cottage industries, production capacity was raised to 50kg hr⁻¹–500kg hr⁻¹ (Ugalahi et al., 2016a) and most of the cottage industries were located in major paddy rice-producing areas. The importance of rice as a food security crop cannot be overemphasized. Rice is a vital crop globally, accounting for over 21% of human caloric requirements (Mohidem et al., 2022). Rice contains a significant number of calories and a wide variety of essential vitamins, minerals, and other nutritional values. Its nutrients are superior to those found in maize, wheat, and potatoes. It is also recognized as a great source of vitamins E and B5 as well as carbohydrates, thiamine, calcium, folate, and iron. Phytic acid and phenols are among the phenolic compounds found in rice, alongside sterols, flavonoids, terpenoids, anthocyanins, tocopherols, tocotrienol and oryzanol. These compounds have been positively linked to antioxidant properties and have been shown to help prevent cardiovascular disease and diabetes (Mohidem et al., 2022).

In sub-Saharan Africa (SSA), rice has become a major staple food as consumption patterns change and consumers' preference for rice increases (Obayelu et al., 2022). The locally produced rice marketing system was characterized by many challenges such as low product specialization, high degree of price differentiation, poor packaging, grading, and standardization (Ogundele, 2014). All these factors led to consumer preference for imported rice brands. Rice importation in Nigeria, which has been rising for the last two decades, is a drain on the country's foreign exchange reserves as Nigeria spends an average of USD 300 million per year to import rice (Johnson, 2013). As a panacea to huge import bills, studies have recommended some improvements to the quality of locally produced rice brands (Alfred & Adekayode, 2014). Rice is becoming an increasingly popular food in Africa because it is easy to store for a large variety of dishes. In Nigeria, rice is a diet of an estimated population of 200 million consumers (USDA, 2023) and it is cultivated widely across the states, extending from the North to the South with most of it grown and consumed in the North west part of the country, of (Kano, Kaduna, Jigawa states), North east part of (Borno and Taraba states) North central at (Benue and Niger states and South Eastern part of the country of (Ebonyi and Enugu State) (Odumade, 2016; Emodi & Madukwe, 2011). Jigawa state is chosen as a major rice-producing state across the country that has consumer behavior issues, therefore this study tend to analyses the consumers' preference on consumption of locally produced rice in jigawa state Nigeria and to examine consumers' willingness to consume local rice in Jigawa State.

2. METHODOLOGY: The study was conducted in Jigawa state. Jigawa state is one of the 36 states of Nigeria, situated in the North western region of the country. The state covers a land area of about 22,410sq Km (Jigawa State Government, 2016). It is bordered on the West by Kano state, on the East by Bauchi and Yobe states and to the North by Katsina and Yobe states, and the Republic of Niger. The state has an estimated population. The population for this study was drawn from for LGA's in Jigawa State. Using a multi-stage sampling procedure, four agricultural zones (Brinin-Kudu, Kazaure, Hadejia and Ringim) of the State were selected for the study. Thus, Dutse, Ringim, Kazaure and Hadejia LGA were selected from Birnin-Kudu, Ringim, Kazaure and Hadejia zones, respectively. Also, the local government headquarters of the selected LGAs were purposively selected based on the concentration of their headquarters (Dutse metropolis, Ringim Township, Kazaure metropolis and Hadejia Township) and the projected in each area was considered (NPC, 2023 projected). The last stage involved the application of the probability proportion to size (PPS) sampling method to select a sample size of 400 respondents, using Yamane et al. (1967) proportion allocation formulae at 95% confidence level.

$$Yamane = \frac{N}{1+N(e)^2} \dots\dots\dots(1)$$

N= sample frame (947,500) e = precision level (0.05)

n= sample size (**399.83 ≈ 400**)

The Bowley's proportion allocation formula was then used in the selection of respondents at each stratum;

$$n_i = n \frac{N_i}{N} \dots\dots\dots(2)$$

Where:

n_i = Sample size at i^{th} strata,

n = Total sample size,

N_i = population at each Strata,

N = Total population

Table 1: Sample Size Selection Framework

Zone	LGA	Selected area	Sample frame	Sample size
Birnin-Kudu	Dutse	Dutse metropolis	335,600	142
Gumel	Ringim	Ringim township	257,100	108
Kazaure	Kazaure	Kazaure metropolis	215,400	91
Hadejia	Hadejia	Hadejia town	139,400	59
Total	4	4	947,500	400

Source: Researcher's Reconnaissance Survey (2022)

The state lies between latitudes 11.00°N to 13.00°N and Longitudes 8.00°E to 10.15°E with a tropical climate while the temperature varies at different times. High temperatures are normally recorded between April and September. The daily minimum and maximum temperatures are 15°C and 35°C. The rainy season lasts from May to September with average rainfall of between 600 millimeters to 1000 millimeters. The southern part of the state has a higher rainfall percentage than the northern part (Jigawa State Agricultural Policy, 2016). The state is situated within the Sudan savannah vegetation zone, but there are traces of Guinea savannah in the southern part of the state. Its total forest covers about 5% due to rainfall characteristics and deforestation primarily due to the use of wood for cooking. The State is mainly populated by the Hausa, Fulani, Mangawa, Badawa and Ngizimawa which are dialects of the Kanuri language (Jigawa State Agricultural Policy, 2016), they constitute significant percentages in Birniwa, Guri and Kirikasamma local government areas. There are other settled tribes both from within and outside Nigeria inhabiting almost all the LGAs of the state with the highest concentration in the state capital.

The topography of the state is generally flat with the northern, central, and eastern parts covered with undulating dunes running in the Southwest to Northeast direction. The area around the state capital Dutse is very rocky with some low hills. The southern and western parts of the state around Birnin Kudu and Kazaure LGAs have the highest elevations with hills as high as 600 millimeters above sea level (Jigawa State Agricultural Policy, 2016). The state is bisected by the Hadejia River and traverses the state from the west to the east through Hadejia-Nguru wetlands and empties into Lake Chad.

Jigawa State is blessed with a large expanse of agricultural land, rivers and flood plains, suitable for crops, livestock and fish production. Based on this over 80% of the State's total land mass is considered arable, which makes it one of the most agriculturally endowed States in Nigeria. The major cultivations in Jigawa State are the rainy and dry season crops. Rain-fed crops include cereals, legumes, sesame, sweet potatoes, bambara nuts, cassava, cotton, okra, roselle and watermelon, and the dry season farming production includes tomatoes, pepper, onions, wheat, sugarcane, carrots, cabbage, lettuce and maize.

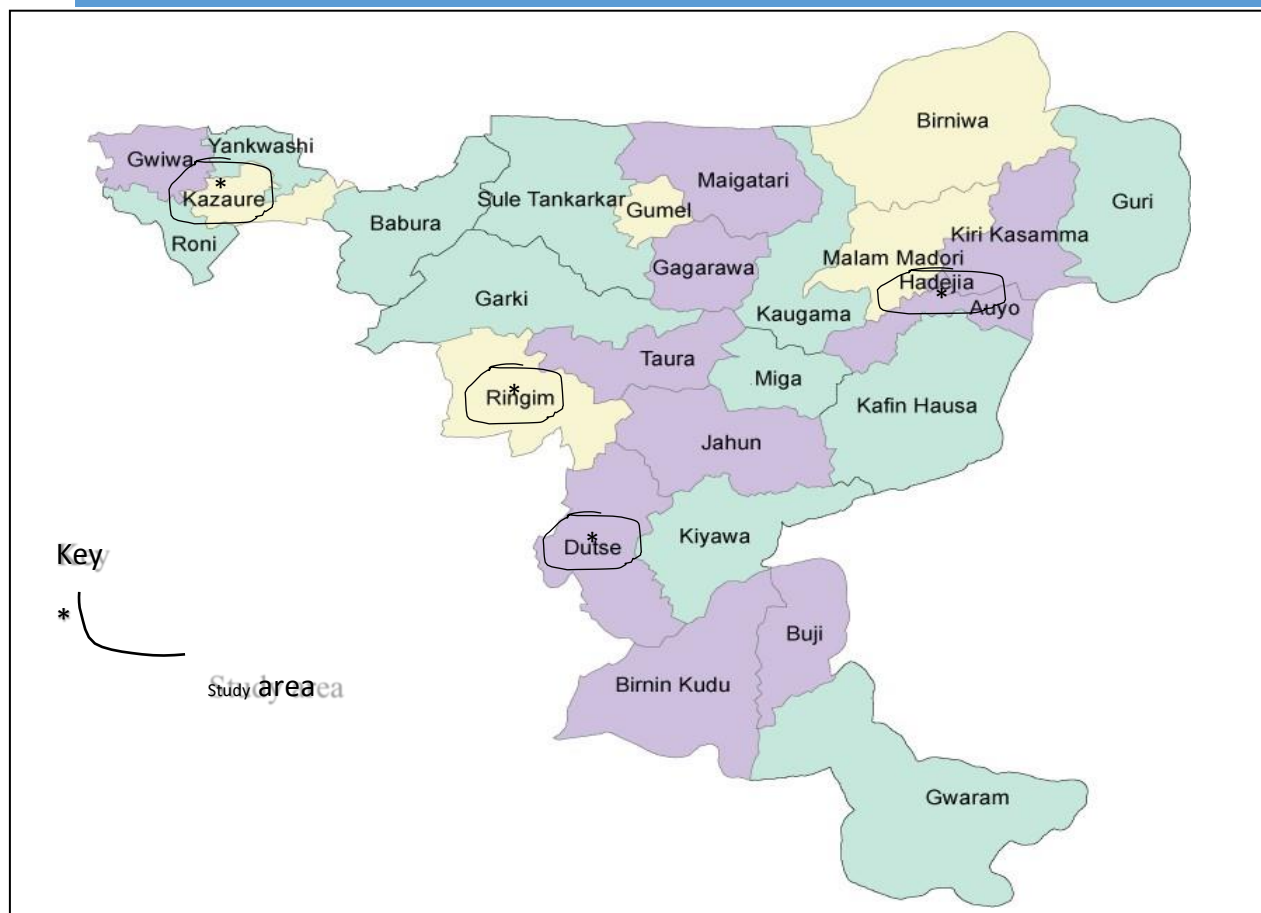


Figure 1: Map of Jigawa state showing the study area.

RESULT AND DISCUSSION

Quality of Local Rice: The mean scores and percentages of different components included in the set of questions for LR quality using a 5-point scale (1 to 5) are shown in Table 2. The results on quality indicated that most of the respondents agreed that they had the intention to consume it. As seen in Table 2, the following items: 'Taste, non-stickiness, and conditions after cooking define quality' had a mean value of 4.7, 'quality is the first requirement no matter the price' and 'quality differs from one brand of rice to another', with a mean value of 4.41 respectively. Then 'there is no relationship between price and quality', with a mean value of 4.39. 'The satisfaction from LR defines quality' had a mean value of 4.30, and then 'Advertisement defines the quality of LR' had a mean value of 4.25. Then 'quality in terms of appeal and aroma', with a mean value of 4.18. 'Taste and swelling ability show quality' followed with a mean value of 4.17, then 'No too much usage of chemicals in processing' had a mean value of 3.28. 'It has a high palatability rate' followed by a mean value of 3.20, then 'I attribute good packaging to the quality of what am buying' with a mean value of 3.09, then the odour is minimal with a mean value of 3.03. While there are no presences of dirt' recorded the lowest mean value (2.53).

The total average mean (3.82) showed that the respondents believed the statements on LR quality influenced their willingness to consume it in the study area. This distribution was in harmony with the findings of Wahyudi et al. (2019) in their study on factors influencing the frequency of purchase of locally produced rice in Indonesia. The result also agrees with that of Demont and Ndour (2015) who showed that there is ample evidence of growing consumer awareness about rice quality attributes. The result of this study aligns with the findings of Opeyemi et al. (2015) who reported similar determinants of locally produced rice to include the fact that its consumption saves money, consumers know its source and because it tastes better, good health benefits and improves the local economy. This result attested that ample evidence exists in support of consumers' growing interest in the quality attributes of rice, especially LPR. This line of thought is in harmony with the findings of Ayeduvor (2018) who noted that factors such as physical appearance, ease of cooking, aroma, absence of foreign material, percentage of broken rice, perception of nutrient content, and origin influence consumer's preferences for particular types of rice are key to consumers' preference.

Table 2: Consumer Preference to Consume Local Rice with Respect to Quality

Statement	Quality					mean	SD
	1*	2*	3*	4*	5*		
For me, quality is the first requirement no matter the price	1.3	8.5	8.3	11.8	70.3	4.41	1.034

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Quality differs from one brand of rice to another	1.0	16.3	10.8	11.8	60.3	4.41	1.197
Advertisement defines the quality of LR	1.5	12.3	10.3	11.8	64.3	4.25	1.145
I define quality in terms of appeal and Aroma	0.8	12.8	12.0	16.8	57.8	4.18	1.116
Taste and swelling ability show quality	1.0	13.3	12.5	14.8	58.5	4.17	1.143
The satisfaction I get from LR defines quality	0.3	10.5	11.5	14.2	63.5	4.30	1.051
There is no relationship between price and quality	0.3	7.5	11.0	15.8	65.5	4.39	0.969
Taste, non-stickiness, and conditions after cooking define quality	1.3	9.0	9.5	14.2	65.8	4.47	2.443
I attribute good packaging to the quality of what am buying	12.0	21.3	26.5	26.3	14.0	3.09	1.229
It has a high palatability rate.	9.8	13.8	33.8	32.0	10.8	3.20	1.113
The odour is minimal	11.8	19.3	30.0	32.3	6.8	3.03	1.121
There is no presences of dirt	28.0	26.8	19.0	17.3	9.0	2.53	1.303
Not too much usage of chemicals in processing it	12.0	13.3	27.3	30.0	17.5	3.28	1.241
Overall mean	3.82						

Source: Field Survey, 2022

Key: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), 5 (strongly agree)

3.1 .1. Packaging of local rice: The good packaging results indicated that most of the respondents agreed that their willingness to consume LR was due to its good packaging. As seen in Table 2, the following statements: ‘Good packaging and quality are best for me’ had a mean value of 3.48, followed by ‘Good packaging sells more than price’, with a mean value of 3.19. Then ‘am moved by colour and attractiveness’, with a mean value of 3.17. Then ‘Good packaging is more specific than even the brand name’ has a mean value of 3.15. Next is, ‘Good packaging is a function of satisfaction for me on purchase’ with a mean value of 3.02. Followed by ‘the packaging appeals only to a minority’ with a mean value of 2.99, then ‘Brand name is very important for me while purchasing rice’, with a mean value of 2.96. While ‘Packaging reflects the quality of the product’, with a mean value of 2.91. The percentages to which the respondents reacted to the items with the least mean shows the following results: strongly disagree (20%), disagree (21.3%), Neither agree nor disagree (20.5%), agree (24.8%), and strongly agree (13.5%). The total average mean (3.11) indicated that the respondents acknowledged that the statements of good packaging are less influenced their willingness to consume LR in the study area. This proposition is in line with the submission of Rahnama (2017) that packaging and labeling related to food safety are hypothesised to positively influence consumer preferences and their frequency of purchasing locally-produced rice (Rahnama, 2017). This result agrees with the opinion of Widayanti et al. (2020) that branded packaged rice is generally better in attributes compared to bulk rice. This is because; a branded package not only aims to attract consumer’s attention but also increases the quality of the rice indirectly. The next attribute of interest to the consumers was the colour or the brightness/whiteness of LR. As such, the appealing nature of rice is all that is needed to spur their interest in LR. It is on this basis that most consumers do consider imported rice to be superior in quality and therefore, use this to differentiate between the local and the imported rice.

Table 3: Consumers Preference to Consume Local Rice with Respect to Packaging

Statement	Percentage (%)					Mean	SD
	1*	2*	3*	4*	5*		
Packaging							
Packaging reflects the quality of the product	20.0	21.3	20.5	24.8	13.5	2.91	1.340
Am moved by color and attractiveness	12.8	19.0	22.5	30.3	15.5	3.17	1.264
Good packaging and quality are best for me	10.8	13.3	19.0	31.0	26.0	3.48	1.298
Good packaging is a function of satisfaction for me on purchase	14.5	21.8	25.5	24.0	14.2	3.02	1.269
Good packaging is more specific than even the brand name	12.0	17.3	28.7	27.5	14.5	3.15	1.220

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Good packaging sells more than the price	11.0	17.0	29.5	26.8	15.8	3.19	1.214
The brand name is very important for me when purchasing rice	13.0	24.0	29.3	21.5	12.3	2.96	1.211
The packaging was so appealing that I could not resist	12.8	18.3	37.8	20.3	11.0	2.99	1.157
Overall mean	3.11						

Source: Field Survey, 2022

Key: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), 5 (strongly agree)

Colour of local rice: The results for colour indicated that most of the respondents agreed that their readiness to consume LR was influenced by its colour. As seen in Table 3, the following statements: ‘Overall satisfaction with LR is a product of colour and quality’ has a mean value of 3.91, followed by ‘Colour adds value to what am paying for’, with a mean value of 3.83. Then ‘Brown rice is the best for me’, with a mean value of 3.76. Then ‘I prefer all white long grain LR’ has a mean value of 3.64. ‘The size, quality or packaging of LR doesn’t matter, I want it gold and shiny’ has a mean value of 3.58. While ‘I get involved more with colour than quality of LR’ records the lowest mean value (3.35). The percentages to which the respondents reacted to the statements with the least mean shows the following results: strongly disagree (9%), disagree (31.3%). Neither agrees nor disagree (16%), agree (3.5%), and strongly agree (40.3%) The total average mean (3.68) indicated that the respondents acknowledged that the items of colour influenced their willingness to consume LR in the study area. This finding was consistent with the studies conducted by Miroso and Lawson (2012), and Cranfield et al. (2008) reported that colour to be one of the main features indicating the high quality of local rice. However, this result is in contrast with the findings of Wahyudi et al. (2019) who observed a negative significant influence of the colour of rice on the frequency of consumers’ purchases of locally-produced rice.

3.1.2.

Table 4: Consumers' preference to Consume Local Rice in Respect to Colour

Statement	Percentage (%)					Mean	SD
	1*	2*	3*	4*	5*		
Colour							
I prefer all white long grain LR	7.0	24.0	16.3	3.8	49.0	3.64	1.455
Brown rice is the best for me	6.0	21.5	16.5	3.0	53.0	3.76	1.428
The size, quality or packaging of LR doesn't matter; I want it gold and shiny.	5.8	26.3	18.5	3.8	45.8	3.58	1.426
I get involved more with color than the quality of LR	9.0	31.3	16.0	3.5	40.3	3.35	1.484
Color adds value to what am paying for	6.5	14.8	20.0	6.5	52.3	3.83	1.369
Overall satisfaction with LR is a product of colour and quality	5.0	15.8	18.0	5.8	55.5	3.91	1.346
Overall mean	3.68						

Source: Field Survey, 2022

Price of Local Rice: The price results indicated that most of the respondents agreed that their willingness to consume LR was influenced by price fluctuations. As seen in Table 5, the following statements: 'The price of LR moderates my purchase' had a mean value of 4.47, followed by 'Anything of value should be expensive for me', with a mean value of 3.75. Then the difference in price matters while choosing purchase', with a mean value of 3.73. Then 'Price is a determinant for purchase' has a mean value of 3.72. 'Satisfaction should be derived from price and not colour' has a mean value of 3.66. 'Price is greatly influenced by good packaging' had a mean value of 3.60, then 'Low price means low quality of produce', with a mean value of 3.42. While 'Does quality affects price' recorded the lowest mean value (3.05). The percentages to which the respondents reacted to the items with the least mean shows the following results: strongly disagree (21.3%), disagree (24.5%) neither agree nor disagree (14.5%), agree (7.8%), and strongly agree (32%). The total average mean (3.68) indicated that the respondents acknowledged that the statements on price influenced their willingness to consume LR in the study area. This result was corroborated by the findings of Razak et al. (2016a) and Khan and Ahmed (2012) who reported that product quality and price were the foundation and critical determinants of consumer satisfaction. According to Wahyudi et al. (2019), the product's price and promotion significantly influenced consumers' frequency of Purchasing locally-produced rice, since consumers' interest in the consumption of LR was found to be dependent on price, increasing the quality of locally-produced rice, applying an appropriate marketing strategy such as offering a relatively lower-priced product compared to the price of imported rice, and product promotion could be potent measures in increasing the intention of consumers to purchase locally-produced rice.

Table 5: Consumer preference to Consume Local Rice in Respect to Price

Statement	Percentage (%)					Mean	SD
	1*	2*	3*	4*	5*		
	Price						
Price is a determinant of purchase	11.0	16.0	13.3	9.8	50.0	3.72	1.479
The difference in price matter when choosing purchase	9.3	19.0	11.8	9.8	50.2	3.73	1.464
Does quality affect the price	21.3	24.5	14.5	7.8	32.0	3.05	1.567
Price is greatly influenced by good packaging	11.3	19.0	14.5	8.8	46.5	3.60	1.493
Low price means low quality of produce	14.2	22.5	11.8	10.0	41.5	3.42	1.544
Anything of value should be expensive for me	8.3	19.8	11.3	10.5	50.2	3.75	1.445
Satisfaction should be derived from price and not colour	10.3	21.6	12.3	9.3	46.8	3.66	1.750
Does the price of LR moderate for you to purchase?	1.3	9.0	9.5	14.2	66.1	4.47	2.743
Overall mean	3.68						

Source: Field Survey, 2022

4.5 Preference to Consume Local Rice: The mean scores and percentages of different components included in the set of questions for the LR consumption intention of the respondents are shown in Table 6. The LR consumption intention results indicated that most of the respondents agreed that they had the intention to consume it. As seen in Table 4.8, the following statements: ‘People do consume local rice in the study area’ (3.54), followed by ‘LR is always affordable’, with a mean value of 3.37. Then ‘it is always accessible’, with a mean value of 3.32. Then ‘It’s just my personal preference to consume LR has a mean value of 3.26, and ‘Then government compels us to start eating local rice due to ban on importation of foreign rice’ has a mean value of 3.25. Then ‘I consume LR because of its availability’, with a mean value of 3.18. ‘The sweetness of LR is okay for me’ followed with a mean value of 3.14, then ‘Due to my low-income earning’ has a mean value of 3.07. Then ‘It’s very easy to cook and eat’, with a mean value of 3.02. And ‘because it tastes better has a mean value of 3.00. Others are, ‘the colour of LR is appealing to my eyes’ (2.94), then ‘Eating LR was recommended by my friends and loved ones’ (2.83), and ‘Advertisement made me start eating local rice’ (2.65). While ‘I farm rice, every season’ records the lowest mean value (2.61).

The percentages to which the respondents reacted to the items with the least mean shows the following results: strongly disagree (29%), disagree (20.8%). Neither agrees nor disagree (20.3%), agree (20.3%), and strongly agree (9.8%). The total average mean (3.08) showed that the respondents provided statements on LR consumption intention that influenced their willingness to purchase it in the study area. This outcome agreed with the finding of Cofie et al. (2024) who affirmed that there is a strong positive and significant relationship between attitude, subjective norms, perceived behavioral control, and intention to consume locally produced rice. The identification of the sweetness of LR rice as one of the prime motivators is not surprising because other than issues like the presence of impurities, consumers in the study area have little or no problem with the taste of LR as earlier indicated, this result negates the findings of Cofie et al. (2024) where it was revealed that the lack of sweet-scented aroma of the local rice, which is usually associated with foreign rice when cooking, is a factor for the lack of preference for the local rice in Ghana. This disparity could be attributed to the processing: parboiling, milling and handling, of LPR in the two countries. The general accessibility, acceptability and consumption of LPR in the area could be explained on the basis of government policy on the importation of foreign rice into the country. This policy leaves consumers with no option but to consume LPR. According to Ajayi and Ajiboye (2020), the knowledge of preference for local rice and its determinants will improve the food security of people and enhance consumers’ satisfaction in the nation which in turn will redirect efforts towards the achievement of the government’s policy objective of becoming self-sufficient in rice production.

The question of the low-income status of consumers in the study area is considered one of the drivers of

consumers' intention to consume LR. This analysis points to the fact that consumer food choice is influenced by food product prices and quality and consumers' income. Common with consumers' behaviour, when there is an increase in income, the households tend to look for variety and exoticism in their food products which is most likely found in imported food products rather than LR. This attitude is seen in our society as a prestige lifestyle. This assertion is supported by the view of Kwakwa et al. (2013) in his study on consumer preferences and willingness to pay for locally produced rice in Ghana. Other characteristics such as colour prompt consumers' interest in purchasing and consuming LPR. In most instances, some locally produced rice could be whiter than some imported rice, the general trend and belief of consumers is that imported rice is usually whiter than local rice. This notwithstanding, consumers in the study area considered the appealing colour of LR as a key driver that spurred their intention to consume LR. Government interventions through policies to promote local production also drive consumers to purchase and consume LR. This is seen prominently in the recent total ban on the importation of rice by Nigeria's government; this policy not only encourages domestic production but equally encourages the consumption of LPR. As noted by Ajayi and Ajiboye (2020), several efforts and policies have been put in place by the government towards making the country self-sufficient in rice production, even though, consumer choice is generally governed by taste, price, convenience, variety, and quality.

Table 6: Consumers' Preference to Consume Local Rice

Statement	Percentage (%)					Mean	SD
	1*	2*	3*	4*	5*		
Preference							
I consume LR because of its availability	13.3	16.5	24.0	31.3	15.0	3.18	1.256
LR is always affordable	10.0	15.0	21.3	36.0	17.8	3.37	1.221
Due to my low-income earning.	13.3	20.3	26.5	26.8	13.3	3.07	1.237
It is always accessibilities	8.8	15.8	22.5	40.5	12.5	3.32	1.145
The sweetness of LR is okay for me	11.8	19.5	25.5	29.5	13.8	3.14	1.222
The colour of LR is appealing to my eyes	11.3	25.5	29.8	25.3	8.3	2.94	1.134
It's very easy to cook and eat	12.8	21.5	26.5	29.3	10.0	3.02	1.192
Because it tastes better	13.8	19.3	30.5	26.0	10.5	3.00	1.194
I farm rice every season	29.0	20.8	20.3	20.3	9.8	2.61	1.346
It's just my personal preference to consume LR	10.8	16.0	25.0	33.0	15.3	3.26	1.211
Do people consume local rice in the study area	11.8	9.3	18.0	35.5	25.5	3.54	1.286
The government compels us to eat local rice due to the ban on the importation of foreign rice	14.5	15.3	20.0	31.0	19.3	3.25	1.324
Advertisement made me start eating local rice	19.3	31.3	23.3	18.3	8.0	2.65	1.209
Eating LR was recommended by my friends and loved ones	19.5	22.3	26.3	20.3	11.8	2.83	1.284
Overall mean	3.08						

Source: Field Survey, 2022

Key: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), 5 (strongly agreed).

- 4. CONCLUSION:** Evidence from this study indicated that households' consumption of local rice was influenced by both socio-demographic factors and quality attributes of local rice. Specifically, most patrons of LR did so because of the price of local rice at ₦65,000/bag which did not fit in to their low-income status. Further, consumers of LR had high inclinations toward rice qualities such as whiteness, smoothness, sweet taste, good and aroma of local rice. Moreover, consumers' willingness to consume local rice were based on the preference of the attributes such as quality, colour, price and packaging (poor finishing, inconsistency in brand name, difficulty in identifying the best

brand name as a result of multiple brands, and the notion that local rice should not be expensive), and ‘consumers ethnocentrism constraint’ (notion that local rice will always be local no matter what, and high influx of imported rice in the country). The implication of this study is that consumer’s choice of preference for local rice is based on some certain attributes that enhance the quality of locally produced rice within the study area and to compete favorably with other foreign rice and reduce importation of rice and also reduce the rejection of locally produced rice, the price of rice has continued to increase almost every day because of its demand as staple food within every household.

5. RECOMMENDATIONS: More processing, Branding and packaging awareness should be carried out by federal and state government and Agricultural agencies should be made to improve households’ consumption of local rice at all levels with 57% of the 6.7million Mt of rice consumed in Nigeria is locally produced with a deficit of 3million Mt. Taking into consideration some factors including socio-demographic (such as age, and income), and quality attributes (taste, aroma, and sweetness) that determine consumers’ preferences in consuming it.

i. Research should focus on understanding and promoting local rice attributes such as colour, quality, price and brand of the rice and perceptions that could enhance trust and loyalty towards sustainable consumption of locally produced within the state.

ii. Investment in local rice processing should be centered on equipment’s that will eliminate stones and sand and also improve local rice cleanliness in order to determine the consumers’ willingness to consume locally produced rice as seen from this finding, effort should be made by government to formulate price control policy on local rice for its affordability by the customer.

iii. High level preference for local rice consumer justify the need for the government to make more effort on improved processing technology to eliminate presence of particles from choice of rice and to enhance good taste for consumer preference.

iv. Consequently, government intervention strategy should focus on promoting local rice by identifying and tackling the factors affecting consumers’ willingness to consume locally produced rice This can be achieved effectively by investment effort which incorporates mechanisms to provide incentives to processors to upgrade their technologies and thereby enhance the quality of the processed rice.

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Agro-Enterprise Income Intensification: A Case of Tomato Production in Akwa Ibom State, Nigeria

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Abstract

The study analyzed farm income intensification of tomato farmers in Akwa Ibom State, Nigeria. Primary data were obtained from 120 tomato farmers using a structured questionnaire. Descriptive statistics and maximum likelihood estimation of Tobit model were employed to analyze the data. The results of the socioeconomic characteristics of tomato farmers indicate that male farmers (71.00%) dominated tomato production in the State. Farmers were relatively young (with a mean age of 39.02 years), educated (with a mean of 12.88 years of schooling), and had a moderate household size (average of 6.00 members) but had low social capital accumulation (average of 1.81 years). The study highlighted relatively low income intensification indices among most tomato farmers in the State, with the mean, minimum, and maximum income intensification index recorded at 0.179, 0.001, and 0.803 respectively. This suggests that the majority of tomato farmers in the State do not heavily rely on income earned from tomato production. The empirical result shows that farmers' age, farming experience, membership in social organizations, years of formal education, access to farm credit, utilization of agricultural extension services, use of fertilizer, and being male farmers are all positive determinants of farm income intensification in tomato production. Conversely, having a larger farm size and increase quantity of hired labour were found to have a negative impact on income intensification. To enhance the income intensification capacity of tomato farmers in the State, it is recommended that farmers should be encouraged to establish cooperatives and participate in adult education programs. Furthermore, providing access to credit facilities, strengthening agricultural extension services, and continuing the fertilizer subsidy program in the State are also recommended.

Key words: Tomato, farmers, income intensification, production

Introduction: Tomato (*Lycopersicon esculentum*) ranks as one of Nigeria's most widely consumed vegetables, and is integral to the dietary habits of its populace (Bolarinwa et al., 2024). It is used in diverse culinary applications and forms a substantial part of daily vegetable intake (Adeosun et al., 2022; Akpan et al., 2024). Nigeria is a major fresh tomato producer in sub-Saharan Africa, ranked 14th in the World and 2nd in Africa (FAO, 2024). According to FAO, (2025), the country's production figures indicate 3.47 million tons in 2021 and 3.68 million tons in 2022, with cultivated areas of 809,602 ha and 702,275 ha, respectively. The yield was recorded at 4.29 tons/ha in 2021 and increased to 5.25 tons/ha in 2022 (FAO, 2024, Akpan et al., 2025). Farmers face challenges with post-harvest losses reaching approximately 60.00%, translating to 2.21 million tons annually (Business Day Newspaper, 2023, FAO, 2024). In 2021, the domestic consumption of tomatoes was estimated at 3.25 million tons, resulting in a deficit of 1.78 million tons per year that incentivizes imports and creating a financial burdens to Nigeria (Balogun, 2020).

Tomatoes are also valued for their medicinal properties, containing vitamins, minerals, fibers, antioxidants, and beta-carotene (Ali et al., 2020; Campestrini et al., 2019). The northern regions dominate tomato cultivation, but escalating insecurity has hindered production, increasing the consumption gap and motivating other regions to engage in tomato farming. Rising prices of tomatoes and other vegetables have led to significant investments in these crops in southern region of the country (Akpan et al., 2018; Akpan et al., 2019; Akpan and Monday, 2021; Bolarinwa et al., 2024). In the southern region of Nigeria, government initiatives aimed at bolstering tomato and other vegetables cultivation include awareness campaigns, provision of agricultural inputs, demonstrations, and processing facilities (Michael et al., 2018; Ogwu et al., 2018; Tawo, 2019, Akpan et al., 2022). Following these initiatives, there is a notable growth in tomato production in the region, with youth development programs and grants facilitating the agribusiness growth (Akwa Ibom State Government, 2025).

Although there have been various interventions from the relevant stakeholders, vegetable farmers (especially tomato and pepper farmers) have continue to encounter numerous challenges that worsen post-harvest losses. These include inadequate resources, insufficient processing infrastructure, recurrent attacks from bandits, soil degradation, conflicts among farming communities, poor transportation networks, youth migration, and escalating rural poverty (Obaniyi et al., 2020; Adisa et al., 2022; Akpan et al., 2023). It is crucial to tackle these issues to ensure the viability and longevity of tomato farming in the region (Akpan & Okon 2019; Adeloye et al., 2023).

Smallholder farmers, representing approximately 90% of the agricultural workforce and typically cultivating less than 2 hectares of land (Onoja, 2023), are pivotal for vegetable cultivation in Nigeria. Given the nutritional needs of the population, sustaining vegetable agriculture is vital. To enhance tomato production, small-scale farmers require

intensified agricultural income, achieved through increasing yield per hectare via high-yield varieties, enhanced fertilizer application, and the increased use of irrigation and pesticides (Aihounton and Christiaensen, 2024). Improved market access can further boost farm incomes through increased production. This income intensification not only strengthens food security but also improves land and labor productivity, promoting greater market engagement and efficient resource utilization. Analysts suggest that enhancing farm incomes can facilitate rural development by enabling investments in agriculture and education, thereby freeing labor for other sectors (Adisa et al., 2022; Akpan et al. 2017). Farm income intensification also ensure better food security and nutrition for a growing populace, potentially reducing environmental impacts by maximizing output on less land. Given these benefits, there's a pressing necessity to identify factors influencing farm income intensification among small-scale tomato growers in the State. Tomato, a vital vegetable in Nigeria, must be consistently produced to meet demand while also increasing farmers' purchasing power. Thus, the study aims to identify policy factors that affect farm income intensification for small-scale tomato farmers in Akwa Ibom State, Nigeria.

Literature Review

Numerous studies have examined the correlation between income and agricultural resource intensification in Nigeria, revealing regional disparities in findings. For example, Nwaru et al. (2010) noted that factors such as enhanced farm output, the adoption of various soil management practices, farming experience, and educational attainment positively influence agricultural intensification among crop farmers in Abia State whereas larger household sizes have a detrimental impact. Similarly, research by Salau et al. (2012) identified variables such as farmers' age, farm size, household size, extension engagement, and market proximity as key influencers of agricultural intensification in western Nigeria. Akpan et al. (2017) further explored drivers of agricultural land intensification and perceived barriers to sustainable land management in Akwa Ibom State, finding an average Herfindahl index of 0.4174, indicating moderate land intensification. Negative contributors to land intensification included non-farm income, labor expenditures, educational levels, farm size, and farmer poverty, while positive factors involved increased fertilizer use, household size, and farm output. Osuji et al. (2021) highlighted that farmers' age, gender, education, net farm income, farm size, extension engagement, and farming experience significantly shaped the adoption of sustainable agricultural practices in eastern Nigeria. Olatunji et al. (2022) pointed out that in south-western Nigeria, agricultural land intensification further depended on the farmer's gender, access to credit, use of inorganic fertilizers, farm size, and extension services. Bentley et al. (2024) reported in northern Nigeria that factors such as farmers' age, frequency of extension contact, farm size, and distance to input markets prominently influenced farm input intensification. Overall, the reviewed literature primarily focus on specific aspects of farm-resource intensification while neglecting the income intensification of small-scale farmers. Enhancing income for small-scale rural farmers is vital as it promotes agricultural economic development, societal welfare, and poverty reduction. Improved farmer income also correlates with increased consumption, economic stimulation, and better access to education and healthcare. Due to variations in environmental, climatic, and edaphic conditions across Nigeria's regions, insights from other regions might not adequately inform policy directions necessary to improve the livelihoods of rural farmers in the southern region. Consequently, there is an urgent need to broaden knowledge regarding farm income intensification among farmers in Akwa Ibom State and the broader south-south region. Focusing on small-scale tomato farmers is key, as they are primarily rural residents facing higher poverty risks, thereby possessing strong motivations to enhance their farm income.

MATERIAL and METHODS

Study Area : The study was conducted in the two agricultural zones of Akwa Ibom State, namely: Abak and Ikot Ekpene agricultural zones. Ikot Ekpene Agricultural Zone consist of five (5) local government areas namely: Ini, Obot Akara, Ikot Ekpene, Ikono and Essien Udim. Abak agricultural zone is made up of five local government areas namely; Abak, Etim Ekpo, Ika, Oruk Anam and Ukanafun. The people are predominantly farmers producing food crops and vegetables such as pepper, tomato, cucumber, fluted pumpkin, melon, sweet potatoes among others.

Sampling Techniques and Sample Size: A multistage sampling procedure was adopted in selecting tomato farmers in the study area. A list of registered tomato farmers was obtained from Akwa Ibom State Agricultural Development Programme (AKADEP) office in both agricultural zones selected. In the first stage, Abak and Ikot Ekpene Agricultural Zones were purposively selected from the existing six Agricultural Zones because they are the major centres for commercial tomato production in the State. In the second stage, a sample frame of one hundred and seventy three tomato (173) farmers (representing the total number of registered tomato farmers in the zones) from the two zones. In the next stage, the representative sample size (Sn) was obtained using the formula developed by Yamane, (1967) as thus:

$$S_n = \frac{N}{1 + N(e^2)} = \frac{173}{1 + 173(0.05^2)} = 120 \dots \dots \dots (1)$$

Where; Sn = representative sample size; N = sample frame; e = absolute error at 5% probability level of type 1 error. Hence, a total of one hundred and twenty (120) registered tomato farmers were selected for the study. The third stage

involved a random selection of one hundred and twenty (120) tomato farmers from the merge list using a ballot system. In the final stage, the selected tomato farmers were contacted and interviewed to obtain the necessary data for the study.

Measuring Farm Income Intensification : Farm income intensification is conceptualized as strategies or action(s) taken within the farm system aimed at increasing farm productivity and profitability often through adoption of modern technologies. It involves maximizing the yield or output per unit of input (land, fertilizer, labor, etc.) and can lead to higher incomes for farmers and efficient resource management. The study adopted the Herfindahl-Hirschman Index method to measure the income intensification index of tomato farmers. The approach is simple to analyze and is well fitted to the data obtained from the farmers. The method allows the farmer's farm income to be compared with the total household income.

Data source: Secondary data were collected from tomato farmers through the use of a well-designed and structured questionnaire. The data collected includes; social and economic data, farm specific and production data among others.

The Herfindahl Index: The Herfindahl index (HI) is defined as the square of the proportion of farm income in the total household income. This was computed per household as follow:

$$HI = \sum_{i=1}^N \left(\frac{Y_k}{Y_n} \right)^2 \dots \dots \dots (2)$$

Where HI represents the Herfindahl or Intensification Index, N denotes the total number of income sources accessible to the household, Y_k signifies the total farm income for the household, and Y_n indicates the overall income for the household, encompassing both farm and non-farm income. The Herfindahl index, as articulated in equation (2), is also referred to as the concentration index. Its value ranges from zero to one, serving as a metric for the degree of income generation intensification within a specific farm household. As the intensification index approaches unity, it indicates that a farmer has maximized the utilization of their farmland for income generation. A perfect score of one (1) denotes complete intensification, while a value nearing zero suggests an increase in agricultural diversification.

Determinants of income intensification: A Tobit model regression was specified to identify determinants of income intensification among tomato farmers. The standard Tobit model for this study is defined as follows:

$$Y_i^* = X_i \alpha_i + U_i \dots \dots \dots (3)$$

$$Y_i = Y_i^*, \text{ if } Y_i^* > 0 \dots \dots \dots (4)$$

$$Y_i = 0, \text{ if } Y_i^* \leq 0 \dots \dots \dots (5)$$

Where Y^* is the latent dependent variable, Y_i is the observed dependent variable, X_i is the vector of the independent variables, α is the vector of coefficients, and the U_i is a stochastic error term and is assumed to be independent, normally distributed with zero mean and constant variance ($U_i \sim \text{iid}, N(0, \sigma^2)$). The explicit form of the Tobit model is presented in equation 6.

$$HI = Z_i = \beta_0 + \beta_1 \phi_1 + \beta_2 \phi_2 + \beta_3 \phi_3 + \beta_4 \phi_4 + \beta_5 \phi_5 + \beta_6 \phi_6 + \beta_7 \phi_7 + \beta_8 \phi_8 + \beta_9 \phi_9 + \beta_{10} \phi_{10} + \beta_{11} \phi_{11} + \beta_{12} \phi_{12} + \beta_{13} \phi_{13} + \beta_{14} \phi_{14} + U_i \dots \dots \dots (6)$$

Where HI represents the farm income intensification index as indicated in equation 2. The marginal effect derived from the Tobit model reflects the immediate impact that a shock in an independent variable exerts on the latent or dependent variable. It quantifies the percentage change in the dependent variable that is attributable to a variation in an explanatory variable. The variables utilized in equation (6) are detailed in Table 1.

Table 1: description of explanatory variables

S/n	Variable	Symbol	Unit	Expected sign
1	Age of a farmer	ϕ_1	Years	Positive or negative
2	Marital status (dummy)	ϕ_2	(1 for married and 0 otherwise)	+
3	Farm experience (years)	ϕ_3	Years	+
4	Socialization (years)	ϕ_4	Years	+
5	Education (years)	ϕ_5	Years	+
6	Farm Credit (naira)	ϕ_6	Naira	+
7	Agric. Extension (number of time(s))	ϕ_7	Number	+
8	Dependent ratio	ϕ_8	ratio	-
9	Farm size (hectare)	ϕ_{10}	Hectares	+
10	Hired labour (mandays)	ϕ_{11}	Mandays	-
11	Fertilizer (kg)	ϕ_{12}	kg	+
12	Manure (kg)	ϕ_{13}	kg	+

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13	Sex	Ø ₁₄	(1 for female and 0 otherwise)	+
14	Quantity of seed planted (grams)	Ø ₁₅	GRAMS	+

Source: Prepared by the authors. Note, dependent ratio = number of children less than 15 years plus number of adult greater than 65 years divided by the household size.

Results and Discussion

The social and economic characteristics of tomato farmers

The summaries of socioeconomic features of tomato farmers are presented in Table 2. The result revealed that the majority of tomato farmers were female. They are likely to participate in the business to provide additional income for the family. Farmers' age distribution revealed an active age population with an average age of 39.02 years. The deduction from the finding is that, tomato farmers are relatively young. This implies that, the enterprise is suitable for youth empowerment programme.

Table 2: Socioeconomic characteristics of tomato farmers

Variables	Min.	Max.	Mean	Std. dev.	Coef. Var.
Age	25.00	55.00	39.02	4.56	0.12
Marital status	0.00	1.00	0.85	0.36	0.42
Farm experience	2.00	15.00	7.00	2.29	0.33
Socialization	0.00	7.00	1.81	3.08	1.70
Education	3.00	21.00	12.88	2.77	0.21
Farm Credit	0.00	500,000	24250	82550	3.40
Agric. Extension	0.00	2.00	0.08	0.26	3.53
Dependent ratio	0.00	0.8.00	2.08	0.98	0.47
Farm size	0.15	0.60	0.55	0.15	0.26
Hired labour	30.00	3690.00	780.75	468.15	0.60
Fertilizer (kg)	0.00	102.50	36.64	21.71	0.59
Manure (kg)	25.00	450.00	95.33	66.84	0.70
Sex	0.00	1.00	0.71	0.46	0.64
Quantity of seed (gram)	0.50	4.00	0.78	0.07	0.09
Household size	1.00	10.00	7.00	2.39	0.15

Source: Prepared by the authors.

The marital status data indicates that most farmers are married, suggesting a strong inclination for tomato production among married households, likely due to the availability of cost-effective family labor, which is essential given the labor-intensive characteristics of tomato farming in the area. Additionally, the average farming experience of tomato growers in the state is approximately 7 years, indicating that tomato cultivation represents a developing agribusiness sector. The participation in social organizations is notably low, with farmers averaging only 1.81 years of membership, and over half do not belong to any social group. This reflects a limited social capital for tomato farmers in the area. The average household size is seven members, reinforcing the significance of family labor in tomato cultivation. Due to the inelastic demand for hired labor in rural areas and the trend of youth migration to urban centres, family labor has become the predominant labor source for small-scale farmers. Notably, all tomato farmers have received some level of formal training, averaging 12.88 years of formal education, which aligns with secondary education. This literacy level suggests that most tomato farmers in the state are prone to innovation adoption and prudent farm decision-making.

Intensification index of tomato farmers: The distribution of intensification indices among tomato farmers is illustrated in Table 3. The findings indicate that 0.83% of tomato farmers are very close to achieving a perfect income intensification stage. In other terms, merely 0.83% of tomato farmers almost entirely depend on income derived from tomato production. Furthermore, the results demonstrate that only 1.67% of the farmers possess an intensification index within the range of 0.601 to 0.800. This range is recognized as the region of increasing income intensification. Conversely, approximately 8.33% and 22.50% of the tomato farmers operate within the intensification index ranges of 0.401 to 0.600 and 0.201 to 0.400, respectively. Likewise, around 66.67% of the farmers exhibited an intensification index of 0.001 to 0.200 units. This finding implies that, majority of tomato farmers in the state are not intensifying their farm incomes from tomato production. Otherwise, it connotes that majority of tomato farmers in Akwa Ibom State do not derive the bulk of their total incomes from tomato production. For instance, over 60.00% of tomato farmers have very low intensification index. This means that, the contribution of tomato income in their total income is very minimal. The higher the index of income intensification, the more dependent would be for the farmers on income generated from tomato production.

Table 3: distribution of Farm income intensification indices among tomato farmers

Range	Frequency	Percentage
0.001 – 0.200	80	66.67
0.201 – 0.400	27	22.50
0.401 – 0.600	10	8.33
0.601 – 0.800	2	1.67
0.801 – 1.000	1	0.83
Total	120	100.00
Minimum	0.001	
Maximum	0.803	

Mean	0.179

Source: Prepared by the authors.

The finding indicates that, majority of tomato farmers in the state are diversifying or depending more on income from other sources rather than incomes from tomato production. The mean and maximum intensification indices stood at 0.179 and 0.803 respectively. The findings connote that, the sustainability of the tomato production in the state can be affected if sufficient innovations are not introduced to ensure consistency in production.

Determination of income intensification among tomato farmers : The Tobit estimates and variance inflating factor (VIF) are presented in Table 4. For the VIF, the result revealed that there is no serious or significant collinearity among explanatory variables specified. The VIF estimates for explanatory variables exceeded unity, but fall below the threshold value of 10. This connotes that the Tobit estimates are consistent, unbiased with minimum variance. The diagnostic tests revealed the value of pseudo R-squared at 0.611. This means that nearly 61.10% of variability in income intensification indices of tomato farmers is associated with the specified independent variables. Also, the estimated Chi square (14) and the sigma estimate indicate that the estimates of the Tobit model has goodness of fit.

Table 4: Tobit estimates of income intensification of tomato farmers in Akwa Ibom State

Variables	Coefficient	Standard error	t-test	Probability	VIF
Constant	0.092	0.124	0.743	0.457	-
Age	0.020	0.010	1.930*	0.0543	1.607
Marital status	-0.048	0.032	-1.474	0.145	7.166
Farm experience	0.005	0.002	3.181***	0.000	4.137
Socialization	0.006	0.002	2.446**	0.014	2.129
Education	0.005	0.001	3.391***	0.000	2.349
Farm Credit	0.015	0.009	1.679*	0.088	1.201
Agric. Extension	0.067	0.021	3.158***	0.000	1.517
Dependent ratio	-0.063	0.051	-1.224	0.315	8.904
Farm size	-0.065	0.021	-3.088***	0.001	4.885
Hired labour	-0.080	0.021	-3.726***	0.000	1.122
Fertilizer	0.055	0.011	4.885***	0.000	1.370
Manure	0.084	0.071	1.178	0.437	1.185
Sex	0.087	0.021	4.143***	0.000	2.418
Quantity of seed	0.006	0.003	0.186	0.986	1.207
Diagnostic tests					
Chi-square(14)	46.49***	Sigma		0.075 (0.007)	
Log-likelihood	140.50	Normality of residues		1.409	
Left-censored observations: 0		Right-censored observations: 0		Pseudo – R ²	0.611

Source: Field Survey Data, 2024. Asterisks, *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

The empirical analysis indicates that an increase in the formal education of tomato farmers results in a 0.005 unit rise in their income intensification index, significant at the 1% level. This suggests that educated tomato farmers are more inclined to enhance their farm income, whereas less educated farmers tend to diversify their income sources. Additionally, gaining formal training enhances the likelihood of farmers adopting modern production techniques and improves their ability to access information that can lead to greater productivity and income. The finding corroborates Nwaru et al. (2010) and Osuji et al. (2021), but contradict Akpan et al. (2017).

Moreover, farming experience is found to have a positive correlation with the income intensification index. An additional year of experience would result in a 0.005 unit increase in income intensification index at 1% probability level. This implies that as farmers accumulate experience, their income intensification tends to improve correspondingly, likely due to their familiarity with income-related challenges such as seasonal variations, diseases, and price fluctuations. The finding aligns with Nwaru et al. (2010) and Osuji et al. (2021).

Membership in social organizations positively affects income intensification indices, with each additional year of membership correlating with a 0.006 unit increase in intensification index. This suggests that consistent interactions with peers provide tomato farmers access to various ideas and information, facilitating the adoption of innovations demonstrated by fellow members.

The analysis finds a significant positive relationship between the age of tomato farmers and their income intensification index, with a slope coefficient of 0.020 at the 10% significance level. Older farmers may have increased resource management skills through experiences and are likely familiar with challenges and the mitigation strategies. The finding is in agreement with the submissions of Salau et al. (2012); Osuji et al. (2021) and Bentley et al. (2024).

Additionally, being female is positively associated with income intensification, where a 10% rise in female farmers corresponds to an approximate 0.87 unit increase in their income intensification indices. This trend may be influenced by high youth unemployment, leading women to engage in agriculture for income support. Furthermore, women's patience may lead to better management of prolonged production processes. The finding is in consonance with Osuji et al. (2021) and Olatunji et al. (2022).

Besides, the findings underscore the importance of fertilizer use in increasing income intensification among tomato farmers, with each unit increase in fertilizer resulting in approximately a 0.055 unit rise in the income intensification

index. Increase use of fertilizers is known to increase farm output leading to increase in farm income. Akpan et al. (2017) and Olatunji et al. (2022) found similar result.

Additionally, farm credit demonstrates a substantial positive association with the farm income intensification index among tomato farmers. An increment of one unit in farm credit leads to a 0.015 unit rise in the income intensification index. Farm credit plays a crucial role in income intensification as it equips farmers with necessary financial resources for investing in advanced farming technologies, enhancing productivity, and subsequently elevating their total income and well-being. The result aligns Olatunji et al. (2022).

Moreover, the coefficient related to agricultural extension services also shows a significant correlation with the income intensification of tomato farmers. An increase in the extension services available to tomato producers results in approximately a 0.067 unit enhancement in their income intensification index. Agricultural extension is critical for income intensification since it facilitates the transfer of new technologies and best practices, allowing farmers to elevate their productivity and earnings. Similar findings have been reported by Salau et al. (2012); Osuji et al. (2021); Olatunji et al. (2022) and Bentley et al. (2024).

Conversely, the estimated coefficient for land size exhibits a significant negative correlation with the income intensification index among tomato farmers. This observation indicates that as the size of the land increases, the income intensification index tends to decrease. Specifically, an increase of one unit in farm size corresponds to a reduction of 0.065 units in the income intensification index of farmers. Given that the majority of farmers operate on a small scale and utilize manual tools, an increase in land size is likely to elevate production costs, often exceeding their financial capacity. Furthermore, as the costs associated with production factors rise, it becomes increasingly challenging for them to achieve optimal resource efficiency. Comparable results have been documented by Salau et al. (2012); Osuji et al. (2021); Olatunji et al. (2022) and Bentley et al. (2024). However, the finding is contrary to Akpan et al. (2017) submission.

Additionally, the coefficient for hired labor demonstrates a significant negative correlation with the income intensification of tomato farmers. This finding implies that a 10% increase in labor utilization would lead to an approximate 0.80% decline in the income intensification index for these farmers. In many rural communities within the state, the labor supply is inelastic, resulting in high costs for hiring labor. Given that tomato production necessitates intensive crop management, the demand for labor is crucial for its sustainable viability. The result corroborates Akpan et al. (2017).

Conclusion, Summary and Recommendations: The current decline in income intensification among farmers in developing nations has consistently attracted the attention of policymakers in the area. This issue is exacerbated by rising youth unemployment, poverty, and food insecurity. Consequently, the study specifically aimed to determine the income intensification index and its influencing factors among small-scale tomato farmers in Akwa Ibom State, Nigeria. The Herfindahl index and Tobit model were utilized to analyze data gathered from tomato farmers. The findings indicated mean, minimum, and maximum values of income intensification at 0.179, 0.001, and 0.803, respectively. Positive factors influencing income intensification among tomato farmers include farming experience, social interactions, years of formal education, access to farm credit, agricultural extension services, fertilizer usage, and the gender of the farmers. Conversely, land size and the use of hired labor were identified as negative factors. To enhance income intensification among tomato farmers in the State, it is recommended to promote adult education programs, encourage the formation of social groups, provide farm credit, and implement more proactive extension services. Additionally, fertilizer subsidies should be made accessible to the farmers.

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Willingness to Pay for Extension Services (Nifor) by Smallholder Oil Palm Farmers in Edo State

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ABSTRACT

This study investigates the willingness to pay (WTP) for extension services provided by the Nigerian Institute for Oil Palm Research (NIFOR) among subsistence oil palm farmers in Edo State, Nigeria. Despite the strategic role of NIFOR in disseminating improved oil palm technologies, adoption among smallholder farmers remains low. The study employed the Contingent Valuation Method (CVM) to elicit responses from 150 purposively selected registered farmers in Ovia North-East Local Government Area, where NIFOR is headquartered. Descriptive statistics were used to summarize the socioeconomic characteristics of respondents, while a Probit regression model was employed to identify factors influencing WTP. Results reveal that 67% of respondents were between 45 – 65 years, 67% were male, and most cultivated between 1 – 4 hectares. Key determinants significantly affecting WTP include age, sex, household size, income, farming experience, access to extension services, and distance to service points. Notably, access to extension services and income had strong positive effects on WTP, while age, household size, and distance negatively influenced willingness. The model exhibited good explanatory power (Pseudo $R^2 = 0.666$), indicating the robustness of the estimated relationships. The findings underscore the importance of proximity, awareness, and economic capacity in determining farmers' demand for extension services. The findings are also crucial for understanding the dynamics of smallholder oil palm farming and can guide policy decisions. It is recommended that the government provide adequate funding to research institutes and educate younger people among the smallholder farmers.

Key words: Willingness-to-pay, NIFOR, Extension Services, Smallholder, Oil Palm,

INTRODUCTION: Oil palm (*Elaeis guineensis*) remains a vital economic crop in Nigeria, especially in southern states like Edo, where it supports rural livelihoods, household food security, and national economic development (Amafade & Ovharhe, 2024). Smallholder oil palm farmers dominate the Nigerian oil palm sub-sector, cultivating small landholdings with limited capital, poor access to technology, and minimal institutional support. Despite Nigeria's historical position as a leading global producer of palm oil in the 1960s, productivity levels have declined due to low-yielding varieties, poor agronomic practices, and weak extension delivery systems (Shehu & Salleh, 2023). Agricultural extension services play a pivotal role in bridging the knowledge and technology gap between research institutions and farmers. They are critical in transferring improved production techniques, post-harvest practices, and market information to rural farmers (Musa *et al.*, 2023). In the oil palm sector, the Nigerian Institute for Oil Palm Research (NIFOR) is the statutory body responsible for generating and disseminating innovations, including improved oil palm seedlings, pest and disease management strategies, and value addition techniques. NIFOR's research has led to the development of high-yielding, early maturing, disease-resistant hybrid oil palm varieties (such as the tenera hybrid) that significantly outperform unimproved palms, with improved seed production and distribution to farmers in Nigeria (Ikuenobe, 2010). The institute also develops agronomic and pest/disease management practices, along with small- and medium-scale processing technologies to support more efficient palm oil production, with a particular focus on smallholder farmers who produce over 80% of Nigeria's palm oil (Ikuenobe, 2010). However, the uptake of NIFOR's innovations by smallholder farmers remains suboptimal, often due to poor access, inadequate funding for extension programs, and a lack of willingness to invest in such services (Olawepo *et al.*, 2021). The willingness to pay (WTP) for extension services has emerged as a significant area of inquiry in agricultural economics. Understanding WTP helps determine whether farmers recognize the value of extension information and are ready to bear some of the costs involved in sustaining its delivery (Olawepo *et al.*, 2021). This is particularly important in light of government efforts to decentralize and commercialize extension services in Nigeria due to dwindling public funding. Identifying the socioeconomic, institutional, and farm-level factors

that influence WTP for NIFOR's extension services among oil palm farmers is essential for designing cost-effective and farmer-responsive outreach models. Despite the strategic importance of oil palm in Edo State's rural economy, many farmers continue to rely on traditional methods with low productivity outcomes (Ikuobase *et al.*, 2025). The poor extension-farmer link has been widely recognized as a major constraint to improved oil palm production (Ikuobase *et al.*, 2025). NIFOR, though endowed with cutting-edge research outputs, struggles to extend its services effectively to smallholder farmers, whose participation is vital for national self-sufficiency in palm oil production (Ikuobase *et al.*, 2025). This study is justified on several grounds. First, it addresses a critical gap in empirical literature on the willingness of smallholder oil palm farmers to invest in extension services, especially those provided by NIFOR. Previous studies on WTP have largely focused on staple crops like groundnut, maize, and cassava (Mishra & Joshi, 2018; Otitoju *et al.*, 2022; Agossou *et al.*, 2023), leaving a dearth of evidence for industrial crops like oil palm. Second, the study provides insight into the potential for cost-sharing or fee-based extension models in the oil palm sector, which is necessary to ensure the financial sustainability of services amid shrinking public budgets. Third, Edo State is a strategic location due to its proximity to NIFOR headquarters, yet paradoxically, many farmers in the state remain underserved by extension agents. Investigating the determinants of WTP in this context will help formulate targeted policy interventions that enhance the uptake of improved technologies and promote inclusive agricultural growth. Finally, understanding the economic behaviour of farmers regarding extension services can inform the scaling-up of demand-driven extension frameworks and public-private partnerships, which are increasingly being advocated in national agricultural policy reforms (FMARD, 2022).

METHODOLOGY: The study was conducted in Edo State, an inland state in southern Nigeria. Created in 1991 from the former Bendel State, Edo State has its capital in Benin City. Administratively, the state is divided into eighteen (18) Local Government Areas (LGAs), grouped into three agro-ecological zones: Edo North, Edo Central, and Edo South (Edo State Agricultural Development Programme [EADP], 2018). The Edo South agro-ecological zone comprises seven LGAs: Oredo, Ovia South-West, Ovia North-East, Ikpoba-Okha, Egor, Ughunmwode, and Orhionmwon. The state has an estimated population of 3,218,332, consisting of 1,640,461 males and 1,577,871 females, with an annual growth rate of 2.7% (National Population Commission [NPC], 2006). Geographically, Edo State lies between longitude 06°04'E and 06°43'E and latitude 05°44'N and 07°34'N. It shares boundaries with Delta State to the south and east, Ondo State to the west, and Kogi State to the north. Ovia North-East LGA was purposively selected for the study due to the presence of the Nigerian Institute for Oil Palm Research (NIFOR), which is located in the area. NIFOR serves as a key institution for the development and dissemination of oil palm research innovations to smallholder farmers. The LGA also has a high concentration of smallholder oil palm farmers and serves as the central meeting, training, and extension point for registered/contact farmers and NIFOR Extension Agents across the state. Meetings are held on a fortnightly basis. A sample size of 150 respondents was selected using proportionate sampling from a sampling frame of 300 registered smallholder oil palm farmers affiliated with NIFOR, based on a 95% confidence level. The formula is given as:

$$S = \frac{N}{1+N(e^2)} \dots \dots \dots (1)$$

Where;

S = sample size

N = Total population of registered smallholder oil palm farmers at the contact centre in the State

e = Critical level (100 – 95) % = 5%

The Contingent Valuation Method (CVM) was employed to elicit farmers' willingness to pay for extension services. This method involves the use of structured surveys with predefined bid prices to determine whether smallholder farmers are willing or unwilling to pay for services at specific price points. Data collected were analysed using descriptive statistics (frequency and percentage) to summarize the socioeconomic characteristics of the respondents, and the probit model was used to identify the factors influencing farmers' willingness to pay (WTP) for extension services. The explanatory variables incorporated in the Probit model were age, sex, marital status, educational level, farming experience, household size, annual income, access to extension services, and distance to the nearest extension service point. The probit model was selected due to the binary nature of the dependent variable (willingness to pay: yes/no). This modelling approach has been widely applied in similar studies to determine the determinants of WTP for specific goods and services (Akinyemi *et al.* 2014).

The Probit model form is:

$$Y = \alpha + \beta_1 X_1 + \beta_n X_n + \varepsilon \dots \dots \dots (2)$$

Y = Willingness to Pay (1 = willing to pay; 0 = otherwise)

α = intercept/constant

$\beta_1 - \beta_n$ = Coefficients of the Variables
 ε = Error Term
 X_1 = Age (years)
 X_2 = Sex (Male = 1 or female = 0)
 X_3 = Marital Status (dummy = 1 or 0)
 X_4 = Educational Level (No)
 X_5 = Farming Experience (years)
 X_6 = Household Size (No)
 X_7 = Annual Income (Naira)
 X_8 = Extension Services (No)
 X_9 = Distance (kg)

4.0: RESULTS AND DISCUSSION

Table 1: The Socioeconomic Characteristics of Subsistence Oil Palm Farmers in Edo State

Variables	Frequency	Percentage
Age		
25 – 45	40	27
45 – 65	100	67
≥ 65	10	6
Sex		
Male	100	67
Female	50	33
Marital Status		
Single	20	13
Married	130	87
Educational Level		
Non formal	30	21
Primary	40	26
Secondary	60	40
Tertiary	20	13
Farming Experience (yrs)		
< 10	20	13
10 – 20	60	40
20 – 30	40	26
≥ 30	30	21
Farm Size (ha)		
1 – 2	60	40
3 – 4	70	47
≥ 5	20	13
Household Size		
1 – 3	50	32
4 – 6	70	47
≥ 6	30	21
Annual Income		
< ₦100,000	25	17
₦100, 000 – ₦200,000	80	53
≥ ₦200,0000	45	30
Total	150	100

Source: Field survey data, 2025

The socioeconomic characteristics of respondents (Table 1) provide insights into their demographic profiles, farming practices, and economic realities. Age distribution shows that 67% are between 45 – 65 years, while 27% are 25 – 45 years, reflecting an aging farming population in Edo State. This trend, consistent with Okwuokenye and Abdurrahman (2022), underscores youth migration to urban areas and raises concerns about sustainability, as younger farmers are often more open to innovation (Begho *et al.*, 2022). Gender distribution indicates male dominance (67%), a pattern linked to cultural constraints on women's access to land (Viashima & Daniel, 2025). However, the 33% female participation suggests scope for inclusive interventions, as

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FAO (2023) highlights women's potential to boost productivity if empowered. Marital status shows 87% are married, implying reliance on family labour but also increased financial obligations (Gbigbi *et al.*, 2024). Education profile reveals 21% without formal education, 26% with primary, 40% with secondary, and 13% with tertiary education. While low education limits technology adoption (Ezekiel *et al.*, 2024), the secondary-educated group offers potential for training, and the tertiary-educated can champion innovation (Verma, 2024).

Farming experience is high, with 66% having 10 – 30 years. While experience supports productivity, it may also foster resistance to new practices (Onomu & Aliber, 2024). Few farmers (13%) have under 10 years of experience, reflecting limited youth involvement (Okwukenye & Abdurrahman, 2022). Farm size is small: 40% manage 1 – 2 hectares, 47% manage 3 – 4 hectares, and 13% operate ≥ 5 hectares, consistent with land fragmentation trends (Obayelu *et al.*, 2019). Household size shows 47% have 4 – 6 members and 21% have more than six, typical of rural Nigeria. Larger households provide labour but also strain resources (Onyemauwa *et al.*, 2023). Annual income indicates 17% earn $< \text{₦}100,000$, 53% earn $\text{₦}100,000 - \text{₦}200,000$, and 30% earn $> \text{₦}200,000$. Many farmers live near or below the poverty line, highlighting the need for interventions to enhance productivity, value addition, and market access.

Table 2: Probit Model Estimates of WTP for Extension Services

Variables	Coefficients	Std. Error	Z-Value	P-Value
Constant	-5.434	2.0230	-2.69	0.0071***
Age	-0.0336	0.0122	-2.75	0.0060***
Sex	0.004	0.001	4.00	0.0001***
Marital Status	-0.681	0.4110	-1.66	0.0968
Educational Level	0.036	0.019	1.89	0.0589
Farming Experience	2.071	0.8220	2.52	0.0118**
Household Size	-0.005	0.002	-2.50	0.0124***
Annual Income	0.002	0.0001	20.00	~0.0000***
Extension Services	4.674	0.006	779.00	~0.0000***
Distance	-0.0458	0.0227	-2.02	0.0433**
Number	150			
Pseudo R ²	0.666			

Source: Field Survey Data, 2025 Significant at 1% = ***, 5% = ** respectively

The Probit model estimates in Table 2 analyse the determinants of Willingness to Pay (WTP) for extension services among smallholder oil palm farmers in Edo State, Nigeria. With a Pseudo R² of 0.666, the model explains 66.6% of the variation in WTP, reflecting strong robustness in capturing socio-economic and demographic influences. The significant constant term (-5.434, $p = 0.0071$) indicates a low baseline WTP, consistent with Oluwamayokun (2018), who observed limited financial resources and reliance on traditional practices among farmers. Age negatively influences WTP (-0.0336, $p = 0.0060$), showing older farmers are less willing to pay, aligning with Osondu *et al.* (2023), who noted younger farmers' openness to innovation. Sex has a positive and highly significant effect (0.004, $p = 0.0001$), suggesting men are more willing to pay due to structural gender inequalities (Viashima & Daniel, 2025). Marital status, though insignificant (-0.681, $p = 0.0968$), hints at reduced WTP from competing household obligations (Oluwamayokun, 2018). Education shows a marginally positive effect (0.036, $p = 0.0589$), supporting Ndem *et al.* (2020) that education enhances awareness of extension benefits. Farming experience has a strong positive effect (2.071, $p = 0.0118$), confirming Taramuel-Taramuel *et al.* (2023) that experienced farmers value professional guidance. Household size negatively affects WTP (-0.005, $p = 0.0124$), consistent with Gbigbi *et al.* (2024), who noted larger households prioritize consumption over farm investment. Annual income is highly significant (0.002, $p \approx 0.0000$), reaffirming its central role in WTP (Shausi *et al.*, 2019). Access to extension services has the largest positive impact (4.674, $p \approx 0.0000$), echoing Ogunniyi *et al.* (2020) that exposure increases perceived value. Distance to service providers reduces WTP (-0.0458, $p = 0.0433$), as distance raises costs and limits accessibility (Ogunniyi *et al.*, 2020). Overall, the model highlights that WTP is shaped by demographic, economic, and structural factors. Addressing barriers such as income constraints, gender disparities, household burdens, and access limitations can significantly improve uptake and effectiveness of extension services among oil palm farmers in Edo State.

CONCLUSION: Smallholder oil palm farmers' willingness to pay for NIFOR extension services in Edo State was tantamount to some associated factors. This is because of the bidding price of a particular product and the likelihood of paying a certain amount for that in monetary terms. This was achieved by examining the socioeconomic characteristics of the farmers and estimating the factors affecting their willingness to pay for the services. The result from the socioeconomic features showed that the majority (67%) of the farmers fall within the 45 – 65 age range, who are in the middle/old age with lesser strength. It could be seen that 66% had post-primary education, which may not equip them with enough managerial skills for agri-business and adopting new technologies. The result showed that 77% had a household size of 1 – 6 persons. The Probit model analysis reveals age, marital status, and household size. Transportation cost and distance were the factors against the likelihood of paying for extension services. In contrast, educational level, farm size, farming experience, income, extension services, and extension visits influenced the likelihood of paying for extension services. Therefore, this study recommends that for efficient and effective extension service delivery government should fund research institutes adequately to carry out their mandates diligently as to avoid putting the burden of cost on the farmers in order to ease the likelihood of the payment of extension services and educated younger people should be involved among the smallholder farmers.

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Biotechnological Approaches in Probiotic Supplementation for Sustainable Fish Health and Aquaculture Productivity

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Abstract

This study evaluated the effects of *Bacillus subtilis* and *Lactobacillus plantarum* probiotics, singly and in combination, on the growth, survival, and water quality of catfish (*Clarias gariepinus*). A total of 180 fingerlings were fed four diets (control, *B. subtilis*, *L. plantarum*, and mixed probiotics) for 60 days. Results showed that probiotic-fed groups outperformed the control in all parameters. The mixed probiotic group achieved the highest final weight (46.8 g vs. 35.2 g control), survival (94 % vs. 81 %), and feed efficiency (FCR 1.34 vs. 1.82). Water quality also improved, with higher dissolved oxygen (6.2 mg/L) and reduced ammonia (0.89 mg/L) compared to the control. These findings demonstrate that probiotics, particularly combined strains, enhance catfish production while promoting sustainable aquaculture.

Keywords: Probiotic, catfish, sustainable aquaculture, diet types, biotechnology technique

Introduction: Aquaculture has been established as one of the fastest-growing food production sectors, contributing over 50 % of global fish consumption (pereira *et al.*, 2022); however, the intensification of farming systems has increased vulnerability to diseases, poor feed efficiency, and deteriorating water quality. Moreover, the antibiotics traditionally used for disease prevention have been reported to contribute to antimicrobial resistance and environmental risks. Although the prevention using antibiotics is effective in the short term, their indiscriminate use has raised serious concerns, such as antimicrobial resistance, disruption of aquatic ecosystems, bioaccumulation in fish tissues, and negative impacts on human health through the food chain (pereira *et al.*, 2022; Abarike *et al.*, 2024). In response to these challenges, the application of biotechnological solutions has gained momentum in aquaculture as reported (Pratama *et al.*, 2017; Abarike *et al.*, 2024; Umaru *et al.*, 2024). One such innovation is the use of probiotics, which have emerged as sustainable alternatives to antibiotics because they promote gut microbial balance, improve nutrient assimilation, enhance immune responses, and reduce pathogen load in culture systems. Moreover, probiotics contribute to bioremediation of water quality by breaking down organic wastes, reducing ammonia accumulation, and stabilizing dissolved oxygen and pH levels (Umaru *et al.*, 2024).

Recent advances in biotechnology have also shown that, molecular tools such as 16S rRNA sequencing, metagenomics, and proteomics enable the identification and functional characterization of novel probiotic strains. While the bioprocessing and fermentation technologies allow mass production of viable probiotics, but the encapsulation and nanotechnology ensure their stability during feed preparation and effective delivery in the fish gut (Pratiwi *et al.*, 2020; Diyaolu, 2024). Globally, catfish (*Clarias gariepinus*) is one of the most widely farmed fish species, largely due to its rapid growth, consumer acceptance, and tolerance to a wide range of environmental conditions (Khobir *et al.*, 2016).

Despite these advantages, their production is still constrained by high-density culture challenges, like bacterial diseases, feed inefficiency, and poor water quality. Thus, incorporating biotechnology-enhanced probiotics into catfish diets presents a promising approach to address these challenges sustainably (Li, Y., and Boyd, 2016). Therefore, this study investigates the effects of dietary supplementation with two well-characterized probiotic strains, *Bacillus subtilis* and *Lactobacillus plantarum*, individually and in combination, on the growth performance, immunological responses, and water quality in catfish.

Materials and Methods: As adopted from the work of Pratama *et al.* (2017), the experiment was carried out using catfish (*Clarias gariepinus*) fingerlings. A total of 200 healthy fish with an initial mean weight of approximately 12.5 g were obtained and stabilized for 14 days in a 300 L clean holding tank before the trial commenced. The holding tank was maintained at room temperature. Then, the water exchange was carried out daily at 30 % to keep ammonia concentrations below 0.5 mg·L⁻¹. During acclimation, the fish were fed a basal diet twice daily at 3 % of their body weight, which was reduced to 2 % two days before the experiment to standardize gut contents.

Following acclimation, the fish were randomly assigned to 12 experimental tanks, each stocked with 15 fish, to represent four treatments in triplicate. The treatments included a control diet without probiotic supplementation (T1), a basal diet supplemented with *Bacillus subtilis* at 1×10⁷ CFU·g⁻¹ of feed (T2), a basal diet supplemented with *Lactobacillus plantarum* at 1×10⁷ CFU·g⁻¹ of feed (T3), and a basal diet supplemented with a mixture of *B. subtilis* and *L. plantarum* each at 1×10⁷ CFU·g⁻¹ (T4). The feeding trial lasted for 60 days, during which fish were sampled for growth measurements at two-week intervals, while blood samples for immune assays were collected at days 0, 30, and 60. Water quality was monitored daily for temperature, pH, and dissolved oxygen, while ammonia and nitrite were analysed three times per week. Mortality was recorded daily. The basal diet used for all treatments was formulated to contain approximately 32 % crude protein, 8 % lipid, ≤5 % fiber, 10 % ash, and ≤10 % moisture. The formulation consisted of 30 % fishmeal, 25 % soybean meal, 20 % maize, 10 % wheat bran, 4 % oil, 2 % vitamin-mineral premix, and 4–7% starch or attractants. All dry ingredients were thoroughly blended in a mixer, after which oil and water were added to form a dough with about 18 % moisture content. The dough was pelletized into 1.5–3 mm pellets, which were dried at 45 °C until the moisture content fell below 10 %, then sieved to ensure uniform size distribution.

Probiotic strains used in the experiment included *B. subtilis* and *L. plantarum*. *B. subtilis* was cultured at 37 °C and 200 rpm for 24 hours, while *L. plantarum* was cultured at 37°C for 24 hours. Cells were harvested by centrifugation at 4,000–6,000 × g for 10 minutes at 4°C, washed twice in sterile phosphate-buffered saline (PBS), and resuspended in PBS. Colony-forming units were determined by serial dilution and plating on selective agar, with nutrient agar used for *Bacillus* and MRS agar for *Lactobacillus*. The concentration was adjusted to 1×10¹⁰ CFU·mL⁻¹ and used fresh in 10 % skim milk. Plate counts were performed before feed incorporation to confirm viability, and tests for contaminants such as coliforms were conducted. Probiotics were incorporated into the diet using a coating method. The required volume of probiotic concentrate to achieve 1×10⁷ CFU·g⁻¹ of feed was mixed with 0.5 % fish oil as a binder and sprayed evenly over the pellets. Pellets were gently tumbled for 10 minutes to ensure uniform distribution, air-dried for 1–2 hours, and stored at 4 °C for short-term use (7 days). Weekly plate counts were performed to verify probiotic viability in the coated feeds.

Fish were reared in tanks with continuous aeration and gentle water flow, where room temperature was maintained. Feeding was done twice daily, in the morning and late afternoon, beginning at 4 % body weight per day and gradually reduced to 3 % as the fish grew. The uneaten feed was collected after 30 minutes, dried, and weighed to determine accurate feed conversion ratios (FCR). Partial water renewals of 30 % were performed twice weekly. Growth performance was evaluated by recording initial and final weights of fish and the cumulative feed consumed. Weight gain was calculated as the difference between final and initial weights, while specific growth rate (SGR) and feed conversion ratio (FCR) were determined using standard formulae. Survival was calculated as the percentage of fish that remained alive at the end of the trial. Water quality parameters, including, dissolved oxygen, and pH, were measured daily using portable meters, while ammonia and nitrite concentrations were determined three times weekly using colorimetric kits.

Results and Discussion

Growth performance of catfish investigation using probiotic supplement: Table 1 presents the growth performance of catfish fed with different probiotic supplements that was investigated over an eight-week period. As observed from the results presented in Table 1, at week 2, the control sample recorded an average weight of 18.4 g from the initial 12 g bases, while fish fed with *B. subtilis* and *L. plantarum* showed improved growth at 20.6 g and 21.4 g, respectively, and the mixed probiotic group exhibited the highest growth at this stage, reaching 22.1 g.

Table 1: Growth performance results of the tested probiotic diet on catfish

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Week	Various Trials			
	Control (g)	<i>B. subtilis</i> (g)	<i>L. plantarum</i> (g)	Mixed probiotic (g)
0	12.5	12.5	12.5	12.5
2	18.4	20.6	21.4	22.1
4	24.3	28.2	30.0	31.2
6	29.6	35.1	37.6	39.0
8	35.2	42.1	44.3	46.8

Similar trend continued at week 4, with the control sample at 24.3 g compared to 28.2 g in the *B. subtilis* and 30.0 g in the *L. plantarum* samples, as similar variations were observed at week 6. Additionally, the differences were most pronounced at the end of the 8-week investigation, where the control fish sample was observed to have grown to 35.2 g, while *B. subtilis*- and *L. plantarum*-supplemented samples achieved 42.1 g and 44.3 g, respectively. However, the mixed probiotic sample showed the highest growth response, attaining a final weight of 46.8 g. Based on the performance growth study findings, the catfish growth was enhanced through probiotic supplementation compared to the control diet.

Water quality data analysis: The water quality results of the catfish probiotic supplementation are shown in Table 2. As observed from the results, the probiotic supplementation had positive effects on the dissolved oxygen, pH, and ammonia levels compared to the control sample, as the dissolved oxygen (DO) control value of 5.1 mg/L was lowest but increased progressively in *Bacillus subtilis* (5.8 mg/L), *Lactobacillus plantarum* (6.0 mg/L), and mixed probiotic groups (6.2 mg/L).

Table 2: The water quality analysis of the various experimental fish holding tanks

Parameters	Various Trials			
	Control	<i>B. subtilis</i>	<i>L. plantarum</i>	Mixed Probiotic
Dissolved Oxygen (mg/L)	5.1	5.8	6.0	6.2
pH	6.9	7.1	7.2	7.3
Ammonia-N (mg/L)	1.42	1.01	0.94	0.89

This improvement as depicted in Table 2 can be attributed to the role of probiotics in enhancing microbial balance within the aquatic system. Specifically, beneficial bacteria stimulate organic matter decomposition more efficiently, reducing oxygen depletion by harmful microbes and thus maintaining higher oxygen availability for fish metabolism as also reported by Pereira *et al.* (2022). Additionally, the pH of the water followed a similar trend, with the control group recording the lowest value (6.9) and the mixed probiotic group the highest (7.3) as presented in Table 2. Thus, the slight increase in pH across treatments is likely due to the metabolic activity of probiotics, which can buffer acidity by reducing organic load and nitrogenous waste. While the ammonia-N levels showed a clear reduction with probiotic supplementation as shown in Table 2, dropping from 1.42 mg/L in the control group to as low as 0.89 mg/L in the mixed probiotic treatment. This is due to the ability of probiotics to improve nitrogen cycling in aquaculture systems as *B. subtilis* is known to enhance nitrification and organic matter breakdown, while *L. plantarum* supports microbial communities that reduce ammonia accumulation.

Impacts of probiotic supplementation in catfish mortality rate: Table 3 depicts the results of survival performance of the catfish studies for 8 weeks when subjected to the different dietary treatments. As observed from the results presented in Table 3, the control set, which received no probiotic supplementation, had the lowest survival, with only about 36 fish remaining, amounting to 81 % survival. However, the probiotic fed replicates exhibited higher survival rates, with fish fed *Bacillus subtilis* recorded 40 survivors (89 %), while those fed *Lactobacillus plantarum* had 41 survivors (92 %) as shown in Table 3. Additionally, the mixed probiotic group achieved the highest survival, retaining 42 out of 45 fish, which translated to 94 % survival.

Table 3: The effects of the dietary treatments on the fish

Treatment	Initial fish stock	% mortality rate	Number of survivors
Control	45	81	36
<i>B. subtilis</i>	45	89	40
<i>L. plantarum</i>	45	92	41
Mixed Probiotic	45	94	42

Therefore, these findings as observed in Table 3 indicate a positive influence of probiotics on fish health and resistance to stress. Moreover, the improved water quality parameters, such as reduced ammonia and higher dissolved oxygen as earlier discussed in Table 2, likely contributed to lower mortality rates in probiotic-supplemented tanks.

Conclusions: Probiotic supplementation significantly enhanced catfish performance. The mixed probiotic group showed a 33 % higher final weight (46.8 g vs. 35.2 g control), 26 % lower FCR (1.34 vs. 1.82), and 23% higher SGR (2.28 vs. 1.85%/day). Survival improved from 81% to 94%, while water quality was better, with dissolved oxygen rising to 6.2 mg/L and ammonia reduced to 0.89 mg/L. These results confirm probiotics, especially the mixed culture, as an effective and sustainable alternative to antibiotics in aquaculture.

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Agricultural Waste-To-Feed Conversion through Biotechnological Interventions for Sustainable Livestock Production in Nigeria

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Abstract

Nigeria faces an annual livestock feed deficit exceeding 20 million metric tons, largely due to high reliance on imported feed ingredients. This study evaluated the potential of corn stover and rice husk wastes as alternative feed resources via microbial fermentation and enzyme-assisted upgrading. The proximate analysis of the residues revealed that crude protein in corn stover increased from 5.2 % (control) to 7.6 % (fermented) and 8.1 % (enzyme-treated), with fiber reduction from 36.0 % to 29.5 % and 27.8 %, respectively. The digestibility improved from 42 % (control) to 65 % and 68 %. Rice husk protein increased from 3.1 % to 4.4 % (fermented) and 4.9 % (enzyme-treated), with digestibility rising from 35 % to 54 % and 57 %. Feeding trials using local goats showed that fermentation and enzyme-treated diets enhanced average daily gain (62-65 g/day) compared with the control (48 g/day), improved feed conversion ratios (8.6-8.7 vs. 10.5), however, there was no mortality rate observed in the three treatments.

Keywords: Agricultural waste, enzymatic treatment, fermentation, sustainable livestock,

Introduction: Livestock production plays a crucial role in ensuring food security, nutrition, and economic stability in Nigeria. However, the sector continues to face a critical challenge of feed scarcity, which accounts for nearly 70 % of total production costs (Afolayan *et al.*, 2024). Nigeria is estimated to face an annual feed deficit of over 20 million metric tons, a gap that has led to heavy reliance on imported feed ingredients such as maize, soybean meal, and fishmeal. This dependence not only inflates production costs but also exposes the livestock industry to market fluctuations and foreign exchange constraints (Afolayan *et al.*, 2024). Nonetheless, large volumes of agricultural waste, such as corn stover, cassava peels, rice husks, groundnut shells, and other crop by-products, are generated annually across farming communities, which are mostly discarded, burnt, or left to decompose, contributing to environmental pollution, greenhouse gas emissions, and waste management difficulties (Ogunbajo. and Belewu, 2021). Whereas, literature (Omotoso and Arilekolasi, 2019; Ogunbajo. and Belewu, 2021; Afolayan *et al.*, 2024) have reported the potential of these residues, ranging from being rich in carbohydrates, fiber, and other nutrients, but their direct utilization in animal feed is limited due to poor digestibility, low protein content, and the presence of anti-nutritional factors.

Recent advances in bioprocessing technologies such as microbial fermentation, solid-state cultivation, and enzyme-assisted hydrolysis have demonstrated strong potential for transforming these low-value residues into high-quality, nutrient-dense livestock feed (Obensuyi *et al.*, 2022). Fermentation can enrich crude protein levels, degrade fiber, eliminate toxins, and enhance the bioavailability of essential amino acids and minerals. While, enzyme supplementation further improves feed conversion efficiency and reduces waste excretion, thereby promoting both animal health and environmental sustainability (Ogunbajo. and Belewu, 2021; Obensuyi *et al.*, 2022). Thus, the rapidly growing population and increasing demand for animal protein in Nigeria, along with the valorization of agricultural wastes into livestock feed, present the need for strategic techniques to achieve food security, reduce feed costs, and minimize environmental burdens. This study, therefore, investigates the potential of corn stover and rice husk residues, processed through microbial and enzyme-assisted methods, to improve nutritional quality and enhance livestock growth performance (Okeniyi *et al.*, 2020; Ogunbajo. and Belewu; 2021).

Methods: As adopted from the works of Adebayo *et al.* (2024) and Ogunbosoye *et al.* (2024), samples of corn stover, and rice husk waste were collected from post harvested farmland, which were sorted to remove the visible contaminants like plastics and stones and then sun dried for three days until a moisture content of about 12 % was achieved. The sample was further dried with an electric oven at 60°C for 3 hours to remove any trace of water, before being subjected to milling process using 2 mm size sieve. Then 5 g of the sample was measured for proximate analysis as adopted from the work of Ogunbosoye *et al.* (2024). Additionally, for the microbial inoculation, a commercial yeast strain (*Saccharomyces cerevisiae*) was propagated at 30°C for 24 hours to assist in culturing *Lactobacillus plantarum* at 35°C, which was monitored using optical density and viable counts with concentrated configuration of 4,000 g for 10 min, in which the cells were resuspended in sterile saline to obtain inoculum suspensions near 1×10^8 CFU·mL⁻¹. For each fermentation run, the yeast and inoculant were mixed 1:1 (v/v) just prior to inoculation so that a final addition rate of 5 mL inoculum per 100 g substrate was used; this delivered approximately 5×10^6 CFU·g⁻¹ substrate as starting microbial load, which is sufficient to dominate the fermentation while avoiding excessive heat generation. Solid-state fermentation (SSF) for lactic acid type upgrading of the waste was carried out by first adjusting the moisture content of the milled substrate to approximately 60 % using sterile distilled water; the moisture was checked by weight and mixing was thorough to ensure even distribution. The moistened substrate was placed into food-grade polypropylene fermentation bags fitted with one-way air vents, inoculated with the combined *saccharomyces-lactobacillus* suspension. These were incubated at 30°C for 72 hours for corn stover and rice husk, and up to 96 hours for the more recalcitrant rice husks, with gentle turning or mixing once every 24 hours to maintain aerobic pockets and avoid overheating. During fermentation, pH and temperature were monitored twice daily; a successful lactic fermentation was indicated by a pH drop to approximately 4.5 within 48 hours. The fermented substrate was oven-dried at 50-60 °C to reduce moisture to about 12 % for storage and incorporation into diets.

Enzymatic upgrading was carried out on a milled substrate that had either been fungal-pretreated or left as raw, depending on the experimental arm. For enzyme treatment, commercial cellulase and xylanase were used. The milled substrate was re-hydrated to 60 % moisture and placed in a stirred jacketed vessel for small-scale (5 kg) reactions. The pH was adjusted to 5.0 using 0.1 M citrate buffer because most cellulases/xylanases have optimal activity near pH 4.5–5.5; cellulase was applied at 0.5 % (w/w) of dry substrate and xylanase at 0.2 % (w/w). The mixture was incubated at 50°C with gentle agitation using magnetic stirrer for 24 hours. After the enzymatic reaction, the slurry was cooled, and dried to approximately 12 % moisture at 60°C. post-treatment processing and diet formulation were performed so treated residues could be compared directly in animal feeding trials. Treated residues (fermented and enzyme-treated) were combined with basal feed ingredients to formulate isoenergetic and isonitrogenous experimental diets containing 30 % residue inclusion on a dry matter basis, to feed the goats. The animal feeding trial was implemented using three (3) healthy goats, where local goats of approximately similar age and initial body weight; they were randomly allocated into three treatment groups (control group receiving untreated residue diet, fermentation-treated residue group, and enzyme-treated residue group). The animals were housed in individual pens to allow measurement of individual feed intake and to prevent cross-feeding. A 14-day adaptation period was observed during which animals acclimated to housing and basal diets; experimental feeding then continued for 56 days (8 weeks). Diets were offered twice daily (morning and evening) and fresh drinking water was provided at every feeding period. Feed offered and refused were recorded daily to calculate voluntary feed intake; body weights were recorded at day 0 and weekly thereafter in the morning before feeding to compute average daily gain. Feed conversion ratio was calculated as dry matter intake divided by weight gain for each animal.

Results and Discussion

Proximate analysis of the feedstock: Table 1 shows the chemical composition and the level of digestibility of the enhanced corn stover, and rice husk as compared to the control feed. As observed from the results, the untreated control corn stover diet contained 5.2 % crude protein, 36 % crude fiber, and 42 % indicating a low nitrogen content, in

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comparison to an increase in crude protein content to 7.6 % and fiber decreased to 29.5 % following the fermentation process, thereby enhancing the digestibility level from 42 to 65 %. Similar trend was also observed in enzyme treatment, with 8.1 % crude protein content, 27.8 % crude fiber, and 68% digestibility as shown in Table 1.

Table 1: The proximate analysis of the feedstock used

Treatment	Crude Protein (%)	Crude Fiber (%)	Digestibility (%)
Corn stover			
Control	5.2	36.0	42
Fermentation	7.6	29.5	65
Enzyme-treated	8.1	27.8	68
Rice husk			
Control	3.1	42.5	35
Fermentation	4.4	32.1	54
Enzyme-treated	4.9	30.5	57

This result proved that; the fermentation and enzyme applications substantially enhanced the feeding value of corn stover by enriching protein and breaking down indigestible fiber, with enzyme treatment showing a better potential. Additionally, similar trend was observed for the rice husk treatment as depicted in Table 1, as the control diet contained 3.1 % protein, 42.5 % fiber content and a digestibility level of 35 %, as compared to the fermentation treatment, protein content 4.4 %, 32.1 % fiber, and digestibility level of 54 %, while enzyme treatment further improved these values to 4.9 30.5, and 57 %, protein, fiber and digestibility level respectively. These results demonstrate that biological treatments can upgrade the nutritive value of rice husk, but its improvement is less pronounced than in corn stover, and the treated husk still falls short of meeting the minimum crude protein requirement for optimal rumen function.

Performance growth evaluation analysis: The results of the feed performance evaluation on the growth of the tested goats are presented in Table 2. As shown in Table 2, the initial sampling goat's average weight was 9 kg in each case, in which the control diet biomass treatment gained an average weight of 0.048 kg per day, reaching a final weight of 13.3 kg after the feeding period of 90 days, but recording a mortality rate of 0 at the end of the investigation period.

Table 2: The performance growth evaluation of the goats

Treatment	Initial Weight (kg)	Avg. Daily Gain (g/day)	Final Weight (kg)	Feed Conversion Ratio (FCR)	Mortality (%)
Control (untreated)	9.0	48	13.3	10.5	0
Fermentation-treated	9.0	62	14.6	8.7	0
Enzyme-treated	9.0	65	14.9	8.6	0

However, the goats that fed on the fermentation-treated feed recorded an average daily gain of 0.062 kg/day and attained a final weight of 14.6 kg, starting from an initial weight of 9.0 kg, with an improved feed conversion ratio of 8.7 and also zero mortality, as shown in Table 2. A similar result was observed from the enzyme-treated feed, with the goat gaining 0.065 kg/day and reaching a final weight of 14.9 kg, amounting to the feed conversion ratio of 8.6, and a mortality rate of zero as well, highlighting the strong positive effect of enzyme and fermentation supplementation on nutrient utilization and growth. Similar improvements in weight gain, feed conversion, and survivability of West African Dwarf goats on treated crop residues have been reported by Ogunbajo and Belewu, (2021) and Okeniyi *et al.* (2020). Therefore, these investigations confirm that value-added treatments of crop residues significantly enhance their nutritive potential and translate into measurable improvements in livestock performance.

Conclusions: The present study confirms that agricultural wastes such as corn stover and rice husks can be effectively valorized into nutrient-rich livestock feeds through microbial fermentation and enzyme-assisted bioprocessing. Treatments improved crude protein by up to 56 % in corn stover and 58 % in rice husk, while reducing fiber content and enhancing digestibility by more than 20 percentage points. Feeding trials further validated the nutritional upgrades, with goats on treated diets showing up to 35 % higher weight gains, better feed conversion ratios, and zero mortality compared to untreated controls. Although corn stover showed greater improvement than rice husk, both residues demonstrated clear potential for contributing to sustainable feed production in Nigeria. The adoption of such waste-to-feed strategies could significantly reduce feed costs, mitigate environmental waste challenges, and support food security in the livestock sector.

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Assessment of Agricultural Extension Service Delivery on Postharvest Loss Management of Millet and Sorghum in Dutse Local Government Area, Jigawa State

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ABSTRACT

This study assessed Agricultural Extension Service Delivery on Postharvest Loss Management of Millet and Sorghum. The study was conducted in Dutse Local Government Area, Jigawa State. Multi-stage sampling procedure was used for this study, where a purposive sampling 184 farmers of the neighboring communities to Federal University Dutse and Jigawa State Agricultural Development Authority (JARDA) was made. Primary data was collected directly from the respondents using a structured questionnaire. All the respondents were male (100%) within the age range of 31-40years, with 79.3% married. About 44.6% of the millet and sorghum farmers had primary education and the main occupation of the farmers is farming (31%). Also 73.3% of the respondents agreed that they had contact with the extension agents, while 88.7% agreed that there is no presence of extension service delivery, with regards to post-harvest loss management technology of Millet and Sorghum in the study area. The respondents 'source of post-harvest information is mostly family and friends (64%). About 56% of the respondent stated that there is no availability of agricultural extension services in the study area. The major causes of post-harvest losses of millet and sorghum are insects/pest/diseases (69%), storage (44.6%) and theft (44.6%). Major limitation of farmers include irregular visit by extension workers/agents (100%), and lack of infrastructural facilities (90.8%). Therefore, the study recommends that extension agents should be pro-active to ensure that there is effective minimization of post-harvest loss. All the limitations of the respondents should be given adequate focus by the ADP office.

Keywords: Postharvest, Losses, Millet, Sorghum, Farmers and Jigawa State

INTRODUCTION

Background to the Study: Development in the agricultural sector, at all levels, is confronted with a huge challenge of how to feed the growing populations sufficiently. Therefore, considerable attention should be directed toward increasing food production by 50–70% to achieve the Sustainable Development Goal 2; food security and right to food (Affognon *et al.*, 2015). Thus, one of the factors to achieve food security is oftentimes forgotten, that is the control of post-harvest

food loss and food waste (GIZ, 2013). Food and Agriculture Organization, FAO (2010), reported that out of the USD 940 billion that is needed for the eradication of hunger in Sub-Saharan Africa in 2050, 47% will be required in the post-harvest sector alone. Even in industrialized countries, food losses and waste amounts to about USD 680 billion. This analysis thus underscores the importance of PHL management in enhancing farm-level productivity and access to food. Post-harvest loss (PHL) entails all measurable decrease or change in edible food mass throughout the supply chain that specifically leads to edible food for human consumption, with minimum loss, maximum efficiency and maximum return (Aulukh *et al.*, 2013). Ansah and Tetteh (2016), opined that, the possibility of feeding the teeming population is shrouded in uncertainty unless serious attention is given to post-harvest losses. Evidently, one of the most important pathways to increasing food availability and strengthening food security is by reducing post-harvest losses and wastes (Tanye, 2016). Also, Goldsmith *et al.* (2015), revealed that preventing food loss and increasing production remains the two realistic alternatives by which the world can meet its ever-rising food demand. It is therefore important to note that food production system consists of two sub-systems – crop production and post-harvest operations systems. This is also, in line with the SDG 12.3 target by 2030 is to halve food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses. However, barely five years to 2030, over one-third of the food produced globally for human consumption (about 1.3 billion tons) is lost or wasted each year along the food supply chain. On the African continent, one of the seven commitments made by the Heads of State and Governments in Malabo, was on ending hunger in Africa by 2025 through direct efforts to reduce Post-Harvest Loss (PHL) by 50% (African Union Commission, 2018). The Malabo Declaration also identified the knowledge management and skill factors including research and development, skills and human development, and awareness and communication as integral components of Post-Harvest Loss management. Cereals crops are important sub-sector of crop production component of agricultural system in Jigawa state, Nigeria and it accounts for about 87.6% of the agricultural sector's output (FGN, 2020). Similarly, Jigawa State is among the well-known in the production of crops, especially cereals (Figure 1). According to Iliyasu and Ahungwa (2015), the Village Listing Survey (2014), predominant cereals grown in the state include Millet (34.6%), Sorghum (32.4%), rice (18.9%), Maize (11.5%) and Wheat (2.4%). It is also worthy to note is that most of the aforementioned cereal crops are usually intercropped with other crops - such as groundnut, sesame and cowpea on the same piece of land and are managed concurrently. Therefore, appropriate to apply the same methodologies in the minimization of pre-harvest and post-harvest loss strategies on a given field (Comprehensive Development Framework (CDF), 2014).

MATERIALS AND METHODS

The Study Area: The study was conducted in Dutse Local Government Area located in the North western corner of Nigeria on Latitude 11°0.704"N and Longitude 9°0.34"E of the Greenwich Meridian. Dutse is bounded in the North by Ringim and Taura local government, BirninKudu in the south and eastward by Kiyawa local government area while the eastern flank is bordered by Kano State. It has a projected population of 431,800 (NBS, 2022).

Sampling Procedure and Sample Size: A multi-stage sampling procedure (a three-stage) was used for this study. In the first stage, a purposive sampling of the neighboring communities to Federal University Dutse was made (Maja, Madobi, Gurungu, Sherifai, Hausawa, Bulori and Kargo). Secondly, a total of 1,916 households were obtained through a survey. In the third stage, probability proportion to size (PPS) sampling method was employed to select a sample size of 184 households as respondents for this study.

Table 1: Sampling procedure and Sample Size

SN	Community	No. of Households (N)	Sample Size (n)
1	Maja	117	11
2	Hausawa	635	61
3	Sherifai	154	15
4	Bulori	163	16
5	Kargo	317	30
6	Gurungu	530	51
	Total	1,916	184

Source: JARDA 2023

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Respondents: As shown in Table 2 all the respondents were male and are within the average age range of 31-40years. This shows that the respondents are within their active productive age range where energy is available for economic purposes, effective memory alertness and agility is higher.

Most of the respondents (79.3%) were married. Marriage confers responsibility according to Bello, *et.al* (2018). About average (44.6%) of the Millet and Sorghum farmers had primary education, 36.4% had no formal education, while 16.3% had secondary education. This implies that the respondents were not really educated as such may affect their understanding and adoption of Postharvest loss management Technology from Extension agents. Only few (2.7%) had tertiary education. This is in line with the findings of Asare *et al.*, (2015) that the education level of tomato farmers in Ghana was low.

Table 2a: Socioeconomic Characteristics of the Respondents

Variables	Frequency	Percentage (%)	Mean ± SD
Age (Years)			
20-30	21	22.8	36.8 ± 12.8

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31-40	89	39.1
41-50	47	27.2
51-60	20	10.9
61 and above	7	
Total	184	100
Gender		
Male	184	100
Female	0	0
Total	184	100
Marital Status		
Single	38	20.7
Married	146	79.3
Divorced	0	0
Total	184	100
Educational Qualification		
Qur'anic Education	67	36.4
Primary Education	82	44.6
Secondary Education	30	16.3
Tertiary Education	5	2.7
Total	184	100

Source: Field Survey 2023

Table 2b shows the continuation of the socioeconomic characteristics of the respondents. From the table, the main occupation of the farmers is farming (31%), 16.8% are Artisans, 15.2% are Artisans, 16.3% are civil servants and 20.7% others. This is also is the gap in registration according to Uduji & Okolo-Obasi, (2018a) seems to be a function of cultural practices. Some of the cultural practices in the country compel women to function under their husbands especially in the farming business. As shown in the table, about 50.5% of the respondents agreed that they only had contact with the Extension agent only on a yearly basis while 37.5% agreed they had contact on a quarterly basis and 12.0% agreed they had contact with extension agents on monthly basis. However, Omotesho, et al. (2012) reported low annual income of agricultural extension agents would affect their ability to afford information and commination technologies. Also slightly above average 52.2% agreed that there is no availability of extension service delivery with regards to Postharvest loss management technology of Millet and Sorghum in the study area. Umar et al., (2015) findings that about 69.0% belongs to farmers' cooperatives and other social groups within the study area.

Table 2b: Socioeconomic Characteristics of the Respondents continued

Variables	Frequency	Percentage (%)
Access to Agricultural Extension Service		
Have access	88	47.8
No access	96	52.2
Total	184	100
Frequency of contact with Extension		
Monthly	22	12.0
Quarterly	69	37.5
Yearly	93	50.5
Membership of farmers' group		
Member	127	69.0
Not member	57	31.0
Total	184	100

Source: Field Survey 2023

Causes of millet and sorghum Postharvest losses in the study area

Table 6 shows that the causes of postharvest losses of Millet and Sorghum are multiple in nature, and sometimes work together to inflict a serious damage on the crops. According to the result, the major causes of postharvest loss of Millet and Sorghum are insect pest and disease (69.0%), theft (44.6%) and storage (44.6%). This finding agree with that of Obse *et al.*, (2021) that the causes of postharvest losses are diseases, insects, rodents, thefts, mechanical damage and storage techniques. This is also in line with Tor and Akpehe (2020) that pest and diseases causes 69.5% of postharvest losses of Fluted pumpkin.

Table 3: Causes of millet and sorghum Postharvest losses in the study area

Causes	VE	%	E	%	NE	%	Mean Scores
Insect/Pest/Diseases	127	69.0	57	57.0	0	0	61.33
Under/Over Maturity	38	20.7	45	24.5	101	54.9	
Mechanical Damages	42	22.8	103	56.0	39	21.2	
Transportation	31	16.9	83	45.1	70	38.0	
Theft	82	44.6	56	30.4	46	25.0	
Storage	82	44.6	64	34.8	38	20.7	
Climatic Conditions	48	26.1	78	42.4	58	31.5	
Others	78	42.4	82	44.6	24	13.0	

Source: Field Survey 2023

Agricultural Extension Services available to the Farmers in the Study Area

Table 5: shows the Available AESs provided to farmers on post-harvest losses of Millet and Sorghum in the study area which are as follows; Field Meeting (12.5%), Method and result Demonstration (20.1%), Regular visit (14.1%), Individual Farmer Training (38.6%), Technical Services (21.2%), Training/Advisory Services (27.7%), Good Linkages (Institution and Farmers) (19.6%), Climatic Change Information (23.9%) and None (56.0%) this implies that, most of the agricultural extension services are not available to the farmers in the study area. According to Ajibola et al., (2015) the results finding that the only method demonstration in the group (mean=2.64) can be considered an effective method because it is close to the scale of 2 (effective).

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Other leading extension teaching methods and sources of information used by respondents in the study area such as farm/home visits of individuals (mean=2.28), and telephone calls of individuals (mean=2.25) were falls within the scale of 1 (not effective). The least utilized sources and means of acquiring information by farmers were information contact and newspaper.

Table 4: Agricultural Extension Services available to the Farmers in the Study Area

Variable	Yes	%	No	%
Field Meeting	23	12.5	161	87.5
Method and result Demonstration	37	20.1	147	79.9
Regular visit	26	14.1	158	85.9
Individual Farmer Training	71	38.6	113	61.4
Technical Services	39	21.2	145	78.8
Training/Advisory Services	51	27.7	133	72.3
Good Linkages (Institution and Farmers)	36	19.6	148	80.4
Climatic Change Information	44	23.9	140	76.1
None	103	56.0	81	44.0

Source: Field Survey 2023

Conclusion: The study assessed the agricultural extension service delivery on postharvest loss management of millet and sorghum in Dutse local government area of Jigawa state. The study revealed that the Agricultural Extension services on postharvest losses of millet and sorghum are not delivered to the farmers; this is due to Irregular visit by extension workers/agents, lack of infrastructural facilities, limited number of field extension officers/agents, lack of finance and lack of updated information on post-harvest loss management of Millet and Sorghum.

Recommendations: The following recommendations are made based on the findings of this research; There should be appropriate monitoring systems by the government in ensuring that frequent extension services are provided to the rural farmers as this will facilitate better adoption of postharvest handling practices and technologies. Targeting Post-Harvest Loss interventions by the government to improve post-harvest handling techniques (especially those on the farm) is a key to reducing post-harvest losses. The government should improve post-harvest handling techniques, awareness creation on better understanding of the true extent of Post-Harvest and research on Post-Harvest Loss. There is need for relevant agencies both governmental and non-governmental to provide, employ and train more extension agents to reduce the limitations militating against the delivery of Agricultural Extension services on Postharvest losses to the respondents. Extension agents should be pro-active to ensure that there is effective monitoring procedure of postharvest activities to minimize losses. Low literacy level should also be addressed through provision of special literacy programme for farmers

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Gender Dynamics in Palm Oil Agriculture and the Economic Sustainability Implications in Imo State

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Abstract

Palm oil production remains a critical component of agricultural systems and economic sustainability in Imo State, Nigeria, with complex gender dynamics shaping farming and processing practices. This study examined the gender roles, practices, and economic contributions in palm oil farming and processing systems in Imo State, focusing on how gender dynamics influence productivity, value chain participation, and economic sustainability. The research employed a descriptive survey design using quantitative and qualitative methods with data collected from 150 palm oil farmers and processors (75 males and 75 females) through questionnaires, interviews, and focus group discussions. Results revealed significant gender differences in palm oil farming and processing practices, with women predominantly involved in fruit harvesting, processing, and kernel extraction activities, while men dominated plantation establishment, climbing for harvesting, and marketing of crude palm oil. Female farmers and processors showed higher engagement in value-addition activities, contributing 78% to palm kernel processing enterprises and 65% to small-scale palm oil processing. However, women faced greater constraints in accessing land for plantation establishment (75% vs 28% for men), modern processing equipment (82% vs 45% for men), and credit facilities (77% vs 48% for men). Despite these challenges, women's participation in palm oil processing contributed significantly to household income generation and rural economic development. The study concludes that addressing gender inequities in resource access and promoting gender-inclusive palm oil farming and processing practices is crucial for enhancing productivity and economic sustainability in Imo State.

Keywords: Gender dynamics, Palm oil farming, Processing practices, Economic sustainability, Value chain

Introduction: Palm oil (*Elaeis guineensis*) stands as one of the most economically significant agricultural commodities in Nigeria, serving as a primary source of income, employment, and foreign exchange earnings for millions of farmers and processors, particularly in the southeastern regions including Imo State. The oil palm industry's contribution to Nigeria's economy extends beyond mere production to encompass complex value chains involving farming, processing, and marketing activities that provide livelihoods for rural communities (Manfre et al., 2013). However, palm oil farming and processing in Nigeria are characterized by distinct gender dynamics that significantly influence production practices, processing outcomes, and economic contributions. In Imo State, palm oil production involves intricate gender-differentiated roles and responsibilities that reflect broader socio-cultural norms, traditional practices, and economic realities. The oil palm tree, being a perennial crop, requires different management approaches compared to annual crops, with specific gender roles evolving around plantation establishment, maintenance, harvesting, and processing activities.

Understanding these gender dynamics is crucial for developing effective agricultural policies and interventions that can enhance productivity and economic sustainability in the palm oil sector. The significance of gender analysis in palm oil farming and processing extends beyond role differentiation to encompass broader questions of economic empowerment, resource access, technology adoption, and sustainable development. Research indicates that women constitute a significant portion of the palm oil processing workforce in Nigeria, contributing substantially to value-addition activities, yet their contributions are often undervalued and their access to productive resources remains limited (FAO, 2019). This gender gap in resource access and recognition has implications for overall sector productivity and economic sustainability.

Palm oil farming and processing in Imo State presents a unique context for examining gender dynamics due to the crop's importance in both smallholder and commercial farming systems. The state's favorable agro-ecological conditions support substantial oil palm cultivation, yet productivity remains below potential levels, partly due to gender-related constraints in farming practices, processing technologies, and market access (Khursheed et al., 2020). The traditional processing methods predominantly employed by women, while culturally significant, often result in lower oil extraction rates and limited market reach compared to modern processing facilities. The economic implications of gender dynamics in palm oil systems are multifaceted. While men typically control plantation ownership and crude palm oil marketing, women dominate processing activities that add significant value to the raw materials. Palm kernel processing, traditionally a female domain, represents a crucial component of the palm oil value chain, contributing to both household income and national economic development. However, women's limited access to modern processing equipment, credit facilities, and market information constrains their ability to optimize economic returns from their activities. Understanding how gender shapes farming practices, processing methods, market participation, and economic outcomes is essential for unlocking the full potential of palm oil production in Imo State. The interplay between traditional gender roles and modern agricultural development presents both opportunities and challenges for sustainable development in the sector.

This study examines gender dynamics in palm oil production and processing practices and their contribution to economic sustainability in Imo State. Specifically, it aims to:

- i. Examine gender-differentiated roles and practices in palm oil farming and processing systems
- ii. Assess the economic contributions of male and female participants to palm oil value chains
- iii. Evaluate gender-based constraints and opportunities in palm oil farming and processing practices
- iv. Determine the relationship between gender dynamics and economic sustainability in palm oil systems

3.0 Research Methodology

3.1 Study Area: The study was conducted in Imo State, located in the southeastern agro-ecological zone of Nigeria. The state has substantial oil palm cultivation areas and traditional processing centers, making it an ideal location for examining gender dynamics in palm oil farming and processing practices.

3.2 Population and Sampling The target population consisted of male and female palm oil farmers and processors in Imo State. A stratified random sampling technique was used to select 150 participants (75 males and 75 females) from major palm oil-producing and processing communities across the state.

3.3 Data Collection and Analysis: Primary data were collected using pre-tested interview schedules and structured questionnaires. Secondary data were obtained from published and unpublished sources. Both quantitative and qualitative data analysis methods were employed. Quantitative data were analyzed using descriptive statistics (frequencies, percentages, and means) and inferential statistics like regression analysis

4.0 Results and Discussion

4.1 Gender-Differentiated Roles in Palm Oil Farming and Processing Practices

Table 1: Gender Roles and Responsibilities in Palm Oil Farming and Processing

Farming Activities	Male Frequency (%)	Female Frequency (%)	Primary Responsibility
Land preparation	135 (90%)	15 (10%)	Male-dominated
Seedling procurement	110 (73%)	40 (27%)	Male-dominated
Planting	120 (80%)	30 (20%)	Male-dominated
Weeding	45 (30%)	105 (70%)	Female-dominated
Fertilizer application	125 (83%)	25 (17%)	Male-dominated
Pruning	140 (93%)	10 (7%)	Male-dominated
Climbing for harvesting	145 (97%)	5 (3%)	Male-dominated
Processing Activities			
Fruit collection	35 (23%)	115 (77%)	Female-dominated

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Farming Activities	Male Frequency (%)	Female Frequency (%)	Primary Responsibility
Fruit sorting	25 (17%)	125 (83%)	Female-dominated
Fruit boiling	20 (13%)	130 (87%)	Female-dominated
Oil extraction	60 (40%)	90 (60%)	Female-dominated
Kernel extraction	15 (10%)	135 (90%)	Female-dominated
Kernel processing	10 (7%)	140 (93%)	Female-dominated
Marketing Activities			
Crude palm oil marketing	120 (80%)	30 (20%)	Male-dominated
Palm kernel marketing	35 (23%)	115 (77%)	Female-dominated
Processed oil marketing	50 (33%)	100 (67%)	Female-dominated

Source: Field Survey, 2025

The analysis of gender roles in palm oil farming and processing reveals distinct patterns of responsibility allocation reflecting both physical requirements and cultural norms. Male participants dominated plantation establishment and maintenance activities, including land preparation (90%), planting (80%), and fertilizer application (83%). The most exclusively male activity was climbing for harvesting (97%), which requires significant physical strength and involves safety risks.

Female participants showed predominant involvement in processing activities, particularly kernel extraction (90%) and kernel processing (93%). These activities require patience, attention to detail, and manual dexterity, traits traditionally associated with women. The high female participation in fruit collection (77%) and sorting (83%) reflects women's involvement in post-harvest activities that bridge farming and processing.

Oil extraction showed more gender balance (40% male, 60% female), indicating that while women dominates traditional processing methods, men participate in larger-scale extraction activities. This pattern suggests potential for increased male involvement in processing activities with appropriate technology and training.

Marketing activities revealed interesting gender patterns, with men dominating crude palm oil marketing (80%) while women controlled palm kernel marketing (77%) and processed oil marketing (67%). This division reflects the types of products each gender primarily produces and their respective market networks.

4.2 Economic Contributions and Value Chain Participation

Table 2: Economic Contributions by Gender in Palm Oil Value Chain

Economic Activity	Male Contribution (%)	Female Contribution (%)	Average Annual Income (₦)
Primary Production			
Plantation establishment	85%	15%	₦450,000
Plantation maintenance	70%	30%	₦320,000
Fresh fruit bunch sales	75%	25%	₦380,000
Processing Activities			
Traditional oil processing	22%	78%	₦420,000
Kernel processing	12%	88%	₦350,000
Value-added products	25%	75%	₦480,000
Marketing Activities			
Crude palm oil trade	80%	20%	₦520,000
Palm kernel trade	30%	70%	₦380,000
Processed products trade	35%	65%	₦450,000

Survey, 2025

The economic analysis reveals complementary gender contributions across the palm oil value chain, with distinct patterns of specialization that optimize household and community economic outcomes. Male participants dominated high-capital activities such as plantation establishment (85%) which require substantial initial investments but generate significant returns.

Female participants showed strong dominance in processing activities, contributing 78% to traditional oil processing and 88% to kernel processing. These activities demonstrate women's crucial role in value-addition, transforming raw materials into marketable products. The higher income from value-added products (₦480,000 annually) compared to raw material sales indicates the economic importance of women's processing activities.

Palm kernel processing, almost exclusively female-dominated (88%), represents a particularly important economic activity for women. Despite requiring minimal capital investment, kernel processing generates substantial income (₦350,000 annually) and provides employment opportunities for women in rural areas.

Men's dominance in crude palm oil trade (80%) reflects their control over large-scale production and established market relationships. Women's strength in kernel trade (70%) and processed products trade (65%) demonstrates their market expertise in value-added products.

4.3 Regression Analysis: Gender Dynamics and Economic Sustainability

Table 3: Regression Analysis of Gender Factors on Economic Outcomes

Variable	Coefficient	Standard Error	t-statistic	p-value
Gender (1=male, 0=female)	0.08	0.06	1.33	0.185
Plantation size	0.25	0.04	6.25	0.000***
Processing involvement	0.30	0.07	4.29	0.000***

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Variable	Coefficient	Standard Error	t-statistic	p-value
Education level	0.12	0.05	2.40	0.018**
Market participation	0.18	0.06	3.00	0.003***
Access to credit	0.22	0.05	4.40	0.000***
Technology adoption	0.15	0.04	3.75	0.000***
Years of experience	0.10	0.03	3.33	0.001***
*Note: ***p<0.01, **p<0.05, p<0.1				
R-squared: 0.72				
F-statistic: 32.15				
Significance: 0.000				

The regression analysis explains 72% of the variation in economic outcomes, indicating that gender dynamics significantly influence economic sustainability in palm oil systems. Processing involvement shows the strongest positive effect on economic outcomes (coefficient = 0.30), highlighting the crucial importance of value-addition activities predominantly performed by women.

Plantation size (coefficient = 0.25) and access to credit (coefficient = 0.22) also significantly influence economic outcomes, suggesting that addressing gender gaps in land access and credit facilities could substantially enhance overall economic sustainability. Interestingly, the gender variable itself (male vs female) does not show statistical significance ($p = 0.185$), indicating that success depends more on access to resources and activities rather than gender dynamism. This suggests that equalizing access to resources and opportunities could eliminate gender-based economic disparities.

4.4 Gender-Based Constraints and Opportunities: The constraint analysis reveals that while both genders face common challenges, women encounter additional gender-specific barriers that significantly limit their full participation in palm oil economic activities. The most pronounced gender disparity appears in land access, with 75% of female participants citing land ownership/access as a major constraint compared to only 28% of male participants. Access to credit facilities presents another significant gender gap, with 77% of women reporting difficulties accessing credit compared to 48% of men. This disparity reflects broader financial sector biases and women's limited collateral assets, particularly land ownership, which banks typically require for agricultural loans. Modern processing equipment access shows the largest gender gap (82% vs 45%), highlighting women's disadvantage in technological advancement. Despite their dominance in processing activities, women's limited access to modern equipment constrains their productivity and economic returns. Male participants face higher constraints in pest and disease management (70% vs 25%), reflecting their primary responsibility for plantation management. However, women's limited access to processing technology (78% vs 35%) presents a more significant barrier to economic advancement given their specialization in value-addition activities.

Conclusion: The study reveals significant gender dynamics in palm oil farming and processing practices in Imo State, with distinct patterns of specialization that reflect both traditional roles and economic opportunities. Women demonstrate strong involvement in value-addition activities, contributing substantially to economic sustainability through processing and kernel extraction activities. However, gender-based constraints, particularly in land access, credit facilities, and modern processing technologies, limit women's full potential in palm oil systems.

The findings indicate that while traditional gender roles persist, women's economic contributions through processing and value-addition activities are crucial for overall system sustainability. The higher potential returns from processed products suggest that supporting women's involvement in value-addition could enhance economic outcomes for all participants. The complementary nature of male and female contributions suggests that gender-inclusive development approaches would be more effective than gender-neutral policies. Men's strength in plantation management and women's expertise in processing create synergistic opportunities for sector development.

Recommendations: Based on the findings, the following recommendations are proposed:

- i. Government and communities should develop policies that ensure equitable land access and ownership rights for both male and female farmers, particularly supporting women's access to land for plantation establishment.
- ii. Government should Create specialized credit facilities that address women's specific needs and constraints, including collateral alternatives and flexible repayment terms aligned with processing income patterns.
- iii. The appropriate authorities should invest in appropriate processing technologies that build on women's existing expertise while improving efficiency and product quality.

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Scaling up Climate-Smart Soil Management Practices among Smallholder Farmers in Imo State

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Abstract

This study examined adoption of climate-smart soil management practices (CSSMPs) among smallholder farmers in Imo State, Nigeria, focusing on adoption levels, determinants, and productivity effects. Data from 240 farmers, obtained through a multistage sampling design, were analysed using descriptive statistics, logistic regression, and ordinary least squares models. Results showed moderate adoption, dominated by mulching (70%), organic manure (62.9%), and crop rotation (59.2%), while agroforestry and conservation tillage were least adopted. Most farmers adopted 2–4 practices, with high-intensity adoption (>6 practices) rare. Logistic results indicated that education, access to extension, credit, market, and farmer groups significantly enhanced adoption, whereas age and experience reduced it. OLS models confirmed adoption intensity as a strong driver of cassava and maize yields. Findings suggest that institutional support and socio-economic capacity are decisive for scaling CSSMPs. Policy implications emphasise extension strengthening, youth and women empowerment, credit expansion, and integration into national adaptation frameworks aligned with SDGs and AU Agenda 2063

Key words: Climate-smart soil management, Adoption intensity, Smallholder farmers, Farm productivity, Imo State.

Introduction: Smallholder agriculture in sub-Saharan Africa is highly vulnerable to climate change, land degradation, and declining soil fertility (Mangole et al., 2025; Gudina et al., 2024). In Nigeria, especially the southeastern states such as Imo, farmers face soil erosion, fertility decline, and erratic rainfall despite modest productivity gains. Climate-smart soil management practices (CSSMPs) including mulching, crop rotation, cover cropping, organic amendments,

conservation tillage, and agroforestry are promoted as pathways to restore soil health, sequester carbon, and enhance resilience (Mpinda et al., 2025; Osabohien et al., 2024). However, adoption remains uneven: while some farmers integrate multiple practices, others adopt none. Evidence shows that education, farm size, income, extension, market access, and perception of climate change significantly shape adoption, while adoption intensity defined by the number of practices adopted often correlates positively with productivity (Ewulo et al., 2025; Ojo et al., 2024). Yet, empirical insights into how socio-economic and institutional factors jointly influence adoption levels and productivity in Imo State remain limited. A knowledge and policy gap persist. Studies in Oyo and other states highlight adoption drivers but often analyse single practices or fail to measure intensity and its productivity effect (Arifalo & Ilesanmi, 2022; Osabohien et al., 2024). Policy frameworks such as Nigeria's Agricultural Promotion Policy encourage extension and credit schemes, but their reach and effectiveness in Imo are under-documented. Without robust evidence, interventions risk targeting practices with low adoption potential or limited productivity impact.

This study addresses these gaps by empirically assessing adoption levels, identifying socio-economic and institutional determinants, and analysing how adoption intensity influences productivity. Using logistic regression for binary adoption and OLS for productivity models, the research contributes theoretically by extending innovation adoption literature to humid forest contexts, and practically by providing locally relevant evidence for scaling CSSMPs. Accordingly, the study was guided by three specific objectives: to determine the level of adoption of CSSMPs among smallholder farmers in Imo State, measured by the proportion of adopters, non-adopters, and adoption intensity; to identify socio-economic factors (such as age, education, household size, farm size, income, and farming experience) and institutional factors (including access to extension services, credit, markets, and farmer group membership) that influence adoption decisions; and to examine the impact of adoption intensity on farm productivity, measured as yield per hectare while controlling for relevant covariates. The study's **justification** rests on both theoretical and policy relevance. Diffusion of Innovation theory (Rogers, 2003) and adoption models highlight that adoption decisions and intensity matter for welfare, yet empirical work often neglects intensity. By explicitly modelling both adoption and intensity, this study closes an analytical gap. Policy relevance is strong: Nigeria is committed under the Paris Agreement, AU Agenda 2063, and national strategies to promote climate-smart agriculture. Imo State faces soil fertility decline and stagnant yields, making CSSMP scaling urgent. Evidence on adoption drivers and intensity–productivity links will guide extension, credit, and climate adaptation programmes.

Literature Review: Adoption of climate-smart soil management practices (CSSMPs) is underpinned by several theoretical frameworks. The **Diffusion of Innovations (DOI) theory** posits that adoption depends on perceived relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). For example, CSSMPs such as mulching are often perceived as simple and low-cost, while agroforestry and conservation tillage may be seen as complex or labour-intensive (Makate et al., 2019). The **Technology Acceptance Model (TAM)** extends this perspective by stressing perceived usefulness (productivity gains) and ease of use as central determinants of adoption (Venkatesh & Davis, 2000). **Institutional theory** (North, 1990; Scott, 2014) and **transaction cost economics** (Williamson, 1981) highlight how access to credit, markets, and extension reduces transaction costs, enabling adoption of CSSMPs (Finizola e Silva et al., 2024). Critics argue these models assume linear adoption processes and often ignore **intensity** (the number or depth of practices adopted), a gap emphasised in recent adoption studies (Izuogu et al., 2025). More recent frameworks such as the **sustainable livelihoods approach** (Chambers & Conway, 1992; Scoones, 1998) and **resilience theory** (Holling, 1973; Folke, 2006) situate CSSMPs within broader livelihood strategies, where adoption is both a response to climate risks and a pathway to resilience (Hailemariam et al., 2024). Integrating these theories provides a holistic understanding of adoption dynamics in Imo State.

Evidence across Nigeria and beyond highlights mixed but converging trends. In the North-West, Saadu et al. (2024) reported high adoption of crop rotation and fertiliser use, with significant income and food security gains. In Borno State, Shehu (2024) showed age, education, and extension access significantly affected adoption, but credit constraints limited uptake. A national synthesis by Izuogu et al. (2025) confirmed education, credit, and institutional linkages as consistent determinants across regions. Cross-country studies add nuance: Mangole et al. (2025) found adoption in Botswana strongly linked to extension and group membership, while Ewulo et al. (2025) reported similar patterns in Nigeria. Productivity effects are clearer in multi-practice adoption: Amankwah et al. (2023) found plot-level adoption of combined practices significantly boosted yields, while Ojo et al. (2024) confirmed sustainable land management improved rice productivity in Ogun State. These findings support the view that adoption intensity, not just binary adoption, is decisive. Methodological strengths include regression-based analysis and large samples, but weaknesses remain in cross-sectional designs and under-representation of humid forest agroecologies like Imo.

CSSMPs encompass a range of soil-based interventions including mulching, composting, crop rotation, cover cropping, agroforestry, conservation tillage, and organic fertiliser application which are commonly featured in CSA practices guides and empirical studies (CGIAR CSA Guide, n.d.; Ibekwe, 2021). The Climate-Smart Agriculture Guide defines them as practices that enhance productivity, resilience, and carbon sequestration (CGIAR, n.d.). Adoption intensity is often operationalised as the count of practices adopted (Gikonyo et al., 2022; Sanusi, 2024), though alternate metrics include

weighted indices or scores (Oyetunde-Usman et al., 2020). Productivity is typically measured as yield per hectare (FAO, 2013; Mbanasor et al., 2024), though some studies use income or food security proxies (Ahamefule et al., 2025). Conceptual debates persist over trade-offs: certain practices enhance resilience but impose increased labour or management cost, influencing farmers' adoption willingness (Finizola e Silva et al., 2024; Ume et al., 2023). Disciplinary variation complicates conceptualisation: agronomists prioritise soil health and biophysical metrics, economists emphasise adoption decisions and welfare outcomes, while sociologists emphasise institutional networks and perception dynamics (Montes de Oca Munguia et al., 2021; Zakari & Muhammad, 2023). For this study, adoption intensity is defined as the number of CSSMPs adopted (0–7), and productivity as yield per hectare of major crops, thereby operationalising both constructs in measurable terms. The literature converges on education, extension access, credit, and group membership as primary drivers of adoption (Finizola e Silva et al., 2024; Ume et al., 2023), while younger farmers tend to adopt more intensively (Hailemariam et al., 2024). However, gaps remain in adoption-intensity studies in southeastern Nigeria under humid forest conditions, particularly linking intensity to productivity a key motivation for this study.

Methodology: The research was conducted in Imo State, southeastern Nigeria, located in the humid forest zone between latitudes 4°45'N and 7°15'N and longitudes 6°50'E and 7°25'E with a land area of around 5,100 sq km (Imo ADP, 2022). Imo State is bordered by Abia State on the East, River Niger and Delta State to the West, Anambra State on the North, and Rivers State to the South (Imo ADP, 2022). There are two main seasons in the state- dry and rainy seasons. The annual rainfall is between 1900mm and 2200mm while the mean annual temperature of 27–30 °C with a relative humidity of about 75% annually (Imo ADP, 2022). Farming is dominated by smallholders producing cassava, maize, yam, and vegetables. Yet soil fertility decline, erosion, and climate variability constrain yields, making climate-smart soil management practices (CSSMPs) vital for sustainable production (Osabohien et al., 2024). A multistage sampling technique was used in selecting 240 respondents. Three agricultural zones in the study area were chosen, followed by four LGAs per zone, then two communities per LGA, from which 10 farmers each were randomly drawn. Yamane's (1967) formula at 95% confidence level guided sample size, adjusted to 240 for representativeness. This ensured variation across agro-ecological and institutional contexts. Data were gathered with structured questionnaires and focus groups. Variables covered socio-economic attributes, institutional access, CSSMP adoption, and yields. Reliability was confirmed by Cronbach's alpha ($\alpha = 0.81$), and content validity by expert review. Pre-testing with 20 farmers outside the sample refined clarity.

In data analysis, descriptive statistics (percentages, frequencies) were used in achieving objective 1. Adoption intensity was measured as a simple count of practices adopted by each farmer (range: 0–7). Adoption rate was computed as:

$$\text{Adoption Rate} = \frac{\text{Number of Adopter of CSSMPs}}{\text{Total sample farmers}} \times 100\% \dots \dots \dots 1$$

Objective 2 was realized using binary logistic regression to model the probability of adopting at least one CSSMP. The model is specified as:

$$\ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \epsilon_i \dots \dots \dots 2$$

where: P_i = probability that the i^{th} farmer adopts CSSMPs (1 = adopter, 0 = non-adopter); $X_{1\dots k}$ = vector of socio-economic and institutional variables; β_0 = constant; $\beta_1 \dots \beta_k$ = coefficients; ϵ_i = error term.

Independent variables for adoption model are: Gender (1 = female, 0 = male); Age (years); Education (1 = secondary or higher, 0 = less); Household size (number); Farm experience (years); Access to extension (1 = yes, 0 = no); Market access (1 = yes, 0 = no); Group membership (1 = yes, 0 = no); and Access to credit (1 = yes, 0 = no).

Objective 3 was achieved using Ordinary Least Squares (OLS) regression with farm productivity (yield per hectare in tonnes for cassava/maize) as the dependent variable. The model is specified as:

$$Y_i = \alpha + \gamma A_i + \sum_{j=1}^k \delta_j X_{ji} + \mu_i \dots \dots \dots 3$$

where: Y_i = productivity (yield per hectare) of the i^{th} farmer; A_i = adoption intensity (number of CSSMPs adopted); X_{ji} = socio-economic and institutional control variables (same as above); and α = intercept, γ , δ_j = coefficients, μ_i = error term.

Variance Inflation Factor (VIF) was computed to check multicollinearity, with values < 5 indicating no concern (Gujarati & Porter, 2009). Classical regression assumptions were tested: Breusch-Pagan test (heteroskedasticity), Durbin-Watson

statistic (autocorrelation), and Jarque–Bera test (normality of residuals). Results confirmed that models were robust, with well-behaved residuals, enhancing confidence in the validity of coefficient estimates.

Results Presentation and Discussion: The results in Table 1 show that women constitute 55.8% of the farming population, reflecting their central role in food crop production in southeastern Nigeria. This gendered pattern resonates with findings from Ghana and Uganda, where women are disproportionately engaged in staple crop cultivation but often face structural disadvantages in land tenure and credit access (Hailemariam et al., 2024; Boudalia et al., 2024). The majority of respondents were within the 31–50 years bracket, indicating an economically active population, yet older farmers showed lower likelihood of adoption (later discussed). Education levels were modest but significant, with 68.7% having some formal schooling, a factor that strongly shapes adoption behaviour. Access to extension (59.2%) and markets (64.2%) was uneven, while access to credit was particularly low (35%). Similar institutional bottlenecks are widely reported in West Africa, where farmers’ limited integration into financial systems constrains their ability to adopt labour- or capital-intensive CSA practices (Wossen et al., 2019).

Table 1: Socio-economic characteristics of smallholder arable crop farmers in Imo State (n = 240)

Variable	Categories	Frequency	Percentage (%)
Gender	Male	106	44.2
	Female	134	55.8
Age Group (years)	≤30	36	15.0
	31–40	70	29.2
	41–50	67	27.9
	51–60	43	17.9
	>60	24	10.0
Educational Attainment	No formal education	38	15.8
	Primary	86	35.8
	Secondary	79	32.9
	Tertiary	37	15.4
Household Size	≤4	82	34.2
	5–7	110	45.8
	≥8	48	20.0
Farm Experience (years)	<10	70	29.2
	10–20	106	44.2
	>20	64	26.6
Access to Extension	Yes	142	59.2
	No	98	40.8
Access to Market	Yes	154	64.2
	No	86	35.8
Membership in Farmers’ Group	Yes	113	47.1
	No	127	52.9
Annual Farm Income (₦)	<200,000	115	47.9
	200,001–400,000	82	34.2
	400,001–600,000	31	12.9
	>600,000	12	5.0
Marital Status	Single	41	17.1
	Married	168	70.0
	Widowed/Divorced	31	12.9
Access to Credit	Yes	84	35.0
	No	156	65.0

In Table 2, results show that cassava (82.5%) and maize (72.5%) were the dominant crops, complemented by yam (50.4%) and vegetables (42.5%). These results confirm the dual role of cassava as a food security and income crop and maize as a cereal staple. The prominence of cassava mirrors findings in southern Nigeria, where cassava’s resilience to poor soils makes it a strategic crop under climate variability (Osabohien et al., 2024). In contrast, maize’s sensitivity to soil fertility and rainfall variability makes it a strong indicator of CSSMP effectiveness, consistent with studies in Kenya and Malawi where CSA adoption stabilised maize yields under drought conditions (Amadu et al., 2020; Wanjira et al., 2023; Nakazibwe, 2022). The choice of these crops for yield analysis therefore enhances the policy relevance of findings.

Table 2: Distributive statistics of arable crops farmed by respondents in the last farming season (n = 240)

Crop	Frequency	Percentage (%)
Cassava	198	82.5
Maize	174	72.5
Yam	121	50.4
Cocoyam	88	36.7
Vegetables (e.g., fluted pumpkin, okra)	102	42.5
Rice (upland/lowland)	39	16.3
Others (melon, groundnut, sweet potato)	27	11.3

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In determining the level of adoption of climate-smart soil management practices (CSSMPs) among smallholder farmers in Imo State, Table 3 shows that mulching (70%), organic manure (62.9%), and crop rotation (59.2%) were the most common practices, while agroforestry (26.3%) and conservation tillage (30.8%) were least adopted. Adoption distribution (Table 4) revealed that 11.7% of farmers had not adopted any practice, 58% adopted 2–4 practices, and only 6.3% adopted six or more. This indicates a moderate adoption intensity, with substantial scope for scaling. Similar moderate adoption levels were reported in North-Central Nigeria, where fewer than 10% of farmers adopted high-intensity packages of climate-smart practices (State of CSA, 2023). The finding reinforces Diffusion of Innovation theory: farmers often adopt incremental innovations that are low-cost and less complex, such as mulching and organic manure, before transitioning to more knowledge-intensive or labour-demanding practices such as agroforestry (Rogers, 2003).

Table 3: Climate-smart soil management practices in the study area (n = 240)

CSSMP Practiced	Frequency	Percentage (%)
Mulching	168	70.0
Compost application	126	52.5
Cover cropping	89	37.1
Crop rotation	142	59.2
Conservation tillage (minimum tillage, zero tillage, ridging across slope)	74	30.8
Agroforestry (intercropping with trees, shelterbelts)	63	26.3
Use of organic manure (farmyard, poultry droppings)	151	62.9

Table 4: Distribution of CSSMP adoption among smallholder farmers in Imo State (n = 240)

Adoption Score (No. of Practices Adopted)	Frequency	Percentage (%)
0 (None)	28	11.7
1	34	14.2
2	46	19.2
3	51	21.3
4	42	17.5
5	24	10.0
6 – 7 (High adoption)	15	6.3
Total	240	100.0

The logistic regression results (Tables 5A and 5B) reveal that the adoption of Climate-Smart Soil Management Practices (CSSMPs) among cassava and maize farmers in Imo State is strongly shaped by socio-economic and institutional factors. Both models were statistically significant (LR χ^2 , $p < 0.001$) and moderately explanatory (Pseudo $R^2 = 0.248$ for cassava; 0.239 for maize). Education was a key determinant, nearly doubling cassava adoption odds (OR = 1.90) and raising maize adoption by 80% (OR = 1.80), underscoring the role of human capital in technology uptake (Izuogu et al., 2025). Extension access more than doubled adoption odds, corroborating institutional theory which stresses reduced transaction costs and improved innovation diffusion (Finizola e Silva et al., 2024). Group membership also strongly boosted adoption (cassava OR = 2.37; maize OR = 2.23), confirming evidence that cooperatives promote peer learning and collective bargaining (Montes de Oca Munguia et al., 2021). Similarly, credit access enhanced adoption (cassava OR = 2.05; maize OR = 1.96), consistent with findings from Zakari and Muhammad (2023) that finance relaxes liquidity constraints and enables investment in labour- or capital-intensive practices.

Conversely, age and farm experience reduced adoption likelihood by about 2–3% annually, implying younger and less experienced farmers are more responsive to innovation. This supports evidence from Shehu (2024), who also found negative effects of age on CSA uptake in Borno State. Gender, while showing positive coefficients, was not statistically significant, reflecting structural barriers such as land tenure and limited credit access, in line with Boudalia et al. (2024). Collectively, these results highlight that CSSMP adoption depends less on socio-economic endowments and more on institutional supports (extension, credit, and farmer groups) that create enabling conditions for uptake. This aligns with institutional theory (North, 1990) while also pointing to demographic inertia as a challenge. Education and institutional linkages thus stand out as consistent enablers, reinforcing the need for policies that integrate human capital development and institutional strengthening.

Table 5A: Logistic regression results on determinants of CSSMP adoption among cassava farmers (n ≈ 198)

Variable	Coefficient (β)	Std. Error	Odds Ratio	p-value	Significance
Constant	-0.912	0.634	0.40	0.156	—
Gender (1 = Female)	0.418	0.259	1.52	0.103	***
Age (years)	-0.023	0.012	0.98	0.049	**
Education (1 = Secondary+)	0.642	0.277	1.90	0.018	**
Household size	0.041	0.026	1.04	0.115	—
Farm experience (years)	-0.031	0.013	0.97	0.020	**
Access to extension (1 = Yes)	0.751	0.293	2.12	0.009	***
Access to market (1 = Yes)	0.437	0.244	1.55	0.078	***
Membership in farmers' group (1 = Yes)	0.861	0.289	2.37	0.002	**
Access to credit (1 = Yes)	0.718	0.281	2.05	0.008	**

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Diagnostics: Log likelihood = -112.5; Pseudo R² = 0.248; LR Chi² (9) = 37.8 (p < 0.001)

Table 5B: Logistic regression results on determinants of CSSMP adoption among maize farmers (n ≈ 174)

Variable	Coefficient (β)	Std. Error	Odds Ratio	p-value	Significance
Constant	-0.773	0.612	0.46	0.201	—
Gender (1 = Female)	0.364	0.246	1.44	0.113	—
Age (years)	-0.020	0.011	0.98	0.056	***
Education (1 = Secondary+)	0.589	0.261	1.80	0.022	**
Household size	0.033	0.023	1.03	0.135	—
Farm experience (years)	-0.026	0.012	0.97	0.027	**
Access to extension (1 = Yes)	0.694	0.281	2.00	0.012	**
Access to market (1 = Yes)	0.386	0.231	1.47	0.091	***
Membership in farmers' group (1 = Yes)	0.804	0.269	2.23	0.004	*
Access to credit (1 = Yes)	0.674	0.264	1.96	0.009	**

Diagnostics: Log likelihood = -101.8; Pseudo R² = 0.239; LR Chi² (9) = 34.6 (p < 0.001)

The OLS regression results presented in Tables 6A and 6B demonstrate that adoption intensity of Climate-Smart Soil Management Practices (CSSMPs) significantly increased yields of cassava ($\beta = 0.221$, $p < 0.01$) and maize ($\beta = 0.185$, $p < 0.01$), indicating that each additional practice adopted raised output by about 0.22 and 0.19 tonnes per hectare respectively. This highlights the cumulative agronomic benefits of integrating multiple practices, consistent with evidence from sub-Saharan Africa that intensification of climate-smart strategies boosts yield and resilience (Osabohien et al., 2024; Yiridomoh et al., 2025). Education also positively influenced productivity (cassava $\beta = 0.171$; maize $\beta = 0.149$, $p < 0.05$), confirming that educated farmers more effectively translate adoption into yield gains (Li, 2024). Similarly, access to extension services significantly improved outcomes (cassava $\beta = 0.201$; maize $\beta = 0.162$, $p < 0.05$), echoing studies in Nigeria and Ghana that highlight extension as vital for correct practice implementation (Finizola e Silva et al., 2024; Hailemariam et al., 2024). Group membership (cassava $\beta = 0.182$; maize $\beta = 0.148$, $p < 0.05$) enhanced productivity through peer learning and collective action (Montes de Oca Munguia et al., 2021), while access to credit (cassava $\beta = 0.214$; maize $\beta = 0.168$, $p < 0.05$) enabled investment in capital-demanding practices, consistent with Zakari and Muhammad (2023).

Conversely, age and farming experience were negatively associated with productivity, with each additional year reducing cassava yield responsiveness by 0.015 tonnes ($p < 0.05$) and farm experience having a similar dampening effect. This suggests that younger, less experienced farmers are more dynamic adopters, reflecting patterns observed in Ghana and Ethiopia where older farmers tended to rely on traditional practices (Hailemariam et al., 2024). The diagnostic statistics ($R^2 = 0.436$ for cassava; $R^2 = 0.408$ for maize) confirm that the models are robust, explaining over 40% of yield variation. Overall, the findings provide empirical confirmation that adoption intensity is more important than isolated practices, while education, extension, credit, and cooperatives create the enabling environment that translates adoption into productivity. At the same time, the negative effects of age and experience highlight the need for targeted, customised extension and incentives for older farmers.

Table 6A: OLS regression results: Effect of CSSMP adoption on cassava yield (n ≈ 198)

Variable	Coefficient (β)	Std. Error	Significance
Constant	1.867	0.418	—
CSSMP adoption score	0.221	0.053	*
Gender (1 = Female)	0.092	0.107	—
Age (years)	-0.015	0.006	**
Education (1 = Secondary+)	0.171	0.083	**
Farm experience (years)	-0.010	0.004	**
Access to extension (1 = Yes)	0.201	0.097	**
Access to market (1 = Yes)	0.125	0.084	***
Membership in farmers' group (1 = Yes)	0.182	0.092	**
Access to credit (1 = Yes)	0.214	0.095	**

Diagnostics: R² = 0.436; F (9,188) = 16.9 (p < 0.001)

Table 6B: OLS regression results: Effect of CSSMP adoption on maize yield (n ≈ 174)

Variable	Coefficient (β)	Std. Error	Significance
Constant	1.298	0.361	—
CSSMP adoption score	0.185	0.048	*
Gender (1 = Female)	0.071	0.099	—
Age (years)	-0.012	0.005	**
Education (1 = Secondary+)	0.149	0.079	**
Farm experience (years)	-0.008	0.003	**

Access to extension (1 = Yes)	0.162	0.091	**
Access to market (1 = Yes)	0.112	0.081	***
Membership in farmers' group (1 = Yes)	0.148	0.086	**
Access to credit (1 = Yes)	0.168	0.089	**

Diagnostics: $R^2 = 0.408$; $F(9,164) = 15.2$ ($p < 0.001$)

Discussion of these findings shows both convergence and divergence with existing literature. Convergence lies in confirming the strong roles of education, extension, and credit, which consistently appear in adoption studies (Saadu et al., 2024; Izuogu et al., 2025). Divergence is observed in the relatively lower adoption of agroforestry and conservation tillage in Imo compared to other regions of Nigeria, where these practices have gained traction (Ewulo et al., 2025). This discrepancy may reflect the humid agroecology of Imo State, where land fragmentation and tenure insecurity limit investment in long-term practices. Theoretically, the results refine Diffusion of Innovations theory by highlighting adoption intensity as a crucial, yet under-modelled, component of the adoption process. They also advance resilience frameworks by showing that CSSMP bundles improve productivity even under smallholder constraints.

From a policy perspective, the evidence demonstrates that without strengthening institutional supports, adoption levels will plateau, and productivity benefits will remain uneven. The clear productivity gains observed among high-intensity adopters underscore the urgency of scaling beyond partial adoption. Linking findings to global debates, this study closes part of the knowledge gap matrix in southeastern Nigeria by providing empirical evidence on adoption intensity and its productivity impact, a missing link in earlier work.

Table 7 presents the Variance Inflation Factor (VIF) diagnostics for the cassava and maize yield models. Across both models, the mean VIF values (1.86 for cassava and 1.77 for maize) are well below the conventional threshold of 10, and even the stricter threshold of 5, indicating no problematic multicollinearity among explanatory variables. The tolerance values, all above 0.39, further confirm that each predictor contributes unique information to the models. In the cassava model, the highest VIF is observed for farm experience (2.54), followed by age (2.36) and education (2.07). These remain within acceptable bounds, suggesting that although some correlation exists between socio-economic factors, it does not distort the regression estimates. Similarly, in the maize model, farm experience (2.37) and age (2.21) record the highest VIFs, but they are still well within the safe range. Notably, CSSMP adoption score, the key variable of interest, has low VIF values in both models (1.42 for cassava and 1.38 for maize), ensuring its estimated effect on yield is not biased by multicollinearity.

In all, these diagnostics affirm the stability and reliability of the regression coefficients, reinforcing confidence in the econometric analysis of adoption effects on crop yields.

Table 7. Variance Inflation Factor (VIF) results for Cassava and Maize yield models

Variable	Cassava Yield Model		Maize Yield Model	
	VIF	Tolerance (1/VIF)	VIF	Tolerance (1/VIF)
CSSMP adoption score	1.42	0.704	1.38	0.725
Gender (1 = Female)	1.18	0.847	1.12	0.893
Age (years)	2.36	0.424	2.21	0.452
Education (1 = Secondary+)	2.07	0.483	1.98	0.505
Farm experience (years)	2.54	0.394	2.37	0.422
Access to extension (1 = Yes)	1.76	0.568	1.69	0.592
Access to market (1 = Yes)	1.63	0.613	1.57	0.637
Membership in farmers' group (1 = Yes)	1.94	0.515	1.82	0.549
Access to credit (1 = Yes)	1.88	0.532	1.76	0.568
Mean VIF	1.86		1.77	

Table 8 reports the diagnostic tests applied to the cassava and maize yield models, providing assurance on the validity of the regression results. The Breusch–Pagan statistics for both crops ($\chi^2 = 1.84$, $p = 0.175$ for cassava; $\chi^2 = 1.67$, $p = 0.196$ for maize) are not statistically significant, indicating that the null hypothesis of homoskedasticity cannot be rejected. This suggests that the variance of residuals is constant across observations, fulfilling a key OLS assumption. The Durbin–Watson statistics (1.95 for cassava and 1.88 for maize) lie close to the ideal value of 2, showing no evidence of first-order autocorrelation in the residuals. Finally, the Jarque–Bera normality tests ($JB = 2.17$, $p = 0.338$ for cassava; $JB = 2.46$, $p = 0.292$ for maize) confirm that the residuals follow a normal distribution, which strengthens the reliability of hypothesis testing within the models.

Taken together, these results imply that the estimated OLS models for cassava and maize yields are robust and statistically sound. The absence of heteroskedasticity, autocorrelation, and non-normality means that coefficient estimates are unbiased and efficient, allowing for valid inferences on the impact of climate-smart soil management practice adoption. This diagnostic robustness enhances the credibility of the study's empirical findings and ensures that policy recommendations drawn from the models rest on solid econometric grounds.

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Table 8: Diagnostic tests of OLS assumptions for cassava and maize yield models

Test	Cassava Model	Interpretation	Maize Model	Interpretation
Breusch–Pagan (Heteroskedasticity)	$\chi^2 = 1.84$ (p = 0.175)	Fail to reject $H_0 \rightarrow$ Homoskedastic	$\chi^2 = 1.67$ (p = 0.196)	Fail to reject $H_0 \rightarrow$ Homoskedastic
Durbin–Watson (Autocorrelation)	1.95	No autocorrelation	1.88	No autocorrelation
Jarque–Bera (Normality)	JB = 2.17 (p = 0.338)	Residuals normally distributed	JB = 2.46 (p = 0.292)	Residuals normally distributed

Conclusion, Recommendations, and Policy Implications: This study assessed adoption of climate-smart soil management practices (CSSMPs) in Imo State, highlighting moderate adoption dominated by mulching, organic manure, and crop rotation, while agroforestry and conservation tillage remained limited. Education, extension, credit, market access, and group membership significantly increased adoption, while younger farmers proved more dynamic adopters. Adoption intensity positively influenced cassava and maize yields, affirming the productivity benefits of multiple practices but also exposing institutional and socio-economic constraints.

Six evidence-based recommendations emerge. First, **strengthen extension systems** by scaling training and ICT platforms (SDG 2, AU Goal 5). Second, **expand credit access** through CSA-targeted microfinance (SDG 8, COP finance). Third, **promote farmer cooperatives** to improve access to inputs and markets (AU Goal 1). Fourth, **design youth-focused interventions** to harness younger farmers' agility (SDG 4, AU Goal 18). Fifth, **mainstream CSSMPs into climate policies**, embedding them in Imo State's adaptation plans (COP28, NDCs). Five, **institutionalise monitoring and evaluation**, tracking adoption intensity as a programme indicator (SDG 17). Six, **embed gender-sensitive programming**, ensuring equitable access for women who form a majority of farmers (SDG 5, AU Goal 17).

Policy implications are clear: institutional levers are decisive, and scaling must move beyond generic CSA promotion to bundled, context-specific interventions. Empirical evidence from Imo confirms that adoption intensity drives productivity, directly supporting food security, resilience, and the objectives of SDGs, COP accords, and AU Agenda 2063.

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Climate-Smart Tomato Production for Food Security and Environmental Sustainability: Influence of Mulching and Variety on Growth and Yield in the Sudan Savanna of Nigeria

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ABSTRACT

A field experiment was conducted during the 2018 rainy season at the Teaching and Research Farm of Bayero University Kano (BUK), located in the Sudan savanna agro-ecological zone of Nigeria, to investigate the effects of mulching and tomato variety

on growth and yield. The experiment was a 4 x 2 factorial laid out in a randomized complete block design (RCBD) with three replicates. The treatments consisted of four mulching materials (jute, grass, plastic, and control) and two tomato varieties (Roma Savanna and Rio Grande). Data were collected on phenology (days to 50% flowering, fruiting, and maturity), vegetative growth (plant height, number of branches), and yield parameters (fruit weight, fresh and dry biomass). Results revealed significant ($p \leq 0.01$) effects of mulching and variety on most measured traits. Jute mulch consistently improved plant performance, producing taller plants (72.78 cm), more branches (21.13), earlier flowering (39 days), and the highest fruit weight (3328 g plant⁻¹), while plastic mulch recorded the poorest results. Roma Savanna variety performed better than Rio Grande in earliness, plant height, and fruit weight. Interaction effects showed that combining Roma Savanna with jute mulch produced the highest yield and vegetative vigor. These findings demonstrate the potential of mulching and variety selection as climate-smart practices for enhancing food security and environmental sustainability in dryland agriculture.

Keywords: Tomato, Mulching, Climate-Smart Agriculture, Food Security, Roma Savanna,

INTRODUCTION: Tomato (*Solanum lycopersicum* L.) is one of the world's most important vegetable crops, contributing significantly to nutrition, household income, and employment. In Nigeria, tomatoes are a staple in diets and a major source of livelihoods, yet production is constrained by low productivity, climate variability, and unsustainable practices that threaten food security and rural incomes (Mohammed et al., 2021; Ter et al., 2023). The Sudan savanna zone of Nigeria faces the dual challenge of high poverty rates and fragile ecosystems. Rainfed agriculture dominates, and farmers are vulnerable to erratic rainfall, high temperatures, and soil degradation. Such stresses reduce yields and increase reliance on food imports, undermining national food security and deepening poverty. Climate-smart agricultural practices are therefore urgently needed to enhance productivity, resilience, and environmental sustainability in dryland systems (Bolarinwa & Agele, 2023). Mulching is a proven adaptation strategy that conserves soil moisture, regulates temperature, reduces erosion, suppresses weeds, and improves soil health. Organic mulches, such as jute and plant residues, also recycle nutrients and support biodiversity, while reducing dependence on synthetic inputs. Similarly, selecting resilient tomato varieties is critical to coping with heat stress and variable rainfall (Abolusoro & Audu, 2025; Yakubu et al., 2024). Despite evidence that mulching and varietal choice independently improve tomato performance, few studies in Nigeria have evaluated their combined effects in the Sudan savanna during the rainy season. This study therefore investigates the influence of mulching and variety on tomato growth and yield, with the aim of identifying climate-smart options for enhancing food security, reducing poverty, and promoting environmental sustainability in dryland agro-ecologies.

MATERIALS AND METHODS

Experimental Site: The trial was conducted during the 2018 rainy season at the Teaching and Research Farm, Faculty of Agriculture, Bayero University Kano (latitude 11°58'N, longitude 8°25'E, 466 m above sea level). The site lies in the Sudan savanna agro-ecological zone of Nigeria, characterized by a unimodal rainfall pattern averaging 834.5 mm annually, mean minimum temperature of 19.4 °C, and mean maximum of 35.1 °C (BUK Meteorological Unit).

Treatments and Experimental Design: The experiment was a 4 x 2 factorial laid out in a randomized complete block design (RCBD) with three replicates. The treatments consisted of four mulching materials (jute, grass, plastic, and control) and two tomato varieties (Roma Savanna and Rio Grande). Each plot measured 3 x 3 m with spacing of 50 cm x 75 cm between plants.

Cultural Practices: Land preparation involved ploughing, harrowing, and ridging. Tomato seedlings were raised in a nursery and transplanted at four weeks after sowing. Mulching materials were applied immediately after transplanting to their respective plots. Weeding was carried out manually, while pest control involved recommended insecticides at regular intervals. Irrigation was provided as supplementary watering when necessary.

Data Collection: Data were collected on several traits, including phenology (days to 50% flowering, fruiting, and maturity), vegetative traits (plant height in cm and number of branches per plant), and yield traits (fruit weight, fresh biomass weight, and dry biomass weight, all measured in g plant⁻¹), while soil temperature was monitored under different mulch treatments.

Data Analysis: Collected data were subjected to analysis of variance (ANOVA) using GenStat (17th edition). Treatment means were separated using Student-Newman-Keuls (SNK) test at 5% probability level.

RESULTS

Effect of Mulch and variety on growth and yield variable so f tomato: Table 1 present the results of the mean square analysis of variance showed a highly significant effect of mulch treatments on soil temperature, number of branches, fruit weight, fresh biomass weight, and dry biomass weight ($P \leq 0.001$). This indicates that the choice of mulching material had a substantial impact on these traits. The mulch treatments also had a significant effect on days to 50% fruiting ($P \leq 0.05$) and plant height ($P \leq 0.05$). However, there was no significant effect of mulch on days to 50% flowering or days to 50% maturity. The variety of tomato had a highly significant effect on fruit weight ($P \leq 0.001$), indicating that the two varieties differed considerably in their yield. Variety also had a significant effect on fresh biomass weight ($P \leq 0.05$). In contrast, there was no significant effect of variety on soil temperature, days to 50% flowering, days to 50% fruiting, days to 50% maturity, plant height, number of branches, or dry biomass weight.

The results presented in Table 2 indicate that mulching materials had a significant effect ($P \leq 0.001$) on most of the measured traits, including soil temperature, days to 50% flowering, days to 50% fruiting, days to 50% maturity, plant height, number of branches, and fruit, fresh, and dry biomass weight. Jute mulch consistently outperformed all other treatments (Figure 1). It was associated with the lowest soil temperature (25.67 °C), which is beneficial for plant health, and led to earlier flowering and fruiting. Furthermore, jute mulch resulted in superior vegetative growth, producing the tallest plants (72.78 cm) and the highest number of branches (21.13). This enhanced growth translated into significantly higher yields, with jute mulch yielding the highest fruit weight (3328 g). Conversely, plastic mulch consistently resulted in the highest soil temperature (29.83 °C), delayed phenological development, and the poorest growth and yield across all traits.

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Table 1. Mean square table for soil temperature and agronomic traits of tomato at BUK during 2018 rainy season

Source of Variation	Df	Soil Temp (°C)	Days to Flowering	50% Fruiting	50% Maturity	Plant Height (cm)	Number of Branches	Fruit Weight (g plant ⁻¹)	Fresh Weight (g plant ⁻¹)	Dry Weight (g plant ⁻¹)
Replication	2									
Mulch	3	20.264**	27.17 **	16.167 **	39.038 **	154.02 **	30.089**	661229**	58801**	3437.5**
Variety	1	0.38 ns	23.010 **	8.167	29.260 **	13.350	5.851	1795.94**	17599*	98.00ns
Error	14	0.41	1.981	3.220	2.004	13.28	4.239	540.55	360.70	216.20

*ns = not significant; * = $p \leq 0.05$; ** = $p \leq 0.01$

Table 2. Mean performance of mulching materials and varieties on tomato growth and yield at BUK (2018 rainy season)

Treatment	Soil Temp (°C)	Days to Flowering (#)	50% Fruiting (#)	50% Maturity (#)	Plant Height (cm)	No. of Branches (#)	Fruit Weight (g)	Fresh Weight (g)	Dry Weight (g)
Mulch(M)									
Grass mulch	26.67b	39.67b	46.83b	60.17b	70.67d	19.13ab	2384b	145b	41.9b
Jute mulch	25.67b	39.00b	46.50b	58.50b	72.78c	21.13a	3328a	281a	73.0a
Plastic	29.83a	41.50a	49.50a	64.00a	61.63b	15.72c	1053d	55d	17.1d
Control	28.33a	43.75a	49.50a	63.08a	65.33a	18.89b	1293c	91c	29.8c
LS	**	**	**	**	**	**	**	**	**
SE±	0.370	0.813	1.036	0.817	2.104	1.186	134.2	34.7	8.49
Variety (V)									
Roma Savanna	27.75	40.00b	47.50	60.33b	68.35	18.23	2288a	170a	42.5
Rio Grande	27.50	41.16a	48.67	62.54a	66.86	19.21	1741b	116b	38.4
LS	NS	**	NS	**	NS	NS	**	*	NS
SE±	0.262	0.575	0.733	0.578	1.488	0.841	94.9	24.5	6.00
Interaction									
M x V	NS	NS	NS	NS	NS	NS	*	NS	NS

*NS = not significant; * = $p \leq 0.05$; ** = $p \leq 0.01$

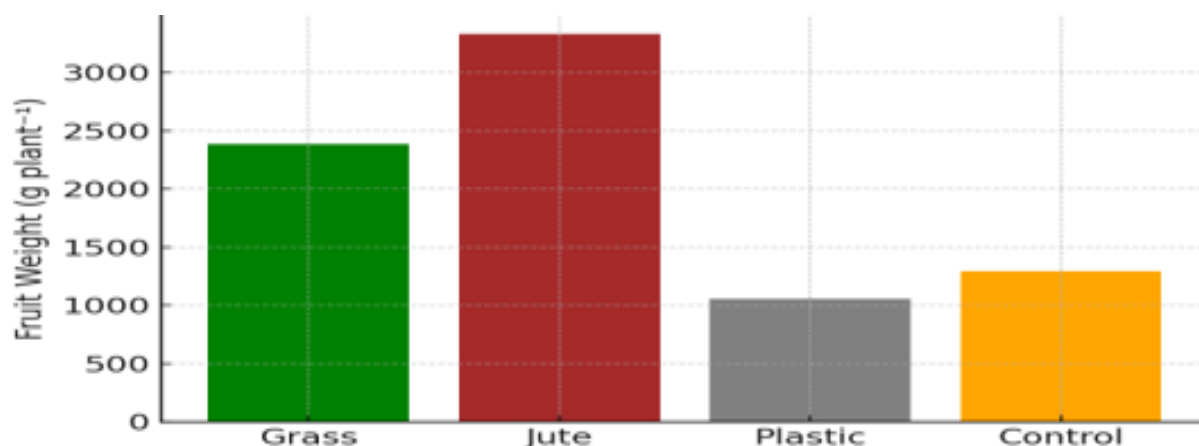


Figure 1. Effect of mulching on tomato fruit weight at BUK during 2018 rainy season.

The two tomato varieties exhibited significant differences for several key traits. The Roma Savanna variety significantly outperformed the Rio Grande variety in terms of fruit weight (2288 g vs. 1741 g) and fresh biomass weight (170 g vs. 116 g) as shown in Figure 2. However, Rio Grande matured later and took longer to flower than Roma Savanna. There was no significant difference between the varieties for soil temperature, days to fruiting, plant height, number of branches, or dry biomass weight. These results highlight the inherent differences in yield potential between the two varieties.

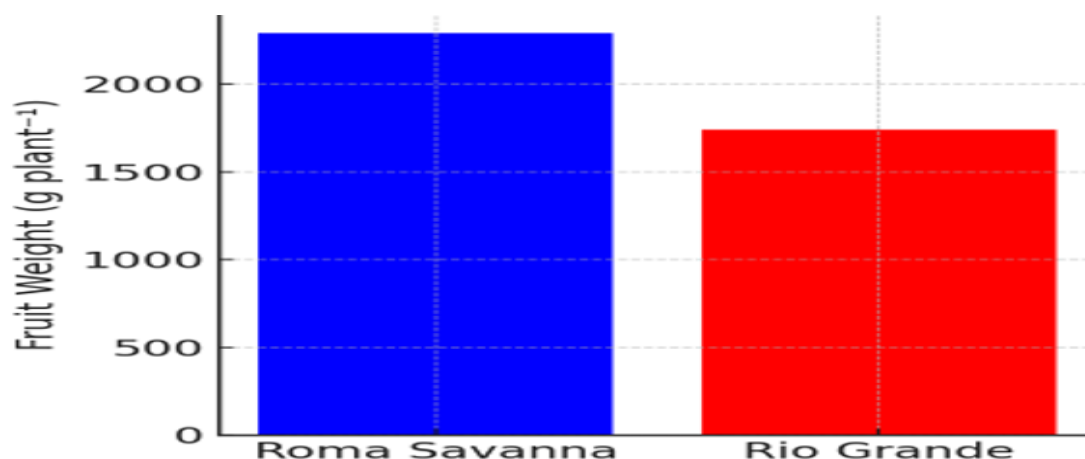


Figure 2. Effect of variety on tomato fruit weight at BUK during 2018 rainy season.

The interaction between mulch and variety was not significant for most traits, suggesting that the effect of mulch on plant performance was largely independent of the variety being grown. However, there was a significant ($P \leq 0.05$) interaction for fruit weight (Figure 3). This indicates that the effect of a particular mulch on fruit yield varied depending on the tomato variety. The combination of the optimal mulch material (jute) with the high-yielding variety (Roma Savanna) likely produced the best results, as the synergistic effects of the two factors maximized productivity.

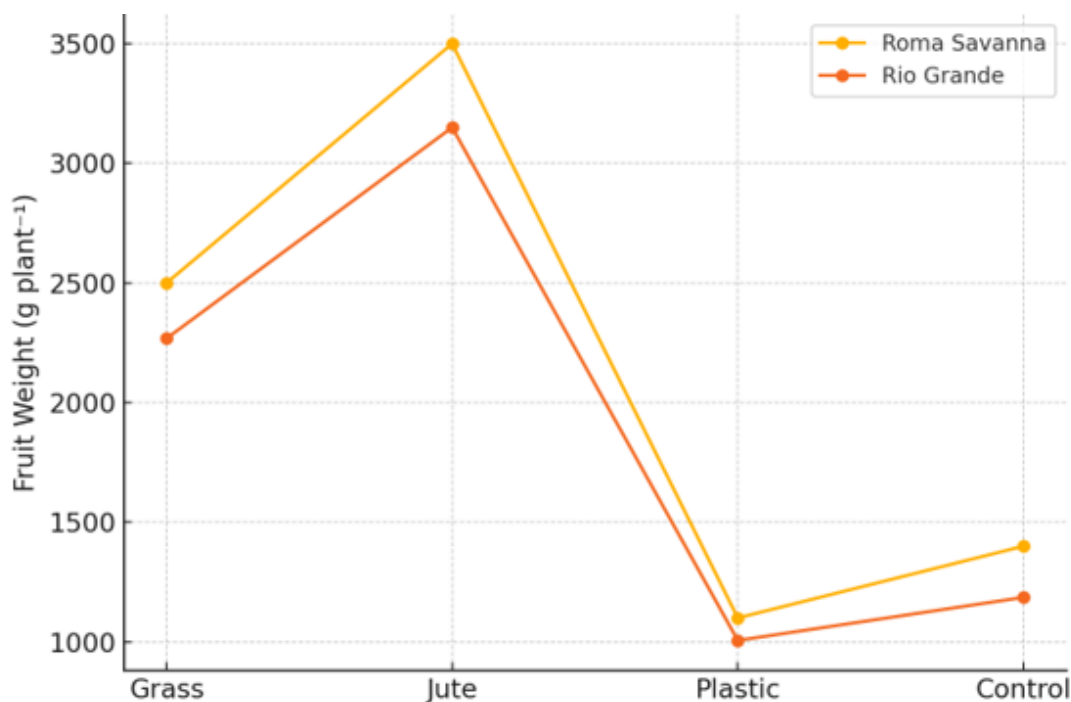


Figure 3. Interaction effect of mulching and variety on tomato fruit weight at BUK during 2018 rainy season.

DISCUSSION

Effects of Mulching on Tomato Performance: The results of this study demonstrate that mulching materials significantly influenced tomato growth, phenology, and yield, confirming their critical role in optimizing crop production under the hot and arid conditions of the Sudan savanna. The superior performance of jute mulch can be attributed to its ability to create a more favorable microenvironment. Its organic nature provides effective insulation, reducing soil temperature fluctuations and conserving moisture, which is crucial for root development and nutrient uptake (Bolarinwa & Agele, 2023). The consistently lower soil temperature under jute mulch directly translated to enhanced vegetative growth, as evidenced by the significant increases in plant height and number of branches. This robust growth is a prerequisite for high yields. The improved physiological conditions under jute mulch also promoted earliness, leading to significantly earlier flowering, fruiting, and maturity compared to other treatments. This is particularly valuable for mitigating crop exposure to terminal drought.

Conversely, the use of plastic mulch led to the poorest outcomes. The dark surface of the plastic likely absorbed and trapped solar radiation, leading to excessively high soil temperatures that cause heat stress and hinder plant growth (Ajibade et al., 2024). This stress can negatively impact physiological processes such as photosynthesis and water use efficiency, explaining the delayed phenology and significantly lower yields. The control treatment (no mulch) also performed poorly, as the exposed soil was prone to high evaporation and temperature extremes. The lack of a significant effect of mulch on certain traits, such as days to maturity, may be due to other overriding genetic or environmental factors that influence the final developmental stage. These findings corroborate previous research on the benefits of organic mulches in promoting soil health and crop productivity, reinforcing their role in climate-smart agricultural practices.

Effects of Variety on Tomato Performance: The inherent genetic differences between the tomato varieties were a primary determinant of yield, reinforcing the importance of varietal selection for achieving food security in diverse agricultural systems (Abolusoro & Audu, 2025). The Roma Savanna variety consistently demonstrated its superior yield potential, producing significantly higher fruit weight and fresh biomass weight compared to Rio Grande. This superior performance can be attributed to its genetic makeup, which likely confers greater resilience and a higher capacity for fruit set and development under these specific environmental conditions (Babatunde & Ojo, 2024).

It is noteworthy that while variety significantly influenced yield components, it had no significant effect on traits such as soil temperature or number of branches. This is expected, as these are primarily influenced by external environmental factors and management practices rather than a plant's genetic characteristics. However, the varieties did differ in their phenology, with Rio Grande exhibiting a later flowering and maturity period. This suggests that while it may have a longer growing cycle, its yield potential under these conditions is not as high as Roma Savanna, making the latter a more suitable choice for commercial production.

Interaction Between Mulch and Variety: The significant interaction observed between mulching and variety for fruit weight highlights the complex relationship between genotype and environment. While jute mulch was the best-performing treatment overall, its effectiveness was dependent on the variety. This finding suggests that certain varietal traits, such as rooting depth or nutrient use efficiency, may be more effectively enhanced by the favorable soil conditions created by jute mulch. The combination of the high-yielding Roma Savanna variety with the effective jute mulch likely created a synergistic effect, maximizing the expression of the variety's genetic potential. This corroborates the findings of other studies that emphasize the importance of integrated management strategies to optimize crop productivity (Meena, 2024; Karim et al., 2024). The lack of a significant interaction for other traits indicates that for those variables, the effects of mulch and variety were independent and additive, meaning that the benefits of each factor could be realized regardless of the other.

CONCLUSION: This study concludes that mulching and varietal selection are effective climate-smart strategies for enhancing tomato productivity in dryland ecosystems. The superior performance of jute mulch in improving soil moisture and temperature conditions, combined with the high-yielding potential of the Roma Savanna variety, represents an optimal integrated management approach. We recommend the adoption of this specific combination for farmers in the Sudan savanna and similar arid regions, as it provides a practical pathway to significantly increase tomato yield and contribute to sustainable agriculture, food security, biodiversity conservation, and poverty reduction.

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Challenges Faced by Small-Holder Wheat Farmers in Achieving Food Security in Jigawa State, Nigeria

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Abstract

The study assessed the challenges faced by smallholder wheat farmers in achieving food security in Jigawa state. Multi-staged sampling technique was used for this study. Primary data were collected from 127 wheat farmers through the use of questionnaire for this study. Analytical techniques used were Descriptive statistics and Food consumption score index. The results from the food consumption score index revealed that 16 percent of the respondents had an "acceptable" food status, 40 percent had "borderline" and 44 percent of the respondents had "poor" food status, the mean food score was 24.16. Major challenges included high costs of irrigation and seeds, lack of access to quality seeds, and pest infestations. Financial constraints were also significant, with 52.8% of respondents lacking access to credit due to high-interest rates and insufficient collateral. Market challenges such as exploitation by middlemen and high transportation costs further constrained the farmers' profitability. It is recommended in the study that financial institutions should develop farmer-friendly loan schemes with lower interest rates and reduced collateral requirements.

Keywords: Food security, Smallholder farmers, Challenges, Wheat

1. INTRODUCTION: With rice and maize, wheat is one of the three grains that are produced worldwide (Adeleke et al. 2023). In 2021, the world's wheat output reached 775.1 million tons. Wheat (*Triticum durum*) is the most commonly farmed crop in the world, with over 218 million ha and roughly 766 million tons global production (Food and Agriculture Organization of the United Nations Statistics (FAOSTAT 2023). According to the amount of wheat produced, China, India, the United States, and Russia are the top four producers worldwide (FAOSTAT, 2023). In Nigeria, wheat is grown over an area of roughly 11,820 hectares, yielding 36,943.8 tons of grain with Kano state having the highest percentages with 19.68%, followed by Jigawa state with 17.69% (NBS 2021), Jigawa state produce a total of 5,854.8 tons of wheat which is only bettered by Kano state with 6,512.8 tons (NBS 2021). It is the most significant grain traded on global markets (Giraldo et al., 2019). It is utilized for animal feed (wheat bran) as well as human food (wheat flour), (Andres and Saenz 2021). Bread, cakes, biscuits, pasta, spaghetti, semolina, and macaroni all contain a fair amount of wheat, making it a significant industrial crop. Composted life stock feeds are made with it offal (Adeleke et al. 2023). Furthermore, wheat offers significant amounts of health-promoting nutrients, such as protein, vitamins, dietary fiber, and phytochemicals (Shewry & Hey, 2015).

Smallholder farmers, who typically cultivate less than two hectares of land, are essential to the agricultural environment. They play a major role in the development of staple crops like wheat, which provide a substantial portion of the world's population with their main supply of calories and protein. Nevertheless, despite all of the difficulties they face, smallholder farmers make a substantial contribution to the world's food production (Kremen et al. (2012), they produce up to 50% of the world's cereal, 60% of its meat, and 75% of its dairy products. In fact, the productivity of the smallholder farmers in their community plays a critical role in meeting the food needs of both urban and rural customers in emerging nations.

Food security is still a problem that needs to be solved on a worldwide scale. It is the state in which everyone has access to enough food that is safe and nourished (Ayala & Meier 2017). "When everyone, everywhere, has physical, social, and financial access to enough, safe, and nourishing food that satisfies their dietary needs and food preferences for an active and healthy life, food security exists" (McDonald, B. L. (2010), the four pillars of food security are availability, access, utilization, and stability (Mbow et al. 2020). A recent assessment on the global food insecurity situation states that about 870 million people are chronically undernourished, making the number of hungry people in the world unacceptable (Parvathamma 2015).

Smallholder wheat farmers in Ringim face a dual challenge: on the one hand, they must navigate the challenges of wheat production, including low yields, limited access to quality seeds and fertilizers, and vulnerability to pests and diseases (Mondal et al.2016). On the other hand, they must also contend with the limitations of irrigation systems, including water scarcity, inefficient water use, and inadequate drainage (Nasreen & Ashraf 2020). These challenges converge to threaten household food security, as smallholder farmers struggle to produce sufficient wheat to meet their families' needs Furthermore, the impact of climate change on wheat production and irrigation systems is expected to exacerbate these challenges. Understanding the interplay between wheat production and irrigation is crucial to developing effective strategies that support smallholder farmers in achieving household food security and sustainable agriculture development.

This study is significant because it sheds light on the critical role that small-scale agriculture plays in ensuring food availability and access for rural households. By examining the effect of wheat farming on household food security, this research provides valuable insights for policymakers, development practitioners, and agricultural extension services seeking to improve the livelihoods of smallholder farmers and enhance food security in rural areas.

Moreover, the study's focus on irrigation farming highlights the importance of water management in agricultural productivity and food security, particularly in areas where water scarcity is a growing concern. By exploring the intersection of agriculture, water management, and food security, this research contributes to a deeper understanding of the complex relationships between these critical development issues.

2. OBJECTIVES

The objectives of the study are to:

- i. Determine the food security status among small-holder wheat household farmers
- ii. Identify the major challenges and constraints faced by small-holder wheat farmers in achieving household food security.

3. RESEARCH METHODOLOGY

3.1 Study Area: The study was carried out in Ringim Local Area (LGA) of Jigawa state. It is located in North-western geopolitical zone Jigawa state, Nigeria. The area is bordered to the west by Kano State, Garki Local Government area to the north, Dutse Local Government Area to the southeast, and Taura and Jahun Local Government Areas to the east. It is situated on latitude 12° 09' 5.15 North and longitude 9° 09' 43.78 East. It has a total land area of 408 square miles (1,057 km²) and a projected population of 192,024 people (NPC, 2006). It is situated within the sub-Saharan of the northern Nigeria, typical of this region, the land is almost flat with few undulating hills and scattered rock extrusions. The climate is hot and dry during summer, cold and dusty in the winter. Rain usually falls between the months of May and September, but the month with the most rain in Ringim is August, with an average rainfall of 7.0 inches. The major occupation in the area is farming, cattle rearing, petty trading. About 80% of the inhabitant were engaged in Agriculture (Jigawa Agriculture and Rural Development Authority, 2021) and due to reducing farm sizes as a result of increasing population, irrigation activities will serve as a source of income to the total farming households.

3.2 Sampling Procedure and Sampling Size: Multistage sampling technique was used to select smallholder wheat farmers in this study. In the first stage, Ringim Local Government Area (LGA) was purposely selected because most of the inhabitants in the area are engaged in wheat farming. Six villages (Chai-chai, Ringim, Yan Dutse, Zangon Kanya, Daurawar, and Dabi) were selected based on the prominence of wheat production in those villages in the second stage. The list of wheat producers was obtained from Jigawa Agricultural and Rural Development Authority (JARDA) for the selected villages. Simple random sampling technique was thereafter employed to select a proportionate sample of 127 respondent in the study from a nested population of 356 wheat farmers identified as shown in the table below.

In determining this sample size (n=127), the Rao soft online sample size calculator as used in Orifah *et al.*, (2020) was employed to determine the sample size at a margin of error of 7% and a confidence level of 95%. The Bowley's proportion allocation formula (Bowley, 1926) is thereafter used to establish the sample proportion from each of the villages selected for the study.

$$n_i = n \left(\frac{N_i}{N} \right)$$

Where:

n_i - The sample size of the i th stratum.

n - The total sample size.

N_i - Population of the i th stratum.

N - The total population (sample frame).

Table 3.1: Sample frame and sample size

L.G.A	VILLAGES	SAMPLE FRAME	SAMPLE SIZE
Ringim	Chai-chai	52	18
	Ringim	101	36
	Yan Dutse	46	16
	Zangon Kanya	30	11
	Daurawar	94	34
	Dabi	33	12
Total	6	356	127

Source: JARDA, 2024

3.3 Method of Data Collection: Data for this study was collected from primary source. The primary data was collected using questionnaire which was administered to smallholder wheat farmers to collect information on demographics, farm characteristics, irrigation practices, crop yields and household food security.

3.4 Method of Data Analyses

3.4.1 Descriptive analysis: Descriptive statistics like means, frequency distribution and percentage was used to identify the major challenges and constraints faced by small-holder wheat farmers in achieving household food security.

3.4.2 Food consumption score index: The Food Consumption Score (FCS) is the most commonly used food security indicator by WFP and partners, including UNHCR. This indicator is a composite score based on households' dietary diversity, food consumption frequency, and relative nutritional value of different food groups. The FCS is calculated by asking how often households consume food items from the 8 different food groups (plus condiments) during a 7-day reference period. In addition to this, the FCS module collects data on sources of the consumed foods acquired by households. The food consumption score index was used to achieve objective (II).

Determine the indicator's value by using the following methodology:

1. Conduct individual interviews with a representative sample of the target household representatives assessing how many days in the past 7 days have the household members eaten foods from any of the 9 pre-defined food groups.
2. For each respondent, multiply the consumption frequency obtained for each food group by its 'weight'
3. For each respondent, sum the weighed food group scores, thus creating his/her food consumption score (FCS).
4. According to the FCS's value, indicate the percentage of households with "poor" FCS (0-21 scores), "borderline" FCS (21.5 - 35 scores), and "acceptable" FCS (more than 35 scores).
5. To calculate the percentage of households with "acceptable" FCS, divide the number of households with FCS higher than 35 scores by the total number of surveyed households. Multiply the result by 100 to convert it to a percentage.

Table 3.2. Food score index threshold

FCS	Profiles
0 – 21	Poor
21.5 – 35	Borderline
(>) 35	Acceptable

Source: nutriverse.io.

Table 3.3. Food items and their weight

S/N	Food items	Food groups	Weight
1	Maize , maize porridge, rice, sorghum, millet pasta, bread and and other cereals	Main staples	2
2	Cassava, potatoes and sweet potatoes, other tubers, plantains Beans, peas, groundnuts and cashew nuts	Pulses	3
3	Vegetables, leaves	Vegetables	1
4	Fruits	Fruits	1
5	Beef, goat, poultry, pork, eggs and fish	Meat and Fish	4
6	Milk yoghurt and other dairy	Milk	4
7	Sugar and sugar products, honey	Sugar	0.5
8	Oils, Fats and Butter	Oil	0.5
9	Spices, tea, coffee, salt, fish powder, small amounts of milk for tea.	Condiments	0

Source: nutriverse.io.

4. RESULTS AND DISCUSSION

4.1. Food Consumption Score Index Result : The food security status of the respondents was presented in the table 4.1. The result revealed that 16 percent of the respondents had an "acceptable" food status, 40 percent had "borderline" and 44 percent of the respondents had "poor" food status. The mean food score was 24.16 with a minimum of 4.5 score and a maximum of 80 score. This implies that majority of the respondents in the study were combined food secured and that wheat farming has significantly improved the food status of the respondents. This findings is in agreement with that of Mupaso et al. (2024) On Assessing the Contribution of Smallholder Irrigation to Household Food Security in Zimbabwe who reported that food Consumption Score results show that 97% of irrigators and 45% of non-irrigators were food secure, and that of Abdiyo (2021) who conducted a study on effect of small scale irrigation on household food security the study grouped households into food secure and insecure

based on their access to irrigation. Accordingly, 80 percent of the non-users and 30 percent of users are found to be food insecure respectively and 20 percent of non-users and 70 percent of the users are food secure.

Table 4.1: food security status of the respondents

Variable	Frequency	Percentage	Mean	Minimum	Maximum
Food security status					
Poor	56	44	24.16	4.5	80
Borderline	51	40			
Acceptable	20	16			
Total	127	100			

Source: Field Survey Data, 2024

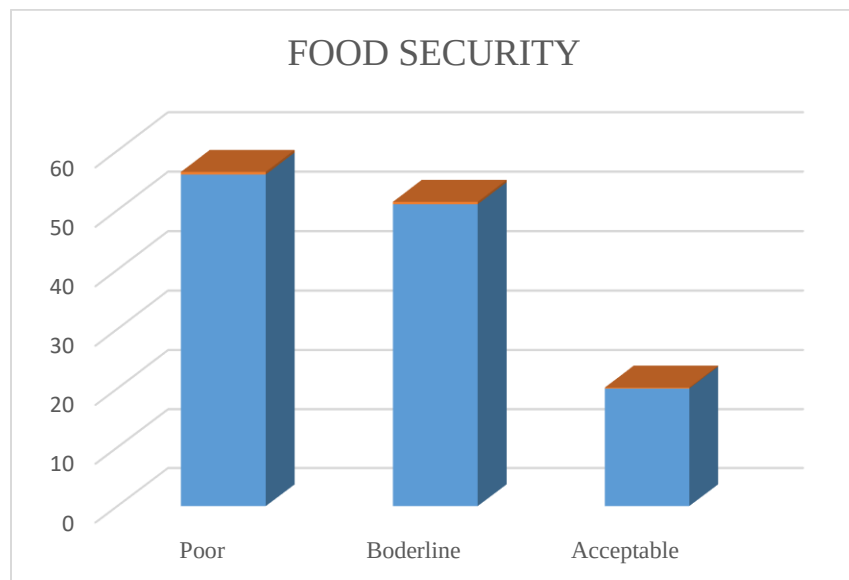


Figure 1: food security status

4.2. Major challenges and constraints faced by smallholder wheat farmers in achieving household food security

Table 4.2, 4.3 and 4.4 revealed the major constraints and challenges faced by smallholder wheat farmers.

4.2.1 Challenges in managing water: The result revealed that 2.4 percent of the respondents reported insufficient water supply as a challenge, 34.6 percent reported poor irrigation infrastructure, 42.5 percent reported high cost of irrigation and 20.5 percent reported poor water quality as a constraint. This implies that high cost of irrigation is the major challenge in managing water.

4.2.2 Constraints in accessing agricultural inputs : The result revealed that 37.8 percent of the respondents revealed high cost of seeds/lack of access to quality seeds as a constraint, 1.6 percent reported lack of access to fertilizer, 4.7 percent reported high cost of pesticide/herbicide, 21.3 percent reported shortage of labor, 0.8 percent reported poor quality farming equipment, 8.7 percent reported both high cost of seeds/lack of access to quality seeds and lack of access to fertilizer, 6.3 percent reported both high cost of seeds/lack of access to quality seeds and high cost of pesticide/herbicide, 10.2 percent reported high cost of pesticide/herbicide and shortage of labor, 2.4 percent reported high cost of seeds/lack of access to quality seeds and poor quality farming equipment, 3.9 percent reported lack of access to fertilizer and high cost of pesticide/herbicide, 0.8 percent reported both lack of access to fertilizer and poor quality farming equipment and 1.6 percent reported both high cost of pesticide/herbicide and shortage of labor. This implies that high cost of seeds/lack of access to quality seeds is the major constraints in accessing agricultural inputs.

4.2.3 Access to financial support: The result revealed that 47.2 percent of the respondent revealed they have access to financial support, 52.8 percent of the respondents revealed they had no access to credit. This implies that majority of the respondents in the study had no access to financial support.

4.2.4 Barriers to credit: The result revealed 7.9 percent of the respondents revealed lack of collateral as a barrier to credit, 21.3 percent revealed high interest rate, 13.4 percent revealed no nearby financial institutions as a constraint and 9.4 revealed complicated application process. This implies that high interest rate is the major barrier to credit

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in the study.

Variable	Frequency	Percentage
Challenges in managing water		
Insufficient water supply	3	2.4
Poor irrigation infrastructure	44	34.6
High cost of irrigation	54	42.5
Poor water quality	26	20.5
Constraints in accessing agricultural inputs		
High cost of seeds/lack of access to quality seeds	48	37.8
lack of access to fertilizer	2	1.6
High cost of pesticide/herbicide	6	4.7
Shortage of labor	27	21.3
Poor quality farming equipment	1	0.8
High cost of seeds/lack of access to quality seeds, lack of access to fertilizer	11	8.7
High cost of seeds/lack of access to quality seeds, High cost of pesticide/herbicide	8	6.3
High cost of seeds/lack of access to quality seeds, Shortage of labor	13	10.2
High cost of seeds/lack of access to quality seeds, Poor quality farming equipment	3	2.4
lack of access to fertilizer, High cost of pesticide/herbicide	5	3.9
lack of access to fertilizer, Poor quality farming equipment	1	0.8
High cost of pesticide/herbicide, Shortage of labor	2	1.6

4.2.5 Challenges in selling wheat produce: The result revealed that 4.7 percent of the respondents revealed low market prices as a challenge in selling wheat, 4.7 percent revealed poor market access (e.g. distance to market), 7.9 percent revealed high transportation costs, 26.8 percent reported exploitation by middlemen, 1.6 percent revealed lack of storage facilities, 2.4 percent revealed unstable demand, 2.4 percent revealed both low market prices and poor market access (e.g. distance to market), 6.3 percent revealed both low market prices and high transportation costs, 3.9 percent revealed both low market prices and exploitation by middlemen, 4.7 percent reported low market prices and lack of storage facilities, 0.8 percent reported low market prices and unstable demand, 4.7 percent reported poor market access (e.g. distance to market) and high transportation costs, 1.6 reported poor market access (e.g. distance to market) and exploitation by middlemen, 3.9 reported poor market access (e.g. distance to market) and lack of storage facilities, 0.8 reported high transportation costs and exploitation by middlemen, 3.9 percent reported high transportation costs and lack of storage facilities, 0.8 percent reported exploitation by middlemen and lack of storage facilities and 18.1 percent reported exploitation by middlemen and unstable demand. This implies that exploitation by the middlemen is the major challenge in selling wheat produce.

4.2.6 Access to government support or NGO: The result revealed that 84.3 percent of the respondents reported they had access to support from government or NGO, while 15.0 percent reported they had no access to government or NGO support. This implies that majority of the respondents had access to government support or NGO.

4.2.7 Other challenges: the result revealed that 73.2 percent of the respondents reported pests and diseases as challenges in wheat production, 7.9 percent reported lack of access to improved wheat varieties, 9.4 percent reported lack of technical knowledge or training, 1.6 percent reported both climate variability (e.g. drought, floods) and Pests and disease, 0.8 percent reported climate variability (e.g. drought, floods) and lack of technical knowledge or training, 0.8 reported pests and diseases and lack of access to improved wheat varieties and 6.3 percent reported both pests and diseases and lack of technical knowledge or training as the major constraints in wheat production. This implies that pests and diseases is a major challenge in wheat production in the study.

Table 4.8: Major challenges and constraints faced by smallholder wheat farmers in achieving household food security (n = 127)
Source: Field survey, 2024

Table 4.9: Major challenges and constraints faced by smallholder wheat farmers in achieving household food security continued (n = 127)

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Source: Field survey, 2024

Variable	Frequency	Percentage
Access to financial support		
Yes	60	47.2
No	67	52.8
Barriers to credit		
Lack of collateral	10	7.9
High interest rate	27	21.3
No nearby financial institutions	17	13.4
Complicated application process	12	9.4
Others	61	48.0
Challenges in selling wheat produce		
Low market prices	6	4.7
Poor market access (e.g. distance to market)	6	4.7
High transportation costs	10	7.9
Exploitation by middlemen	34	26.8
Lack of storage facilities	2	1.6
Unstable demand	3	2.4
Low market prices, Poor market access (e.g. distance to market)	3	2.4
Low market prices, High transportation costs	8	6.3
Low market prices, Exploitation by middlemen	5	3.9
Low market prices, Lack of storage facilities	6	4.7
Low market prices, Unstable demand	1	0.8
Poor market access (e.g. distance to market), High transportation costs	6	4.7
Poor market access (e.g. distance to market), Exploitation by middlemen	2	1.6
Poor market access (e.g. distance to market), Lack of storage facilities	5	3.9
High transportation costs, Exploitation by middlemen	1	0.8
High transportation costs, Lack of storage facilities	5	3.9
Exploitation by middlemen, Lack of storage facilities	1	0.8
Exploitation by middlemen, Unstable demand	23	18.1

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Table 4.10: Major challenges and constraints faced by smallholder wheat farmers in achieving household food security continue

Variable	Frequency	Percentage
Access to government support or NGO		
Yes	107	84.3
No	20	15.7
Total	127	100.0
Other challenges		
Pests and disease	93	73.2
Lack of access to improved wheat varieties	10	7.9
Lack of technical knowledge or training	12	9.4
climate variability (e.g. drought, floods), Pests and disease	2	1.6
climate variability (e.g. drought, floods), lack of technical knowledge or training	1	0.8
Pests and disease, lack of access to improved wheat varieties	1	0.8
Pests and disease, lack of technical knowledge or training	8	6.3

Source: Field Survey Data, 2024

CONCLUSION AND RECOMMENDATIONS: This study provides a detailed exploration of the food security status and the challenges faced by smallholder wheat farmers in Ringim Local Government Area, Jigawa State, Nigeria. The findings indicate that wheat farming significantly contributes to food security among these households, with 16% of respondents achieving acceptable food security, 40% being borderline, and 44% categorized as poor. Despite these contributions, the majority of farmers remain food insecure, underscoring the need for targeted interventions. The study identifies critical challenges in water management, access to agricultural inputs, financial support, and market constraints. The high cost of irrigation, lack of quality seeds, and exploitation by middlemen were highlighted as major impediments to achieving food security. Furthermore, the lack of access to credit, high-interest rates, and absence of nearby financial institutions compound these challenges. Environmental factors, such as pests, diseases, and climate variability, further threaten wheat productivity and sustainability. Government and non-governmental support are crucial in addressing these issues, as most respondents reported benefiting from such assistance. However, there remains significant room for improvement, particularly in areas like technical training, access to improved wheat varieties, and comprehensive water management solutions. The findings emphasize the importance of multi-faceted approaches that address agricultural, financial, and infrastructural barriers while strengthening resilience to environmental challenges. Policy measures should focus on enhancing access to affordable credit, improving irrigation infrastructure, and empowering farmers through education and access to high-quality inputs. Additionally, establishing fair market practices and reducing exploitation by middlemen can further enhance the economic viability of wheat farming. Ultimately, these measures will not only improve food security among smallholder wheat farmers in Ringim but also contribute to broader agricultural sustainability and rural development in Nigeria.

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The Promise of Mangrove Ecological Zone: A Review of Resource Benefits and Management Constraints in Akwa Ibom State, Nigeria

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Abstract

The study reviewed mangrove resource ecosystem's benefits and management constraint in Akwa Ibom State, Nigeria in a bid to understand the extent at which this ecological zone has contributed to the socio-economic well -being of the rural dwellers in Ibeno as well as its effects on the environment. 400 copies of questionnaires were administered to respondents in the study area who were farmers, fishermen, fish traders, fuel wood dealers, boat builders and many others. Five (5) communities were sampled for the study where semi-structured interviews were carried out to examine the benefits rural people derived from the mangrove ecological zone. The data generated from field study was further processed using chi-square to ascertain whether there is significant impact of institutional arrangement on mangrove ecosystem stability. Multiple regression sought to ascertain the effect of stakeholders' management on mangrove ecosystem stability. The correlation coefficient = 0.981 was gotten meaning that there is a strong positive relationship between Y (stakeholders' management) on the five independent variables (X₁, X₂, X₃, X₄, and X₅). By implication, it shows that institutional arrangement contributed significantly on the integrity of mangrove ecosystem. The study identified among others that mangrove ecological zone provides food, raw materials, fisheries and job opportunities to the inhabitants and ecological functions particularly climate change mitigation, coastal flood protection, phyto-remediation function and nurseries for aquatic lifeform. It was revealed that over-exploitation due to population increase of local users, demand for products from mangrove ecological zone and the economic condition of the region are key constraints. Thus, suggestions made were that stakeholders should put up policies that would address the complexities of the ecosystem by taking cognizance of the livelihood protection of people whose livelihood is intricately link to the ecosystem, socio-cultural factor which keeps the users from migrating to other communities, the priority to address environmental problems in the region alongside plans to downsize dependence on natural ecosystem for livelihood.

Keywords: Promise, Mangrove Ecological Zone, Resource Benefits, Management Constraints, Akwa Ibom State, Nigeria

1.1 Introduction: Mangroves ecological zone is a complex environment with vast resources. Studies shown that mangrove are forested wetland ecosystems found along the saline and tidal coastlines of the tropics and sub-tropics (Constant et al, 2021; IUCN 2020a). Mangroves are complex inter-tidal forests that thrive at the interface between dry-land and open seas, in tropical and subtropical regions of the world. This ecosystem is the mainstay of enormous biological and abiotic resources. Moreover, mangroves ecological zones are known for their hydrological and chemical cycling abilities (Crawford, 2021; Kairo and Mwita, 2020). They also contribute to stabilizing coastlines, protecting coastal communities from tropical storms and surges, coastal flooding, sustaining coastal water resources, food security, and aquaculture. This natural resource belt facilitates optimum ecosystem balance and decarbonisation, and contributes substantially to biodiversity protection. A study by Chuku et al (2021) noted that coastal ecosystem provides tangible and intangible benefits to the local people who inhabit the earth's water environment. Tangible benefits of mangroves are those connected to timber and non-timber products, fishes etc, whereas, the intangible benefits concern ecological and social functions, such as coastal protection against wave and current abrasion, shelter and habitat for wildlife, and ecotourism. Mangrove ecological zone is heavily raped in the 21st century at an alarming rate that had never been experienced. The reasons for this devastating effect of anthropogenic influence are linked to greed of users in an attempt to amass the economic benefits at the detriment of other. Other factors are intricately linked to encroachment of human settlements due to population increase, over-population and competitiveness of resource users to harness the largest portion, expansion and conversion of wetlands into agricultural hub, development of coastal-based industries like boat making, aquaculture and mineral exploitation (Ashokkumar and Irfan, 2018; Sinsin, et al, 2021). Mangroves possesses a strong adaptive capacity, and by surviving in-between contaminated land and salty ocean, it can withstand certain external stress. While trying to strive in a competitive ecosystem, mangrove have evolved incredible mechanisms to enable them to cope with the high concentrations of salt and tidal forces. Studies have proven that mangroves require freshwater inflow, which brings silt with it as substrate for support and nutrients from upstream, and they do not thrive in stagnant water (Adanguidi, et al 2020; Adjonou, et al 2021; Iftekhar and Takama 2007).

Studies have also indicated that about 70 species of true mangrove exist globally and out of this, a total of 17 species exist in 26 countries of Sub-Saharan Africa. African mangrove ecological zones are uniquely widespread along the west coast from Senegal to the Congo, and are known to grow locally in East Africa, interlinked with coastal lagoons, tidal estuaries and deltas (O'Leary, et al 2020). On a global assessment, mangrove stretches across 118 countries, covering about 13.7 million ha. Studies have shown

that by country statistics, Asia has the largest mangrove reserve (42%), followed by Africa (20%), North and Central America (15%), Oceania (12%) and South America (11%) respectively (O'Leary, et al 2020).

In South Asia, mangrove spread over 4.8 million ha, a sharp decreased from 5.07 million ha recorded as at 1997. Indonesia, Brazil, Nigeria and Mexico are some of the largest global mangrove reserve (Virni et al 2021). South East Asia contributes to 35.6% of world's mangrove reserve, mostly around Indonesia (59.8%), Malaysia (11.7%), Myanmar (8.8%), Papua New Guinea (8.7%), Thailand (5%) and Vietnam (2.1%) (O'Leary, et al 2020; Siddiqi, 2001; Sathirathai and Barbier 2001).

Mangrove is found in 19 African countries scattering over an estimate d 30,000 km² landmass. Out of this, about 75% is situated in West Africa and the remaining in East and Central Africa (Zanvo, et al, 2021). Nigeria takes the lead in Africa's regional mangrove ranking followed by Mozambique, Guinea Bissau, Madagascar and Guinea. The Northern and Central America are some of the largest remnants of mangrove, contributing about 15% of global mangrove with its major reserve found in Texas, Florida and Louisiana (Duke, 2006). As at 2020, mangrove in USA covers 266,179 ha. In addition, majority of mangrove within Oceania are found in Australia with a total area of 1.9 million ha. Key areas in the region that are committed to mangrove conservation include Fiji, New Zealand, Papua New Guinea and Solomon Island. Mangrove ecosystem is rich in Niger Delta where it stretches along the coastline up to Akwa Ibom State and Cross River State.

The mangrove ecosystem in Cross River State is complex and cut across communities such as Anantigha, Duke/Cobham Town, Efut Obufa Esuk, Henshaw Town, Mbukpa/Akani Esok Orok etc. In Nigeria generally, extensive studies on mangrove has been carried out by Imoh Ukpong for decades (Ukpong, 1992, 1994, 1995a, 1995b, 1998, 1999). Considering the economics of mangrove, so many households have derived their livelihood from it (Ukpong, 1998; Adams, 1993; Adite 2002). Fishermen depends on the mangrove ecological zone for their daily catch. Timber dealers are so wealthy in Nigeria because of the demand for timber in building and construction industry. In fact, the cost of timber and fuel wood has skyrocket beyond control in the past few years across the states in Nigeria. The implication of high cost of timber and non-timber products is that a higher level of degradation in coastal areas will be seen in the next years to come. On daily basis, truckloads of timber and non-timber products are harvested and transported into urban centres within the nation and beyond. There is commonality of inter-continental timber and non-timber's products' transaction along Nigeria's coast. Community leaders and state actors that should be protecting the ecosystem are directly involved in the rape of mangrove ecological zone (Abraham et al 2022).

The quest to restore stability along the world shore line led to series of conventions. including Convention on Wetlands, signed in Ramsar, Iran in 1971, in which member countries declare their commitment to "stem the progressive encroachment on and loss of wetlands" (The Convention on Wetlands 1971). In spite of uncontrolled degradation of mangrove through human activities, some protected ecological zone still exist in some countries of the world. Among such are the *Grand Bassam* (Ramsar Site) which consists of a mosaic of ecosystems near the estuary of the Comoé River with multipurpose livelihood functions including tourism, artisanal fishing, birds and wildlife sanctuary. The ecological zone provides shelter for endangered species, habitat for chimpanzees, lesser white-nosed monkeys, and sooty mangabeys, as well as a spawning and nursery site for different mollusks, fish and crustaceans (Dehairs and Koedam 2005).

In Ghana, mangrove swamps are very restricted in area and distribution and rarely develop beyond the thicket stage. The most developed mangroves are found in the west of the country along the low-lying coastal belt between Côte d'Ivoire and Cape Three Points (UNEP 2007; Seung et al 2021; Sagoe et al, 2021; Asante et al 2017).

The major mangrove ecological zone of the region is Densu delta (Ramsar Site) which is an estuary containing sand dunes, scattered mangrove stands, lagoons, salt pans, marsh, and scrub. It also served multiple functions ranging from fish resources, fuel wood, salt production, timber and non-timber product. In Guinea, Iles Tristao (Ramsar Site) an estuarine complex of extensive mangrove forests exist (Nyangoko et al, 2022). The ecosystem promotes traditional fishing, habitat for birds and hippopotamuses, rice cultivation, and small-scale horticulture. The area supports nesting and wintering birds and hippopotamuses. The mangrove belt of Akwa Ibom State is not left out in the global benefiting and raping of natural resource base. At Uta Uwa estuary in Ikot Abasi and Okoroette in Eastern Obolo, mangrove acts as a nurseries and spawning ground for fishes, wine production base, habitat for flora and fauna, shoreline protection, food security etc. Efforts have been made over the years to protect this environment but some issues arising from rural poverty, continuous exploration and exploitation of minerals and greed among resource users have made it difficult to manage this environment effectively. The question now arise as to what policy would be effectively adopted so as to improve the management of mangrove ecosystem and if possibly managed, and as to what alternative livelihood would be provided to those whose livelihood were either directly or indirectly attached to mangrove ecological zone. In the light of this dilemma, study aimed at connecting the socio-economic complexities with conservation practices' barriers influencing the integrity of mangrove in Ibene LGA, Akwa Ibom State.

Materials and Methods: The study was conducted in Ibene Local Government Area. The composition of mangrove ecological zone in Ibene is so rich with abundant and diversity of marine fishes and other aquatic lifeforms like crabs, periwinkles, prawns, water birds, lobsters and many others. Besides, Ibene being part of the Stubb creek forest is endowed with many forest resources such as wildlife, shrubs, aquatic plants, nypa palm and other mangrove, *Elaeis guineensis*, *ceiba*, *musanga* and *raffia*. The study employed a mixed research method by using both primary and secondary data sources; questionnaires, interview and field observation. Five communities were purposively sampled. The communities are endowed with mangrove resources and are situated within the stubb creek forest ecosystem. Bill Godden (2004) formula for finite population was employed in determining sample

size and 400 sample size was obtained. Descriptive statistical technique as used included tables, figure and charts as well as simple percentages in analysing the data. The data was analysed through the use chi-square statistical technique.

Results and Discussions: From the study, mangrove forest resources were identified which included fisheries, timber and non-timber among others. The analysis showed that 110 respondents (27.5%) agreed that mangrove resources found in Ibeno are fisheries, 50 respondents (12.5%) agreed on timber/non-timber, 30 respondents (7.5%) on sand/gravel, 80 respondents (20%) on forest, 50 respondents (12.5%) on non-fishes product, 60 respondents (15%) on water and 20 respondents (5%) on solid mineral. Based on the socio-economic impact of mangrove ecosystem, 100 respondents with 25% agreed that the socio-economic impact of mangrove resources in their community is on job provision 5% on savings of money in bank, 2.5% on steady flow of income, 5% on building of houses, 5% on purchase of vehicle, 5% on payment of children school fee, 12.5% on food security, 20% on improved household income, 10% on revenue generation, 7.5% on reasonable household investment as well as 12.5% on opening of new business. The different livelihood opportunities in mangrove ecological zone are shown below.



Figure 1: Logging Spotted during field work

The study equally revealed that the mangrove ecological zone protect the coastal environment and a total of 95 respondents with 23.75% agreed that mangrove ecosystem support gully erosion control, 100 respondents with 25% on biodiversity preservation, 105 respondents with 26.25% on coastal flooding, 120 respondents with 30% on fisheries production and 80 respondents with 12% agreed on aquatic habitat.

Based on the human activities facing management of mangrove ecosystem, the analysis showed that 40 respondents (10%) agreed that deforestation is one of the challenges facing mangrove ecological zone, 94 respondents (23.50%) on coastal flooding, 90 respondents (22.50%) on water pollution, 91 respondents (22.75%) on land degradation and 85 respondents (21.25%) on waste disposal.

Conclusion: Mangrove ecosystem in Ibeno has largely been removed, modified and converted in line with the needs, aspirations and socio-economic realities of the inhabitant. The once protected ecosystem has been heavily degraded by human activities and coupled with alien species that are competing with the naturally existing plants such as *elaeis guineensis*, *ceiba*, *musanga*, *nypa* palm, mangrove trees and shrubs. The over-exploitation of this rich ecosystem calls for urgent management option that would meet the socio-economic needs of the rural people since this has been their source of livelihood over the years. Management of mangrove is one of the targets of the global sustainable development. The proposed United Nations (SDGs) recognises wetlands management as one of the key solutions for addressing global issues including poverty, water, food, climate and hunger. Effective ecosystem

management is intricately linked with the attainment of goal 1, 2 (poverty, hunger). In Ibeno LGA where human activities on the ecosystem is so intensive, management of mangrove ecological zone will be a curative measures against recurrent coastal flooding, land contamination, water pollution and biodiversity loss. Considering the socio-economic implications of mangrove ecological zone to rural dwellers, wise use of these resources would to a larger extent alleviate poverty and hunger in the region. The following recommendations can be useful in managing mangrove ecological zone in the study area:

- (i) Rehabilitate degraded mangrove areas with suitable species in partnership with communities and other stakeholders.
- (ii) Implementation of environmental laws that could arrest all forms of environmental problems in the ecological zone including waste disposal, illegal mining, deforestation and resources over-exploitation.
- (iii) Undertake periodical monitoring of the mangroves areas
- (iv) Promote best farming practices in the areas adjacent mangroves and the hinterlands.
- (v) Use spatial plans to map out areas for future development. This will include areas for protection as well as utilisation without encroaching into mangrove areas.
- (vi) Empower community through formation of Community Forest Associations (CFAs), where there are none and strengthen existing ones to enhance partnership with government in management of mangroves.
- (vii) Provision of alternative Job as well as Infrastructural development to boost rural economy.
- (viii) Training of local dwellers on the relevance of managing the ecological zone for their livelihood and environmental purposes.

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Condition Factors and Rearing Water Quality Parameters of Wild-Caught Atlantic Tarpon *Megalops atlanticus* Raised in Brackish Water Ponds: Implications for Capture Based Aquaculture in Nigerian Coastal Waters

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ABSTRACT

The present study assessed the condition factors and water quality parameters of pond-raised Atlantic Tarpon (*Megalops atlanticus*) collected from brackish-water ponds in Ilaje Local Government areas of Ondo State. Three farms were sampled and the assessed farms used dug-out ponds for culturing wild-caught tarpon juveniles, which were fed with trash fish and shrimps. Twenty fish specimens were collected from each farm and pooled together (totaling sixty), after which their lengths and weights were measured and the condition factors determined, following standard procedures. Water samples were taken from the cultured ponds and analysed. The results showed that smaller fish had higher condition factors values, which decreased as fish grew in these ponds. Significant variations were observed in salinity, although no signs of distress were observed on the fish. It can be concluded that *M. atlanticus* should be raised in larger ponds to ensure optimum fish growth.

KEYWORDS: Tarpon, brackish water, condition factors, aquaculture, ponds

INTRODUCTION: Nigeria is a coastal state with a long coastline stretch of 853 km from the south-west end of Badagry Lagoon to the southeastern tip of Cross River, near Calabar (Coche 1982). The brackish water (a mixture of fresh and saltwater of salinity ranging between 15 and 30 ‰) of Nigeria is a large water body of estuaries, backwaters, creeks, mangroves and lagoons occurring along the nation's coastlines, including the Niger Delta region (Sylvanus and Gao 2007). The country has over 729,000 hectares of land that is potentially suitable for mariculture and brackish water aquaculture (Sylvanus and Gao 2007; Amosu *et al.* 2013). However, these resources remain unexploited for commercial farming, as the culture of marine and brackish water fish species in Nigeria is almost non-existent (Anetekhai-Agenuma 2010). With these huge saline mangrove swamps, brackish water resources and several commercially important fish species along the coastline, brackish water aquaculture should be developed as a tool for promoting coastal agri-business. This may involve adopting diverse strategies for fish production, including capture based aquaculture (which relies on wild seed supply), to ensure sustainable food security and livelihood diversification in the Nigerian coastal communities. Furthermore, Teletchea and Fontaine (2012) reported that 70% of the 250 farmed finfish species recorded in the 2009 FAO database for cultured fish production dependent on the supply of the wild seed resources for stocking. Similarly, Nigeria needs to utilise her wild fish seeds through capture based aquaculture, to enable her achieve increased aquaculture production.

The Atlantic Tarpon (*Megalops atlanticus*) is a tropical/sub-tropical and warm/temperate fish abundant in the Atlantic Ocean, in the Eastern Atlantic area of Africa, which extends from Mauritania to Angola, but are concentrating around the Gulf of Guinea zone where the thermocline is always close to the surface (Schneider *et al.* 2000). *M. atlanticus* has been identified as economic marine/brackish-water fish species for many decades along the Nigerian coastline, as this species plays a major role in the commercial artisanal fisheries among the coastal community dwellers where it is regarded as highly priced food fish (Emmanuel and Ross, 2019). A search through the literature shows that very few research reports are available on this fish species in spite of its economic potentials in Nigeria. Key among these literatures includes Anyanwu (2004) who researched on the biology, fishery and culture potentials of the Atlantic Tarpon (*M. atlanticus*) in coastal waters of Western Nigeria. Emmanuel and Ross (2019) also assessed the morphometric characteristics and feeding habits of *M. atlanticus* in the Ogudu Creek, Lagos, Nigeria.

(Anyanwu *et al.* 2007) reported further that traditionally subsistence farming of tarpon is being practiced in some coastal communities of Ondo State, where young fish are caught from the wild, stocked in earthen brackish water ponds, fed with fish by-catches and are harvested for domestic consumption. However, the detailed information on the capture-based culture methods employed by these local farmers (which may serve as basis for future research and commercial propagation) is grossly lacking. It may be necessary to understand the water quality parameters of the brackish water pond farming and determine if these pond environments are suitable for this fish species, as part of the study aiming at enhancing culture of wild seed tarpon.

An important biometric tool for assessing the wellness of fish under a given condition is the condition factor (K) derived from the length and weight of the fish (Le Cren, 1951). It is an easy, fast and non-invasive assessment tool used in fisheries management but are also employed in aquaculture to help determine whether fish are properly nourished in relation to its environment. K measures the deviation of an organism from the average weight in a given sample in order to assess suitability of a specific water environment for growth of fish (Yilmaz *et al.*, 2012; Mensah, 2015). It can be used to compare the inter- and intra-specific "condition", "fatness" or well-being of fish from the same or contrasting habitats. It is a useful index for the monitoring of feeding intensity, age and growth rates in fish, and it can be used as an index to assess the status of the aquatic ecosystem in which the fish live (Anene, 2005). Although strongly influenced by both the biotic and abiotic environmental variables, and fluctuates by interaction among feeding habits, parasitic burden and fish physiological conditions yet, the condition factor reflects recent physical

and biological circumstances of a fish (Le Cren, 1951). The present study therefore aimed at assessing the wellness of different sizes of Tarpon using condition factor indices and to provide useful information regarding water quality parameters of this fish under brackish water culture conditions

MATERIALS AND METHODS

Study area and Tarpon farming condition: The study was carried out in Ilaje Local Government Areas of Ondo State. Three communities namely Mahin (6.1703° N, 4.7996° E), Ugbonla (6.1433° N, 4.7912° E) and Olotu (6.1257° N, 4.7582° E), designated as Farm A, Farm B and Farm C respectively, were purposively selected based on preliminary findings regarding existence and concentration of Tarpon farms in this area (Figure1). These areas were also chosen due to their different proximities to the Atlantic Ocean which can influence their water salinities through sea incursion. A farm was then selected in each of these communities based on the willingness of the farmers to test-crop his fish for assessment. The assessed farms used dug-out ponds for culturing/fattening tarpon juveniles. The juveniles were obtained from the wild during February – April 2022. Only tarpon fish were stocked in the ponds and were fed with trash fish/shrimps while the rearing water in the ponds was exchanged occasionally throughout the culture period. The fish were expected to be ready for harvesting and sale by December 2022.

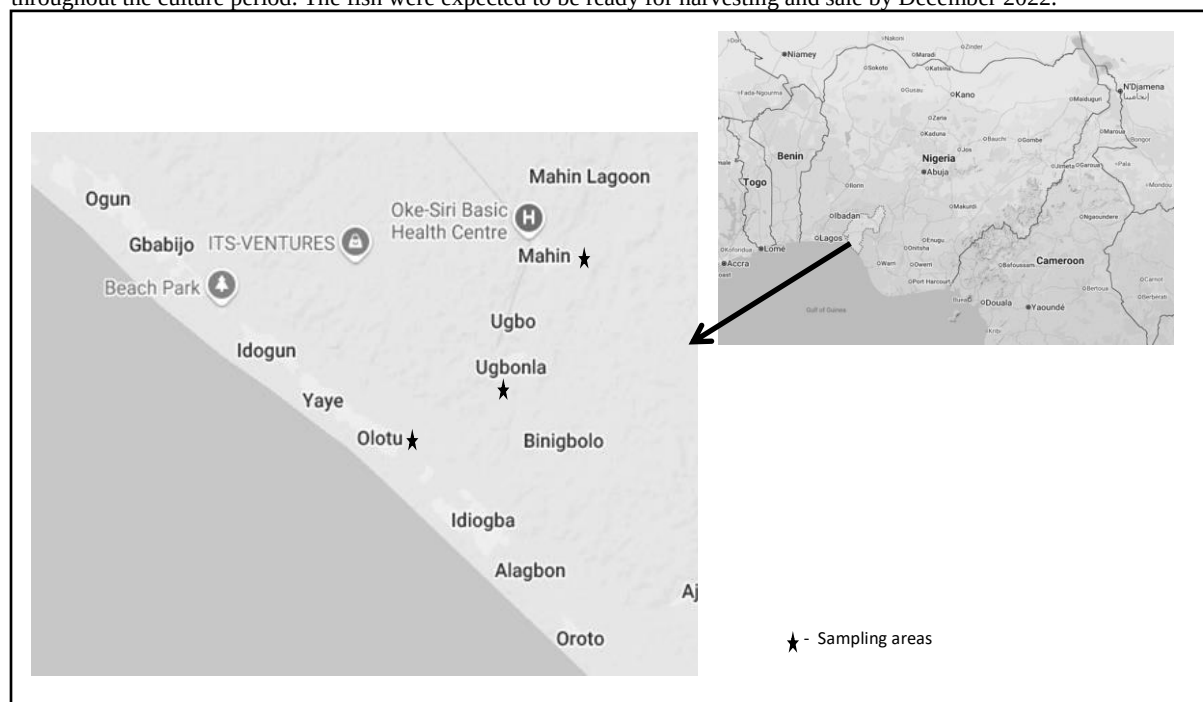


Figure 1: Map of the study area showing the sampling stations

Collection of fish and water samples: The sampling was done in August 2022 (when the fish were 4 – 6 months of culture). The fish were partially harvested from the rearing ponds using dragnet. Twenty fish specimens were collected from each farm and were evaluated immediately for length and weight measurement. Similarly, water samples were taken with water sampling bottles at the depth of 0.5 m below the surface in each of the sampled ponds. Once collected, the water samples were stored in ice box and transported immediately to the laboratory for further examination.

3.4. Fish analysis: The total lengths of each fish samples were determined using a measuring board and their weights determined using a weighing balance. The weight of each fish was achieved by placing each *M. atlanticus* on an electronic weighing balance and the result was recorded to the nearest decimal point in grams. The length measurement was recorded in centimeters while the weight measurements were recorded in grams. All fish specimen from the three farms were pooled together, totaling sixty in all. The condition factor of *M. atlanticus* was calculated using Bagenal and Tesch (1978) method as:

$$K = 100 \times W / L^3$$

Where

W = weight of fish in grams

L = length of fish in centimeters

K = condition factor

The condition factors were then grouped based on fish length for better understanding and interpretation

Water quality analysis: Temperature and transparency of water samples from each pond were measured *in situ* using pocket type digital thermometer and secchi disc respectively. At the laboratory, water quality parameters, namely, pH, conductivity, dissolved oxygen, were measured using handheld pH/oxygen/conductivity meters equipped with a sensor, 325 Oxygen Sensor (WTW), a SenTix 20 probe (WTW), and a conductivity sensor (WTW).

Statistical analysis; The statistical analyses were done using Statistical Package for Social Sciences (SPSS version 20) and Microsoft Excel 2007. The data from water quality analysis from each farm were recorded as mean $\pm$ standard deviation. One way analysis of variance (ANOVA) was used to compare means of the parameters among the sampled farms while Duncan Multiple Range test was employed to separate means where significant differences existed. The results of condition factors of the sampled fish were presented in ranges and means.

RESULTS: The total lengths of pond raised *M. atlanticus* examined from the three farms in Ilaje LGA of Ondo State ranged from 26 cm to 64 cm. Similarly, the examined specimens had total weights ranging from 415 g to 1153 g. The results of the condition factors of the examined fish specimen are presented in Tables 1. It was observed that smaller fish had higher K values while bigger fish had smaller K values. Similarly, fish group with length range of 21 - 30 cm had the highest mean K value of 2.08, while those of length range of 61 – 70 cm had the lowest mean K value of 0.43.

The results of the physico-chemical parameters of pond water used to culture *M. atlanticus* in three farms are presented in Table 2. While temperature, and ammonia level in the three farms were found to be statistically ($p>0.5$) the same, other parameters were significantly different. It was observed that salinity, total dissolved solids, dissolved oxygen and conductivity were significantly highest in farm B, whereas, pH was significantly highest in farm C

Table 1: Analysis of condition factors of pond raised *M. atlanticus* of different sizes

Fish size (cm)	Mean length (cm)	Condition factor range	Mean condition factor
21 – 30	28.3	1.82 - 2.36	2.08
31 – 40	37.5	0.90 - 1.32	1.19
41 – 50	41.6	0.97 - 0.75	0.93
51 – 60	56.1	0.41 - 0.64	0.47
61 – 70	65.4	0.39 - 0.47	0.43

Table 4.5 Physico-chemical parameters of water samples from three Tarpon farms

Parameters	Farm A	Farm B	Farm C
Temperature (°C)	27.2 $\pm$ 0.90 ^a	26.9 $\pm$ 1.20 ^a	26.9 $\pm$ 0.70 ^a
Transparency (cm)	12.5 $\pm$ 0.75 ^a	14.00 $\pm$ 0.50 ^a	17.80 $\pm$ 0.25 ^b
Ph	6.74 $\pm$ 0.02 ^a	7.24 $\pm$ 0.05 ^b	6.57 $\pm$ 0.03 ^a
Conductivity (mg/l)	366.29 $\pm$ 3.53 ^a	378.60 $\pm$ 5.88 ^a	420.65 $\pm$ 5.21 ^b
Total Dissolved Solid (mg/l)	185.61 $\pm$ 5.21 ^a	191.38 $\pm$ 3.56 ^a	214.43 $\pm$ 8.66 ^b
Dissolve Oxygen (mg/l)	7.25 $\pm$ 010 ^a	7.94 $\pm$ 0.50 ^a	9.68 $\pm$ 0.35 ^b
Nitrate(mg/l)	2.55 $\pm$ 0 09 ^a	3.15 $\pm$ 0.05 ^b	1.47 $\pm$ 0.01 ^a
Ammonia(mg/l)	0.86 $\pm$ 0.01 ^a	0.97 $\pm$ 0.03 ^a	0.51 $\pm$ 0.01 ^a
Salinity(mg/l)	15.36 $\pm$ 1.94 ^a	37.48 $\pm$ 1.50 ^b	44.9 $\pm$ 0.98 ^c

Values were recorded from triplicate samples as means standard deviation. Means with different superscripts on a row were significantly ($P<0.05$) different.

DISCUSSION: An important biometric tool is the relative condition factor (K) that was derived from the LWRs (Le Cren, 1951). K measures the deviation of an organism from the average weight in a given sample in order to assess suitability of a specific water environment and growing conditions of fish (Yilmaz *et al.*, 2012; Mensah, 2015). An overall fitness for fish species is assumed when K values are equal or close to 1. Higher condition factors reflect a better nutritional status and better adaptation of the fish to its immediate environment (Hamandishe *et al.*, 2018). In this study, smaller fish had higher K values, which decreased as fish grow. This observation might be related to the differences in food availability and consequence of physicochemical features on the life cycle of fish species (Le Cren, 1951). It appeared from this study that the trash fish fed to pond-raised *M. atlanticus* might not be adequate to meet the nutritional needs of the growing fish beyond 600 g body weight. More so, farmers in the sampled farms

were not offering food to their fish on the basis of fish requirements as being done in conventional hatchery based aquaculture, hence the reduction in its condition factor.

It should be noted that the gut fullness was not investigated as part of the fish analysis since it was documented in literature that the fullness status was not likely to be linked to the condition factor (Hanjavanit *et al.*, 2013). In fact, when the fish gets enough food for its growth, K will be greater than one corresponding to optimum growth condition. The fish might have an empty stomach at collection even though it is consuming sufficient food for its growth and survival in its habitat. Besides food availability, wild *M. atlanticus* adult live in large ocean waters and is primarily found down to 30m deep in warm coastal waters, bays, estuaries and mangrove-lined lagoons (Whitehead and Vergara, 1978). Tarpon can tolerate brackish and sometimes, freshwater (Hureau, 1984), but these environments may not be conducive for optimum growth of adult fish, whose habitat is principally a marine environment, as confirmed in this study. Of note among the water quality parameters tested in this study is the salinity contents of the different samples. The variations observed could be due to the closeness of the farms to the Atlantic Ocean. However, the fish showed tolerance to these salinity variations.

CONCLUSION: The present research provides comprehensive information of condition factors of pond-raised *Megalops atlanticus* in relation to its environment of culture. Condition factors of fish showed that smaller fish had better values, which decreased as fish grow in ponds. Larger ponds are therefore suggested for fish above 41 cm (600 g) to ensure that optimum fish growth is attained for increased productivity and commercialization. The study pinpoints the potentials of *Megalops atlanticus* as a candidate species for capture based aquaculture in the coastal communities of Ondo State, and by extension the entire Nigerian coastal areas.

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Effects of Varying Rates of Rabbit Manure and Npk Fertilizer on the Growth and Yield Performance of *Amaranthus* (*Amaranthus Hybridus* L.)

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ABSTRACT

This study evaluated the effects of rabbit manure (RM) and NPK 15-15-15 fertilizer, applied individually and in combination, on the growth and yield performance of *Amaranthus hybridus* L. The experiment was conducted at the Teaching and Research Farm of Ekiti State Polytechnic, Isan-Ekiti, using a randomized complete block design (RCBD) with six treatments replicated three times. Treatments included varying combinations of RM (1- 4 t/ha) and NPK fertilizer (50 - 200 kg/ha), with applications split between one and three weeks after transplanting. Standard agronomic practices were followed, and seedlings were spaced at 20 cm × 20 cm to achieve a density of 250,000 plants/ha. Growth parameters—including plant height, stem diameter, number of leaves, leaf area, and branch count—were measured weekly, while yield attributes such as fresh biomass, shoot and root weight, and marketable yield were assessed at harvest. Results showed that all fertilized treatments significantly outperformed the control. The combination of 3 tons/ha RM + 50 kg/ha NPK consistently produced superior growth and yield metrics, matching or exceeding the performance of full NPK application (200 kg/ha) while using 75% less inorganic fertilizer. The findings underscore the effectiveness of integrating organic and inorganic fertilizers for improving crop productivity, promoting sustainable nutrient management, and reducing chemical fertilizer dependence in *Amaranthus* cultivation.

Keywords: Rabbit manure, NPK fertilizer, growth and yield, amaranthus, varying rates.

INTRODUCTION: *Amaranthus* species are essential in the fight against food and nutrition insecurity (Amulu *et al.*, 2021). *Amaranthus hybridus*, also referred to as smooth pigweed or green amaranth, is a nutrient-demanding, quickly growing plant that thrives on proper fertilization for maximum development and yields (Awopegba and Awodun, 2023). *A. hybridus* is a source of dietary nutrients and medications due to the high levels of vitamin A and flavonoids found in its leaves (Ekeke *et al.*, 2019).

Amaranthus hybridus responds well to both organic and inorganic fertilizers, albeit the type and rate of fertilizer application. Research on organic fertilizers, such as poultry manure and cow dung, demonstrates that *A. hybridus* significantly enhances growth and productivity (Ikani *et al.*, 2024). Plant height, stem girth, and leaf area are also improved by compost and cow dung, sometimes outperforming NPK (Inyang *et al.*, 2018; Sanni, 2016). NPK fertilizers promote growth and yield; however they may not always be as effective as organic fertilizers (Adekiya *et al.*, 2019).

Overuse of chemical fertilizers is associated with dangers to the environment and human health (Zaib *et al.*, 2023). Nutrient runoff can contaminate water supplies and cause diseases, including methemoglobinemia and elevated cancer risks (Zeeshan *et al.*, 2024). Several problems include excessive nitrogen losses that result in greenhouse gas emissions, such as nitrous oxide, and fertilizer runoff that damages ecosystems (Aziz *et al.*, 2022). The application of synthetic fertilizers raises questions about sustainability, even though they are essential for food production (Guye, 2015).

Rabbit and pig manure, among other organic fertilizers, increases soil phosphorus, nitrogen, and organic carbon content (Zhang *et al.*, 2023). This has a favourable impact on the physico-chemical properties of the soil as well as its microbial communities, which in turn promotes the growth and production of vegetables (Zhang *et al.*, 2023). Rabbit manure, due to its low moisture, high lignocellulose content, and good fertilizer effect, has been studied extensively for its impact on various crops. Research has shown that rabbit manure compost can significantly enhance the growth parameters of different plants (Li *et al.*, 2022). Fresh rabbit excrement (faecal pellets) has the highest percentage of nitrogen among livestock manures, with 2.4% nitrogen, 0.6% potassium, and 1.4% phosphorus (Awopegba *et al.*, 2024). Maize plants treated with rabbit compost tea exhibited improved growth parameters such as plant height, stem girth, number of leaves, and leaf area, highlighting the effectiveness of rabbit manure as an organic fertilizer (Awopegba *et al.*, 2024). The integrated use of organic and inorganic fertilizers is more effective in managing soil fertility (Yusuf & Olowoake, 2019). Combining chemical fertilizers with organic manure helps mitigate nutrient deficiencies (Malhi *et al.*, 2013). This study aims to evaluate the effects of varying rates of rabbit manure, NPK fertilizer and their combined application on the performance of *Amaranthus* (*A. hybridus* L.).

MATERIALS AND METHODS: This study evaluates the effects of varying rates of rabbit manure and NPK 15-15-15 fertilizer on the growth and yield performance of *Amaranthus hybridus*. The study was carried out at the Teaching and Research Farm of Ekiti State Polytechnic, Isan-Ekiti in the forest-savannah transition zone with bimodal rainfall averaging 1320 mm annually. The experiment was laid out in a randomized complete block design (RCBD) with six treatment combinations replicated three times,

totalling 18 plots (each 2 m × 2 m) per site. The land area for each experimental field was 190 m², with 1 m alleys separating plots. Manual land preparation was followed by nursery raising of *A. hybridus* seedlings for two weeks before transplanting at 20 cm × 20 cm spacing (equivalent to 250,000 plants/ha). Rabbit manure was applied one week after transplanting by broadcasting, while NPK (15-15-15) fertilizer was side-placed three weeks after transplanting (Table 1). Irrigation was done as needed using 20 litres of water per plot applied with a cordless sprinkler. Growth parameters-including stem diameter, number of leaves, plant height, branch count, and leaf area-were recorded weekly starting two weeks after transplanting. Stem diameter was measured using a digital vernier caliper (in cm), height with a meter rule (in cm), and leaf area (in cm²) estimated using the equation 1:

$$\text{Leaf area (cm}^2\text{)} = 0.654 \times (L \times W) \dots\dots\dots (i)$$

Where L is leaf length and W is maximum leaf width (Managa & Nemadodzi, 2023). Yield components such as fresh biomass, root and shoot biomass, inflorescence weight, seed yield, and marketable yield were assessed using a digital weighing balance and standardized to tonnes per hectare using equation 2 below: (Falodun & Edafe, 2020).

$$\text{Yield (t/ha)} = \frac{\text{Plot yield (kg)}}{\text{Plot size (m}^2\text{)}} \times \frac{10,000 \text{ m}^2 \text{ (hectare)}}{1,000 \text{ (tonnes)}} \dots\dots\dots (ii)$$

All collected data were subjected to analysis of variance (ANOVA) using the PROC GLM function in STAR v2.0.1 (IRRI, 2013). Treatment means were separated using Tukey's HSD test at a 5% probability level ($P < 0.05$).

Table 1: List of fertilizer treatment combinations

Acronym	Treatment description
T ₁	0 RT + 0 NPK
T ₂	100 kg ha ⁻¹ of NPK applied at 1 WAT + 100 kg ha ⁻¹ of NPK applied at 3 WAT
T ₃	2 t ha ⁻¹ of RM applied at 1 WAT + 2 t ha ⁻¹ of RM applied at 3 WAT
T ₄	2 t ha ⁻¹ of RM applied at 1 WAT + 100 kg ha ⁻¹ of NPK applied at 3 WAT
T ₅	3 t ha ⁻¹ of RM applied at 1 WAT + 50 kg ha ⁻¹ of NPK applied at 3 WAT
T ₆	1 t ha ⁻¹ of RM applied at 1 WAT + 150 kg ha ⁻¹ of NPK applied at 3 WAT

RM = Rabbit manure, WAT = Weeks after transplanting, T₁ = Control, T₂ = NPK (15-15-15) fertilizer at 200 kg ha⁻¹, T₃ = RM at 4 t ha⁻¹, T₄ = RM at 2 t ha⁻¹ plus NPK at 100 kg ha⁻¹, T₅ = RM at 3 t ha⁻¹ plus NPK at 50 kg ha⁻¹, T₆ = RM at 1 t ha⁻¹ plus NPK at 150 kg ha⁻¹.

RESULTS AND DISCUSSION: All fertilizer treatments significantly increased plant height compared to the control at all growth stages (Table 2). This improvement is evident as the control consistently had the lowest values. Combining RM and NPK generally produced superior results compared to applying either alone at the tested rates. Ngala et al. (2021) also demonstrated that integrating NPK, biofertilizers, and poultry manure produced the highest maize plant height and biomass. The combinations often achieved heights comparable to or exceeding the full NPK rate (200 kg/ha) while using less inorganic fertilizer (Awopegba et al., 2024). Plant heights and treatment rankings showed some variation between the two locations, indicating site-specific responses. The combination of 3 tons/ha RM + 50 kg/ha NPK consistently produced the tallest or among the tallest plants from Week 5 onwards, achieving the highest final height (74.40 cm at Week 7) statistically with other treatments that had combined RM and NPK combinations. NPK (200 kg/ha) fertilizer significantly boosted height over the control and RM alone. It was often statistically similar to the best combinations in the mid-stages but was generally surpassed by at least one combination by Week 7 at both sites. Similarly, Awopegba et al. (2024) reported that combining rabbit compost tea with NPK fertilizer significantly improved maize growth parameters compared to individual applications. While beneficial, applying rabbit manure alone (4 tons/ha) was less effective for promoting height than NPK alone or any of the RM+NPK combinations.

Table 3 presents the effect of rabbit manure (RM) and NPK fertilizer, both individually and in combination, on the number of leaves of *Amaranthus hybridus* L. at different weeks after transplanting. The highest number of leaves was observed at 7 weeks after transplanting (WAT) in the treatment with NPK at 200 kg/ha, reaching 68.20 leaves. The control group consistently recorded the lowest leaf counts across all weeks. Treatments involving the combined application of RM and NPK significantly outperformed those with only RM or control, suggesting a synergistic effect that enhanced vegetative growth. In support, studies on *Moringa oleifera* (Sarwar et al., 2018) and chilli (Kamrunnahr et al., 2024) consistently show improved vegetative growth parameters when using combined treatments. Among the combinations, balanced applications of RM and NPK produced optimal leaf development. The control consistently produced the smallest stem diameters (Table 4) across all growth stages ($p < 0.05$). NPK fertilizer alone (200 kg/ha) produced the thickest stems during early growth (weeks 2–4) at EKSPOLY, while combinations of rabbit manure (RM) and reduced NPK outperformed sole applications in later stages (weeks 6 – 7). The optimal combination with the thickest stems is at 3 tons/ha RM + 50 kg/ha NPK (peak: 1.31 cm at week 7). Rabbit manure alone (4 tons/ha) matched NPK alone at Week 4 but lagged significantly thereafter (Shaji et al., 2021). Fertilization effects intensified over time, with the greatest treatment differences occurring at Weeks 6–7. Critically, combinations like 3 tons/ha RM + 50 kg/ha NPK achieved superior or comparable results to full-rate NPK using 75% less synthetic fertilizer, demonstrating significant potential for sustainable nutrient management.

Fertilization significantly enhanced leaf area in *Amaranthus hybridus* compared to the control from Weeks 5 to 7 (Table 5), although no significant differences were observed among treatments at Week 4. Treatments such as the combined application of rabbit manure (RM) plus NPK, NPK treatments alone and RM treatment alone statistically had similar results. Fertilization considerably enhanced the number of branches in *Amaranthus hybridus* as compared to the control from weeks 5 to 7, while there were no significant differences between treatments at week 4 (Table 6). The highest branch counts during weeks 5–7 were regularly

produced by a combination of 3 tons/ha rabbit manure + 50 kg/ha NPK and NPK fertilizer applied alone at 200 kg/ha, reaching a peak of 6.50 and 6.10 branches in week 7, respectively.

NPK alone (200 kg/ha) maximized root biomass (5.04 t ha⁻¹). The 3 tons/ha rabbit manure + 50 kg/ha NPK yielded the highest fresh weight (26.50 t ha⁻¹) and matched NPK alone in shoot biomass, marketable yield, and edible yield (Table 7). It's noteworthy that statistically all the treatments performed the same way for marketable and edible yield except the control. Rabbit manure alone (4 tons/ha) improved yields versus the control but was consistently outmatched by optimized combinations. Ikani et al. (2024) and Inyang et al. (2018) established that combined application of organic and inorganic fertilizers improved plant height, leaf number, stem girth, and yield.

CONCLUSION: The study demonstrated that integrating rabbit manure (RM) with NPK 15-15-15 fertilizer significantly enhanced the growth and yield performance of *Amaranthus hybridus* compared to sole applications or the control. While NPK alone (200 kg/ha) produced strong vegetative growth, the combination of 3 tons/ha RM + 50 kg/ha NPK consistently achieved comparable or superior results across key parameters such as plant height, stem diameter, leaf number, branch count, and fresh biomass yield. This optimized combination not only improved performance but also reduced chemical fertilizer input by 75%, highlighting its potential for sustainable and cost-effective nutrient management in amaranth cultivation. Thus, integrating organic and inorganic fertilizers offers a viable strategy for improving crop productivity while enhancing soil health and reducing environmental impact.

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Table 2: Effect of rabbit manure and NPK fertilizer on plant height of *Amaranthus hybridus* L. at different stages of growth

Treatments	Weeks after Transplanting					
	2	3	4	5	6	7

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	EKSPOLY, Isan-Ekiti					
Control	8.81f	12.72f	21.28f	30.69f	38.25f	47.24f
NPK at 200 kg/ha	9.95a	17.66a	24.87a	40.56b	57.64b	72.15b
RM at 4 tons/ha	8.89e	14.99e	22.05e	36.23e	50.20e	65.80e
RM at 2 tons/ha + NPK at 100 kg/ha	9.04d	16.44b	24.74b	38.78c	51.10d	71.05c
RM at 3 tons/ha + NPK at 50 kg/ha	9.61b	15.23c	23.51c	41.23a	58.14a	74.40a
RM at 1 ton/ha + NPK at 150 kg/ha	9.10c	15.16d	22.23d	38.23d	53.48c	70.20d

Means with the same letter in the same column are not significantly ($p > 0.05$) different, as indicated by Tukey's HSD test.

Table 3: Effect of rabbit manure and NPK fertilizer on the number of leaves of *Amaranthus hybridus* L. at different stages of growth

Treatments	Weeks after Transplanting					
	2	3	4	5	6	7
	EKSPOLY, Isan-Ekiti					
Control	7.50d	9.40e	11.00f	24.80f	32.80f	39.50f
NPK at 200 kg/ha	8.20a	13.80a	13.20a	35.20a	50.25a	68.20a
RM at 4 tons/ha	7.20e	12.20d	12.50d	34.40b	46.45d	58.54e
RM at 2 tons/ha + NPK at 100 kg/ha	7.80c	13.10c	12.90b	32.80d	45.40e	61.40d
RM at 3 tons/ha + NPK at 50 kg/ha	7.60d	13.45b	12.70c	33.60c	49.62b	66.12b
RM at 1 ton/ha + NPK at 150 kg/ha	8.00b	8.00f	11.94e	31.25e	47.40c	62.50c

Means with the same letter in the same column are not significantly ($p > 0.05$) different, as indicated by Tukey's HSD test.

Table 4: Effect of rabbit manure and NPK fertilizer on stem diameter of *Amaranthus hybridus* L. at different stages of growth

Treatments	Weeks after Transplanting					
	2	3	4	5	6	7
	EKSPOLY, Isan-Ekiti					
Control	0.20d	0.27f	0.43f	0.58f	0.72f	0.91f
NPK at 200 kg/ha	0.23a	0.39a	0.62b	0.79b	1.02c	1.24b
RM at 4 tons/ha	0.20d	0.32d	0.64a	0.74d	0.93e	1.09e
RM at 2 tons/ha + NPK at 100 kg/ha	0.21c	0.35b	0.50d	0.75c	0.95d	1.12d
RM at 3 tons/ha + NPK at 50 kg/ha	0.21c	0.34c	0.60c	0.71e	1.09a	1.31a
RM at 1 ton/ha + NPK at 150 kg/ha	0.22b	0.29e	0.48e	0.80a	1.05b	1.22c

Means with the same letter in the same column are not significantly ($p > 0.05$) different, as indicated by Tukey's HSD test.

Table 5: Effect of rabbit manure and NPK fertilizer on leaf area of *Amaranthus hybridus* L. at different stages of growth

Treatments	Weeks after Transplanting			
	4	5	6	7
	EKSPOLY, Isan-Ekiti			
Control	12.04a	14.14d	15.12c	17.52b
NPK at 200 kg/ha	13.46a	18.23a	24.50a	26.74a
RM at 4 tons/ha	12.54a	15.33bcd	20.12b	25.24a
RM at 2 tons/ha + NPK at 100 kg/ha	13.06a	16.95abc	20.67b	25.38a
RM at 3 tons/ha + NPK at 50 kg/ha	13.50a	17.91ab	25.40a	26.41a
RM at 1 ton/ha + NPK at 150 kg/ha	12.11a	15.22cd	21.66b	25.14a

Means with the same letter in the same column are not significantly ($p > 0.05$) different, as indicated by Tukey's HSD test.

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Table 6: Effect of rabbit manure and NPK fertilizer on number of branches of *Amaranthus hybridus* L. at different stages of growth

Treatments	Weeks after Transplanting			
	4	5	6	7
	EKSPOLY, Isan-Ekiti			
Control	0.10a	0.60c	1.10c	1.67c
NPK at 200 kg/ha	0.33a	2.27a	4.20a	6.10a
RM at 4 tons/ha	0.17a	0.83bc	3.40b	4.50b
RM at 2 tons/ha + NPK at 100 kg/ha	0.27a	1.13b	3.20b	4.30b
RM at 3 tons/ha + NPK at 50 kg/ha	0.33a	2.33a	4.40a	6.50a
RM at 1 ton/ha + NPK at 150 kg/ha	0.17a	1.00bc	3.60b	4.40b

Means with the same letter in the same column are not significantly ($p > 0.05$) different, as indicated by Tukey's HSD test.

Table 6: Effects of rabbit manure and NPK fertilizer on *Amaranthus hybridus* yield parameters

Treatments	Fresh Weight Biomass (t ha ⁻¹)	Shoot Wet Biomass (t ha ⁻¹)	Root Wet Biomass (t ha ⁻¹)	Marketable Yield (t ha ⁻¹)	Edible Yield (t ha ⁻¹)
	EKSPOLY, Isan-Ekiti				
Control	16.10f	12.52b	3.58c	11.15b	7.85b
NPK at 200 kg/ha	26.30b	21.26a	5.04a	19.73a	13.56a
RM at 4 tons/ha	24.40d	20.34a	4.06bc	18.82a	12.72a
RM at 2 tons/ha + NPK at 100 kg/ha	24.60c	20.16a	4.44ab	19.08a	12.51a
RM at 3 tons/ha + NPK at 50 kg/ha	26.50a	21.82a	4.68ab	19.98a	13.51a
RM at 1 ton/ha + NPK at 150 kg/ha	23.53e	19.78a	3.72c	18.46a	12.04a

Means with the same letter in the same column are not significantly ($p > 0.05$) different, as indicated by Tukey's HSD test.

Microbial Contamination and Pathogenic Profiles of Street-Vended Fruit Salads in Owerri Metropolis.

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INTRODUCTION: Fruit salads are widely consumed due to their health benefits and convenience, particularly in urban areas such as Owerri Metropolis, Imo State, Nigeria. However, their minimal processing, lack of preservatives, and absence of heat treatment make them highly susceptible to microbial contamination. Factors such as poor sanitation, inadequate storage, and unsafe handling practices by street vendors further increase the risk. Globally, foodborne illnesses affect approximately 600 million people annually, causing over 400,000 deaths (WHO, 2020). In Nigeria, the risks are amplified by weak food safety regulations and infrastructure. Several studies across Nigerian cities have documented high microbial contamination in fresh cut fruits. For instance, research in Lagos and Abuja revealed bacterial and fungal contamination, including *E. coli*, *Staphylococcus aureus*, *Aspergillus*, and *Penicillium* (Adeyemi et al., 2017; Olorunfemi et al., 2020). Enteric bacteria such as *Salmonella* spp., *Vibrio parahaemolyticus*, *Shigella* spp., and *Listeria monocytogenes* are frequently implicated in foodborne outbreaks and are capable of producing toxins and evading antibiotics (Nazir et al., 2024; Oyeyipo et al., 2022). Contamination may also stem from pesticide residues, heavy metals, and poor hygiene in processing facilities. Despite widespread consumption, there is limited data on the bacterial quality and pathogenic traits of fruit salads in Owerri Metropolis. This gap prompted the current study to investigate the presence, virulence traits, and antimicrobial resistance of enteric bacteria in fruit salads, thereby informing public health strategies to improve food safety in the region.

MATERIALS AND METHODS

Study Area: The study was carried out in Owerri Metropolis, Imo State, Nigeria. It involved markets, retail shops, supermarkets, roadside retailers and markets within Douglas Road, Relief Market, IMSU Junction, Port Harcourt Road, as these urban areas have high foot traffic and diverse food vending sites.

Fruit Salad Source, Collection and Processing: A Total of 44 fruit Salad samples consisting of mixed fruit samples of pineapple (*Ananas comosus*) and watermelon (*Citrullus lanatus*), bananas, apples, pawpaw; from different area of Owerri Metropolis. These samples were collected from different clusters of retailers, supermarkets, roadside retailers in Orji Flyover, Ama JK, Douglas Market, IMSU Junction, Portharcourt Rd, and Relief Market. They were collected in sterilized sampling bags aseptically following the method of American public Health Association (APHA, 1998) and transported under aseptic conditions to the laboratory, as soon as possible for processing on the same day of collection. Samples were classified into two categories such as A (Salad with milk) and B (Salad without milk).

Preparation of the media : The following media were used for culturing: Nutrient agar (total heterotrophic aerobic bacterial counts), MacConkey Agar (Total coliform counts), Chromocult Coliform agar (CCA), Oxoid Salmonella – Shigella Agar, Mannitol Yolk Polymyxin Agar and Thiocitrate Bile Salt Sucrose Agar. All the media were prepared according to the Manufacturer's specification.

Sterilization of materials : As stated in Willey et al. (2008), conical flasks (Pyrex), prepared media and other plastic materials were sterilized by autoclaving at 121°C for 15 minutes at a pressure of 15 Psi. Glass wares such as pipettes, glass spreader, Petri dishes, measuring cylinder, and other glass materials were sterilized in the laboratory hot air oven at a temperature of 160°C for 1 hr before use.

Pre- Enrichment and Enumeration of Enteric Bacteria: According to the method of Budiarmo *et al.* (2021), 25 g of ready to eat fruit salad with or without milk samples were mashed aseptically and then inoculated in buffered peptone water and Rapport

Vassiliadis media for pre-enrichment cultures. The media were then stored at 37°C in a rotary shaker for 16 - 24 h. Pre-enrichment cultures would nourish cells damaged during the storage and yield high cell concentrations (Sangadkit *et al.*, 2016). Cell cultures were serially diluted to 10⁻⁴ with 0.1 % phosphate saline buffer solution (0.85%). Next, 0.1 mL cell cultures were inoculated from the 10⁻⁴ dilutions using the spread plate technique on the surfaces of chromocult coliform agar (CCA), Oxoid Agar (SSA), Thiocitrate Bile Salt Sucrose Agar, Mannitol Yolk Polymyxin Agar (MYP) and Nutrient Agar for coliform (pink to violet colour), *Salmonella* (purple), *Bacillus cereus* (turquoise to pea-cock blue colour) and total aerobic mesophilic bacteria (TAMB), respectively. The plates were incubated at 37 ± 1 °C and 30 ± 1 °C for 48 h. The colonies that emerged were counted using a colony counter and calculated coliform forming unit per gram (CFU/g) of fruit salad.

Isolation and Maintenance of Stock Cultures of Pure Bacterial Isolates: Discrete colonies of bacterial isolates were respectively and repeatedly sub-cultured onto Petri dishes containing freshly prepared nutrient agar to obtain pure (cultures) isolates. Thereafter, the pure microbial isolates were stocked in Bijou bottles containing 10 % of sterilized glycerol solution (autoclaved at the temperature of 121°C for 15 minutes) and kept refrigerated at 4 °C for subsequent characterization and further use (Umana *et al.*, 2017).

RESULTS

Bacterial Load of Fruit Salad with Milk Samples: The microbiological analysis of fruit salad samples with milk collected from various locations in Owerri Metropolis revealed high levels of bacterial contamination. **Total Heterotrophic Bacterial Count (THBC)** was exceedingly high in many samples, with five samples (D, H, I, P, and U) recorded as **Too Numerous to Count (TNTC)**. The remaining samples showed THBC ranging from **7.18 to 7.50 Log CFU/g**, far above acceptable thresholds, indicating significant microbial presence. All 16 samples showed **elevated coliform counts**, ranging from **5.85 Log CFU/g** (sample B) to **7.30 Log CFU/g** (sample H). These high counts suggest possible **fecal contamination**, poor handling, and unsafe hygienic practices. **Salmonella/Shigella species** were present in **12 out of 16 samples**, with sample Q (Relief Market) recording the highest count of **6.78 Log CFU/g**, followed by sample D with **6.04 Log CFU/g**. Four samples had no detectable presence. **Vibrio species** were also widespread. The highest *Vibrio* count was in **sample D (7.12 Log CFU/g)**, followed by **samples W (6.45)** and **β (6.51)**. No *Vibrio* was detected in samples B, I, P, and Θ. *Bacillus cereus*, a known foodborne pathogen, was found in 11 samples, peaking at **6.32 Log CFU/g** in sample D. However, it was absent in samples H, Q, W, Q, and Θ. Overall, **sample D (Ama JK milky salad 2)** showed the **highest contamination across all indicators**, making it the most hazardous. Conversely, **sample Θ** had lower microbial levels and no detected pathogens apart from coliforms and THBC.

Table 4.1 Bacterial Load of Fruit Salad with Milk Samples

	Bacterial flora/fruit salad sample	THBC	Total count	coliform	Salmonella count	Shigella	Total count	Vibrio	Total count	Bacillus cereus count
1	B	7.50	5.85		0.00		0.00			6.08
2	D	TNTC	7.18		6.04		7.12			6.32
3	H	TNTC	7.30		5.78		6.00			0.00
4	I	TNTC	6.23		5.30		0.00			6.19
5	K	7.18	7.08		5.70		6.18			6.10
6	L	7.30	6.65		5.48		5.00			6.18
7	P	TNTC	7.15		0.00		5.00			6.05
8	Q	7.40	7.00		5.30		5.00			0.00
9	U	TNTC	7.23		5.60		6.25			6.25
10	W	7.30	7.26		5.60		6.45			0.00
11	B	7.36	6.85		5.30		6.51			6.11
12	E	7.20	6.32		0.00		5.00			5.61
13	Q	7.32	7.00		6.78		6.51			0.00
14	Θ	7.23	6.85		0.00		0.00			0.00
15	R ²	7.31	5.90		5.60		0.00			6.02
16	g	7.30	7.00		1.78		6.51			0.00

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Key: CFU/g = Coliform forming unit, THBC = Total heterotrophic bacterial count, sp = Species, TNTC = Too numerous to count; B = Ama JK milky salad 1; D = Ama JK milky salad 2; H = Orji Flyover milky salad 1; I = Orji Flyover milky salad 2; K = Port harcourt Road milky salad 1; L = Port harcourt Road milky salad 2; P = IMSU milky salad 1; Q = IMSU milky salad 2; U = Douglas milky salad; W = PH Road milky salad 3; β = Relief Market milky salad; ϵ = Douglas milky salad 2; Ω = Relief Market milky salad 2; θ = Ama JK milky salad 3; R^2 = IMSU milky salad 3; q = Douglas milky salad 3.

3.2 Bacterial Load of Fruit Salad without Milk Samples

The microbiological analysis of fruit salad samples **without milk** from various locations in Owerri Metropolis revealed **widespread contamination** and high bacterial loads. Several samples, including F, J, M, N, O, R, V, Z, γ , and IV, recorded **Too Numerous to Count (TNTC)** values for **Total Heterotrophic Bacterial Count (THBC)**, indicating excessive microbial contamination. Other samples had THBC values ranging from **7.08 to 7.41 Log CFU/g**, with **sample T** showing the highest measurable count. **Coliform bacteria**, indicators of fecal or environmental contamination, were found in **all samples**, with levels ranging from **6.00 Log CFU/g** (sample E) to **7.08 Log CFU/g** (sample G). This universal presence highlights major concerns in hygiene and handling practices. **Salmonella/Shigella species** were detected in **13 out of 21 samples**, with **sample M** showing the highest count at **6.63 Log CFU/g**. However, **eight samples**, such as E, F, J, and others, had no detectable levels, possibly reflecting better hygiene or random absence.

Vibrio species were detected in **14 samples**, with the highest count in **sample N (6.61 Log CFU/g)**, followed by Z and γ . Their presence suggests possible use of **contaminated water** during preparation. **Bacillus cereus**, a known cause of foodborne illness, was found in **16 samples**, peaking at **7.23 Log CFU/g** in **sample V**, and significantly high in others like G and T. It was absent in five samples, including K and α . **Sample M (Ama JK non-milky salad 3)** stood out with the **highest combined microbial contamination**, testing positive for all indicators. These findings strongly suggest **poor sanitation, unsafe food handling, and lack of regulation**. The results underscore the **urgent need for food safety education, vendor hygiene enforcement, and public health monitoring** in urban street-vended fresh fruit products.

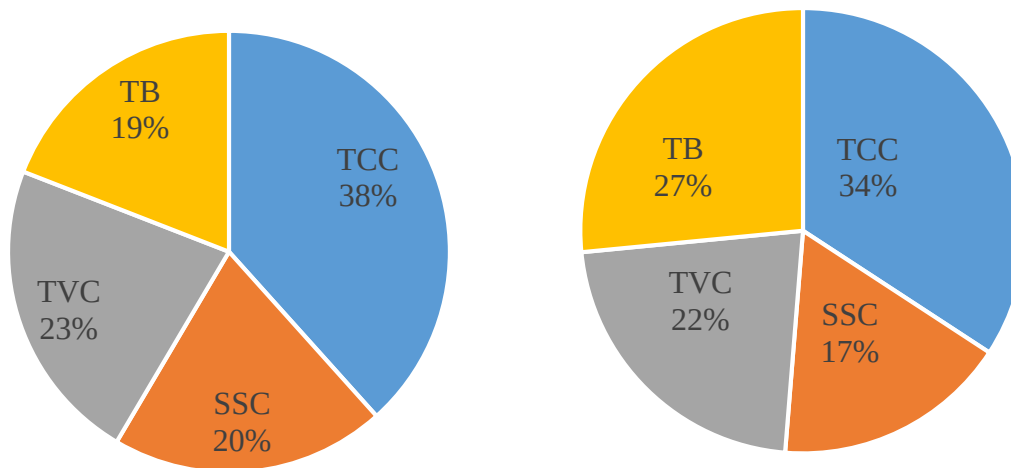


Figure 3.1: Percentage abundance of Coliform, *Salmonella*, *Vibrio* and *Bacillus cereus* in the fruit salad with and without milk sample

Table 3.2: Bacterial load (Log CFU/g) of fruit salad without milksample

S/N	Bacterial flora/fruit salad sample	THBC	Total count	coliform	Salmonella count	Shigella	Total Vibrio count	Total Bacillus cereus count
1	A	7.30	7.00	5.60	0.00			6.85
2	C	7.34	6.93	5.78	5.30			6.90
3	E	7.40	6.00	0.00	5.00			6.92
4	F	TNTC	6.43	0.00	0.00			6.82
5	G	7.34	7.08	5.78	0.00			7.18
6	J	TNTC	6.95	0.00	5.00			6.88
7	K	7.38	6.96	5.70	6.18			0.00

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8	M	TNTC	6.65	6.63	6.40	6.98
9	N	TNTC	6.92	6.20	6.61	6.82
10	O	TNTC	6.94	5.00	0.00	6.85
11	R	TNTC	6.96	0.00	5.00	6.87
12	S	7.23	6.90	0.00	5.60	0.00
13	T	7.41	6.60	0.00	5.60	7.12
14	V	TNTC	6.92	6.04	5.78	7.23
15	X	7.36	6.70	5.48	5.00	0.00
16	Y	7.10	6.28	6.34	5.00	6.60
17	Z	TNTC	6.19	6.43	6.56	6.97
18	α	7.31	6.93	0.00	0.00	0.00
19	γ	TNTC	7.03	0.00	6.11	5.98
20	IV	TNTC	6.82	5.70	5.70	6.92
21	$\hat{A}$	7.08	6.48	0.00	0.00	0.00

Key: CFU/g = Coliform forming unit, THBC = Total heterotrophic bacterial count, sp = Species, TNTC = Too numerous to count; A = Orji Flyover non – milky salad; C = Ama JK non – milky salad; E = Ama JK non – milky salad 2; F = Relief market non – milky salad; G = IMSU non – milky salad; J = Relief market non – milky salad 2; K = Port harcourt Road non – milky salad; M = Ama JK non – milky salad 3; N = Relief market non – milky salad 3; O = Port harcourt Road non – milky salad 2; R = Ama JK non – milky salad 4; S = IMSU non – milky salad 2; T = Ama JK non – milky salad 5; V = Orji Flyover non – milky salad 2; X = Douglass Road non – milky salad; Y = Orji Flyover non – milky salad 3; Z = Orji Flyover non – milky salad 4; α = Ama JK non – milky salad 5; β = Relief market non – milky salad 4; γ = Douglass Road non – milky salad 2; IV = Douglass Road non – milky salad 3; $\hat{A}$ = Orji Flyover non – milky salad 5.

Discussion: The findings from this study revealed significant microbial contamination in ready-to-eat fruit salad samples. Several samples recorded bacterial counts that were *too numerous to count (TNTC)*, indicating poor hygienic handling and exposure to contaminated water or surfaces. Similar high microbial loads in ready-to-eat fruits and salads have been documented by Iroha et al. (2014), who attributed such contamination to improper washing and handling during processing and sale.

Conclusion: This study has clearly demonstrated that ready-to-eat (RTE) fruit salads sold in Owerri Metropolis are heavily contaminated with potentially pathogenic and multidrug-resistant bacteria. The microbial load of the samples ranged from 7.08 to 7.50 Log CFU/g, with several samples being too numerous to count (TNTC), far exceeding international safety thresholds for fresh produce. Coliforms were present in 100% of the samples, indicating widespread fecal contamination likely due to poor hygiene, unsafe water sources, and inadequate preservation methods.

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***Spondias dulcis* Parkinson: Integration of Tree Species into Agroforestry Practices for Climate-Smart Agriculture in the Niger Delta Region**

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Abstract

Climate change threatens agricultural sustainability in Nigeria's Niger Delta, a region already grappling with land degradation, salinity, and erratic rainfall. Climate-smart agriculture (CSA), especially agroforestry, offers a sustainable approach to boost productivity and resilience. This paper explores the integration of *Spondias dulcis* (ambarella), an underutilized tropical fruit tree, into agroforestry systems. With rapid growth, adaptability to poor soils, and multiple benefits; soil stabilization, carbon sequestration and fruit production, *S. dulcis* aligns well with CSA goals. It supports nutrition, income diversification, and biodiversity. However, adoption remains low due to lack of awareness, poor seedling access, and weak policy support. The paper recommends targeted research and extension training to scale its adoption and contribute to resilient farming in the Niger Delta.

Keywords: *Spondias dulcis*, agroforestry, climate-smart agriculture, food security, environmental sustainability

1. Introduction: Agriculture is becoming more and more threatened by climate change in areas that are both economically and environmentally susceptible, such as the Niger Delta in Nigeria. Food security and rural livelihoods are at risk due to increasing rates of floods, salt, soil degradation, and unpredictable rainfall (Ugochukwu & Ertel, 2008; Adewuyi & Baduku, 2012). Climate-smart agriculture (CSA) provides a comprehensive strategy to improve resilience, productivity, and emission reduction in response (FAO, 2013; Dissanayaka et al., 2025). Integrating trees into agricultural landscapes, or agroforestry, is a crucial CSA tactic that enhances biodiversity, stabilizes soils, sequesters carbon, and diversifies revenue streams (Nair & Garrity, 2012; Mbow et al., 2014). Agroforestry offers a natural remedy to repair damaged lands and improve livelihoods in the Niger Delta, where environmental stresses and rural poverty converge (Ajayi et al., 2011). A fast-growing deciduous tree in the Anacardiaceae family, *S. dulcis* (ambarella) is underappreciated in spite of its low input requirements, nutritional fruit, and adaptability (Morton, 1987; Orwa et al., 2009). Although it is found in southwestern Nigeria, its potential in the Niger Delta is still largely unrealized, despite the fact that its characteristics—drought tolerance, deep roots, moderate canopy, and rapid growth—fit the objectives of agroforestry (Ragone, 1997; Leakey, 2012).

This study evaluates the species botanical traits, environmental roles, and socioeconomic contributions in order to determine how it can improve CSA in the Niger Delta. It also identifies barriers and suggests ways to increase its widespread adoption. **2. Botanical Description and Distribution of *S. dulcis*** *S. dulcis* Parkinson, often called June plum or ambarella, is a deciduous tree that grows quickly and belongs to the Anacardiaceae family, which also includes cashew and mango (Orwa et al., 2009). Originating in the Indo-Malay and South Pacific regions, it has been extensively brought to tropical regions such as Southeast Asia, the Caribbean, and Africa (Morton, 1987). With a spreading crown, pinnate leaves that shed annually, and a straight stem, *S. dulcis* typically grows to a height of 10 to 20 meters. It yields an oval drupe that is 6 to 9 cm long, and its tiny, yellowish-white flowers draw pollinators. Rich in fiber and vitamin C, the fruit ripens from green to golden yellow and can be eaten raw or processed into sauces, jams, and juices (Ragone, 1997; PROTA, 2008; Leakey, 2012).

The species has great ecological adaptability. It grows best in humid and sub-humid areas with 1,000–2,500 mm of annual precipitation. It can withstand a variety of soil types, particularly loamy soils that drain well. Since of its deep roots, it is perfect for agroforestry systems since they help stabilize the soil and control erosion (Nair & Garrity, 2012; ICRAF, 2019). Despite being more prevalent in the southwestern region of Nigeria, its cultivation is growing as a result of increased interest in fruit trees that aren't being used (Fruits of Nigeria, 2016; Ogunbanjo et al., 2020). Its adoption is relevant for climate resilience in the Niger Delta because of its soil-enriching litter, moderate canopy, and compatibility with mixed agricultural systems (FAO, 2013; Ajayi et al., 2021; Dissanayaka et al., 2025).

3. Agroecological Context of the Niger Delta Region: The Niger Delta, one of Africa's most agriculturally significant and environmentally diverse regions, is situated in southern Nigeria. In addition to seasonal flooding and great biodiversity, it boasts tropical rainforests, mangroves, wetlands, and a humid climate with yearly rainfall surpassing 2,000 mm (Nwilo & Badejo, 2006; Wikipedia, 2025b). Despite this abundance of nature, the area has serious environmental problems that reduce agricultural output.

As a result of climate change and unsustainable land-use practices including slash-and-burn and monocropping, major concerns include soil degradation, deforestation, unpredictable rainfall, salinity, and oil pollution (Ajayi & Akinnifesi, 2007; Ugochukwu & Ertel, 2008; Ojo, 2024). Particularly for smallholder farmers who have little access to better inputs or market infrastructure, these problems lead to decreased yields, deteriorating soil fertility, and rising food insecurity (Akinyele, 2009). Under these circumstances, agroforestry has become a feasible climate-smart strategy. Farmers can rehabilitate degraded lands, increase biodiversity, improve soil health, and increase resistance to climate shocks by combining trees with crops (Mbow et al., 2014; Singh et al., 2023). The Niger Delta and other humid lowland agroecologies are ideal for *S. dulcis* because of its quick growth, adaptability, and fruit value (Orwa et al., 2009). In most smallholder systems, however, underutilized trees like *S. dulcis* are still uncommon (Arowolo et al., 2020). Sustainable and resilient land use strategies, better nutrition, and stronger local food systems could all result from intentional integration.

4. The Role of Agroforestry in Climate-Smart Agriculture

Agroforestry plays a key role in climate-smart agriculture (CSA), helping to achieve its three main goals of lowering greenhouse gas emissions, improving climate change resilience, and raising production (FAO, 2013; Dissanayaka et al., 2025). In areas like the Niger Delta, where agricultural systems are subject to stress from both the environment and human activity, these objectives are particularly critical.

Agroforestry improves resilience by building diverse systems that can withstand floods, droughts, and pests; it increases productivity by improving soil structure, water retention, and nutrient cycling; and it helps mitigate climate change by sequestering carbon in soils and tree biomass (Zomer et al., 2009; Nair & Garrity, 2012; Mbow et al., 2014; Arslan et al., 2023). Depending on the species and environment, agroforestry systems in sub-Saharan Africa have been demonstrated to store 0.29 to 15.21 metric tons of carbon per hectare yearly (Mbow et al., 2014).

The choice of species is essential. Because of their rapid growth, adaptability, and numerous advantages—fruit production, shade, organic matter, and erosion control—multipurpose trees like *S. dulcis* are perfect for CSA-aligned agroforestry (Orwa et al., 2009; Fruits, 2016). It is especially well suited for smallholder systems in the Niger Delta due to its minimal input requirements and compatibility with food crops.

Agroforestry has socioeconomic benefits in addition to technical ones, such as reducing food insecurity and diversifying income through year-round products like fuelwood and fruits (Ajayi et al., 2011). Therefore, agroforestry is a strategic way to achieve CSA in ecologically stressed areas, especially when combined with underutilized, climate-resilient species like *S. dulcis*.

5. Potential of *S. dulcis* in Agroforestry Systems: Significant ecological and financial advantages can be obtained by incorporating *S. dulcis* into agroforestry systems, especially in climate-stressed areas like the Niger Delta. *S. dulcis* is a diverse, fast-growing fruit tree that helps achieve CSA objectives by increasing resilience, increasing productivity, and aiding in carbon sequestration (Nair & Garrity, 2012; Leakey, 2014). It's perfect for smallholder farms because it works with multistrata systems, such as mixed cropping and home gardens. Within 4 to 5 years, fruiting usually starts, and the market demand for its tart, vitamin-rich fruit is rising (Orwa et al., 2009; Fruits, 2016). According to Nair and Garrity (2012), the tree's moderate canopy reduces evapotranspiration and weed pressure while enabling intercropping with shade-tolerant crops like yams and green vegetables. *S. dulcis* improves soil fertility, microbiological activity, and structure by adding organic matter from fruit peels and leaf litter. According to Leakey (2014), its deep roots stabilize sloping or flood-prone ground, aid in water penetration, and reduce erosion. In addition to thriving in low-input environments and being drought-tolerant, the species is appropriate for repairing degraded soils in marginal areas (Orwa et al., 2009; Mbow et al., 2014). In terms of ecology, it promotes biodiversity by drawing pollinators and beneficial wildlife, which helps control pests. Its importance in climate mitigation initiatives is increased by its function in both above- and below-ground carbon storage (Zomer et al., 2009). In the Niger Delta, *S. dulcis* has the potential to be a keystone species for sustainable agroforestry with the right backing.



Figure 1: *S. dulcis* tree species with its fruit

Table 1: Utilization of Parts of *S. dulcis*

Tree Part	Uses	Purpose / Application
Fruit (ripe)	Eaten fresh; processed into juices, jams, sauces, and chutneys	Nutritional food; value-added products; income generation
Fruit (unripe)	Pickled or consumed with salt/spices; high in vitamin C	Culinary delicacy; appetite stimulant
Leaves	Used as animal fodder; pounded for use in traditional medicine (e.g., treatment of wounds)	Livestock feed; wound healing, skin care, fever relief
Stem Bark	Boiled or ground for use in herbal remedies (e.g., sore throat, cough, diarrhea)	Traditional medicine; antimicrobial and astringent
Roots	Used in decoctions for gastrointestinal issues, pain relief, and infections	Traditional medicinal use
Wood	Used for light construction, tool handles, and fuelwood	Household utility; energy source
Flowers	Attract pollinators (bees, butterflies)	Biodiversity support; ecosystem service
Leaves and Fruit Waste	Used as mulch or compost	Soil improvement; organic fertilizer
Whole Tree / Canopy	Provides shade in agroforestry systems; regulates microclimate	Crop protection; water conservation; temperature moderation
Tree Architecture	Suitable for home gardens, intercropping, and compound farming	Agroforestry integration; space-efficient cultivation

Source: Orwa et al., 2009 & Fruits (2016).

6. Socioeconomic and Livelihood Impacts: There are substantial economical advantages for rural people in the Niger Delta when *S. dulcis* is included into agroforestry systems. It supports food security, income diversification, rural employment, and gender equity—all of which are important pillars of climate-smart agriculture—in addition to ecological functions (Nair & Garrity, 2012; Singh et al., 2023). Consumed fresh or processed into juice, jam, and dry snacks, the fruit is high in vitamin C and antioxidants and is becoming more and more popular locally (Fruits, 2016). Particularly for women and young people engaged in informal marketplaces and small-scale agro-enterprises, this opens doors for value-added processing (Ajayi & Akinnifesi, 2007). According to Orwa et al. (2009), smallholder farmers find it appealing due to its low maintenance and modest input requirements, especially in marginal or degraded locations. *S. dulcis* contributes to the development of regional economies as well. It supports household income and informal trade in home gardens and compound farms by acting as a commercial asset during fruiting seasons (Hamilton & Friess, 2016). By incorporating it into farming systems, smallholder participation in value chains, rural entrepreneurship, and market connections can all be strengthened. The tree's contribution to dietary diversity also helps low-income households fill nutritional gaps. According to Fruits (2016), the species contributes to improved public health outcomes by increasing access to reasonably priced, vitamin-rich fruits and decreasing reliance on imported foods.

Table 2: Nutritional Content and Benefits of *S. dulcis*

Nutrient / Component	Approximate Value (per 100g edible portion)	Health / Nutritional Benefits
Vitamin C (Ascorbic Acid)	200–250 mg	Boosts immunity, promotes skin health, aids iron absorption
Dietary Fiber	3.2–5.0 g	Supports digestion, reduces cholesterol, promotes satiety
Carbohydrates	10–13 g	Provides energy
Calcium	15–20 mg	Strengthens bones and teeth
Iron	0.5–1.2 mg	Supports red blood cell production, prevents anemia
Vitamin A (Beta-carotene)	Trace amounts	Supports vision and immune function
Antioxidants	High (polyphenols, flavonoids)	Neutralizes free radicals, reduces inflammation and oxidative stress
Water Content	~85%	Keeps body hydrated, aids metabolism
Low Fat	<0.5 g	Ideal for low-fat diets
Low Calories	~45–55 kcal	Suitable for weight-conscious and diabetic diets

Source: Fruits (2016)

7. Environmental Benefits and Climate Resilience: Agroforestry systems that incorporate *S. dulcis* have significant environmental advantages that support climate resilience and ecosystem restoration, two key components of climate-smart agriculture (CSA). (Ajayi & Akinnifesi, 2007; Hamilton & Friess, 2016) Such multifunctional species are particularly helpful in areas that are degraded and prone to flooding, such as the Niger Delta. *S. dulcis* increases organic matter, water retention, and nutrient cycling by enhancing soil fertility and structure through fruit peel breakdown, leaf litter, and root biomass (Orwa et al., 2009; Fruits, 2016). Its strong roots help anchor the soil and stop erosion, especially in lowland areas that are susceptible. The tree helps control the microclimate as well. As climate variability increases, its moderate canopy buffers temperature extremes, lowers evapotranspiration, and offers shade (Arslan et al., 2023). It enhances agroecosystem functions by providing habitat for birds and small mammals and promoting biodiversity by drawing pollinators, seed dispersers, and beneficial insects (Fruits, 2016). Importantly, by sequestering carbon in soil and biomass, *S. dulcis* helps mitigate climate change by offsetting greenhouse gas emissions (Nair & Garrity, 2012; Hamilton & Friess, 2016). Research indicates that fast-growing trees like *S. dulcis* can store a substantial amount of carbon per hectare in agroforestry systems. Through the incorporation of perennial structure into agricultural landscapes, *S. dulcis* contributes to year-round ecosystem services and lessens dependence on susceptible annual crops, which is essential for enhancing climate resilience in areas such as the Niger Delta.

8. Challenges and Constraints to Adoption of *S. dulcis*: Several socioeconomic, institutional, and ecological barriers limit the use of this species in Niger Delta agroforestry systems, despite its promise. For climate-smart agriculture (CSA) to fully benefit, these issues must be resolved. A major obstacle is the lack of technical expertise and farmer awareness. Since *S. dulcis* is not as well-known as other fruit trees, many smallholders are not aware of its integration tactics or methods of propagation (Ajayi & Akinnifesi, 2007). Lack of access to high-quality planting supplies also makes adoption more difficult. Due to the lack of approved sources or established nurseries, farmers frequently depend on unofficial or wild stock, which results in uneven productivity (Orwa et al., 2009). Its popularity is further limited by the absence of varietal improvement in comparison to more commercialized species. The tree's commercial viability is diminished by insufficient market development, underdeveloped value chains, limited processing capacity, and low consumer awareness (Fruits, 2016). Farmers are deterred from investing as a result, especially those who work in regions with limited resources or uncertainty.

There are ecological barriers as well. Despite its adaptability, *S. dulcis* may not thrive in extremely salinized or wet soils, and in some places, its non-native status raises questions regarding ecological compatibility (Hamilton & Friess, 2016). Socially, smallholders may be discouraged from trying out less well-known species due to risk aversion and a preference for familiar crops (Singh et al., 2023). To fully realize the agroforestry potential of *S. dulcis*, these limitations must be addressed by research, policy inclusion, market incentives, input support, and focused awareness.

9. Conclusion and Recommendation: The integration of *Spondias dulcis* into agroforestry systems represents a viable pathway for achieving climate-smart agriculture (CSA) in the Niger Delta. As demonstrated in this study, the species offers a range of ecological and socioeconomic benefits—from improving soil health and enhancing biodiversity to supporting income diversification, nutrition, and climate resilience. Its adaptability to humid tropical conditions, fast growth, and low input requirements position it as an ideal candidate for sustainable land-use transformation in a region increasingly affected by land degradation and climate variability. However, adoption remains limited due to challenges such as lack of farmer awareness, poor access to quality planting materials, weak market structures, and insufficient policy support. Addressing these gaps requires integrated efforts. Research institutions must prioritize varietal development and agroecological trials of *S. dulcis*, while extension programs should include it in farmer training's and demonstration plots. Value chains must be developed to support small-scale processing and market linkages, particularly targeting women and youth. Access to reliable germplasm can be facilitated through local nurseries and seed distribution networks. Additionally, CSA and agroforestry policies should explicitly support underutilized species like *S. dulcis*, with site-specific planning that reflects the ecological realities of the Niger Delta.

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Effect of Substituting Sundried Watermelon (*Citrullus lanatus*) Peel Meal for Yellow Maize Meal on Feed Utilization, Growth, Body Composition and Survival in *Clarias Gariepinus* Juveniles

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ABSTRACT

Rising demand and expensive nature of conventional fish feed ingredients necessitate a continuous search for cheaper alternative ingredients. This study assessed the effect of substituting sundried watermelon (*Citrullus lanatus*) peel meal (WMPM) for yellow maize meal on feed utilization, growth, body composition and survival of the African catfish, *Clarias gariepinus*. Six isonitrogenous diets were formulated at 40% crude protein level in which WMPM was added at 0%, 20%, 40%, 60%, 80% and 100% levels and designated as Diets 1, 2, 3, 4, 5 and 6 respectively. Diets were administered twice daily (7:00 – 7:30 am and 17:00 – 17:30 pm) at 5% body weight to 360 *C. gariepinus* juveniles inside eighteen plastic bowls for 8 weeks. Mean weight gain (MWG), specific growth rate (SGR), feed conversion ratio (FCR), protein intake (PI) and percentage survival (PS) were determined. Data obtained were analyzed using analysis of variance (ANOVA) at $p < 0.05$. Final carcass crude protein (53.12 - 63.44%) significantly exceeded the initial value (53.08%). Apart from the fish reared on the control diet, the fish fed Diet 2 (20% WMPM-based diet) had the highest MWG (23.99 ± 0.15 g), SGR ($3.49 \pm 0.01\%$ /day), FCR (0.96), PI (9.09) and PS (85%) while those placed on Diet 6 (100% WMPM-based diet) had the lowest values of these growth indices. This study indicated that up to 20% substitution of watermelon peel meal for yellow maize meal effectively improved growth and feed utilization in *C. gariepinus* while higher substitution beyond 20% level caused progressively reduced feed utilization and growth.

Key words: *Clarias gariepinus*; *Citrullus lanatus*; Nutrition; Feed conversion; Growth

INTRODUCTION: Rapid human population growth without a consistently corresponding increase in animal protein production has been identified as one of the main challenges facing developing countries including Nigeria (Olopade *et al.*, 2015). Inadequate consumption of animal protein among most Nigerians has been documented (Collins, 2007). The daily animal protein intake is less than 10 g which is markedly below the value of 35 g per day recommended by the Food and Agriculture Organization (FAO, 2014). This wide margin between the recommended protein intake and the average human consumption rate has necessitated a continuous demand for animal protein by the Nigerian populace. This growing demand for the required protein production can be satisfied through fish culture (Olopade *et al.*, 2015) because fish products constitute about 22% of animal protein supply in sub-Saharan Africa and 40% of animal protein consumption in Nigeria (FAO, 2003). In order to maximize nutritional and economic benefits, research efforts have concentrated on increasing the utilization of unconventional agricultural and/or plant by-products to replace conventional feed ingredients. Incorporation of agricultural or plant by-products such as leaf and peel meals in aquaculture feed production is fast attracting global attention owing to their enormous availability, nutrient contents and economic feasibility (Udo and John, 2015). Watermelon (*Citrullus lanatus*) peel is a typical plant by-product which has not been commonly utilized as fish feed. The peels are usually scraped off the inner fleshy pulp (mesocarp), discarded indiscriminately as a waste and dumped in landfills, rivers or on unregulated grounds. Large quantities of these peels are known to aggravate environmental pollution and thereby constitute serious hazards to human health. Moreover, there is less competition on the use of these peels by man, livestock and industries. It is also cheap to buy and available in all geo-political areas of Nigeria and the tropics, a quality which makes it a good candidate for fish feed production. The nutritive value of watermelon peel has hitherto not been effectively explored. Hence, there is scanty available literature information on its utilization in fish feed production. Therefore, this study aimed to assess the effect of sun-dried watermelon peel meal as a substitute for yellow maize meal on the growth, feed utilization, body composition and survival of *C. gariepinus* juveniles.

MATERIALS AND METHODS

Study location: This eight-week feeding trial was conducted in the Fish Nutrition Research Laboratory of the Department of Fisheries and Aquaculture Technology, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria.

Collection and processing of fresh watermelon peels into watermelon peel meal: Twelve kilograms (12 kg) of fresh watermelon peels used for this study were collected from several watermelon vendors within Okitipupa Local Government Area, Ondo State, Nigeria where they were discarded as waste. The peels were rinsed in clean water, sun-dried for 14 days, milled into a powdery form (meal) and stored in an air-tight container prior to use.

Formulation and preparation of experimental diets: Other ingredients were purchased from a reputable feed mill and ground separately into a powdery form. Six iso-nitrogenous (40% crude protein) diets were formulated as shown in Table 1. Sun-dried watermelon peel meal (WMPM) was added as a feed additive at graded levels of 0 (control diet without WMPM), 20, 40, 60, 80 and 100% in the diets which were respectively designated as Diet 1, Diet 2, Diet 3, Diet 4, Diet 5 and Diet 6. Each diet was prepared by thoroughly mixing the ingredients inside a mixer (Hobart A-2007 Model, Hobart Ltd, London, UK) while palm oil and warm water were added to homogenize the dry mixture into a uniform paste. Each diet paste was steam-pelleted through a 2-mm die Hobart pelletizer (A-2007 Model, Hobart Ltd, London, UK). The pellets were sufficiently sun-dried for three days, cooled to room temperature and kept in separate air-tight containers prior to use.

Experimental design and fish handling procedure: This study adopted a completely randomized design comprising six treatments with three replicates each. A total of 400 *C. gariepinus* juveniles were bought from a reliable fish hatchery in Okitipupa, Ondo State, acclimated to the experimental conditions in four fiberglass tanks (1 m × 1 m × 0.5 m) for 7 days and manually fed twice daily with 2 mm Aler Aqua feed to visual satiation. At the start, 360 uniform-sized fish (initial mean weight: 3.97±0.28 g) were weighed in batches on a high-precision scale (OHAUS LS, Model 2000) and randomly assigned into 18 plastic aquaria (50 × 40 × 40 cm³) at twenty fish per aquarium containing 25 litres of water each. The fish were fed manually twice daily (07:00 - 08:00 and 17:00 - 18:00 hrs) at 5% body weight in two equal rations. Water temperature in the aquaria was read with mercury-in-glass thermometer, dissolved oxygen values measured through Hydrolab Model “Multi 340I/SET” while pH values were determined using pH meter (Jenway 3015 pH meter). Fish in each aquarium were batch-weighted weekly and weight changes recorded accordingly.

Proximate analysis of experimental diets and fish carcass composition: Eight grams (8 g) of each diet sample, six pre-experimental fish specimens and four post-experimental fish specimens per treatment were randomly collected and kept frozen to determine the proximate composition of diets and whole-fish carcass. The proximate parameters analyzed included crude protein, crude lipid, crude fibre, total ash, moisture content and nitrogen-free extract (AOAC, 2011).

Table 1: Gross ingredient composition (g/100g diet) of experimental diets

Dietary Ingredients	0% WMPM Diet 1 Control	20% WMPM Diet 2	40% WMPM Diet 3	60% WMPM Diet 4	80% WMPM Diet 5	100% WMPM Diet 6
Watermelon peel meal	0.00	5.00	9.99	14.99	19.98	24.98
Yellow maize	24.98	19.98	14.99	9.99	5.00	0.00
Groundnut cake	22.35	22.35	22.35	22.35	22.35	22.35
Fish meal	22.35	22.35	22.35	22.35	22.35	22.35
Soybean meal	22.35	22.35	22.35	22.35	22.35	22.35
Shrimp meal	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix	1.00	1.00	1.00	1.00	1.00	1.00
Vegetable oil	1.00	1.00	1.00	1.00	1.00	1.00
Table salt	1.00	1.00	1.00	1.00	1.00	1.00
Cassava starch	3.00	3.00	3.00	3.00	3.00	3.00
Total (g)	100.00	100.00	100.00	100.00	100.00	100.00

Biological evaluation of feed utilization and fish growth response

Fish growth response and feed utilization indices were evaluated according to Adesina and Agbatan (2021) as follows:

$$\text{Mean weight gain (MWG)} = (W_2 - W_1) \text{ g}$$

where: W_1 = initial mean weight (g); W_2 = final mean weight (g)

$$\text{Percentage weight gain (\%)} = \frac{\text{Mean weight gain (g)} \times 100}{\text{Initial mean weight (g)}}$$

$$\text{Feed intake (g)} = \text{WFI}_1 + \text{WFI}_2 + \text{WFI}_3 + \text{WFI}_4 + \dots + \text{WFI}_n$$

where: WFI = weekly feed intake of fish per treatment (g);
duration

1, 2, 3, 4, ...n = first week to the last week of the experimental

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Mean feed intake (g)}}{\text{Mean weight gain (g)}}$$

$$\text{Specific growth rate (\%/day)} = ((\ln W_f - \ln W_i) \times 100) / (t \text{ (days)})$$

where: $\ln W_f$ = natural logarithm of the fish final weight; $\ln W_i$ = natural logarithm
experimental duration in days.

of the fish initial weight; t =

$$\text{Protein intake (g of protein in 100 g fish)} = \frac{\text{feed intake} \times \% \text{ crude protein in diet}}{100}$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Mean weight gain}}{\text{Mean protein intake (g of protein in 100 g of diet/fish)}}$$

$$\text{Nitrogen metabolism (NM)} = (0.549 \times (W_i + W_f) \text{ t}) / 2$$

where: W_i = initial mean weight of fish; W_f = final mean weight of fish; t = experimental period in days; 0.549 = metabolism factor

$$\text{Percentage survival, PS(\%)} = \frac{\text{Final number of fish harvested} \times 100}{\text{Initial number of fish stocked}}$$

Statistical analysis: The data obtained on proximate indices, feed utilization, growth and carcass composition of *C. gariepinus* juveniles were analyzed through one-way analysis of variance (ANOVA) using the SPSS Statistics 22.0 version (IBM, USA). Differences among the treatments were determined using Tukey's multiple range tests and were considered as being statistically significant at $p < 0.05$ (Zar, 1996). All the data presented in this study were expressed as means of triplicate values $\pm$ standard deviation.

RESULTS AND DISCUSSION

Proximate composition of sun-dried watermelon peel meal-based diets fed to *C. gariepinus* juveniles: Table 2 shows the result of the proximate analysis of the experimental diets. Crude protein values (39.51 – 40.59%) of the diets were nearly uniform and revealed no significant difference ($p > 0.05$). These values satisfy the protein requirements of *C. gariepinus* fingerlings and support the assertion of Adegbesan *et al.* (2018) that the ideal growth rate and feed conversion efficiency in *C. gariepinus* could be attained within 38 - 42% dietary protein. The present values also corroborate 39.40 – 41.40% and 43.97 – 44.28% respectively reported by Adesina *et al.* (2020) and Iheanacho *et al.* (2018) for melon peel meal-based diets. The observed values of crude lipid, total ash, crude fibre, moisture and nitrogen-free extract contents indicated significant difference ($p < 0.05$). Crude lipid values (15.41 – 22.06%) exceed 4.15 – 4.37% and 5.50 – 6.50% respectively previously reported for melon peel meal-based diets (Iheanacho *et al.*, 2018; Adesina *et al.* (2020) while nitrogen-free extract values (12.08 – 21.10%) are much below 24.60 – 31.45% and 31.56 – 32.86% respectively documented by Adesina *et al.* (2020) and Iheanacho *et al.* (2018) for melon peel meal-based diets.

Table 2: Proximate composition of graded levels of sun-dried watermelon peel meal-based diets fed to *C. gariepinus* juveniles

Dietary treatments	Crude protein	Crude lipid	Total ash	Crude fibre	NFE	Moisture
Diet 1	40.59 $\pm$ 2.02	17.67 $\pm$ 1.62 ^b	12.43 $\pm$ 1.12 ^b	6.08 $\pm$ 0.72 ^b	18.96 $\pm$ 1.61 ^b	4.32 $\pm$ 0.23 ^c
Diet 2	39.51 $\pm$ 1.75	22.06 $\pm$ 2.01 ^a	12.69 $\pm$ 0.71 ^b	7.46 $\pm$ 0.03 ^a	12.08 $\pm$ 1.04 ^d	6.22 $\pm$ 0.15 ^a
Diet 3	39.78 $\pm$ 2.03	15.41 $\pm$ 1.81 ^c	11.50 $\pm$ 0.56 ^c	7.23 $\pm$ 0.01 ^a	21.10 $\pm$ 2.03 ^a	5.00 $\pm$ 0.04 ^b
Diet 4	39.73 $\pm$ 2.51	18.31 $\pm$ 0.93 ^b	12.35 $\pm$ 1.40 ^b	7.78 $\pm$ 1.47 ^a	14.97 $\pm$ 0.81 ^c	6.87 $\pm$ 1.02 ^a
Diet 5	40.02 $\pm$ 1.62	16.82 $\pm$ 1.31 ^c	11.65 $\pm$ 0.81 ^c	6.59 $\pm$ 0.76 ^b	18.92 $\pm$ 1.72 ^b	6.64 $\pm$ 0.82 ^a
Diet 6	39.81 $\pm$ 2.52	17.21 $\pm$ 1.25 ^b	15.75 $\pm$ 0.34 ^a	6.54 $\pm$ 0.52 ^b	16.26 $\pm$ 1.82 ^{bc}	4.44 $\pm$ 0.01 ^c

Means with different letters on the same column differ significantly ($p < 0.05$) (Tukey's multiple range tests).

Carcass proximate composition of *C. gariepinus* juveniles fed graded levels of sun-dried watermelon peel meal-based diets

Chemical composition of the experimental fish carcass (Table 3) followed an irregular trend and showed significant ($p < 0.05$) variations among the treated fish. This suggests that addition of sun-dried watermelon peel meal affected their body composition. Crude protein values (53.12 – 63.44%) obtained in the post-experimental fish carcasses were significantly ($p < 0.05$) higher than 53.08% in the pre-experimental fish carcass, an observation corroborating the report of Adesina *et al.* (2020) on *C. gariepinus* fingerlings fed melon seed peel meal-based diets. This result suggests enhanced synthesis of tissue protein in the experimental fish (Tiamiyu *et al.*, 2015) as reflected in fish growth and weight gain (Fountoulaki *et al.*, 2003). Likewise, the values of the crude lipid, total ash, nitrogen-free extract and moisture contents observed in the experimental fish carcass showed significant variations ($p < 0.05$). Besides, the moderately high carcass lipid content suggested improved lipid synthesis in the fish (Fountoulaki *et al.*, 2003) which could be associated with an increase in the dietary crude lipid content.

Table 3: Carcass composition of *C. gariepinus* juveniles fed graded level of sun-dried watermelon peel meal based-diets

Dietary treatments	Crude protein	Crude lipid	NFE	Total ash	Moisture
Initial values	53.08 $\pm$ 2.03 ^c	14.46 $\pm$ 1.03 ^b	12.63 $\pm$ 1.04 ^a	14.72 $\pm$ 2.01 ^a	5.08 $\pm$ 0.14 ^a
Diet 1	63.44 $\pm$ 1.02 ^a	9.96 $\pm$ 0.72 ^d	11.21 $\pm$ 0.76 ^{ab}	11.15 $\pm$ 1.08 ^c	4.24 $\pm$ 0.01 ^b
Diet 2	61.18 $\pm$ 2.04 ^{ab}	12.92 $\pm$ 1.44 ^c	9.59 $\pm$ 0.91 ^b	12.32 $\pm$ 0.92 ^c	3.99 $\pm$ 0.23 ^b
Diet 3	53.12 $\pm$ 1.09 ^c	20.56 $\pm$ 2.08 ^a	7.94 $\pm$ 1.11 ^c	14.25 $\pm$ 1.04 ^b	4.13 $\pm$ 0.63 ^b
Diet 4	53.77 $\pm$ 1.11 ^c	15.18 $\pm$ 1.36 ^b	12.48 $\pm$ 1.16 ^a	13.19 $\pm$ 0.87 ^b	5.38 $\pm$ 0.71 ^a
Diet 5	60.24 $\pm$ 2.01 ^b	12.68 $\pm$ 0.93 ^c	10.05 $\pm$ 1.31 ^b	12.96 $\pm$ 1.04 ^b	4.07 $\pm$ 0.48 ^b
Diet 6	61.16 $\pm$ 2.10 ^{ab}	14.62 $\pm$ 1.51 ^b	8.17 $\pm$ 0.82 ^c	12.67 $\pm$ 0.76 ^b	3.38 $\pm$ 0.67 ^c

Means with different letters on the same column differ significantly ($p < 0.05$) (Tukey's multiple range tests).

Growth response and feed utilization in *C. gariepinus* juveniles fed sun-dried watermelon peel meal-based diets

Table 4 shows the growth and feed utilization indices which revealed significant variations ($p < 0.05$) among the fish groups exposed to the various diets. Acceptability of the diets progressively significantly ($p < 0.05$) diminished from the fish fed Diets 1 to 6 and was inversely proportional to the increase in the inclusion level of sun-dried watermelon peel meal. Mean weight gain (MWG) and specific growth rate (SGR) were highest (24.63 g and 3.53%/day) in the fish fed Diet 1 (Control), closely followed by those fed Diet 2 (23.99 g and 3.49%/day) and lowest (18.02 g and 3.05%/day) in the fish fed Diet 6 respectively. The MWG values are lower than 37.38 – 48.27 g reported by Adesina *et al.* (2020) on *C. gariepinus* fingerlings but surpass as well as reflect better growth compared to 9.10 – 23.97 g observed by Iheanacho *et al.* (2018) on *Oreochromis niloticus* juveniles fed melon seed peel meal-based diets. Also, the SGR values (3.05 – 3.53 %/day) surpass and reflect better growth compared to 1.4 – 1.56 %/day

recorded for *C. gariepinus* fingerlings (Adesina *et al.*, 2020). The reduced growth beyond 20% sun-dried watermelon peel meal inclusion probably resulted from reduced digestion and utilization of diets at higher levels which could be associated with residual anti-nutrients in the diets as reported by Adewolu (2008). Fakunle *et al.* (2013) stated that toxic components or anti-nutrients in most plant by-products may irritate the digestive tract and cause reduced feed intake and growth. Furthermore, Nwanna *et al.* (2009) stated that very high inclusion levels of unconventional carbohydrate sources have often resulted in poor fish growth.

Feed conversion ratio (FCR) values (0.91 – 1.16) recorded in this study indicate efficient feed utilization by the experimental fish and closely harmonize with 0.5 – 2.36 reported in the past related studies involving melon seed peel and watermelon peel meals (Babale, 2016; Iheanacho *et al.*, 2018; Adesina *et al.*, 2020). According to DeSilva (2001), the ideal FCR values range between 1.2 and 1.8 for fish fed adequately prepared diets. The values of protein intake (PI) progressively diminished from the fish fed Diets 1 to 6 while those fed Diets 1 – 3 had significantly ($p < 0.05$) higher values (9.00 – 9.34) than 6.94 – 8.34 in those fed Diets 4 – 6. The values of protein efficiency ratio (PER) (2.60 – 2.76) significantly ($p < 0.05$) differed and revealed an irregular trend. Percentage survival (PS) was high (70.0% - 85.5%) and varied significantly ($p < 0.05$) across the treatments. These survival values closely align with 82.22 – 100% earlier reported for *C. gariepinus* fingerlings and *O. niloticus* juveniles fed similar diets (Iheanacho *et al.*, 2018; Adesina *et al.*, 2020). Such high level of survival indicates that feeding *C. gariepinus* juveniles with sun-dried watermelon peel meal did not cause serious fish mortality. Moreover, it signifies considerable acceptability of the experimental diets by fish which could be attributed to careful fish handling, proper feed processing, suitability and non-toxicity of sun-dried watermelon peel meal inclusion in *C. gariepinus* diet.

Table 4: Growth response and feed utilization indices of *C. gariepinus* juveniles fed sun-dried watermelon peel meal-based diets

Parameters	0% WMPM Diet 1 (control)	20%WMPM	Diet 2	40%WMPM	Diet 3	60%WMPM	Diet 4	80%WMPM	Diet 5	100% WMPM	Diet 6
Mean initial weight (g)	3.97±0.21 ^a	3.95±0.32 ^a		3.96±0.14 ^a		3.97±0.24 ^a		3.98±0.41 ^a		3.99±0.37 ^a	
Mean final weight	28.60±2.01 ^a	27.94±1.14 ^a		23.51±0.72 ^c		26.99±1.43 ^b		26.01±0.68 ^b		22.01±1.34 ^d	
Mean weight gain (g)	24.63±1.63 ^a	23.99±2.15 ^a		19.55±1.23 ^c		23.02±1.42 ^{ab}		22.03±2.47 ^b		18.02±0.84 ^c	
Percentage weight gain (%)	620.40±5.73 ^a	607.34±4.85 ^b		488.75±6.94 ^d		579.85±4.51 ^c		553.52±3.91 ^c		451.63±6.19 ^e	
Specific growth rate (%/day)	3.53±0.05 ^a	3.49±0.21 ^a		3.18±0.01 ^c		3.42±0.02 ^b		3.35±0.03 ^b		3.05±0.12 ^c	
Total feed intake (g)	460.00±5.65 ^a	460.00±3.75 ^a		452.60±4.35 ^b		420.00±3.75 ^c		402.60±4.65 ^{cd}		348.60±2.85 ^d	
Mean feed intake	23.00±2.07 ^a	23.00±1.63 ^a		22.63±4.25 ^a		21.00±2.32 ^b		20.13±1.65 ^b		17.43±2.36 ^c	
Percentage survival rate (%)	70.00±2.00 ^b	85.00±1.34 ^a		85.00±2.17 ^a		70.00±2.50 ^b		75.00±1.67 ^b		85.50±2.50 ^a	
Feed conversion ratio	0.93±0.18 ^b	0.96±0.07 ^b		1.16±0.03 ^a		0.91±0.63 ^b		0.91±0.12 ^b		0.97±0.10 ^b	
Nitrogen metabolism	500.67±4.53 ^a	490.21±3.92 ^a		423.99±3.23 ^c		475.91±5.61 ^{ab}		462.38±4.54 ^b		399.67±5.07 ^d	
Protein efficiency ratio	2.64±0.14 ^b	2.64±0.14 ^b		2.17±0.23 ^b		2.76±0.01 ^a		2.73±0.03 ^a		2.60±0.12 ^b	
Protein intake	9.34±1.21 ^a	9.09±0.81 ^a		9.00 ±0.67 ^a		8.34±1.01 ^b		8.06±0.73 ^b		6.94±0.59 ^c	

Means with different letters on the same row differ significantly ($p < 0.05$) (Tukey's multiple range tests).
WMPM = watermelon peel meal

CONCLUSION AND APPLICATION: The results from this study demonstrated that the juveniles fed Diet 1 (control diet without sun-dried watermelon peel meal) exhibited superior growth and feed utilization which were marginally followed by those fed Diet 2 (20% sun-dried watermelon peel meal inclusion). It was observed that further inclusion of sun-dried watermelon peel meal as a substitute for yellow maize meal in *C. gariepinus* juveniles' diet above 20% caused progressively reduced growth and feed utilization. The study, therefore, revealed that higher inclusion levels of sun-dried watermelon peel meal reduced growth and feed utilization in *C. gariepinus*. Other processing methods should be explored to increase the utilization of watermelon peel meal, reduce the cost of fish feed production and thereby maximize aquaculture profitability.

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Effect of Lead Mining on the Livelihood Structure and Food Security Dynamics of Agribusiness Households in Ebonyi State, Nigeria

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Abstract

This study investigated the effect of lead mining on the livelihood structure and food security dynamics of agribusiness households in Ikwo Local Government Area of Ebonyi State, Nigeria. The study specifically examined their livelihood structures over the past decade, food security status, factors affecting food security and livelihood diversification decision. A multi-stage sampling technique was used to select a sample of 60 agribusiness households. The Foster-Greer-Thorbecke (FGT) model for food security assessment and probit regression analysis for identifying food security and livelihood diversification determinants were all employed. The findings revealed a predominantly middle-aged workforce, with significant economic diversification and a concerning shift towards mining as a primary income source, increasing from 7% to 93% over the past decade. This transition raised food security concerns, with 63% of respondents classified as food insecure. Key factors positively influencing food security included own food production, education level, and livelihood diversification, while age, household size, and losses due to mining negatively impacted food security outcomes. Based on these findings, policy interventions that enforce stricter environmental regulations to mitigate the adverse effects of mining on agricultural land and water resources is highly recommended. Policymakers and community leaders must consider integrated approaches that balance mining activities with sustainable agricultural practices to ensure long-term food security and community resilience

Introduction: Lead mining is an economic activity that involves extracting lead from the earth. It's a prominent economic activity worldwide, involving the extraction of lead from the earth's crust. Lead mining can have profound effects on the livelihood structure and dynamics of rural agribusiness households in the agricultural sector as a whole (both internationally and locally), particularly in terms of food security. According to Halie et al. (2024), Castro-Bedrinana et al. (2021) and Hiwatari et al. (2024), the extraction and processing of lead ores can lead to both direct and indirect impacts on the agricultural sector, influencing the livelihood choices and food security of rural communities. Environmental degradation from lead mining significantly threatens agricultural productivity and food safety by releasing toxic substances that contaminate soil, water, and crops. Studies have shown that lead mining activities result in elevated concentrations of lead and other heavy metals in agricultural soils, which can be taken up by crops, thereby compromising the safety of locally produced food and posing health risks to consumers (Mandel et al., 2022). As observed by Sharifi et al. (2023), this contamination leads to reduced soil fertility, degraded water quality, and increased health risks, collectively diminishing agricultural productivity among rural agribusiness households. The need for extensive research in Ebonyi State, particularly around mining communities on the profound effects of lead mining on the livelihood structure and food security dynamics of rural agribusiness households follows documented evidences that mining activities lead to land degradation, reduced agricultural productivity, and increased health risks due to heavy metal contamination in soils and food crops, which directly threaten local food security and household well-being (Orji et al., 2021; Obasi et al., 2020). The study specifically examined the livelihood structure of the agribusiness households for the past 10 years, determined the food security status of the respondents and factors affecting food security, and assessed the influence of lead mining on the food security and livelihood dynamics of the affected populations.

Methodology: The study was conducted in Ikwo Local Government Area of Ebonyi State. Primary data was collected with the use of structured questionnaires administered to the respondents in the affected areas. A multi-stage sampling technique was adopted for this study. Four (4) communities affected by lead mining were randomly selected. They are Enyime Nchifu normally know as Nwakpu, Enyim agalegu popularly known as Royal salt, Oyikwa and Ohankwu. In the next stage, fifteen (15) agribusiness households were randomly selected from the four (4) communities making it a total of 60 respondents. In order to achieve the objective of the study both descriptive (frequencies and percentages) and inferential statistical techniques (Foster Greer Thorbecke and Probit regression model) were employed. The FGT is given as: $P_\alpha = \frac{1}{N} \left(\frac{z - y_i}{z} \right)^\alpha 1(y_i \leq z)$

α = FGT food insecurity index which takes values 0,1,2,

P_0 = food insecurity headcount;

P_1 = food insecurity depth

P_2 = food insecurity severity.

n = Total number of households.

z = Food security line.

p = Number of households below the food security line

y_i = Per-capita monthly food expenditure of the household.

Determinants of food security: The Probit regression was employed to analyze the drivers of food security. The model is specified as:

$$Y^* = \beta_i X_i \varepsilon_i$$

$\{Y = 1 \text{ if } Y^* > 0\}$

Or

$\{Y^* = 0 \text{ if otherwise}\}$

Where:

Y^* = Food Security (food secure = 1, otherwise = 0)

X_1 = Age of the respondents (years)

X_2 = Education of household head (years)

X_3 = Agribusiness experience (years)

X_4 = Sex of household head (1 = male, 0 = female)

X_5 = Total household income (Naira)

X_6 = Access to credit (yes = 1, no = 0)

X_7 = Off-farm participation (yes = 1, no = 0)

X_8 = Own production (Kg)

X_9 = Cooperation membership (member = 1, non-member = 0)

X_{10} = Assets ownership (Naira)

ϵ_i = Error Term-

Results and Discussion: Livelihood structure of the respondents

Table 1 presents the livelihood structure of the respondents

Table 1: Livelihood structure of the respondents

Livelihood activity	Last 10 years		Currently	
	Frequency	Percent	Frequency	Percent
Mining activities	4	7	56	93
Trading	18	30	42	70
Crop processing	35	58	25	42
Crop production	35	58	25	42
Poultry and livestock	23	38	37	62

Source: Field survey, 2024

The results in Table 1 show a dramatic shift over the past decade, with mining activities rising significantly from just 7% to 93% currently, indicating a substantial transition towards mining as a primary source of income. Conversely, traditional activities such as crop processing and production have decreased from 58% to 42%, reflecting the community's adaptation to changing economic circumstances driven by mining opportunities. Mining operations are associated with reduced food availability, land dispossession, water pollution, and a decline in crop yields, all of which threaten food security and the sustainability of traditional livelihoods (Wegenast & Beck, 2020; Obodai et al., 2024; Schacklenton, 2020; Diallo & Soumah, 2023; Nunoo et al., 2023).

Food security status of the respondents

Table 2 presents the food security status of the respondents.

Table 2: Food security status of the respondents

Food security status	Frequency	Percent (%)
Food insecure	38	63
Food secure	22	37
Total	60	100

Source: Field survey, 2024

The results in Table 2 reveal that a significant majority (63%) are classified as food insecure, while only 37% are considered food secure. This high level of food insecurity suggests that many households face challenges in accessing sufficient and nutritious food, which may be exacerbated by economic pressures and the recent shift towards mining activities as a primary livelihood. Studies in mining communities have documented alarming levels of food insecurity, with over half of surveyed populations experiencing moderate to severe food insecurity, and mining identified as a substantial contributor to these challenges (Obodai et al., 2024; Amayi et al., 2024).

Determinants of food security of the respondents: To examine the food security status of the respondents, the probit model was employed. The Pseudo R-squared value of 0.625 implies that 62.5% of changes in the food security level of the respondents were explained by changes in the independent variables included in the model. The result is presented in Table 3. Notably, the coefficients for own food production, level of education, and livelihood diversification are positively correlated with food security at a 1% level of significance, suggesting that increased food production and higher educational attainment contribute to better food security outcomes.

Table 3: Determinants of food security of the respondents

Variables	Coefficient	Standard error	Z
Constant	.0719	1.185	0.062
Age (years)	-.055	.020	-2.751**
Own food production (Kg)	0.234	.067	3.493***
Household size	-.282	.103	-2.753**
Total household income (₦)	.472	.375	1.269
Level of education	.038	.009	4.222***
Cooperative membership	-.073	.189	-0.392
Diversification	.580	.122	4.765***
Losses	.121	.069	1.779*
LR chi2(8)	12.819		
Log-likelihood	-33.023		
Pseudo R ²	0.625		

Source: Field survey, 2024

Conversely, the negative impact of age, household size, and losses due to mining activities on food security highlights the vulnerabilities faced by larger households and older individuals, as well as the detrimental effects of

environmental degradation associated with mining practices. This finding aligns with recent research that emphasizes the importance of education and diversification in enhancing food security (Bahiru et al., 2023).

Determinants of livelihood diversification of the respondents: To examine the determinants of the livelihood diversification of the respondents, the probit model was employed. The Pseudo R-Squared value of 0.729 implies that 73% of changes in the decision to diversify livelihood from agriculture into other income activities were explained by changes in the independent variables included in the model. The result is presented in Table 4. The positive impact of education on livelihood diversification aligns with findings from recent studies, which emphasize that higher educational attainment equips households with better skills and knowledge to explore various income-generating activities (Habib et al., 2023).

Table 4: Determinants of livelihood diversification of the respondents

Variables	Coefficient	Standard error	Z
Constant	4.791	2.611	1.831*
Age (years)	-.056	.026	-2.115**
Farm size (Hectares)		-.013	.287
Household size	.073	.129	0.573
Gender (M=1, F=0)	-.198	.509	-0.394
Level of education	.075	.021	3.571
Cooperative membership	.559	.271	2.066**
Losses (₹)	.423	.241	1.757*
Climate change	1.452	.722	2.018**
Low yield (yes=1, no=0)	1.477	.741	2.001*
Income from farming (₹)	-2.056	1.120	-1.841*
LR chi2(12)	23.432		
Log-likelihood	-23.834		
Pseudo R ²	0.729		

Source: Field survey, 2024

Additionally, cooperative membership appears to facilitate access to resources and networks that can support diversification efforts (Habib et al., 2023). The influence of climate change and losses from mining suggests the need for households to adapt their strategies in response to environmental challenges and economic pressures (Bernzen et al., 2023).

Conclusion and Recommendations: A dramatic shift was noted in the community's livelihood over the past decade, with mining activities increasing from 7% to 93%, while traditional agricultural practices declined. This transition raised concerns about long-term sustainability and food security, as 63% of respondents were classified as food insecure. The probit estimates revealed that own food production, education level, and livelihood diversification, household head age, household size, and mining-related losses all impacted food security. Similarly, educational attainment, cooperative membership, age of household head and reliance on farming income significantly impacted diversification decision. While the current trends indicate a significant economic shift towards mining, policymakers and community leaders must consider integrated approaches that balance mining activities with sustainable agricultural practices to ensure long-term food security and community resilience.

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Evaluation of the Acrolein-Induced Hepatorenal Redox Perturbation and Immunosuppressive Response in Male Wistar Rats.

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ABSTRACT

Abstract Acrolein (AC), an unsaturated aldehyde is a ubiquitous environmental toxin, primarily generated from combustion processes, including cigarette smoke, vehicle exhaust, and industrial emissions. This study evaluated the acrolein-induced hepatorenal perturbation and immunosuppressive response in male Wistar rats. The experimental animals were acclimatized for one week; three groups of six (6) male Wistar rats (150±4g per body weight) each were randomly assigned. The group 1 (control) were given only water, whereas group 2 and 3 (experimental groups) were given acrolein of 2.5 mg/kg and 5.0 mg/kg doses orally for 30 days. The results revealed that acrolein (AC) exposure elicited significant oxidative burden, shown by elevated status of oxidative degradation of lipids (LPO) and decreased status of antioxidant markers like superoxide dismutase (SOD), catalase (CAT), reduced glutathione (GSH), glutathione- S-transferase (GST), and glutathione peroxidase (GSH Px). There was also a concomitant increase in inflammatory stress markers such as myeloperoxidase (MPO), and nitric oxide (NO). This ultimately resulted to a notable increase ($P < 0.05$) in the activities of the immunosuppressive enzymes such as tryptophan 2, 3-dioxygenase (TDO), and indoleamine 2, 3-dioxygenase (IDO), in a dose-dependent manner in both the hepatic and renal organs. Data show the induction of oxidative/inflammatory stress and an accompanying Boost in the immunosuppressive TDO and IDO activities in the liver and kidney of male Wistar rats exposed to acrolein, suggesting that these alterations in the oxidative, immunosuppressive, and inflammatory markers are caused by acrolein.

Keywords: Acrolein, indoleamine 2,3-dioxygenase, antioxidant, oxidative burden.

1.0 INTRODUCTION: Acrolein (AC), an intermediate for the synthesis of acrylic acid, medicines, and other chemical products, can be generated when glycerol is highly degenerated (Peivasteh-Roudsari *et al.*, 2024; Jiang *et al.*, 2022; Iyer *et al.*, 2022). It has a molecular weight of 56.06 g/mol (Jiang *et al.*, 2023), a boiling point, and a melting point of 52.3 °C and -87.8 °C respectively (Haynes, 2015). AC is soluble in water (2.11×10^{-5} mg/L at 20 °C) (Yalkowsky *et al.*, 2010); it is also soluble in ethanol, ether, and acetone; slightly soluble in chloroform (Haynes, 2015). As a simple α , β -unsaturated aldehyde (Aizenbud *et al.*, 2016), AC is found in food substances (Jiang *et al.*, 2022), water (Zhao *et al.*, 2016), the environment (Schieweck *et al.*, 2021) in general as a result of several human actions, including cooking at a very high temperature, burning fossil fuels (Burcham, 2017), emitting exhaust from cars, and the misuse of pesticides (Zhong *et al.*, 2024; Gupta *et al.*, 2020; Aizenbud *et al.*, 2016). Acrolein whether exogenous or endogenous is highly toxic and can have numerous negative consequences on health (Rietjens *et al.*, 2022; Burcham, 2017; Moghe *et al.*, 2015a). Air inhalation, food consumption, and endogenous discharge are the main routes, through which humans are exposed to AC (Burcham, 2017). Studies have explored the link between AC and various chronic illnesses affecting the liver and kidneys resulting in some illnesses including alcoholic liver disease, diabetes (Hikisz and Jacenik, 2023; Feroe *et al.*, 2016), and cardiovascular disease (Henning *et al.*, 2017). Moreover, new research has revealed that nucleic acid damage caused by AC contribute in tumors development (Tsai *et al.*, 2021), thereby decreasing intracellular GSH levels and disrupting cell signaling pathways (Averill-Bates & Tanel, 2023), specifically those about redox pathway (Moghe *et al.*, 2015b). Research has revealed the deleterious effects of AC on the liver and kidneys (Zirak *et al.*, 2019; Burcham, 2017; Benin & Leikauf, 2020), which result in oxidative stress (Aydın *et al.*, 2022), inflammation (Feng *et al.*, 2022), and interference in cellular function, summing up in liver damage and liver problems like hepatocellular carcinoma and fibrosis (Liu *et al.*, 2017; Moghe *et al.*, 2015a; Mohammad *et al.*, 2012). AC toxicity causes damage, inflammation, and renal cell death in the kidneys, resulting in renal dysfunction and nephropathy (Levin *et al.*, 2017). Hepatorenal redox perturbation, an essential driver of the pathophysiology of the liver and kidney (Kamel *et al.*, 2023; Ndisang, 2018), is majorly characterized by increased oxidative stress and decreased antioxidant status (Ndisang, 2018). It is also plays a critical role in drug-induced liver and kidney injury (Vangaveti *et al.*, 2021), and in metabolic diseases like diabetes and obesity (Suzuki and Yamamoto, 2020). The need for interventions that restore redox homeostasis arises because tissue damage (Akanji *et al.*, 2021), inflammation (Wang *et al.*, 2020), fibrosis, and organ failure (Tretter *et al.*, 2021; Santos *et al.*, 2021) are induced from redox dysregulation. Investigating the intracellular redox signaling pathways involved in the regulation of the hepatorenal axis may help in the early diagnosis and monitoring of kidney and liver diseases (Kong *et al.*, 2019), thereby improving the accuracy of the diagnosis and therapeutic outcome (El-Sherbeeny *et al.*, 2021). Therefore, this study evaluates the Acrolein-induced hepatorenal redox disturbance and immunosuppressive effect in the male Wistar rats.

2.0 MATERIALS AND METHODS

2.1 Animal Protocol: This study involved adult Wistar rats aged 8 weeks at Alex Ekwueme Federal University in Nigeria. They were kept in plastic cages with good ventilation provided with feed, water, and exposure to a tropical 12-hour illumination /12-hour Nighttime of a tropical environment, following guidelines from the US National Academy of Science.

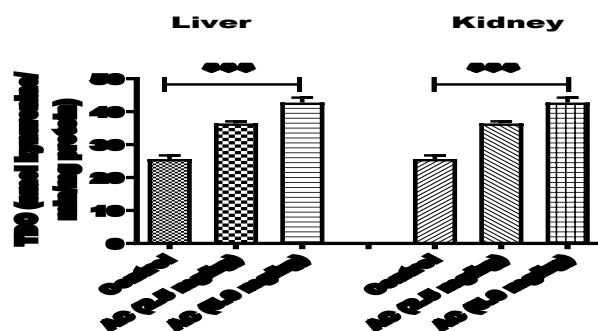
2.2 Experimental Design: A completely randomized controlled design is used in the experiment to assess the toxicity of AC. Three groups of six rats each were randomized to a plastic cage for the 31-day study after a week of acclimation.

2.3 Animal Treatment: Group 1: Received distilled water (2 mL per kilogram of body weight) daily for 30 consecutive days. Group 2: Was given AC orally in distilled water at a dosage of 2.5 mg per kilogram of body weight daily over a 30-day period. Group 3: Was given AC orally in distilled water at a dosage of 2.5 mg per kilogram of body weight daily over a 30-day period. Observation of the animals throughout the study were done keenly. The animals were euthanized via cervical dislocation 24 hours following the final treatment on Day 31. Immediately, the **hepatic and renal organs** were harvested and weighed. Some tissue samples were then frozen for later biochemical analysis.

2.4 Assessment of antioxidant/oxidative burden parameters: The rats' tissues were homogenized in 50 mM Tris-KCl buffer (pH 7.4) with 1.15% potassium chloride. The resulting homogenate was then centrifuged at 10,000 g for 15 minutes at 4 °C. After that, the supernatant was gathered to measure the activity of catalase (CAT) by modifying the Clairborne, 1995 approach, and superoxide dismutase (SOD) activity using the Misra and Fridovich method, which was adapted by Ebokaiwe *et al.*, 2015. The method of Jollow *et al.* (1974) was used to quantify reduced glutathione (GSH) at 412 nm. The Rotruck *et al.* 1973 method was used to measure the glutathione peroxidase (GSH-Px) activity. Using the methodology outlined by Farombi *et al.* (2000), the quantity of malondialdehyde (MDA) was used to measure lipid peroxidation (LPO), which was subsequently expressed as micromoles of MDA per mg of protein. The method outlined by Eiserich *et al.* (1998) was used to measure myeloperoxidase (MPO) activity.

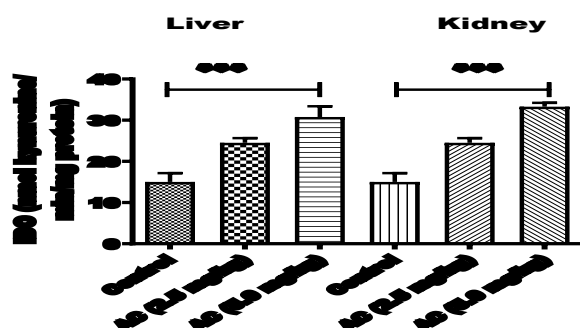
2.5 Assessment of inflammatory biomarkers/ immunosuppressive enzymes: Myeloperoxidase (MPO) activity in hepatic and renal tissue was calculated using the methodology outlined by Eiserich *et al.* (1998). By detecting the nitrite levels in the tissue samples using the Griess reagent, nitric oxide was ascertained in accordance with Moshage *et al.* (1995). Using Kudo and Boyd's (2000) methodology, immunosuppressive indoleamine 2, 3-dioxygenase (IDO) and tryptophan 2, 3-dioxygenase were assessed.

3.0 RESULTS



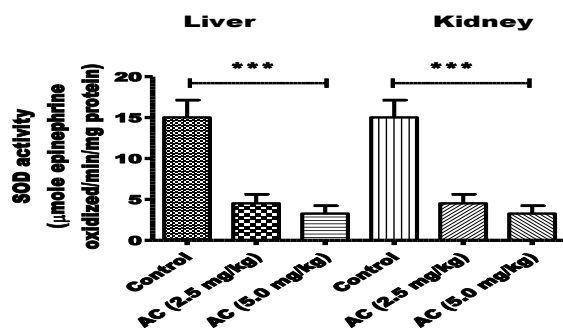
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein.

Figure 1: Activity of Tryptophan 2, 3-Dioxygenase activity in male Wistar rats.



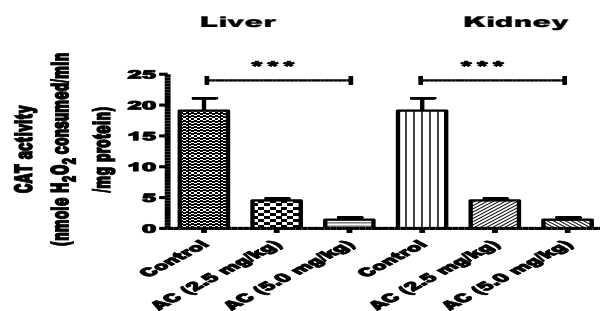
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein.

Figure 2: Activity of Indoleamine 2, 3- dioxygenase (IDO)



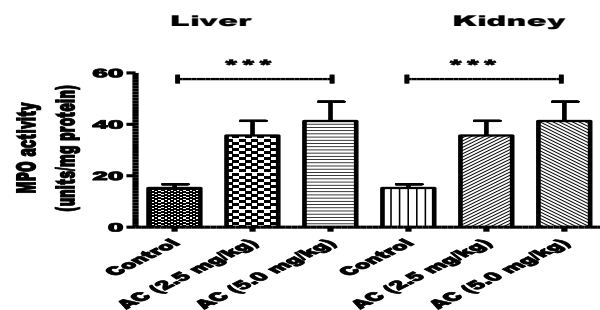
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein.

Figure 3: Activity of Superoxide dismutase (SOD)



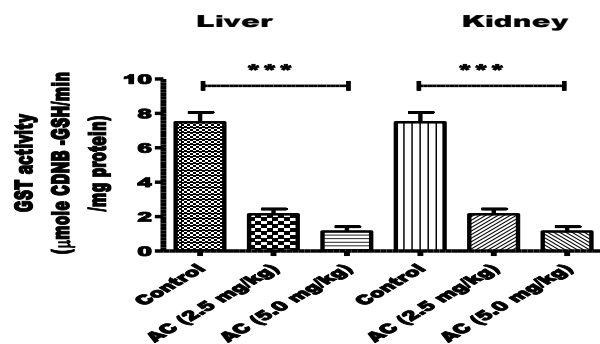
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein.

Figure 4: Activity of Catalase (CAT)



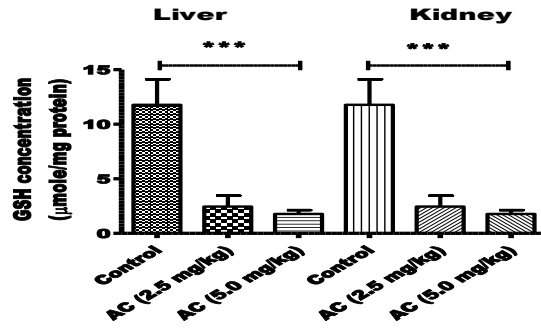
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein.

Figure 5: Activity of Myeloperoxidase (MPO)



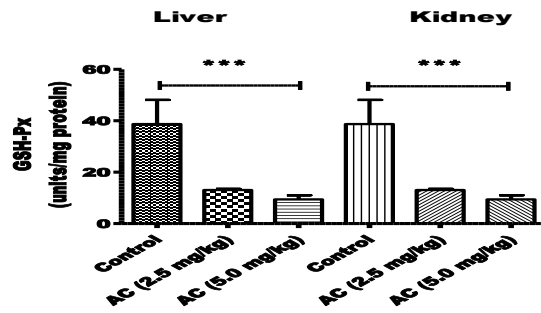
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein

Figure 6: Activity of reduced Glutathione-S-Transferase (GST)



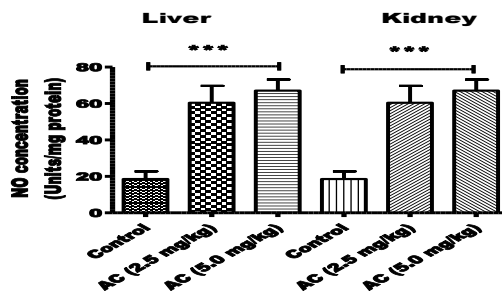
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein

Figure 7: Activity of Glutathione (GSH)



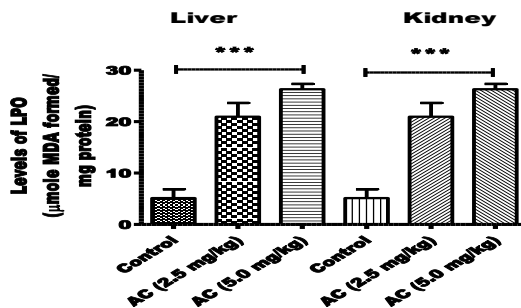
The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein

Figure 8: Activity of Glutathione peroxidase (GSH-PX)



Data are presented as mean $\pm$ SD ($n = 6$); *** = $p < 0.0001$, AC= acrolein.

Figure 9: Level of Nitric Oxide (NO) concentration



The data are expressed as mean $\pm$ standard deviation (SD) for a sample size of six ($n = 6$); *** = $p < 0.05$, AC= acrolein.

Figure 10: Levels of Lipid Peroxidation (LPO)

3.1 DISCUSSION: Results showed that TDO, and IDO activities in the hepatic and renal tissues increased dose-dependently. This result also indicated the increased liver and kidney TDO and IDO resulted in oxidative stress

leading to disruption of some metabolic pathways which aligned with other studies that demonstrated that oxidative stress induction and metabolic pathway modifications caused by AC in different tissues have been seen to increase IDO expression in liver dysfunction models, especially when it involves response to inflammatory cytokines such as IFN- γ (Xu *et al.*, 2021). The administration of AC significantly decreased the liver and kidneys' SOD and CAT activities. This reduction in SOD and CAT activities in the kidney and liver suggested a compromised antioxidant defense (Hong *et al.*, 2021). The result aligns with other studies showing that AC causes oxidative stress, which lowers SOD and CAT activity in a variety of tissues. For example, reports on models of liver and renal injury have demonstrated that exposure to AC is associated with increased oxidative damage and inflammation, which can impair SOD and CAT activities (Alfarhan *et al.*, 2020; Zhou *et al.*, 2022). The rats' liver and kidney MPO activities were markedly elevated when AC was given to them. Research has demonstrated that AC tends to cause inflammation and oxidative damage, which raises MPO activity. This is in agreement with the work of the ATSDR (2021) and NTP (2006), which revealed that exposure to AC raised MPO levels in the liver and kidneys, pointing out an increased inflammatory response and neutrophil infiltration. The current study demonstrated that administering AC to rats significantly decreased the liver and kidneys' GST activities. The lowering of GST activities is a result of AC administration. This report aligns with the data presented by Xiong *et al.* (2018), which revealed that rats exposed to AC had a reduced activity of GST in the liver and kidneys, suggesting that these organs' detoxifying processes were greatly affected. Also, AC exposure was linked to lower GST levels in renal tissues and is associated with higher oxidative stress and inflammatory marker levels, according to recent research by Finch *et al.* (2022). The current investigation demonstrated that administration of AC considerably reduced the liver and kidneys' GSH concentrations. This reduction demonstrated acrolein's capacity to cause cytotoxicity by reducing GSH and was linked to elevated oxidative stress and inflammatory response. Mohammad *et al.* (2012) discovered that AC conjugates with GSH resulting in a reduction in the availability of this crucial antioxidant in hepatic cells. GSH-PX activities in the liver and kidneys were markedly decreased by AC treatment. To support the idea that AC weakens antioxidant defenses, Mohammad *et al.* (2012), found that exposure to AC in animal models results in decreased GSH-PX activity in liver tissues. The administration of AC significantly elevated the liver and kidneys' nitric oxide (NO) concentrations. According to the study by Xiong *et al.* (2018), exposure to AC causes the elevation of inducible nitric oxide synthase (iNOS) expression, which is attributed to higher NO levels in renal tissues. The results indicating elevated NO levels after the AC was given to the rats agree with those of other research studies in the review. The administration of AC considerably increased the liver and kidneys' MDA concentration. These data suggested that acrolein's capacity to cause oxidative stress and compromise cellular antioxidant defenses led directly to the increase in MDA level. The results, which showed elevated MDA after AC administration, agree with those of other research papers in the literature. Alongside this rise in MDA, there was a reduction in the activity of antioxidant enzymes such as GSH-PX.

4.0 CONCLUSION: The results collectively demonstrated the deleterious effect of AC on the health of the liver and kidneys in male Wistar rats, which are marked by elevated oxidative stress, inflammation, and immunosuppression in addition to compromised antioxidant defenses. Oxidative stress and inflammation are probably exacerbated by the elevated enzymes of the indoleaminergic pathway (TDO and IDO), and inflammatory and oxidative stress markers such as MPO, NO, and MDA. Decrease in GSH-PX, GSH, GST, CAT, and SOD indicate that the oxidative damage was not sufficiently countered.

Recommendation: Future research should explore antioxidants, such as N acetylcysteine or vitamin E, to mitigate acrolein-induced oxidative stress and hepatorenal toxicity. Also, Government agencies and health organizations should increase awareness of acrolein toxicity, particularly in occupational settings, to reduce its health impacts.

Contribution to knowledge: This study provides detailed insights into how acrolein induces oxidative stress and disrupts redox homeostasis in hepatic and renal tissues. The study enhances understanding of acrolein's role in suppressing immune function, contributing to the broader field of immunotoxicology and validating the use of male Wistar rats as a suitable experimental model for studying environmental toxin-induced hepatorenal impairment.

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Contribution of Involvement in Fish Farming to Food Security Status of Fish Farmers in Oyo State

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ABSTRACT

Fish farming holds promise for enhancing food security; however, its specific contributions to the food security status of fish farmers remain underexplored. *This study seeks to fill this gap by assessing the contributions of involvement in fish farming to the food security status of farmers in Oyo State, ascertaining the benefits derived from fish farming, involvement in fish farming activities, and food security status among farmers in the study area.* A multistage sampling procedure was employed to select 115 respondents from the study area. Structured interview schedules and questionnaires were used to gather responses from the respondents. Data were analyzed using descriptive and inferential statistics at $p = 0.05$. The benefits derived from fish farming included income generation ($\bar{x} = 2.33$), improved nutrition ($\bar{x} = 2.32$), improved confidence ($\bar{x} = 2.26$), employment opportunities ($\bar{x} = 2.20$), improved skills ($\bar{x} = 2.11$), and improved savings ($\bar{x} = 2.09$). The result indicates that a majority (64.3%) of fish farmers are highly involved in fish production activities, while 35.7% of them exhibit low involvement. About 51.3% of fish farmers were food insecure, whereas 48.7% were food secure. There was correlation between the level of involvement in fish farming activities and food security ($r = 0.012$, $p < 0.05$). It is recommended that farmers should adopt measures to reduce pollution and enhance water quality in fish farming, including proper waste management, water quality monitoring, improved pond design, efficient water exchange systems, biofiltration, control of external pollutants, and increased training and awareness.

Keywords: Food security; Involvement; Fish farming; Earthen pond; Weighing.

INTRODUCTION: The fishery subsector plays a notable role in the Nigerian economy as it ranked third after the crop and livestock sub-sectors which ranked first and second, respectively, in terms of contribution to the gross domestic product (Bassey et al., 2015). Nigerians are large consumers of fish with an estimated demand of 1.4 million tons and it remains one of the main products consumed in terms of animal protein (Ali et al. 2008). In addition to nutritional benefits of fish, it is also important in animal feed formulation and source of raw materials for agro-allied industries. In Nigeria, the fish species which are commonly cultured include *Tilapia* spp, *Heterobranchus niloticus*, *Clarias gariepinus*, *Mugiespp*, *Chrisichthysnigrodigitatus*, *Hetero nitoticus*, *Ophiocephalus obscure*, *Cypinuscarpio* and *Megalo* spp. Food, both in quantity and quality is an important factor for a healthy and productive life as well as for a nation to sustain its development (Oke, 2015). A household is said to be food secured when every member of the household has access at all times to sufficient food that contain the essential nutrients required by individual to actively and healthily perform their daily activities (Robert, Qsadare and Inem, 2019). Fish farming initiatives not only contribute to increased food availability but also play a pivotal role in improving dietary diversity and nutritional outcomes, particularly in communities with limited access to animal protein (Ekanem et al., 2018). Furthermore, the economic benefits derived from fish farming, including income generation and employment opportunities among others. Food security remains a critical challenge in many parts of Nigeria, particularly in urban and peri-urban areas where population growth and economic pressures have intensified the need for sustainable food production systems. This challenge is particularly pronounced in Oyo state among smallholder farmers who rely on diverse agricultural activities to sustain their livelihoods. Among these activities, fish farming has emerged as a potentially significant contributor to food security, providing not only a source of income but also a direct supply of protein-rich food for households. Despite the recognized potential of fish farming, there is limited empirical evidence on its actual contribution to the food security status of farmers. The interplay between fish farming and food security is complex, involving factors such as income generation, access to markets, and the nutritional value of fish in household diets. Furthermore, the extent to which fish farming can mitigate food insecurity in this area remains underexplored, particularly in the context of small-scale operations. This gap in knowledge is critical as it impedes the formulation of effective policies and interventions that could enhance the role of fish farming in achieving food security. This study seeks to address this gap by examining the contributions of involvement in fish farming to the food security status of farmers in Oyo State. Specifically the study ascertain the benefits derived from fish farming in the study area; ascertain the level of involvement of fish farmers in preproduction, production and post-production activities on the farm; and assess the level of food security of fish farmers in the study area.

METHODOLOGY: The study was carried out in Oyo State which is located in the southwestern region of Nigeria. It is one of the 36 states in the country, with Ibadan as its capital and largest city. The state is bounded by Kwara State to the north, Osun State to the east, Ogun State to the south, and the Republic of Benin to the west. Oyo State covers an area of approximately 28,454 square kilometers and has a population engaged predominantly in agriculture, including crop farming, livestock rearing, and aquaculture. The state is divided into 33 local government areas and is known for its diverse ethnic composition, with the Yoruba ethnic group being the majority. Its favorable climate, arable land, and availability of water bodies make it suitable for various agricultural activities, including

fish farming, which has been gaining popularity as a source of livelihood and food security. The population of the study were registered fish farmers in Oyo state. A two stage sampling technique was employed to select the sample size for this study. The Oyo State Agricultural Development Programme (OYSADEP) structure was used for the study. OYSADEP is divided into 4 zones i.e. Ibadan/Ibarapa, Oyo, Ogbomoso and Saki zones. In the first stage, 20% of the Oyo State Agricultural Development Programme (OYSADEP) structure was selected using a purposive sampling technique to give Ibadan/Ibarapa and Oyo zone as they have more fish farmers registered with OYSADEP than in other zones. Fish farmers under OYSADEP were registered at zonal level without further delineation to blocks and cells due to their localization. The second stage involved using simple random sampling technique to sample 30% of the 230 functional registered fish farmers registered with OYSADEP in Ibadan/Ibarapa zone, this gave 69 registered farmers, and 30% of the 153 respondents in Oyo zone to give 46 respondents, giving a total sample size of 115 respondents for the study. A list of twenty-three items was generated from literature on all fish farm operations. This list was segmented into preproduction farm activities, production activities, and postproduction activities. Frequency of involvement in all the fish farming operations was measured on a scale of always involved, sometimes involved, and never involved, with scores of 2, 1, and 0 allocated respectively. Weighted mean score was used to rank their involvement in fish farm operations. Benefits derived from involvement in fish farming were listed on an eight-item scale. Scores of 0, 1, and 2 were assigned for not a benefit, benefit, and strong benefit. Items were scored to form a composite score. Weighted mean score was used to rank their benefits from fish farming. Respondents' food security was measured using a scale adapted from the Household Food Insecurity Access Scale (HFIAS) of the United States Agency for International Development (2012). Nine questions, also known as domains, were given for the respondents to respond to in order to assess fish farmers' extent of household food security with a recall period of four weeks (30 days), using response options of never, rarely, sometimes, and often. The responses were scored as follows: 3 for Often, 2 for Sometimes, 1 for Rarely, and 0 for Never. The level of food security was determined using the mean as the benchmark to categorize food security as food secure and food insecure. Respondents whose indices were from the mean and above were categorized as being food insecure, while those below the mean were categorized as being food secure. Data analysis involved descriptive statistics, encompassing frequency counts, percentages, mean scores, and standard deviation. Inferential statistics Pearson Product Moment correlation was applied to test the study hypothesis.

RESULTS AND DISCUSSION

Frequency of involvement of farmers in fish farming activities on the farm: The management operations in fish farming activities were categorised into pre-production, production and post-production activities in Table 1.

Pre-production activities: As revealed in Table 1, In pre-production activities, 53% of farmers were always involved in input purchases, making it the most consistently performed task. Water quality treatment followed closely, with 53% always involved. Liming of the pond ranked third, with 53% of farmers consistently engaging in this task. Emmanuel, Adegbite, and Kolawole (2014) emphasized the importance of carefully calculating the amount of lime used in fish farming. They noted that excessive lime can raise water pH levels too high, potentially leading to ammonia toxicity and increased fish mortality. Species selection had lower involvement, with 41% of farmers consistently participating. Clearing, netting to control pests, and fertilization were less frequently performed, with large percentages of farmers never involved in these activities, indicating low engagement.

Production activities: In the production phase, feed production was the most prioritized activity, with 58.4% of farmers always involved, reflecting its importance for fish growth. Fish stocking ranked second, with 41.7% always involved, emphasizing its role in initiating production. Feeding ranked third, with 55.7% always engaged, highlighting its significance in maintaining fish health and growth. Other activities, such as pond management, medication, test cropping, and disease control, showed moderate engagement, indicating a need for more consistent attention to these areas. Spawning was the least performed activity, likely due to reliance on external suppliers or lack of technical expertise.

Post-production activities: In post-production activities, weighing was the most frequently performed task, with 46.1% of farmers always involved, highlighting its importance for market readiness and stock management. Grading ranked second, indicating its value for categorizing fish for better pricing and market appeal. Record keeping ranked third, showing its importance for tracking production. Processing for marketing ranked fourth, though less frequently performed due to resource or infrastructure limitations. Selling was moderately involved, suggesting challenges in direct marketing. Packaging was the least prioritized activity, with 46.1% of farmers never involved, likely due to a lack of resources or its perceived irrelevance for small-scale production.

Table 1: Frequency of involvement of respondents in fish farming activities on the farm

Variables	Never involved		Sometime involved		Always involved	
	F	%	F	%	F	%
Preproduction						
Input purchases	27	(23.5)	27	(23.5)	61	(53.0)
Liming of pond	6	(5.2)	82	(71.3)	27	(23.5)
Water quality treatment	13	(11.3)	62	(53.9)	40	(34.8)
Specie selection	10	(8.7)	83	(72.2)	22	(19.1)
Fertilization	53	(46.1)	29	(25.2)	33	(28.7)
Clearing	23	(20.0)	69	(60.0)	23	(20.0)
Netting to control pest	23	(20.0)	69	(60.0)	23	(20.0)
Production						
Spawning	54	(47.0)	37	(32.2)	24	(20.9)
Pond management	28	(24.3)	64	(55.7)	23	(20.0)
Feed purchasing	51	(44.3)	47	(40.9)	17	(14.8)

Feed production	24	(20.9)	33	(28.7)	58	(58.4)
Feeding	21	(18.3)	64	(55.7)	30	(26.1)
Medication	31	(27.0)	59	(51.3)	25	(21.7)
Diseases control	30	(26.1)	68	(59.1)	17	(14.8)
Fish stocking	31	(27.0)	36	(31.3)	48	(41.7)
Test cropping/ routine check	29	(25.2)	69	(60.0)	17	(14.8)
Cropping	51	(44.3)	43	(37.4)	21	(18.3)
Post production						
Processing for market	24	(20.9)	71	(61.7)	20	(17.4)
Grading	21	(18.3)	42	(36.5)	52	(45.2)
Packaging	53	(46.1)	33	(28.7)	29	(25.2)
Selling	29	(25.2)	70	(60.9)	16	(13.9)
Weighing	16	(13.9)	46	(40.0)	53	(46.1)
Record keeping	15	(13.0)	67	(58.3)	33	(28.7)

Source: Field survey, 2024

Level of on involvement in preproduction, production and post-production activities on the fish farm

Table 1b presents data on the level of on involvement in preproduction, production and post-production activities on the fish farm. The result indicates that a significant majority (64.3%) of fish farmers are highly involved in fish production activities, while a smaller proportion (35.7%) exhibit low involvement. The high level of involvement among most fish farmers suggests strong engagement in fish farming activities, potentially contributing to enhanced fish production and food security in the area.

Table 1b: Level of on involvement in preproduction, production and post-production activities on the farm

Level of fish production activities	F	%
High	74	64.3
Low	41	35.7
Total	115	100

Source: Field Survey, 2024 Mean $\pm$ SD = 22.08 $\pm$ 4.785, Min value=0.00 Max value=48.00

Benefits derived from fish farming: The highest-ranked benefit is income generation, with a weighted mean score ($\bar{x}$ = 2.33). This finding implies that fish farming plays a crucial role in enhancing the economic well-being of farmers by serving as a significant source of income. Improved nutrition ($\bar{x}$ = 2.32) ranks second, highlighting the role of farming in ensuring access to healthy, diverse food, promoting better health outcomes for farmers and their households. In third place is improved confidence ($\bar{x}$ = 2.26), suggesting that fish farming practices have strengthened farmers' self-esteem and decision-making capabilities, underlining the personal growth associated with agricultural activities. Employment opportunities ($\bar{x}$ = 2.20) rank fourth, showing that farming not only provides employment for farmers but also generates job opportunities for others in the community, contributing to the local economy. Improved savings ($\bar{x}$ = 2.11) rank fifth, while improved skills ($\bar{x}$ = 2.09) follow, indicating that farming enables farmers to save and manage their finances better, providing a cushion for future needs and uncertainties. A lower level of dependency ($\bar{x}$ = 2.06) is another benefit that ranks highly, reflecting the economic independence that farming provides. Farmers increasingly rely on their own resources rather than external support. Finally, diversification of income ($\bar{x}$ = 2.00) ranks lowest, suggesting that fish farming may be primarily viewed as a standalone income source rather than a complementary livelihood activity, highlighting the need to promote its integration with other income-generating ventures.

Table 2: Benefits derived from fish farming

Benefits derived	Not a benefit		Benefit		Strong benefit		WMS	Rank
	F	%	F	%	F	%		
Improved nutrition	22	(19.1)	34	(29.6)	59	(51.3)	2.32	2 nd
Diversification of income	21	(18.3)	73	(63.5)	21	(18.3)	2.00	8 th
Employment opportunity	16	(13.9)	60	(52.2)	39	(33.9)	2.20	4 th
Income generation	22	(19.1)	33	(28.7)	60	(52.2)	2.33	1 st
Improved savings	15	(13.0)	75	(66.1)	25	(21.7)	2.09	6 th
Improved skill	2	(1.8)	60	(52.2)	34	(29.6)	2.11	5 th
Lower level of dependency	19	(16.5)	69	(60.0)	27	(23.5)	2.06	7 th
Improved confidence	21	(18.3)	42	(36.5)	52	(45.2)	2.26	3 rd

Source: Field survey, 2024 F – Frequency % - Percentage WMS - weighted mean score

Food security of fish farmers: Table 3a findings reveal varying levels of food security among fish farmers. 45.2% of farmers rarely worry about not having enough to eat, while 26.1% sometimes worry. In terms of food availability, 58.3% sometimes have enough food, and 24.3% rarely have enough. Regarding access, 54.8% rarely have access to enough food, while 21.7% sometimes do. 47% of farmers never worry about the quality and variety of food, and 24.3% sometimes do. For meeting household food needs, 34.8% often have enough food, while 30.5% sometimes do. Financial challenges are noted, with 44.3% rarely having enough money to buy food, and 20.9% often face this issue. When it comes to providing nutritious meals, 50.4% rarely manage to do so, and 22.6% sometimes can. In terms of food availability at all times, 44.3% often have food available, while 20.9% sometimes do. Lastly, 43.5% often limit the size or variety of meals, and 27% sometimes do, indicating significant food insecurity.

Table 3a: Food security of fish farmers

Variables	Never F %	Rarely F %	Sometimes F %	Often %	F
Did you worry that your household would not have enough to eat?	18 (15.7)	52 (45.2)	30 (26.1)	15 (13.0)	
Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	13 (11.3)	28 (24.3)	67 (58.3)	7 (6.1)	
Did you or any household member have to eat a limited variety of foods due to a lack of resources?	10 (8.7)	63 (54.8)	25 (21.7)	17 (14.8)	
Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	54 (47.0)	17 (14.8)	28 (24.3)	16 (13.9)	
Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	21 (18.3)	19 (16.5)	35 (30.5)	40 (34.8)	
Did you or any household member have to eat a fewer meals in a day because there was not enough food?	21 (18.3)	51 (44.3)	19 (16.5)	24 (20.9)	
Was there ever no food to eat of any kind in your household because of lack of resources to get food?	22 (19.1)	58 (50.4)	26 (22.6)	9 (7.8)	
Did you or any household member go to sleep at night hungry because there was not enough food?	21 (18.3)	19 (16.5)	24 (20.9)	51 (44.3)	
Did you or any household member go a whole day and night without eating anything because there was not enough food?	12 (10.4)	22 (19.1)	31 (27.0)	50 (43.5)	

Source: Field survey, 2024.

Level of fish farmers' food security: The findings in Table 3b reveal the level of food security among fish farmers. The Table reveals that 51.3% of respondents were food insecure, whereas 48.7% were food secure. The findings imply that a significant proportion of fish farmers (51.3%) are food insecure, indicating that despite being food producers, many still struggle to access sufficient and nutritious food for their households. This suggests underlying challenges such as low income, high production costs, or limited access to markets and support services. The fact that only 48.7% are food secure highlights the need for targeted interventions to improve the livelihoods and food access of fish farmers in the study area.

Table 3b: Level of fish farmers' food security

Level of food security	F	%
Food insecure	59	51.3
Food secure	56	48.7
Total	115	100

Source: Field survey, 2024 Mean $\pm$ SD = 45.76 $\pm$ 8.736, Min value=0.00 Max value=18.00

Correlation analysis of farmers' involvement in fish farming and their food security status

The findings presented in Table 4 indicate there was correlation between the level of involvement in fish farming activities and food security ($r = 0.012$, $p < 0.05$) This is a statistically significant positive relationship, suggesting that greater involvement in fish farming activities is associated with improved food security. The higher the farmer's involvement, the better the likelihood of achieving food security.

Table 4: Correlation analysis of respondents' involvement in fish farming and food security status

Source: Data analysis, 2024 *Significant at the 0.01 level

Variables	r-value	p-value	Decision
Involvement	.233*	.012	S

CONCLUSION AND RECOMMENDATIONS: The study stresses several key management practices in fish farming, with input purchases, water quality treatment, and feed production being the most frequently performed activities. On the other hand, activities such as spawning, disease control, and test cropping were less frequently executed. Majority of fish farmers are highly involved in fish production activities, while a smaller proportion exhibit low involvement. In terms of food security, a mixed picture emerges. While some farmers rarely worry about food availability, many face concerns regarding their ability to access or afford sufficient and nutritious food. These results suggest that food insecurity is a significant challenge for fish farmers, with issues like inadequate access to food, poor purchasing power, and limitations in the size and variety of meals being prominent. More than average of the respondents enjoyed food security. The study concludes that the higher the farmer's involvement, the better the likelihood of achieving food security. Based on the findings of the study, the following recommendations are made: Farmers should implement measures to reduce pollution and improve water quality management, which are key challenges in fish farming. Measures such as proper waste management. Water quality monitoring, improved pond design, efficient water exchange systems, use of biofiltration, control of external pollutants, training and awareness. Provide more training on advanced fish farming practices, disease control, and sustainable pond management to improve production efficiency.

Facilitate access to affordable loans and savings programs to help farmers invest in their operations and overcome financial barriers.

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Behavioural and Physiological Responses of African Catfish (*Clarias gariepinus*) to Sub-Lethal Exposure of Cypermethrin

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Abstract

The indiscriminate use of synthetic pyrethroids in agriculture has raised concerns regarding their ecotoxicological impact on non-target aquatic organisms. This study assessed the sub-lethal effects of cypermethrin, a commonly used pyrethroid insecticide, on juvenile *Clarias gariepinus*. Juveniles of mixed sex and uniform size were acclimated and exposed to varying sub-lethal concentrations of cypermethrin (0.004, 0.008, 0.012, and 0.016 ml/L) alongside a control group under laboratory conditions for eight days. Water quality parameters, behavioural responses, and mortality rates were evaluated. Physico-chemical parameters showed significant deviations across treatments, particularly in pH, dissolved oxygen, and electrical conductivity. Significant behavioural anomalies including hyperactivity, vertical positioning, erratic swimming, reduced feeding, gasping for air, and spiral movement were observed in exposed groups, particularly at higher concentrations. The opercular ventilation rate and tail fin movement were also altered. Mortality rates increased significantly with cypermethrin concentration, ranging from 23.33% in the lowest treatment to 93.33% in the highest, while the control group recorded no mortality. These findings suggest that cypermethrin, even at low concentrations, can disrupt behavioural and physiological functions in *C. gariepinus*, likely due to its neurotoxic effects. The study concludes that cypermethrin poses a substantial risk to aquatic fauna and recommends regulatory actions, alternative pest control methods, and continued ecotoxicological monitoring to mitigate the ecological impact of pesticide runoff. The observed changes offer valuable indicators for assessing pesticide pollution in freshwater ecosystems.

Keywords: Water quality; Mortality rate; Aquatic eco-toxicology; Pesticide pollution; Insecticide impact

INTRODUCTION: The African catfish (*Clarias gariepinus*) is one of the most economically important freshwater fish species in sub-Saharan Africa, widely cultivated due to its fast growth, tolerance to low oxygen levels, omnivorous feeding habits, and high market demand (Olufeagba et al., 2022). However, the increasing expansion of aquaculture and agricultural activities has raised concerns about the contamination of freshwater systems by agrochemicals, particularly synthetic pesticides such as cypermethrin. Cypermethrin is a broad-spectrum, synthetic pyrethroid insecticide extensively used in agriculture for the control of insect pests. Although it exhibits low toxicity to mammals and relatively rapid degradation in the environment, it is highly toxic to aquatic organisms even at low concentrations (Velmurugan et al., 2021). In aquatic systems, cypermethrin can accumulate in sediments and persist, leading to chronic exposure of non-target species such as fish. While lethal concentrations can cause immediate mortality, sub-lethal exposure may result in a range of physiological and behavioral disturbances that affect growth, reproduction, and survival (Fahmy et al., 2020). In many regions of Nigeria, the unregulated and excessive use of cypermethrin and other pesticides has led to the contamination of surface waters, particularly in areas adjacent to farmlands (Akpan et al., 2023). *Clarias gariepinus*, commonly found in such waters and frequently used in aquaculture, is susceptible to pesticide exposure, which may not always result in death but can cause significant sub-lethal effects. These include behavioral changes such as erratic swimming and hyperactivity, and physiological disruptions such as hematological and biochemical alterations (Okomoda et al., 2022). However, despite the ecological and economic importance of this species, there is a paucity of comprehensive data on its sub-lethal responses to cypermethrin, especially under conditions that mimic real-world environmental exposure.

Investigating the behavioral and physiological responses of *Clarias gariepinus* to sub-lethal doses of cypermethrin is essential for early detection of environmental contamination and for understanding the broader ecological consequences of pesticide runoff. Behavioral and physiological biomarkers are cost-effective tools for environmental monitoring, providing early warning signs of sub-optimal environmental conditions (Hedayati et al., 2021). Moreover, such studies support the development of guidelines for safe pesticide use and contribute to sustainable aquaculture and ecosystem management in regions where agriculture and aquaculture coexist. Therefore, this study evaluated the behavioral and physiological responses of *Clarias gariepinus* to sub-lethal exposure of cypermethrin and discuss the implications of the observed effects for aquaculture, fish health, and environmental monitoring.

MATERIALS AND METHODS

Fish and Cypermethrin Sources: Juveniles of *Clarias gariepinus* of mixed sexes and fairly uniform sizes were obtained from a fish farm in Okitipupa, Ondo State, Nigeria, and transported in plastic containers to the outdoor holding tanks in the Teaching and Research Farm of the Department of Fisheries and Aquaculture Technology, Olusegun Agagu University of Science and Technology, Okitipupa. Fish were acclimated in the tanks for a period of two (2) weeks in dechlorinated tap water under prevailing weather conditions and natural photoperiods. During acclimation, fish were fed with a commercial feed (42% protein) at 5% body weight daily in two rations i.e. 7:00hrs and 17:00hrs (Ajibare and Ayeku, 2024). Feeding was stopped 24 hours prior to the commencement of the experiment. Cypermethrin was obtained at a concentration of 50g/L as a commercially available insecticide from an agrochemical outlet in Okitipupa.

Water Quality Monitor: Water quality properties (temperature, pH, electrical conductivity and dissolved oxygen) of the test solution and the control were monitored every 24 hours (Owolabi *et al.*, 2021), to ensure they are within suitable range for the growth of the fish. Fish were not fed during the experiment (Ayoola 2008).

Exposure of Fish to Cypermethrin (Sub-lethal Toxicity Bioassay): At the end of the acclimatization period, juvenile *Clarias gariepinus* with an initial mean weight of 3.62 ± 0.0 g were used for the sub-lethal toxicity bioassay. Based on results from a preliminary range-finding test, the 96-hour LC_{50} of cypermethrin (0.027ml/L) was determined and used to select sub-lethal exposure concentrations (Ali *et al.*, 2018; Amaeze *et al.*, 2020). A total of 150 juvenile fish were randomly distributed into fifteen (15) plastic aquaria ($42.5 \times 30.5 \times 22.5$ cm), each containing 50 L of dechlorinated water, at a stocking density of 10 fish per tank. The experiment consisted of five treatments (including a control) in triplicates. The fish were exposed to cypermethrin concentrations of 0.000 ml/L (control), 0.004 ml/L, 0.008 ml/L, 0.012 ml/L, and 0.016 ml/L. Fish were fed commercial pelleted feed at 5% of body weight per day, divided into two rations. The exposure period lasted for eight (8) days.

Behavioural Studies: Observations on behavioural responses were made after exposure (Ajibare and Ayeku, 2024). As a reference point for assessing morphological or behavioral changes, the control group was used for comparison with cypermethrin-exposed fish. Observable changes were recorded when they occurred in at least 10% of the fish within each test aquarium. The opercular ventilation frequency and tail fin beat rates were observed as beats per minute using a stopwatch. The opercular ventilation frequency/count and tail fin movement were determined twice daily at predetermined time intervals (Owolabi *et al.*, 2021). Observations were made for fishes in each aquarium and the mean recorded. The results were pooled and daily averages determined.

Mortality: Examination of the experimental set-up for fish mortality was made at the end of 4, 8 and 46 hours post exposure and then twice daily before termination of the experiment (Ajibare and Ayeku, 2024). Juveniles of *Clarias gariepinus* were certified dead when there was cessation in opercular movement and a gentle prodding elicited no response. The number of dead fish was recorded against the time of death in a tabular form in each treatment (Oluah *et al.*, 2020). Dead fish were immediately removed to avoid dissolved oxygen depletion (Kumari, 2020).

Quality Assurance/Quality Control: A standard operating procedures was carried out for sample collection, preparation and analysis. The use of laboratories and personnel that are accredited and certified for fish toxicology assessment were made mandatory to ensure that this research work met recognized quality standards. Proper sampling techniques were used to track samples accuracy. All equipment and instruments used in this research work were used to ensure accuracy and precision (Ajibare and Ayeku, 2024).

Statistical analysis: The statistical analysis was carried out using Statistical package for social sciences version 20. The data were expressed as mean $\pm$ standard deviation and multivariate analysis of variance was used to show significant variations at $p < 0.05$. Waller Duncan statistics was used to ascertain the source of variations at $p < 0.05$.

Results

Physico-chemical parameters of water: The effect of varying concentration of Cypermethrin on the physico-chemical properties of the exposed water tank was presented in Table 1. The highest value of pH was recorded in Treatment 4 (8.08 ± 0.35) while Control recorded the lowest value of pH (6.81 ± 0.30). Treatment 4 also recorded the highest value of Temperature ($28.50 \pm 0.76^\circ\text{C}$) and the lowest value was recorded in control ($28.00 \pm 0.53^\circ\text{C}$). The highest value of Dissolved Oxygen was recorded in Treatment 1 ($6.24 \pm 0.28\text{mg/L}$) while treatment 5 recorded the lowest value of Dissolved Oxygen ($5.48 \pm 0.96\text{mg/L}$). The highest value of Electrical Conductivity was recorded in Treatment 5 ($38.89 \pm 0.43\mu\text{Scm}^{-1}$) while Treatment 2 recorded the lowest value of Electrical Conductivity ($32.04 \pm 0.63\mu\text{Scm}^{-1}$). Generally, significant variation were recorded across the treatments except for Temperature.

Table 1: Water quality parameters of the exposed tanks

Parameters	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Temp $^\circ\text{C}$	28.00 ± 0.53^a	28.13 ± 0.35^a	28.25 ± 0.46^a	28.38 ± 0.74^a	28.50 ± 0.76^a
pH	6.81 ± 0.30^a	7.18 ± 0.34^b	7.40 ± 0.33^b	7.72 ± 0.17^c	8.08 ± 0.35^d
DO(mg/L)	6.24 ± 0.28^b	6.04 ± 0.71^b	5.83 ± 0.84^{ab}	5.62 ± 0.28^a	5.48 ± 0.96^a
EC(μScm^{-1})	33.63 ± 0.37^a	32.04 ± 0.63^a	35.34 ± 1.04^b	38.63 ± 0.55^c	38.89 ± 0.43^c

Means $\pm$ SD along the same row with heterogeneous superscript are significantly different ($p < 0.05$).

4.2 Behavioural Response of *Clarias gariepinus* Juveniles Exposed to Different Concentration of Cypermethrin

This study examined and presented the behavioural changes of *Clarias gariepinus* juveniles exposed to Cypermethrin in Table 2. The behavioural pattern of control were normal, all fins were moving well, there was no erratic movement and they fed well whereas Treatment 1 showed vertical positioning, gasping for oxygen, resting at the bottom e.t.c. Treatment 2 also showed loss of appetite, hyperactiveness, frequent surface to bottom movement, limited movement e.t.c. Treatment 3 showed hyperactiveness, vertical positioning, shooting or upright position of the barbel, resting at the bottom e.t.c. Treatment 4 exhibited frequent surface to bottom movement, spiral movement, hyperactiveness, vertical positioning, swimming at the bottom e.t.c (Table 2).

Table 2: Behavioural Changes of *C. gariepinus* exposed to cypermethrin

Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Normal	Vertical positioning, gasping for oxygen, resting at the bottom, horizontal positioning, hyperactiveness, limited movement, under appetite, reduced	Vertical positioning, gasping for oxygen, resting at the bottom, horizontal positioning, loss of appetite, hyperactiveness, under-activeness, frequent surface to bottom movement, limited movement, shooting/upright position of the barbell.	Vertical positioning, gasping for oxygen, resting at the bottom, horizontal positioning, loss of appetite, hyperactiveness, under-activeness, frequent surface to bottom movement, limited movement, shooting/upright position of the barbell.	Vertical positioning, hyperactiveness, under-activeness, gasping for oxygen, resting at the bottom, reduced appetite, horizontal positioning, shooting/upright position of the barbel, frequent surface to bottom movement, limited movement, holding out of the pectoral and pelvic fin, spiral movement, swimming at the bottom.

4.6 Mortality Rate

The effect of varying concentration of Cypermethrin on the mortality rate of *Clarias gariepinus* juveniles was presented in Table 3. The Table indicated that 0% mortality was recorded in Control (0.00±0.00ml), while 7 (23.33±5.77%), 19 (63.33±5.77%), 26 (86.67±5.77%), 28 (93.33±11.55%) mortality was recorded in Treatment 1, Treatment 2, Treatment 3 and Treatment 4 respectively.

Table 2: Mortality rate of *Clarias gariepinus* juveniles exposed to different concentration of Cypermethrin

Control		Treatment 1		Treatment 2		Treatment 3		Treatment 4	
N	%	n	%	n	%	N	%	n	%
0	0.00±0.00 ^a	7	23.33±5.77 ^b	19	63.33±5.77 ^c	26	86.67±5.77 ^d	28	93.33±11.55 ^d

Means±SD along the same row with different superscript are significantly different (p<0.05). n= number of fish; %= percentage of fish.

Discussion: The physico-chemical parameters of the water were assessed from samples collected from tanks containing fish exposed to varying concentrations of cypermethrin. Temperature, an important factor due to its influence on other water quality properties (Hussain et al., 2019), ranged from 28.00 ± 0.53°C to 28.50 ± 0.76°C across the exposed groups. Elevated water temperatures can accelerate chemical reactions, reduce oxygen solubility, and increase odour due to anaerobic processes (Xu et al., 2021). The pH values of water from the exposed tanks ranged between 7.18 ± 0.34 and 8.08 ± 0.35. pH is defined as the logarithm of the reciprocal of hydrogen ion activity at a given temperature. The variation in pH values could be attributed to fluctuations in carbon dioxide, carbonate, and bicarbonate concentrations in the water (Zarantoniello et al., 2021). Nevertheless, all pH values remained within the acceptable range of 6.5–8.5 (Hussain et al., 2019). The observed values for dissolved oxygen and electrical conductivity were consistent with the findings of Olufeagba (2022).

Behavioural changes observed in the exposed fish mirrored those reported in previous studies (Hoseini et al., 2019; Akter et al., 2020; Zarantoniello et al., 2021; Ajibare and Ayeku, 2024). Notably, hyperactivity during the first 12–24 hours post-exposure appeared to be an escape response to the toxic environment. Such hyperactivity is widely recognized as an early indicator of nervous system disruption due to pesticide toxicity, which affects both physiological and biochemical functions (Hussain et al., 2019). Similar behavioural symptoms have been documented by Hedayati et al. (2021) in common carp exposed to cypermethrin, including increased opercular movements, mucous secretion, jerky motion, side-floating, and erratic, fast swimming—indicative of central nervous and cardiovascular system distress.

Sharma et al. (2019) also reported comparable signs in *C. gariepinus*, such as rapid and erratic swimming, partial loss of equilibrium, intense opercular and pectoral fin activity, reduced feeding, fin haemorrhages, and skin damage—all of which were also observed in the present study. Velisek et al. (2018), in their study on metribuzin toxicity in common carp, recorded similar symptoms, including accelerated respiration, loss of movement coordination, and abnormal positioning. Abnormal behaviours such as incessant jumping, air gulping, restlessness, loss of equilibrium, increased opercular activity, surface-to-bottom movement, and sudden bursts of speed were consistent with observations reported by Ullah et al. (2018) and Opote et al. (2021). These behaviours suggest respiratory distress, likely resulting from cypermethrin-induced damage to the gills. As exposure time and concentration increased, the fish exhibited lethargy and reduced activity.

The mortality rate of juvenile *C. gariepinus* rose significantly with increasing concentration and duration of cypermethrin exposure. Respiratory impairment due to gill damage was likely a major cause, supporting the findings of Ullah et al. (2018) and Sharma et al. (2019) that pesticides adversely affect respiratory organs. Mortality may have occurred either through direct poisoning or indirectly by making the aquatic environment uninhabitable. In either case, cypermethrin was identified as the cause of death. Notably, the higher the concentration of cypermethrin, the greater the mortality rate. This supports the assertion by Hussain et al. (2019) that each toxicant has a threshold concentration, beyond which survival drastically decreases. Below this threshold lies the tolerance zone, while above it lies the zone of resistance. Increased exposure to cypermethrin also contributed to higher mortality, underscoring its high toxicity to juvenile *C. gariepinus*, even at low concentrations. Absorption of the toxicant through the gills or intestinal lining may have disrupted the fish's osmoregulatory functions, potentially impairing water quality parameters, behavioural patterns, growth, condition factor, haematological and biochemical indices, and ultimately, survival. Given the critical role of tissues and organs in fish physiology and metabolism, any functional impairment can have lethal consequences (Asifa et al., 2015).

Conclusion: The findings of this study confirm that cypermethrin is toxic to juvenile *Clarias gariepinus*. Observed behavioural alterations included hyperactivity, startled responses, rapid opercular movements, loss of equilibrium, skin discoloration, extension of pectoral and pelvic fins, abdominal swelling, increased mucus secretion, and periods of immobility preceding mortality. Exposure to sub-lethal concentrations of the toxicant led to significant changes in mortality rates, water physico-chemical parameters, and fish behavioural responses. Given the widespread use of insecticides, continued toxicity assessments involving diverse fish species and aquatic invertebrates are strongly recommended. Moreover, new formulations of insecticides should be evaluated under various environmental conditions to account for variables that could influence toxicity and serve as reference points for future studies. The indiscriminate use of insecticides, particularly near aquatic ecosystems, should be discouraged. Instead, environmentally sustainable alternatives, such as biological control methods, should be promoted. While the complete elimination of pesticide use may be impractical, the adoption of non-persistent and highly selective insecticides is advisable over the continued use of persistent, broad-spectrum chemicals. Regulatory authorities must intensify efforts to develop and enforce environmental policies that regulate insecticide use. Periodic reviews of such policies should be conducted to incorporate emerging scientific evidence and ensure the protection of aquatic life.

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Pre-Liminary Investigation of the Performance of Potato (*solanum tuberosum* L) Varieties using Different Polythene Bags in Nigeria

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Abstract

A study was conducted to determine the effect of bag sizes and variety on the growth and yield of potato. The research was conducted during the dry season farming of 2025 farming season at the Teaching and Research Farm of Department of Agricultural Science, Federal University of Education, Pankshin, Plateau State. Treatments consisted of 3 different sizes of empty polythene bags (U, empty urea bag, C, cement bag, and N, empty bag of NPK 20 10 10) and 3 potato varieties (J, Jelly, M, Madabel, C, Connect). Factors were combined to give 9 treatment combinations that were laid out in a 3³ split plot arrangement in a Randomized Complete Block Design (RCBD) and replicated 3 times. Data was subjected to Analysis of Variance (ANOVA) and means that were significantly different from each other were separated using LSD. Results revealed that wider bag size particularly urea bag (40 cm wide) consistently yielded significant vegetative, yield parameters and total yield (t/ha) for all the treatment combinations. Treatment Mu gave higher plant heights while the least plant heights were obtained in treatment Jn. Mu treatment gave more number of seed tubers per plant while Ju produced more ware tubers per plant. Total yield (t/ha.) showed that treatment Cou and Ju produced the highest yield of 29.6 t/ha and 29.4 t/ha respectively. It is concluded that planting potato in large bags is more beneficial than raising same in smaller bags. Treatment Mu produced more seed tubers per plant while treatments Cou and Ju produced more ware tubers per plant. Total yield (t/ha.) showed that treatments Cou and Ju produced 29.6 t/ha and 29.4 t/ha respectively. It is concluded that planting potato in larger bags produced more beneficial vegetative and yield of potato than raising same in smaller bags. Mu treatment produced more seed tubers per plant while treatments Cou and Ju produced more ware tubers per plant. Potato growers interested in seed multiplications should choose variety marabel to plant in urea bag while those interested in ware tubers (market size) should go for connect varieties planted in urea bag. For total yield per hectare, connect variety planted in urea bag is the option.

Key words: Empty urea bag, Empty NPK 20 10 10, Empty cement bag, seed tubers. Ware tubers

INTRODUCTION: In Nigeria, particularly on the Plateau, potato farming plays a crucial role in the livelihood of many farmers. However, traditional farming methods face several challenges, including limited arable land, soil degradation, pest infestations, and unpredictable weather patterns exacerbated by climate change (Masvodka and Mapuwei, 2019; Bello and Mohammed, 2022).

These challenges have necessitated the exploration of innovative and sustainable farming techniques to enhance potato production and ensure food security (Nwosu and Onuoha, 2022; Eze, and Uka, 2021; Nguyen and Tran, 2021). One such innovative technique is the use of polythene bags for potato cultivation (Mowers *et al.*, 2023).

This method, often referred to as "bag gardening," involves growing potatoes in large polythene bags filled with soil or other growing media. Bag gardening offers several potential benefits, including efficient use of space, improved soil management, better pest control, and enhanced crop yields (Oyewole and Obioha; 2020; Jones and Cooper, 2018; Davis and Kumar, 2020). It is particularly advantageous in areas with limited access to fertile land or where soil conditions are not ideal for traditional farming (Nwosu and Onuoha, 2022; Adesina *et al.*, 2020). Conventional farming practices often involve the extensive use of chemical inputs, which can degrade soil health and have long-term environmental impacts. These issues have led to suboptimal yields, threatening food security and the livelihoods of farmers.

There is a growing need for sustainable farming methods that can enhance productivity while minimizing ecological harm. Innovative agricultural practices such as the use of polythene bags for potato cultivation have been explored to address the over use of synthetic chemical and limited space for farming. Despite the potential benefits, there is limited empirical data on the performance of potatoes grown using polythene bags in Nigeria. This gap in knowledge necessitates a preliminary investigation to assess the viability and effectiveness of this cultivation method in the local context. For this reason, the main objective of this study is to evaluate the performance of potatoes grown using polythene bags, addressing key issues related to growth, yield, resource utilization and economic viability. While the specific objectives were; (a) assess the growth and performance of potatoes cultivated in polythene bag and (b) evaluate the yield quantity of potatoes grown in polythene bags.

RESEARCH METHODOLOGY: The treatments consisted of 3 varieties of potato (Connect, Co; Jelly, J; Marabel, M; 2 empty bags of fertilizer, Urea, U (40 cm wide). NPK 20, 10,10, N (20 cm wide) and 1 empty bag of cement Ce (30 cm wide).

The treatments were combined to give a total of 9 treatment combinations as follows: Jce (variety Jell planted in empty cement bag), Mu (Marabel variety planted in empty urea bag), Mce (Marabel variety planted in empty cement bag), Cou (variety Connect planted in empty urea bag), Mn (Marabel variety planted in empty NPK fertilizer bag), Con (Connect variety planted in empty NPK fertilizer bag), Coce (Connect variety planted in empty cement bag), Jn (variety Jelly planted in empty NPK fertilizer bag) and Ju (variety Jell planted in empty urea bag). The treatments were laid out in a 3³ split plot arrangement in a randomized complete block design (RCBD) and replicated three (3) times making a total of 27 plots.

RESULTS

Effect of different bag sizes and variety on plant height and number of leaves of potato.: Results of effect of bag sizes and variety on plant height and number of leaves of potato are presented in Table 1. Results revealed that

plant heights and number of leaves varied significantly ($p \leq 0.05$) affected across treatments at different weeks after planting (WAP). Result at 4WAP showed that treatments Mu had the highest plant height of 19.3 cm while treatments Cou and Ju produced the same number of plant height (18.0 cm) at 4WAP. Treatment Mn produced the least plant height of 13.3 cm. Results showed similar pattern in plant heights at 6 and 8 WAP.

Similarly, larger bags produced a greater number of leaves of potato compared to smaller bags. Treatment Cou had the same number of leaves (10) with treatment Ju at 4 WAP. This was followed by treatment Mu with 9 number of leaves. The least (6) number of leaves were recorded in treatment Mce as well as treatment Coce. Results showed similar trend across all the periods of data collection

Table 1: Bag sizes and variety on plant height and number of leaves of potato

<i>Treatments</i>	Plant height (cm)			Number of leaves		
	4WAP	6WAP	8WAP	4WAP	6WAP	8WAP
<i>Jce</i>	15.5	19.5	22.0	7	10	15
<i>Mu</i>	19.3	22.0	25.0	9	14	16
<i>Mce</i>	14.5	16.2	20.0	6	9	14
<i>Cou</i>	18.0	20.1	23.5	10	15	20
<i>Mn</i>	13.3	14.5	17.6	7	11	14
<i>Con</i>	14.3	16.0	18.0	7	12	15
<i>Coce</i>	10.8	12.6	14.0	6	9	14
<i>Jn</i>	14.2	15.1	28.0	8	16	23
<i>Ju</i>	18.0	21.5	24.0	10	16	24
<i>LSD (0.05)</i>	0.321	0.397	0.321	0.321	2.99	5.20
<i>F-pv</i>	<0.029	< 0.045	< 0.029	< 0.029	< 0.029	< 0.018

Key: LSD (0.05): fisher's least significant; F-pv = probability value; Jce = variety Jelly planted in empty cement bag; Mu = Marabel variety planted in empty urea bag; Mce = Marabel variety planted in empty cement bag; Cou = Connect variety planted in empty urea bag; Mn = Marabel variety planted in empty NPK bag; Con = Connect variety planted in empty NPK bag; Coce = Connect variety planted in empty cement bag; Jn = variety Jelly planted in empty NPK bag; Ju = Jelly variety planted in empty urea bag.

Effect of bag sizes and variety on stem girth of potato: The results of effect of bag size and variety on stem girth are presented in Table 2. Results depicted high significance ($p \leq 0.05$) effect among larger bag and smaller bag sizes. At 4 WAP, the larger stem girth (3.8 cm) were obtained in treatment Ju followed by treatment Mu with 3.6 cm. The least stem girth (2.3 cm) were obtained in treatment Jn. Results showed similar trend across all the period of data collection.

Table 2: Bag sizes and variety on stem girth of potato

Treatment	Stem girth (cm)		
	4WAP	6WAP	8WAP
Jce	3.1	4.3	5.7
Mu	3.5	4.7	5.8
Mce	3.2	4.3	5.5
Cou	3.6	4.9	5.8
Mn	2.4	3.9	4.6
Con	2.5	3.7	4.7
Coce	3.1	4.1	5.8
Jn	2.3	3.8	4.3
Ju	3.8	4.9	5.7

LSD (0.05)	0.010	0.012	0.014
F-pv	< 0.045	< 0.025	< 0.028

Key: LSD (0.05): fisher's least significant; F-pv = probability value; Jce = variety Jelly planted in empty cement bag; Mu = Marabel variety planted in empty urea bag; Mce = Marabel variety planted in empty cement bag; Cou = Connect variety planted in empty urea bag; Mn = Marabel variety planted in empty NPK bag; Con = Connect variety planted in empty NPK bag; Cce = Connect variety planted in empty cement bag; Jn = variety Jelly planted in empty NPK bag; Ju = Jelly variety planted in empty urea bag.

Effect of bag sizes on yield parameters and yield of potato crop.: Results on number of seed tubers per plant, number of ware tubers per plant, weight (kg) of seed tubers per plant, weight (kg) of ware tubers per plant and total yield (t/ha.) are presented in Table 3. Results indicated high significant ($p \leq 0.05$) effect of. Number of seed tubers per plant were highest (15) in treatment Mu which was followed by treatment Ju with 14 number of seed tubers per plant. The least (4) number seed tubers per plant were obtained in both treatments Con and Cce. Similarly, larger bags produced more number of ware tubers per plant compared to smaller size bags. Treatments Cou and Ju had the same number (8) of ware tubers per plant. This was followed by treatment Mu with 6 number of ware tubers per plant. The least number (2) of ware tubers per plant were obtained in treatments Coc.

Effect of bag sizes and variety on the weight of seed tubers and ware tubers per plant showed significant ($p \leq 0.05$) effect among treatment across all the periods of data collection. Larger size bags produced larger seed tubers and ware tubers, weight per plant relative to the smaller bags for all varieties of potato tested. Treatment Ju produced seed tubers with bigger (6.6 kg) sizes which was followed by treatment Mu with 5.6 kg per plant. The least seed weight (2.1 kg) per plant was obtained in treatment Jce. Similarly, larger bag sizes yielded bigger ware tuber weight per plant compared to the smaller bag sizes. Treatment Ju had bigger (8.3 kg) ware tubers per plant. This was closely followed by treatment Cou with 7.6 kg per plant. The least ware weight per plant were obtained in treatment Jce with 3.0 kg weight per plant. Yield (t/ha.) showed that treatment Cou yielded the highest (29.6 t/ha.) potato yield which was followed by treatment Ju with 29.4 t/ha. per hectare. The least (20.2 t/ha) yield were obtained in treatment Jn

Table 3: Yield parameter and yield of potato.

Treatment	Number of seed tubers per plant	Number of ware tubers per plant	Weight of seed tubers per plant (Kg)	Weight of ware tubers per plant (Kg)	Yield (T/ha)
Jce	8	3	2.1	3.0	20.2
Mu	15	6	4.3	5.3	28.2
Mce	6	4	3.2	4.2	21.4
Cocu	10	8	5.6	7.6	29.6
Mn	5	4	5.3	7.4	23.3
Con	4	3	3.5	4.3	23.2
Coc	4	2	3.3	4.2	21.6
Jn	6	3	4.2	5.4	22.1
Ju	14	8	6.6	8.3	29.4

Key: LSD (0.05): fisher's least significant; F-pv = probability value; Jce = variety Jelly planted in empty cement bag; Mu = Marabel variety planted in empty urea bag; Mce = Marabel variety planted in empty cement bag; Cou = Connect variety planted in empty urea bag; Mn = Marabel variety planted in empty NPK bag; Con = Connect variety planted in empty NPK bag; Cce = Connect variety planted in empty cement bag; Jn = variety Jelly planted in empty NPK bag; Ju = Jelly variety planted in empty urea bag.

Discussion: The study revealed that plant height, number of leaves, and stem girth were significantly ($p \leq 0.05$) influenced by the size of the growing container and the variety of potato planted. Overall, plants grown in the larger urea bags (40 cm wide), particularly under the JU (Jelly variety planted in empty urea bags) and Cou (Connect variety grown in empty urea bags) and Mu (marabel variety planted in empty urea bags) treatments consistently exhibited superior vegetative growth. The enhanced performance in the larger bags can be attributed to better root expansion due to the increased space, which allowed for improved nutrient and water uptake, greater aeration, and reduced root competition. This created a more favorable microenvironment for plant growth, resulting in taller plants with more leaves and stronger stems capable of supporting vigorous development. These findings are consistent with the reports of Hossain, 2005; Brown and Williams, 2021; Donnelly and Munger, 2003 and Miller and Brown, 2021, who emphasized that physical space and nutrient availability are critical factors in promoting healthy vegetative growth in potatoes. In contrast, plants grown in smaller cement bags (20 cm wide), such as Jce (Jelly variety grown in cement bags) and Mce (Marabel variety planted in cement bags) showed comparatively lower growth across all parameters, with reduced heights, fewer leaves, and thinner stems, suggesting that limited root zone space restricted their development. Plants cultivated in medium-sized NPK bags (30 cm wide), like Cn (Connect variety grown in NPK bags) and Mn (Marabe variety planted in empty NPK bags), demonstrated intermediate growth performance, indicating that while moderate space supported better growth than smaller bags, it was still less effective compared to the larger urea bags.

Overall, the results affirm that larger container size combined with variety to promote better plant height, leaf production, and stem girth. This is in line with the findings of Kanwal and Shoaib 2006; Ibe and Aja, 2021, who noted that environmental factors like space and nutrients significantly influence plant growth. Following the vegetative growth observations, the yield data further confirmed the critical role of container size and variety selection on growth performance and yield of potato. Plants grown in the largest urea bags (40 cm wide), particularly

under Mu (Marabel in urea bag) and Ju (Jelly in urea bag) treatments, recorded the highest number of seed tubers per plant while ware tubers were better under treatments Cou and Ju. The total yield showed that treatments Cou gave 29.6 t/ha. while treatment Ju gave a yield of 29.4 t/ha. This yield is far above the average yield of 3.1 to 3.8 in the Nigeria. This results therefore come as a cheering news nearing the yield from other African countries such as Kenya and Ethiopia who have reported average yield of over 15 t/ha. while South Africa has reported an average yield of over 30 t/ha. of potato yield (Zework; Tefera; Solomon and Asmamaw, 2024). This is an indication that raising of potato in container can be of great economic value to the farmers. The researchers concluded that planting potato in larger bags is more beneficial in wider urea bags. Variety marabel produced more seed tubers per plant while variety connect and jelly produced more ware tubers per plant inside urea bags. Connect planted in urea bags gave the highest plant yield per hectare. Potato growers interested in seed multiplication should go for urea bags to plant marabel while those interested in ware tubers (market size) adopt jelly planted in urea bags. For total yield per hectare, the choice is connect variety planted in urea bags.

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Growth Response of *Khaya Senegalensis* and *Parkia Biglobosa* using Rotten Cassava Peel and Grinded Cassava as an Organic Fertilizer

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ABSTRACT

This study determines the growth response of *Khaya senegalensis* and *Parkia biglobosa* seedling using cassava peel and grinded cassava as an organic fertilizer. Experimental design used was 2x3x10 factorial using (three planting media: rotten cassava peel, grinded cassava and control). The experiment was arranged in a Completely Randomized Design (CRD) with six (6) treatments and ten (10) replicates for the period of six weeks. Parameters taken were seedlings height (m), stem girth diameter (mm) and number of leaves. Data collected was subjected to the Analysis of Variance (ANOVA) and means separation using Least Significant Difference (LSD). Result of week three revealed that height mean was highest (175.9) in grinded cassava, followed (171.1) rotten cassava peel and lowest (141.1) control in *Parkia biglobosa*. Stem girth, *Parkia biglobosa* has highest mean (0.71) in grinded cassava, followed (0.60) grinded cassava and lowest in control (0.40) both in *Khaya senegalensis*. Number of leaves has highest mean in rotten cassava peel (13.2), followed control (12.8) both *Parkia biglobosa* and lowest mean (0.4, 0.4, 0.4) in rotten cassava peel, grinded cassava and control respectively in *Khaya senegalensis*. Result of week six revealed that height mean was highest (33.32) in rotten cassava peel, followed by control (30.2) in *Parkia biglobosa* and lowest mean (23.4) grinded cassava in *Khaya senegalensis*. Stem girth, has highest mean (1.03) in rotten cassava peel, followed by control (0.87) both in *Parkia biglobosa* and lowest mean in control (0.40) grinded cassava in *Khaya senegalensis*. Number of leaves has highest mean in rotten cassava peel (20.3), followed control (19.1) both *Parkia biglobosa* and lowest mean (11.0, 11.0, 11.0) in rotten cassava peel, grinded cassava and control respectively in *Khaya senegalensis*. Rotten cassava peel mixture emerged taint to performed excellently in all the treatments and species wise, increase soil nutrient, and fertility that support growth of species and impact on structure/aeration. It is recommended that, Organic fertilizers can be adopted as a treatment when raising *Khaya senegalensis* and *Parkia biglobosa* seedlings for fodder crop production.

Keyword: *Khaya senegalensis*, *Parkia biglobosa*, Organic fertilizer and growth parameters

INTRODUCTION: *Khaya senegalensis* is a deciduous evergreen tree that belongs to the Meliaceae family with common name African mahogany tree. *Khaya senegalensis* is a tree, 15 – 30m high up to 1m in diameter with a clean bole to 8 – 16m, buttress not prominent or absent, bark dark grey, with small thin, reddish, tinged scale, slash dark pink to bright crimson, exuding a red sap. (Orwa *et al.*, 2009). *Khaya senegalensis* comprises four (4) species in mainland Africa of which one or two of them are endemic to the Comoros and Madagascar. *Khaya* species strongly resemble each other in flower and fruit, and differences are more prominent in their leaflet. (Arbonnier, 2004). Some of the species in the genus of *Khaya* are: *Khaya senegalensis*, *Khaya grandifolia*, *Khaya ivorensis*, *Khaya anthotheca*. Foliage of *K. senegalensis* is typically used as a fodder source in combination with that from a number of other trees of the African savannah, such as *Faidherbia albida* and *Balanites aegyptiaca* (Walter 2001; Mamman *et al.*, 2023). Spatial and temporal proximity of *K. senegalensis* to other fodder yielding trees is a key factor in determining the value of individual trees as fodder sources (Wittig and Hahn-Hadjali 2001). The bark of *K. senegalensis* is also useful for livestock, being used to treat a range of diseases including liver fluke, ulcers and internal ailments associated with mucous diarrhoea (World Agroforestry Centre 2004).

Parkia biglobosa (named after the famous Scottish botanist and surgeon Mungo Park by Robert Brown in 1926) has long been widely recognized as an important indigenous multipurpose fruit tree whose uses include food, medicine, manure, tannin, shade, wind-breaks, bee food, stabilization of degraded environment, livestock feeds, fuel, fibre, fish poison and several other domestic uses (Sadiku, 2010). African locust bean, as it is commonly known, is a tree legume that belongs to the family MIMOSOIDAE. It is a wide spread savannah tree. The locust beans are the mature seeds that come from the parkia pods. The pods are harvested and processed into the fermented product known as „Iru“, „Dawadawa“ and „Ogiri“ in the Yoruba, Hausa and Igbo Languages respectively (Sadiku, 2010). It is characterized by its fruits, which are elongated pods, 5-11 inches long, legume tree that reaches 20-30 m high, cylindrical trunk that reaches 130m in diameter, The leaves are alternate and bipinnately compound, 30-40 m long, bearing up to 17 pairs of pinnae. and found in clusters. It flowers from December to March and brings out fruits from February to July. The immature fruits are green and brown when it is mature. The mature seeds are made up of husk which is embedded in dark brown pod (Orwa *et al.*, 2009; Koornneef, *et al.*, 2016). Fertilization with organic to nursery or forest seedlings is one of the most crucial factors with a positive effect on seedling quality, performance and establishment (Aluko *et al.*, 2014). Inadequate management of nursery soil can result in depletion of soil fertility and corresponding reduction in seedlings growth. However, efficient supply of nutrients in proper proportion leads to efficient growth and development of seedlings (Rafiqul *et al.*, 2004). Organic fertilizer (Cassava peel and grinded cassava) is rich in microbial diversity, containing different species of bacteria, protozoa and yeast (Randhawa and Kullar, 2011). The availability of this nutrients to plant contributes to growth and yield. Deficiency of mineral element to plant is evident to poor yield (Raines, 2011). Nitrogen is outstanding among other nutrients; it is required in larger quantities by most crops (Margues *et al.*, 2006). Maintaining adequate fertility of forest nursery soils is of paramount importance to ensure production of high-quality planting stock.

MATERIALS AND METHODS: The study was conducted at the Nursery unit of the Department of Forestry and Wildlife Management of Modibbo Adama University Yola located between Latitudes; 9° 20' 32''N and 9° 20' 36''N and Longitudes; 12° 30' 18''E and 12° 30' 21''E. Adamawa State falls under the Sudan, Southern and Guinea Savannah types of vegetation and it experiences distinct dry and wet seasons with temperature ranges from 27°C to 40°C and relative humidity vary with seasons ranges from 20-80% (Adebayo and Tukur, 2010). The wet or rainy season lasts from April to October, and is characterized by single maxima in August and September. During this season, the moisture laden south west trade wind from the Atlantic Ocean blows over the area. Seventy percent of the total rainfall in the area falls within four months of May-September (Adebayo, 2020).

DATA COLLECTION: Fresh seeds of *Khaya senegalensis* and *Parkia biglobosa* seeds was collected from a mother tree at Girei Local Government. *Gliricidia sepium* cassava Peel was collected mixed with topsoil and allowed to rotten, cassava was grinded into powdered form mixed with topsoil. Both rotten cassava peel and grinded cassava were then filled into the polythene bags. After germination (8days), the seedlings were carefully pricked from the germination bed and then transplant into the polythene bags filled with sand containing rotten cassava peel and grinded cassava. Data collection on the seedlings commenced three Weeks after Planting (WAP). Parameters taken were height using meter rule, diameter using veneer caliper and number of leaves by counting.

STUDY DESIGN: The experiment was arranged in a Completely Randomized Design (CRD) with six (6) treatments and ten (10) replicates. Stem diameter (mm), seedlings height (m) and leaf production was assessed. The data collected was subjected to the Analysis of Variance (ANOVA) and the means were separated using LSD.

RESULTS

Growth response of Grinded Cassava and Rotten cassava on the growth of *Parkia biglobosa* and *Khaya Senegalensis* Seedlings for Week Three: Table 1 showed growth response of grinded cassava and rotten cassava peel on the growth of two seedlings. The average plant height for *Khaya senegalensis* seedlings was highest in the Rotten cassava treatment (14.78m) and lowest in the control treatment (13.00m). The grinded cassava treatment had a plant height of 13.71m. For *Parkia biglobosa* seedlings, the average plant height was highest in the grinded cassava treatment (17.11m) and lowest in the control treatment (12.70m). The rotten cassava treatment had a plant height of 13.50 m. The average stem girth for *Khaya senegalensis* seedlings was highest in the rotten cassava treatment (0.53m) and lowest in the grinded cassava treatment (0.41m). The control treatment had a stem girth of 0.57m. For *Parkia biglobosa* seedlings, the average stem girth was highest in the grinded cassava treatment (0.62 m) and lowest in the control treatment (0.52 m). The rotten cassava treatment had a stem girth of 0.51 m. The average number of leaves for *Khaya senegalensis* seedlings was highest in the rotten cassava treatment (4.20) and lowest in the control treatment (4.00). The grinded cassava treatment had a number of leaves of 4.00. For *Parkia biglobosa* seedlings, the average number of leaves was highest in the rotten cassava treatment (16.90) and lowest in the grinded cassava treatment (15.20). The control treatment had a number of leaves of 14.90.

Table 1: Growth response of Rotten cassava peel and Grinded cassava on the growth of *Parkia biglobosa* and *Khaya Senegalensis* Seedlings for Week Three

Replicate	(Rotten cassava) <i>Khaya senegalensis</i>	(Grinded Cassava) <i>Khaya senegalensis</i>	(control) <i>Khaya senegalensis</i>	(Rotten cassava) <i>Parkia biglobosa</i>	(Grinded Cassava) <i>Parkia biglobosa</i>	(control) <i>Parkia biglobosa</i>
1	15.5	15.5	15	14.4	22.1	14
2	14.6	13.5	14.3	13.4	16.5	17
3	15.6	13.2	14.2	12	17.5	11
4	17.1	12.5	13.9	13.8	17.6	15.8
5	15	14	14.5	13.5	16.5	12
6	14.1	15.5	14.3	14.8	16.6	10
7	15	10.5	14.2	10.6	17.4	10
8	13.9	12.3	13.9	14.7	15.8	11.2
9	14.5	12.5	12.8	13	19.2	11
10	12.5	10.5	10	14.8	11.9	15
Sum	155.5	146.6	156.1	171.1	175.9	141.1
Mean	15.55	14.66	15.61	17.11	17.59	14.11
CO-VARIANCE	2.57	1.45	0.19	11.44	0.83	4.41

Replicate	(Rotten cassava) <i>Khaya senegalensis</i>	(Grinded Cassava) <i>Khaya senegalensis</i>	(control) <i>Khaya senegalensis</i>	(Rotten cassava) <i>Parkia biglobosa</i>	(Grinded Cassava) <i>Parkia biglobosa</i>	(control) <i>Parkia biglobosa</i>
1	0.6	1	0.4	0.5	0.5	0.6
2	0.5	0.5	0.4	0.5	0.9	0.5
3	0.3	0.6	0.3	0.5	0.8	0.6
4	0.5	0.4	0.4	0.5	0.5	0.5
5	0.5	1	0.4	0.5	0.5	0.5
6	0.6	0.4	0.3	0.5	0.6	0.5
7	0.4	0.5	0.4	0.5	0.5	0.5
8	0.9	0.4	0.5	0.6	0.8	0.5
9	0.4	0.4	0.6	0.5	0.5	0.4
10	0.6	0.5	0.4	0.5	0.6	0.6
Sum	5.6	6.0	4.0	5.5	7.1	5.1
Mean	0.56	0.6	0.4	0.55	0.71	0.51

CO-VARIANCE	3.796	2.855	1.823	28.796	21.846	28.396			
Number of leaves									
Replicate	(Rotten cassava) <i>Khaya senegalensis</i>	(Grinded Cassava) <i>Khaya senegalensis</i>	(control) <i>senegalensis</i>	<i>Khaya</i>	(Rotten cassava) <i>Parkia biglobosa</i>	(Grinded Cassava) <i>biglobosa</i>	<i>Parkia</i>	(control) <i>biglobosa</i>	<i>Parkia</i>
1	4	4	4		17	18		17	
2	4	4	4		16	13		16	
3	4	4	4		17	14		14	
4	4	4	4		17	15		13	
5	4	4	4		22	16		18	
6	4	4	4		12	14		15	
7	5	5	5		16	15		14	
8	4	4	4		15	16		14	
9	5	5	5		20	15		14	
10	4	4	4		17	16		17	
Sum	40	40	40		132	127		128	
Mean	0.4	0.4	0.4		13.2	12.7		12.8	
CO-VARIANCE	0.032	0.034	0.034		0.051	0.034		0.119	

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Plant height	Between Groups	131.979	5	26.396	7.383	.000
	Within Groups	193.054	54	3.575		
	Total	325.033	59			
Stem girth	Between Groups	.245	5	.049	2.472	.044
	Within Groups	1.072	54	.020		
	Total	1.317	59			
Number of leaves	Between Groups	2041.933	5	408.387	206.102	.000
	Within Groups	107.000	54	1.981		
	Total	2148.933	59			

Growth response of Grinded Cassava and Rotten cassava on the growth of *Parkia biglobosa* and *Khaya Senegalensis* Seedlings for Week Six

Table 2 showed growth response of grinded cassava and rotten cassava on the growth of *Parkia biglobosa* and *Khaya senegalensis* seedlings for week six. The average plant height for *Khaya Senegalensis* seedlings was highest in the rotten cassava treatment (23.35 m) and lowest in the grinded cassava treatment (23.10 m). The control treatment had a plant height of 23.30 m. For *Parkia biglobosa* seedlings, the average plant height was highest in the rotten cassava treatment (33.22 m) and lowest in the grinded cassava treatment (26.50 m). The control treatment had a plant height of 26.80 m.

The average stem girth for *Khaya senegalensis* seedlings was highest in the control treatment (0.82 m) and lowest in the grinded cassava treatment (0.70 m). The rotten cassava treatment had a stem girth of 0.79 m. For *Parkia biglobosa* seedlings, the average stem girth was highest in the rotten cassava treatment (1.10 m) and lowest in the grinded cassava treatment (0.70 m). The control treatment had a stem girth of 0.91m.

The average number of leaves for *Khaya senegalensis* seedlings was highest in the grinded cassava treatment (11.30) and lowest in the rotten cassava treatment (10.60). The control treatment had a number of leaves of 11.30. For *Parkia biglobosa* seedlings, the average number of leaves was highest in the rotten cassava treatment (26.10) and lowest in the grinded cassava treatment (19.30). The control treatment had a number of leaves of 21.30.

Table 2: Growth response of Grinded Cassava and Rotten cassava on the growth of *Parkia biglobosa* and *Khaya Senegalensis* Seedlings for Week Six

Plant Height								
Replicate	(Rotten cassava) <i>Khaya Senegalensis</i>	(Grinded Cassava) <i>Khaya Senegalensis</i>	(control) <i>Khaya Senegalensis</i>	(Rotten cassava) <i>Parkia biglobosa</i>	(Grinded Cassava) <i>Parkia biglobosa</i>	(control) <i>Parkia biglobosa</i>		
1	25	25	24	35.2	30	35		
2	25	23	24	31	26	26		
3	22	23	26	30	32	25		
4	25	23	25	30	27	25		
5	21	21	22	30	32	34		
6	25	22	23	30	25	22		
7	25	22	24	37	22	22		
8	23	23	24	40	21	24		
9	22	26	20	32	25	31		
10	21	23	21	37	25	24		
Sum	245	234	237	333.2	288	302		
Mean	24.5	23.4	23.7	33.32	28.8	30.2		
CO-VARIANCE	0.88	1.15	0.81	43.22	8.42	20.42		

Stem girth							
Replicate	(Rotten cassava) <i>Khaya Senegalensis</i>	(Grinded Cassava) <i>Khaya Senegalensis</i>	(control) <i>Khaya Senegalensis</i>	(Rotten cassava) <i>Parkia biglobosa</i>	(Grinded Cassava) <i>Parkia biglobosa</i>	(control) <i>Parkia biglobosa</i>	
1	0.9	0.7	0.9	1.1	0.7	1.1	

2	0.8	0.7	0.9	1.1	0.7	1.1
3	0.8	0.7	0.9	1.1	0.7	1.1
4	0.9	0.7	0.9	1.2	0.7	1.2
5	0.9	0.7	0.8	1.1	0.7	1.1
6	0.9	0.7	0.9	1.1	0.7	0.1
7	0.9	0.7	0.5	1.1	0.7	0.1
8	0.9	0.7	0.6	1.1	0.7	1.1
9	0.9	0.7	0.9	1.1	0.7	1.1
10	0.9	0.7	0.9	1	0.7	1.1
Sum	8.1	7.0	8.1	10.3	7.1	8.7
Mean	0.81	0.7	0.81	1.03	0.71	0.87
CO-VARIANCE	0.032	0.034	0.034	0.051	0.034	0.119

Number of leaves						
Replicate	(Rotten cassava) <i>Khaya senegalensis</i>	(Grinded Cassava) <i>Khaya senegalensis</i>	(control) <i>Senegalensis</i>	<i>Khaya</i>	(Rotten cassava) <i>Parkia biglobosa</i>	(Grinded Cassava) <i>Parkia biglobosa</i>
1	11	11	11		29	22
2	11	11	11		15	22
3	12	12	12		25	20
4	12	12	12		25	19
5	11	11	11		30	20
6	11	11	11		24	18
7	11	11	11		30	17
8	11	11	11		24	18
9	11	11	11		29	17
10	11	12	12		30	20
Sum	110	110	110		203	156
Mean	11.0	11.0	11.0		20.3	15.6
CO-VARIANCE	3.79	4.65	3.83		11.98	6.76

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Plant height	Between Groups	757.287	5	151.457	15.146	.000
	Within Groups	539.981	54	10.000		
	Total	1297.268	59			
Stem girth	Between Groups	1.145	5	.229	6.081	.000
	Within Groups	2.034	54	.038		
	Total	3.179	59			
Number of leaves	Between Groups	2117.950	5	423.590	70.664	.000
	Within Groups	323.700	54	5.994		
	Total	2441.650	59			

DISCUSSION: The increment of height, stem girth, and number of leaves of *Khaya senegalensis* and *Parkia biglobosa* seedlings used in potting mixture treated with rotten cassava peel, grinded cassava and control as an organic fertilizer showed variations in the growth parameters measured. The results from height of rotten cassava and control treatments were significant ($p < 0.05$) in *Khaya senegalensis*, also grinded cassava and control treatments was significant ($p < 0.05$). The results reveal rotten cassava is effective potting mix for *Khaya senegalensis* while grinded cassava is effective in *Parkia biglobosa* seedlings than the control in week three. Furthermore, week six results show significant ($p > 0.05$) in *Khaya senegalensis* and not significant in *Parkia biglobosa* seedlings ($p < 0.05$) mix with rotten cassava peel and grinded cassava. The difference between stem girth rotten cassava and grinded cassava treatments was significant ($p < 0.05$). This suggests that rotten cassava is more effective potting mix for *Khaya senegalensis* seedlings than grinded cassava. Grinded cassava and control treatments was not significant ($p > 0.05$) for *Parkia biglobosa*. The results of height and stem girth for *Khaya senegalensis* are significant and agree with the study of (Arnold, 2004; Mamman et al., 2023), they reported that organic fertilizer gradually release more nutrients to species over a longer time, enabling growth. Also, rotten cassava peel and grinded cassava shows significant at ($p < 0.05$). This enable rotten cassava to be more effective potting mix for *Parkia biglobosa* seedlings than grinded cassava in week six. Application of rotten cassava peel and grinded cassava in relation to control responded differently on the number of leaves at ($p > 0.05$) in *Khaya senegalensis* and *Parkia biglobosa*. The results showed that there is a significant difference between rotten cassava peel and grinded cassava. Rotten, grinded and control recorded highest mean in *Parkia biglobosa* and lowest in *Khaya senegalensis*. This shows the essentiality of cassava as organic fertilizer. This result is in conformity with the study of (Mamman et al., 2023), which indicated that species treated with organic fertilizer is best for growth. Week six revealed that rotten cassava peel, grinded cassava and control were significant ($p < 0.05$) in potting mix for *Parkia biglobosa* seedlings, which recorded highest in number of leaves than grinded cassava lowest. This could also be as a result of comparatively higher rotten cassava peel concentration in potting mixture treated with *Parkia biglobosa*, which is more of an enhancement in the vegetative growth of seedlings.

CONCLUSION: In conclusion, results of this study revealed that all treatments applied were valuable sources of organic fertilizer for the growth of *Khaya senegalensis* and *Parkia biglobosa*. They greatly improved growth performance of plants. Seedling treatment with rotten cassava peel demonstrates better growth in height, stem girth

and number of leaves in both species. The results also attest that both species can grow for successful plantation establishment, use for domestic consumption based on the objective of management.

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Efficacy of Botanicals and Synthetic Insecticide Products against Maize Weevils (*Sitophilus zeamais* L.) Infestation on Maize in Ikwo L.G.A. Ebonyi State, Nigeria

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ABSTRACT

This experiment was conducted at the Crop and Soil Science Laboratory of the Department of Agriculture, Alex Ekwueme Federal University, Ndufu-Alike, (AE-FUNAI) in 2023 to study the efficacy of Neem (*Azadirachta indica*), Eucalyptus (*Eucalyptus globulus*) and phosphine against maize weevils (*Sitophilus zeamais* L.) infestation on stored maize. The treatments consisted of plant powders at two different levels (2.5 g/kg and 5 g/kg) with a fumigant (phosphine at 0.01 g/kg) and a control. There were ten (10) treatment combinations replicated four times and laid out in a complete randomize design (CRD). Infested maize seeds were source from local market and cultured in the lab under ambient room temperature. Clean maize seeds were sourced from the Institute of Agricultural Research (IAR), Zaria. Data was collected on Percent mortality and percent repellence. All collected data were subjected to analysis of variance (ANOVA) and means were compared using Bonferroni test. The results revealed that Eucalyptus 2.5 g/kg and phosphine 0.01 g/kg significantly influenced high mortality of *Sitophilus zeamais* that resulted to lesser seed damage and weight loss. The leaf powders had significantly ($P \leq 0.05$) recorded high percentage repellence effect, which resulted to less percentage F1 generations emergence. Based on these findings therefore, higher percentage insect mortality, and higher repellence percentage as well as lower emergence of F1 generation, was achieved with application of botanicals serving as a good replacement for synthetic insecticides. Further study is suggested to make valid recommendation to farmers, as well as ascertain shelf-life after treatment.

Keyword: Maize, Insect pest, Storage, Botanicals, Protection

INTRODUCTION: Maize (*Zea mays* L.) is the most vital food and income crop for millions of rural farm households. It belongs to the family of poaceae and it is one of the major cereal crops in Africa, which currently accounts for up to 20 % of domestic food production and provides well over 50% of stable calories (Midega *et al.*, 2016). The crop is grown primarily for human consumption, but surpluses are used in feeding livestock and other industrial purposes. Maize contains approximately 72% starch, 10% protein, and 4% fat, supplying a high energy density of 365 Kcal/100g (Ranum *et al.*, 2014). Besides its nutritive values, it is also a good source of quality edible oil (Saddam *et al.*, 2016). According to FAO (2021) the United States of America is the highest producer of maize in the world, while Nigeria is the highest producer in Africa. In Nigeria, maize is grown across all agro-ecological zones ranging from the forest zone through the savannah and Sahel zones (IITA, 2014). It is produced by small-holder farmers in Nigeria contributing about 80% of the total maize production in the country where it is grown in low- and mid-altitude areas due to relatively high temperature which favours insect infestation (Emeka *et al.*, 2022). Nigeria loses over 13.5% of her maize production, a major staple food to pests annually (IITA, 2014). Storage insects are the primary cause of loss for maize grains in storage and constitute a great constraint to the realization of food security. The maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), is a primary field and store pest of maize, leading to huge post-harvest losses worldwide. Adults and larvae feed on undamaged grains, causing weight losses of about 40% of the total grain yield. The larvae are the internal feeders and internal feeding affects seed viability (Ojo and Omoloye, 2016). The attack may start in the mature crop when the moisture content (MC) of the grain has fallen to 20-18% (Radha, 2014). Erenso and Berhe, (2016) reported that, in order to reduce serious losses experienced during storage, various techniques and control methods have been developed and more are still being developed. Insects and other pests can be effectively controlled by using synthetic chemical treatments, by fumigating produce with phosphine or dusting them with malathion, pirimiphos-methyl or permethrin (Ileke and Oni, 2011). The negative impact resulted to pest resurgence, insect genetic resistance, rising treatment costs, high persistence, and poor application knowledge, which has also led to serious environmental pollution affecting human health and causing death of non-target organisms (Jayaraj *et al.*, 2016). Recently, there is a steady increase in the use of plant products as a cheaper, renewable and ecologically friendly means of controlling insect pest infestations of stored cereal and grains especially in the tropics where the resource poor farmers are found (Emeka *et al.*, 2020). Several plants derived botanicals, e.g., powders, oils, extracts from neem, castor, eucalyptus, etc. which are in use as grain protectants contain secondary metabolites that can effectively mitigate various insect pests through feeding and ovipositional deterrence, metamorphosis inhibition, and insect repellence (Ferdenache, 2019). Therefore, there is the need to explore this alternative, environmentally friendly approach especially with botanicals that are found in the area for better management of maize weevils in store.

MATERIALS AND METHODS: The study was conducted in the Crop Science Laboratory of the Department of Agriculture, Alex Ekwueme Federal University, Ndufu-Alike, (AE-FUNAI) which is situated between Latitude 6° 13' North and Longitude 8° 14' East under an ambient temperature of 27±2°C and 78±2% relative humidity. Maize infested with *Sitophilus zeamais* L. was sourced from Nwakpu market and the insect pest was cultured and kept in one-liter kilner jars for two weeks to enable weevil multiplication. Maize variety (SAMMAIZ-51) was sourced from Institute of Agricultural Research (IAR), Zaria. The materials were disinfested and kept in a cool dry place until when it is needed. Ten pairs of matured *S. zeamais* were introduced into four Kilner jars each containing 250 grams of clean, disinfested maize seeds and covered with muslin cloth for aeration. Two weeks later, the older insects were

sieved out and subsequently observed for the emergence of teneral insects used for the experiment. The teneral insects were sexed using external morphological characteristics in identification.

Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus globulus*) leaves were source from the Research and Demonstration Farm within the environment, air-dried for 14 days and then ground using a Kalsi grinder supreme. The resultant fine powders were sieved through a 0.25mm mesh and stored in air-tight containers. Synthetic chemical named 'codo' with the active ingredient (phosphine gas) was used as a check (Chadda, 2016).

Twenty five grams (25 g) of clean maize seeds were weighed into ten Kilner jars/bottles with different concentrations (2.5 g, and 5.0 g) of ground powders of *E. camaldulensis* and *M. oleifera*, and 0.010 g of phosphine gas as check while maize seeds in the control were not treated giving a total of forty treatment combinations. The maize grain and powder of all the treatment were mixed homogenously. To each bottle and treatment, ten (10) teneral weevils (5males and 5 females) were introduced. The Kilner jars/bottles were covered with muslin cloth and perforated lid. The experiment was arranged in a completely randomized design (CRD) and replicated four times.

The insects were probed to determine those that recovered after the treatment and subsequently examined daily to record mortalities. Insects that did not respond to probing were regarded dead. Adult mortality data were collected using Abbott's formula as reported by Yohannes *et al.*, 2014 while percent repellence used Area preference method as described by Akinbuluma and Ewete (2014). All data collected were subjected to Analysis of Variance (ANOVA) and means were separated using Bonferroni test at 5% level with GenStat 2017 statistical package.

RESULT AND DISCUSSIONS

Contact toxicity of plant powders and F1 of *Sitophilus zeamais* in stored maize: The effect of plant materials on percentage mortality as affected by *Sitophilus zeamais* in stored maize is presented in table 1. The result shows that the least percentage mortality (35 %) was recorded in control while the highest percentage mortality was recorded on eucalyptus 2.5g (100 %) and phosphine 0.01g (100 %). Grains treated with neem at 5 g recorded least percentage mortality of 60 %, followed by grain treated with Neem at 2.5g which recorded 70% compared to the positive check, eucalyptus at 5g performed better than other treatments. In treatment combination, Neem (2.5 g) + eucalyptus (2.5 g) gave 65 % which was better compared to control which gave 35%. The result shows that there was significant difference ($P \leq 0.05$) between of the treatments when compared with the untreated (control). This indicates that the adult weevils when exposed to the botanicals at lower rate exerted more effect than at a higher rate. The trend of weevil mortality in this study was not dose-dependent, and aligns with the work of Emeka *et al.*, (2020) which states that botanicals exert their potency at rather lower rates than higher dosages.

The effect of plant materials on F1 generation count as affected by *Sitophilus zeamais* in stored maize is presented in table 3. The result shows that the least F1 generation count (0.00) was recorded in Phosphine at 0.01g, while the highest F1 generation count was recorded on the control (21.75) followed by neem 5g which recorded (14.25), eucalyptus 5g which recorded (10.25). In treatment combination, Neem (5g) + Eucalyptus (2.5g) recorded the lowest F1 generation count (3.25) while the highest (16.00) was recorded on neem (2.5g) + eucalyptus (5g) which was lower when compared to control (21.75). The result shows that there was a significant difference ($P \leq 0.05$) between of the treatments as compared with the untreated (control). This result agrees with Mandudz (2016) findings that there is positive relationship between concentration plant leaf powder and insect pest mortality.

The effect of plant materials and phosphine on percentage seed damage as affected by *Sitophilus zeamais* in stored maize is presented in table 1. The result shows that the least percentage seed damage (0.00 %) was recorded in Phosphine at 0.01 g and Eucalyptus at 2.5 g while the highest percentage seed damage was recorded on the Eucalyptus (18.08 %), with control having (17.98 %). In treatment combination, Neem (2.5 g) + Eucalyptus (2.5 g) recorded the lowest seed damage (3.63 %) while the highest (23.20 %) was recorded on Eucalyptus (5.0 g) + Neem (2.5) which was higher when compared to control (17.98 %). The result shows that there was no significant difference ($P \geq 0.05$) between of the treatments as compared with the untreated (control). This supports Erenso and Berhe (2016) that stated mixing dried botanical leaves with grain in storage confers protection against pests.

Repellence effect of plant powders on *Sitophilus zeamais*: The effect of plant materials on percentage repellence as affected by *Sitophilus zeamais* in stored maize is presented in table 2. The result shows that, at 1 hour the least percentage repellence (25%) was recorded on eucalyptus 5g while the highest percentage repellence was recorded on neem 2.5g (55%), followed by neem 5g which recorded (45%) repellence. At 2 hours, the results showed that, the least percentage repellence (25%) was also recorded on eucalyptus 5g, followed by neem 2.5g which recorded (40%), while the highest percentage repellence was recorded at neem 5g (65%), followed by eucalyptus 2.5g which recorded (60%). The result shows that there was no significant difference ($P \geq 0.05$) among the treatments. Findings here agree with Aref *et al.*, (2015), that stated the ability of botanicals to protect and act as repellent to storage insect pests. Also studies by Harminder *et al.*, (2019) showed that Eucalyptus leaf powder has repulsive consequences on the ability to smell and taste (feed on grains) of *S. zeamais*.

CONCLUSION AND RECOMMENDATION: The experiment focused on using available plant materials that are environmentally friendly in the management of stored produce pests. This is to discourage the incessant and rampant use of pesticide that are hazardous to human health and that of the environment. From our findings, eucalyptus (2.5 g) yielded 100 % mortality effect as compared with phosphine (0.01 g). The combination Neem (5.0 g) and Eucalyptus (2.5 g) recorded 85 % mortality while other treatments and their combinations recorded above 50 % whereas control recorded 35 % which was the least percent mortality, respectively. Also, F1 generation recorded

the lowest on Eucalyptus (2.5 g) and control produce the highest. All treatment and treatment combinations were less than 15, which show the ability of these botanical powders to reduce/limit emergence of progeny. The repellence effect of the botanicals increased over time and was able to discourage reproduction and damage rather than killing them rapidly. Therefore, these botanicals are eco-friendly, easy to prepare and generally safe compared to synthetic compounds, we recommend it to local farmers for economic benefits since they have the potential to solve worldwide agricultural, public health, population, and environmental challenges while ensuring food security especially in maize production. Further work in this area of research is needed to evaluate acceptability and adoption as it affects farmers in this locality.



Fig. 1: Experimental set up



Fig. 2: Male and female from an exit hole



Fig. 3: Close capture of Sitophilus zeamais

Table 1: Effect of Botanicals and Phosphine on percentage mortality and F1 generation of stored maize

Treatment (g)	% Mortality	F1 Generation	% Seed damage
Control	35.00b	21.75a	17.98a
Eucalyptus (2.5)	100.00a	0.25c	0.00a
Eucalyptus (5.0)	77.50a	12.00abc	18.08a
Neem (2.5)	70.00a	10.25abc	11.33a
Neem (5.0)	60.00ab	14.25abc	16.65a
Treatment combination			
Neem (2.5) + Eucalyptus (2.5)	65.00ab	4.50bc	3.63a
Neem (2.5) + Eucalyptus (5.0)	72.50ab	16.00ab	23.20a
Neem (5.0) + Eucalyptus (2.5)	85.00a	3.25bc	6.75a
Neem (5.0) + Eucalyptus (5.0)	70.00ab	10.25abc	14.75a
Phosphine (0.01)	100.00a	0.00c	0.00a
Mean	73.5	9.20	11.20
SE ±	18.08	6.06	10.39
CV (%)	34.00	92.70	130.80

Means in a column followed by the same letter(s) are not significantly different at 5 % level of probability using Bonferroni Test

Table 2: Effect of Botanicals on percentage repellence on stored maize

Treatment (g)	1 Hour	2 Hours
Eucalyptus (2.5)	55.00a	60.00a
Eucalyptus (5.0)	25.00a	25.00a
Neem (2.5)	55.00a	40.00a
Neem (5.0)	45.00a	65.00a
Treatment combination		
Neem (2.5) + Eucalyptus (2.5)	65.00a	45.00a
Neem (2.5) + Eucalyptus (5.0)	40.50a	40.00a
Neem (5.0) + Eucalyptus (2.5)	35.00a	30.25a
Neem (5.0) + Eucalyptus (5.0)	20.00a	15.25a
Mean	45.00	47.5
SE ±	18.56	18.41
CV (%)	35.10	38.9

Means in a column followed by the same letter(s) are not significantly different at 5 % level of probability using Bonferroni Test

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Population Ecology of Plants of Food and Medicinal Products in a Community-Managed Moist Rainforest in Akwa Ibom State, Nigeria

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ABSTRACT

Considering the socio-economic importance of many edible and medicinal plant species which are found in the forests, there is insufficient data to help conservation. Thus, Ikot Efre Itak Community-owned rainforest in Ikono Local Government Area, Akwa Ibom State, Nigeria was assessed for diversity and abundance of plant species of edible and medicinal products using combination of systematic and random sampling techniques. The data collected were subjected to non-parametric and descriptive analyses. A total of eighty-four plant species were encountered in the forest with distribution as trees (34), Shrubs (23), Herbs (16) and Climbers (11). In the tree life-form, *Macaranga barteri* had the highest population density of 62 per/ha while *Brachystegia eurycoma*, *Coelocaryon preusii* and *Dacryodes edulis* had the least population of 2 per/ha apiece. In shrub category, the population density varied from 300 to 1,750 per/ha with *Bambusa vulgaris* having the highest of 1,750 per/ha, while *Heinsia crinata* had the least of 300 per/ha. In herb life-form, the population density varied from 75 to 5,400 per/ha, with *Nephthylis constanta* having the highest population density of 5,400 per/ha, while *Costus afer* had the least of 75 per/ha. That of climber life-form varied from 150 to 1,250 per/ha, with *Selaginella myosurus* having the highest population density of 1,250 per/ha and *Gloriosa superba* had the least of 150 per/ha. The species richness of 1.625, 0.803, 0.468, and 0.713 were computed for the trees, shrubs, herbs and climbers respectively. With most tree species having low population density, it is therefore proffered that the forest should be primarily managed for production of non-timber products of food and medicine, rather than timber or wood alone management that often leads to deforestation, and eventual loss of biodiversity.

Keywords: Tropical rainforest, plants, food, medicine, conservation, sustainable management

INTRODUCTION: The Nigerian rainforest is an integral of the world tropical rainforest which has been adjudged the most biological diverse ecosystem on earth (Gillespies *et al.*, 2004, ITTO, 2011). The tropical rainforest ecosystem is a huge source of basic needs of man for food, medicine, energy and shelter. The rainforest has been viewed and managed over the years as an ecosystem of crop of merchantable timber trees, rather than a composite of interdependent biodiversity of multiple value. Consequently, the Nigerian rainforest has been widely indiscriminately exploited for timber, thereby culminating in degradation, denudation and rife destruction. The rainforest now generally occurred in isolated small patches (Olajide, 2018). The estimated total coverage of rainforest is 95,372 km² of the country's landmass of 983,213 km² (Akpan-Ebe, 2021). The rainforest is stocked with diversity of plant species that produce edible and medicinal products in the forms of fruits, seeds, leaves, twigs, nut, barks, floral and roots. The edible plant materials from the rainforest ecosystem are mostly available at the seasons of the year when the cultivated crops are not yet mature (Oni and Gbadamosi 1998, Olajide, 2018). The edible forest products constitute important and cheap sources of vitamins, minerals, protein, carbohydrate, fat and oil of the diet of the rural people. The World Health Organisation (WHO) estimated that 80% of the population of sub-Saharan Africa relies on plant based medicine for everyday health-care needs (Bannerman, 1993 and Ande, 2006). Many plant species have been identified by the local people to contain therapeutic ingredients. The people have for ages been depending on these plant materials for their health-care needs. Natural forests generally provide the only medicine available to the largest proportion of the world's population of which 90 – 95% is in the developing world, and the high concentration of different chemicals in some plants serve as raw materials for the production of modern drugs (FAO, 1985 and Ande, 2006). With the seemingly unabated high rate of destruction and conversion of rainforest ecosystem to different ecosystems in Nigeria, a lot of plant species, which are sources of food and medicine are disappearing.

Thus, this paper is a report of a study on the diversity and stock density of plant species that produce food and medicinal products in a community-managed rainforest in Akwa Ibom State, Nigeria. It is hoped that the information gathered would help conservation and sustainable management of the forest and other similar tracts of rainforest.

MATERIALS AND METHODS

Study Area: The study was carried out in Ikot Efre Itak community owned rainforest in Ikono Local Government Area, Akwa Ibom State, Nigeria (Figs. 1 & 2). The forest covers an area of 29.57ha (IWADU, 2000). The area has mean annual rainfall of 2400 mm, mean minimum and maximum temperatures of 25°C and 30°C respectively. The mean relative humidity is about 83%. The soil is predominantly silt-loam.

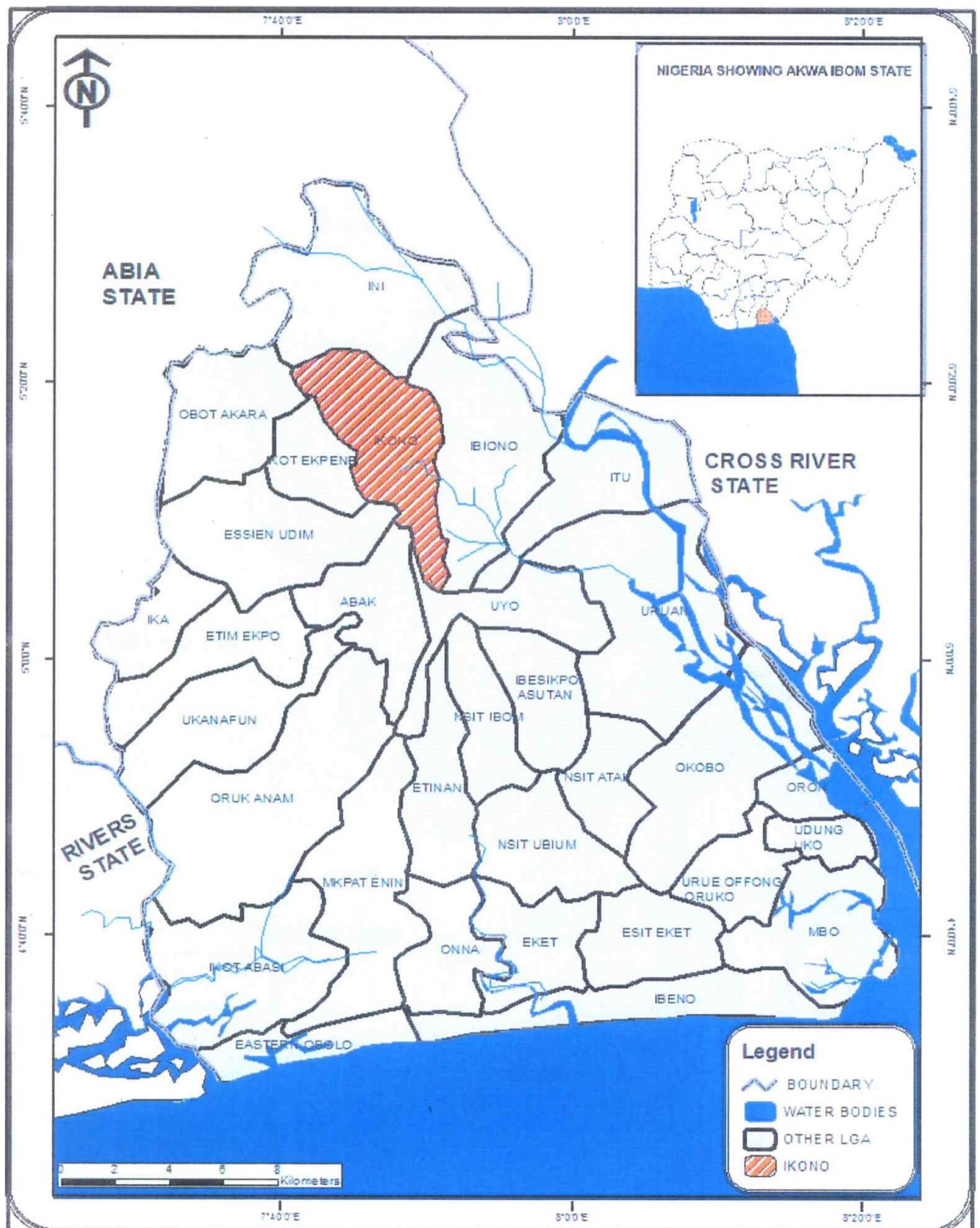


Fig. 1: Map of Akwa Ibom State showing Study area in Ikono Local Government Area
 Source: Department of Geography and Regional Planning, Uniuyo (2019).

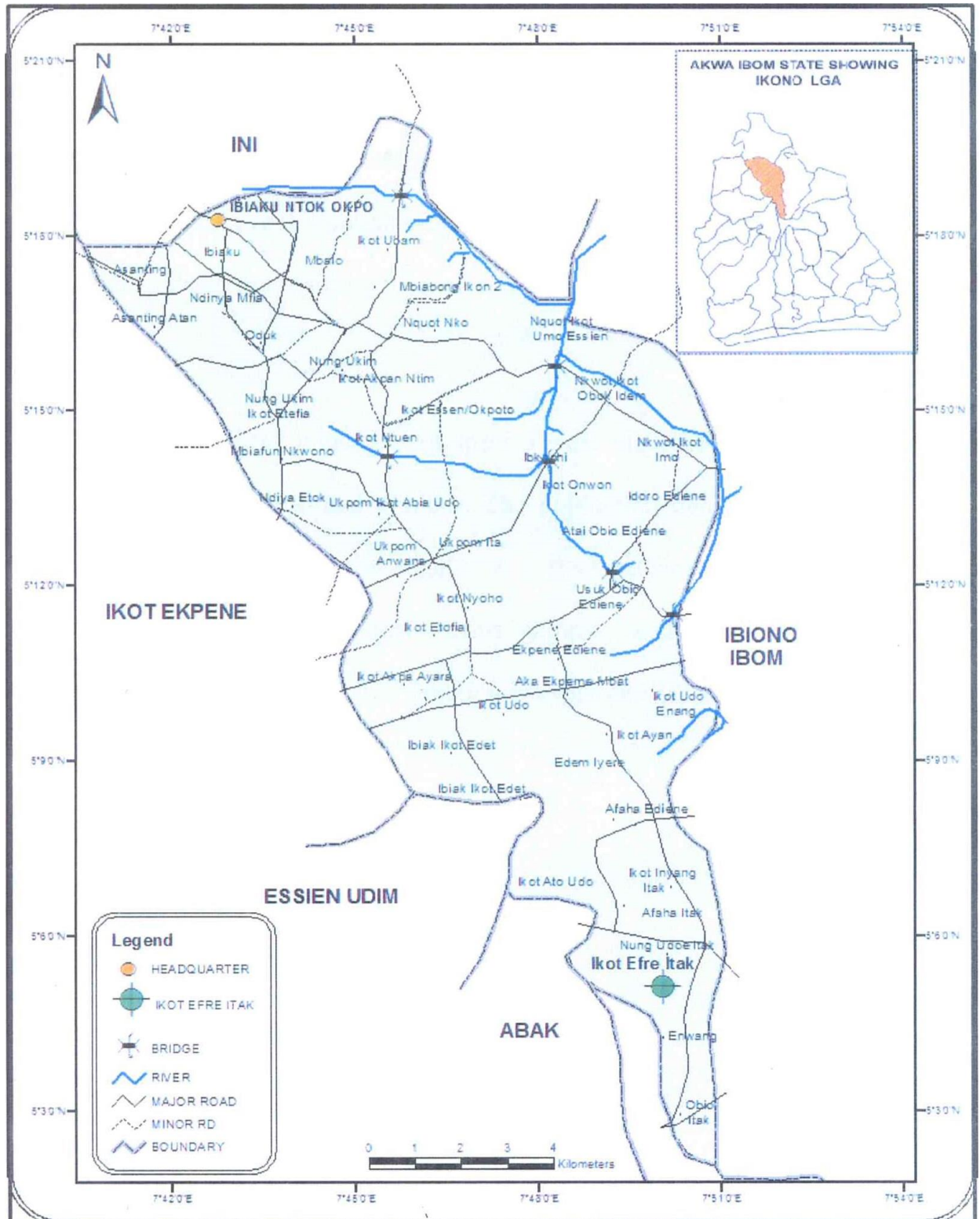


Fig. 2: Map of Ikono Local Government Area showing Ikot Efre Itak Village.
Source: Department of Geography and Regional Planning, UniUyo (2019).

Reconnaissance Survey: Reconnaissance Survey was carried out to familiarize with the terrain of the forest. Some of the natives of the area were consulted and interviewed on the edible and medicinal product they usually collected from the forest. The most apparent signs of disturbances in the forests were timber harvesting poles cutting for firewood, part of the forest cleared and burnt for farming activities and tree-bark removal for medicines.

Data Collection: A combination of systematic and random sampling techniques was employed in the course of collecting data. Five meters away from the main access routes into the forest, four 200m line transects were laid at 50m away from one another and perpendicular to the main access routes into the forest. Along each transect, four 20m by 20m quadrats were randomly laid in an alternate order on each transect for the enumeration of tree species of edible and medicinal products. One 5m x 5m sub-quadrat was laid at the centre of each 20m x 20m quadrat for enumeration of shrubs, herbs and climbers. The total number of quadrats and sub-quadrat was sixteen (16) apiece. It implied that a total area of 6,400m² (0.64ha) were enumerated for trees and 400m² (0.04ha) for the shrubs, herbs and climbers. Data collections were made both in the rain and dry seasons to ensure adequate data collection on both perennial, biennial and annual plant species. In the course of data collection, three native men whose ages ranges between 50- 60 years were involved in the plant identification and to ascertain different parts of the plant used as food and medicine. Specimens were collected from the plants that could not be scientifically identified on the field, and were thereafter identified at the Herbarium Laboratory of the Department of Botany and Ecological Studies of University of Uyo, Nigeria.

Data Analysis: Plant species were classified into four life-forms, viz; tree, shrub, herb and climber. The population density of each species per hectare was determined from its population in the total areas of quadrats assessed using the relationship stated as follows:

$$D = \frac{x}{A} \times 1ha$$

Where,

D = Population density per/ha

x = number of individual species (i)

A = Total area of all the quadrats (0.64ha for trees and 0.04ha for shrubs, herbs and climbers)

The species richness index was calculated for each life-form using Menchinick's index formula given below (Menchinicks, 1964; Ogbebu, 2005; Etigale *et al*, 2017).

$$R = \frac{s}{\sqrt{N}}$$

Where,

R = species richness index

s = number of species enumerated and

N = total number of individuals enumerated

RESULTS: A total of 34 species of edible and medicinal products were encountered in the tree life –form. The study showed that, the population density of the tree life-form varied from 2 to 62 per/ha with *Macaranga barteri* had the highest estimated population density of 62 per/ha, while *Brachystegia eurycoma*, *Coelocaryon preusii* and *Dacryodes edulis* had the least population density of 2 per/ha apiece (Table 1). In the shrub life-form, 24 species were encountered. The population density varied from 300 to 1,750 per/ha. *Bambusa vulgaris* with the frequency of (70) had the highest population density of 1,750 per/ha, while *Heinsia crinata* with the frequency of (12) had the least population density of 300 per/ha (Table 2). In the herb life- form, a total of 16 species were enumerated. The population density varied from 400 to 5,000 per/ha. *Nephthylis constanta* had the highest estimated population density of 5,000 per/ha while *Aspelia africana* and *Combratum racemosum* had the least of 400 each per/ha (Table 3). Also, a total of 11 species were encountered under climber life-form. The population density varied from 150 to 1,250 per/ha. *Selaginella myosurus* had the highest of 1,250 per/ha while *Gloriossa superba* had the least of 150 per/ha (Table 4).

It was observed that the parts of the plants used as food and medicine varied from leaf, stem, root, seed, bark, fruit, tuber and latex (Table 5a - d).

Table 1: Population density of individual plant species of tree life-form

S/N	Species	Family	Population density (per ha)
1	<i>Albizia ferruginea</i>	Fabaceae	25
2	<i>Alstonia boonei</i>	Apocynaceae	17
3	<i>Anthocleista djalonesis</i>	Loganiaceae	19
4	<i>Antiaris Africana</i>	Moraceae	42
5	<i>Baphia nitida</i>	Papilionaceae	3
6	<i>Bombax buonopzense</i>	Bombaceae	6
7	<i>Bosquiea angolensis</i>	Moraceae	47
8	<i>Brachystegia eurycoma</i>	Fabaceae	2
9	<i>Canarium schwenfurthii</i>	Burseraceae	42
10	<i>Coelocaryon preusii</i>	Myristicaceae	2
11	<i>Coula edulis</i>	Olaceae	27
12	<i>Gossypium hirsutum</i>	Malvaceae	6
13	<i>Dacryodes edulis</i>	Burseraceae	2
14	<i>Dacryodes klaineana</i>	Burseraceae	36
15	<i>Daniella ogea</i>	Fabaceae	5
16	<i>Dracaena arborea</i>	Dracaenaceae	44
17	<i>Elaeis guineensis</i>	Arecaceae	47
18	<i>Ficus exasperate</i>	Moraceae	22
19	<i>Irvingia gabonensis</i>	Irvingiaceae	3
20	<i>Macaranga barteri</i>	Euphorbiaceae	62
21	<i>Musanga cecropiodes</i>	Cecropiaceae	36
22	<i>Newbouldia laevis</i>	Bignoniaceae	9
23	<i>Pentaclethra macrophylla</i>	Papilionaceae	22

24	<i>Pterocarpus mildbraedii</i>	Papilionaceae	5
25	<i>Pterocarpus osun</i>	Fabaceae	6
26	<i>Piptadeniastrum Africana</i>	Leguminosae	14
27	<i>Ruthmania hispida</i>	Rubiaceae	3
28	<i>Sterculia tragacantha</i>	Sterculiaceae	36
29	<i>Strombosia postulate</i>	Olacaceae	3
30	<i>Spondias mombin</i>	Anacardiaceae	53
31	<i>Syncepalium dulsificum</i>	Sapotaceae	23
32	<i>Terminalia superba</i>	Combretaceae	9
33	<i>Uapaca guinensis</i>	Euphorbiaceae	3
34	<i>Xylopia aethiopica</i>	Annonaceae	3

Table 2: Population density of individual plant species of shrub life-form

S/N	Species	Family	Population Density (per ha)
1	<i>Alchornea cordifolia</i>	Euphorbiaceae	1,125
2	<i>Anthonatha macrophylla</i>	Fabaceae	1,125
3	<i>Araliopsis soyauxii</i>	Rutaceae	750
4	<i>Bambusa vulgaris</i>	Poaceae	1,750
5	<i>Barteria nigritiana</i>	Passifloraceae	450
6	<i>Carpolobia lutea</i>	Polygaceae	1,050
7	<i>Cola millenii</i>	Steculiaceae	700
8	<i>Cnestis ferruginea</i>	Clinaraceae	975
9	<i>Garcinia manii</i>	Clusiaceae	1,000
10	<i>Hannoa klaineana</i>	Simaroubaceae	350
11	<i>Harungana madagascariensis</i>	Hypericaceae	700
12	<i>Heinsia crinata</i>	Rubiaceae	300
13	<i>Icacina trichantha</i>	Icacinaceae	625
14	<i>Laccosperma secundiflorum</i>	Arecaceae	1,375
15	<i>Lansianthera Africana</i>	Bignoniaceae	1,250
16	<i>Longacarpus griffonianus</i>		450
17	<i>Maesobotrya barteri</i>	Euphorbiaceae	1,575
18	<i>Mallotus oppositifolius</i>	Euphorbiaceae	400
19	<i>Melastomastrum capitatum</i>	Melastomataceae	975
20	<i>Microdesmis pubarula</i>	Pandaceae	1,500
21	<i>Milleffia thoningii</i>	Leguminosae	500
22	<i>Sorindela mildbriedii</i>	Anacardiaceae	700
23	<i>Voacanya Africana</i>	Apocynaceae	875

Table 3: Population density of individual plant species of herb life-form

S/N	Species	Family	Population density (per ha)
1	<i>Aframomum sceptrum</i>	Zingiberaceae	3,500
2	<i>Anchomanes difformis</i>	Araceae	1,375
3	<i>Argemone Mexicana</i>	Papaveraceae	2,500
4	<i>Aspelia Africana</i>	Asteraceae	400
5	<i>Asystasia gangetica</i>	Acanthaceae	2,025
6	<i>Chromolaena odorata</i>	Asteraceae	1,525
7	<i>Combratum racemosum</i>	Combretaceae	400
8	<i>Costus afer</i>	Costaceae	3,025
9	<i>Hibiscus surattensis</i>	Malvaceae	500
10	<i>Justicia schimperiana</i>	Acanthaceae	2,975
11	<i>Laportea aestuans</i>	Urticaceae	8,75
12	<i>Nephthylis constanta</i>		5,000
13	<i>Palisota hirsute</i>	Commelinaceae	3,000
14	<i>Piper umbellacum</i>	Piperaceae	450
15	<i>Thaumatococcus daniellii</i>	Marantaceae	857
16	<i>Urena lobate</i>	Malvaceae	750

Table 4: Population density of individual plant species of climber life-form

S/N	Species	Family	Population density (per ha)
1	<i>Adenopus breviflorus</i>	Vitaceae	450
2	<i>Cissus quadrangularis</i>	Vitaceae	300
3	<i>Combretum mfuconalum</i>	Combretaceae	500
4	<i>Gloriosa superba</i>	Colchicaceae	150
5	<i>Gnetum africanum</i>	Gnetaceae	250
6	<i>Gongronema latifolium</i>	Asclepiadaceae	300
7	<i>Ipomoea involucre</i>	Convolvulaceae	700
8	<i>Loranthus apyllus</i>	Cactaceae	300
9	<i>Physalis angulate</i>	Solanaceae	1,000
10	<i>Selaginella myosurus</i>	Selaginellaceae	1,250
11	<i>Smilax anceps</i>	Smilacaceae	750

The spaces richness indices of 1.625, 0.803, 0.468 and 0.713 were computed for trees, shrubs, herbs and climbers respectively.

Table 5a: Plants of tree life-form producing edible and medicinal products

S/N	Plant Species	Family	Ibibio Name	Common/English Name	Uses	Parts Used
1	<i>Albizia ferruginea</i> (Gill and Perr Benth.	Fabaceae	Ubam	Albizia	Medicinal	Bark, Root
2	<i>Alstonia boonei</i> De Wild.	Apocynaceae	Ukpo	Stool Wood	Medicinal	Latex, Root
3	<i>Anthocleista djalonesis</i> A. Chev.	Loganiaceae	Ibu	Cabbage tree	Medicinal	Bark
4	<i>Antiaris africana</i> Engl.	Moraceae	Afia Ofriyo		Medicinal	Bark, Root
5	<i>Baphia nitida</i> Lodd.	Fabaceae	Ofuo	Camwood	Medicinal	Stem/Root
6	<i>Bombax buonopzense</i> P.Beauv.	Bombaceae	Ukim	Red flowered silk Cotton tree	Medicinal	Bark
7	<i>Bosquiea angolensis</i> Ficalho	Moraceae	Uyie	Akee apple	Medicinal	Leaf, Bark and Root
8	<i>Brachystegia eurycoma</i> Harms	Fabaceae	Odukpa	Okwen	Medicinal	Bark, Root
9	<i>Canarium schwenfurthii</i> Engl.	Burseraceae	Ebenetidong	African Canarium	Edible	Fruit
10	<i>Coelocaryon preusii</i> Ward.	Myristicaceae	Uno Idim		Edible/Medicinal	Fruit Bark, Root
11	<i>Coula edulis</i> Baill	Olaceae	Ekom	Walnut	Edible/Medicinal	Seed, Bark
12	<i>Gossypium hirsutum</i> L.	Malvaceae	Ofo	Cotton	Medicinal	Bark, Root
13	<i>Dacryodes edulis</i> (G. Don) H.J. Lam.	Burseraceae	Eben		Edible	Fruit
14	<i>Dacryodes klaineana</i> (Pierre) H.J.Lam.	Burseraceae	Eben Ikot		Medicinal	Leaf, Bark and Root
15	<i>Daniella ogea</i> (Harms) Rolfe ex Holl.	Fabaceae	Enang eto		Medicinal	Bark, Root
16	<i>Dracaena arborea</i> (Wild). Link Enum Hort	Dracaenaceae	Okono		Medicinal	Bark, Root
17	<i>Elaeis guineensis</i> Jacq.	Arecaceae	Eyop	Oil palm tree	Edible	Fruit
18	<i>Ficus exasperate</i> Vahl.	Moraceae	Ukwok	Sand paper tree	Medicinal	Leaf, Bark
19	<i>Iringia gabonensis</i> (Aubry-Lecomte ex O. Rorke)Baill	Iringiaceae	Uyo	Bush mango	Edible	Fruit, Stem
20	<i>Macaranga barteri</i> Mull. A.rg.	Euphorbiaceae	Akpa		Medicinal	Leaf, Root
21	<i>Musanga cecropiodes</i> R. Br	Cecropiaceae	Uno	Cork wood	Medicinal	Bark, Root
22	<i>Newbouldia laevis</i> (P.Beauv) Seemann ex Bureau	Bignoniaceae	Itumo		Medicinal	Bark, Root
23	<i>Pentaclethra macrophylla</i> Benth	Fabaceae	Ukana	African oil beans	Edible/Medicinal	Seed, Bark
24	<i>Pterocarpus milderbraedii</i> Harms	Leguminosae	Mkpafer		Edible	Leaf
25	<i>Pterocarpus osun</i> Craib	Fabaceae	Ukpa	Cam wood	Medicinal	Bark, Root
26	<i>Piptadeniastrum africana</i> Hook Brennan	Leguminosae	Ukong		Medicinal	Bark, Root
27	<i>Ruthmania hispida</i> (K. Schum) Fanger lind	Rubiaceae	Okukin		Medicinal	Fruit, Leaf, Bark, Root
28	<i>Sterculia tragacantha</i> Lindl.	Steculiaceae			Edible/Medicinal	Leaf, Bark
29	<i>Strombosia postulate</i> Oliv.	Olaceae	Ekom ubak		Medicinal	Root, Bark
30	<i>Spondias mombin</i> L.	Anacardiaceae	Nsukakara	Hog plum	Medicinal	Leaf, Bark, Root
31	<i>Synsepallum dulsificum</i> (Schum.&Thonn)Daniell	Sapotaceae	Mkpantuk		Edible/Medicinal	Fruit
32	<i>Terminalia superba</i> Engl and Diels	Combretaceae	Afia eto	Whit afara	Medicinal	Bark, Root
33	<i>Uapaca guineensis</i> Mull.-Arg	Euphorbiaceae	Nkpenek	Red-cedar	Medicinal	Bark, Root
34	<i>Xylopia aethiopica</i> (Dunal) A. Rich	Annonaceae	Ata	African pepper	Edible/Medicinal	Root, Stem, Bark, Root

Table 5b: Plants of shrub life-form producing edible and medicinal products

S/N	Plant Species	Family	Ibibio Name	Common/English Name	Uses	Parts Used
1	<i>Alchornea cordifolia</i> (Schum. Thonn) Mull.Arg	Euphorbiaceae	Mbom	Christmas bush	Medicinal	Leaf, Root
2	<i>Anthonatha macrophylla</i> P. Beauv.	Fabaceae	Nya		Medicinal	Leaf, Root
3	<i>Araliopsis soyauxii</i> Engl.	Rutaceae	Editan eto		Medicinal	Leaf, Stem, Root
4	<i>Bambusa vulgaris</i> Schrad ex Wend.	Poaceae	Nyanyaha inyang	Bamboo	Medicinal	Leaf
5	<i>Barteria nigritiana</i> Hook	Passi floraceae	Ekpanekpang	Ant tree	Medicinal	Leaf, Root

6	<i>Carpolobia lutea</i> G. Don	Polygaceae	Ikpafum	Cattie stick	Edible/Medicinal	Fruit, Root
7	<i>Cola millenii</i> K. Schum	Steculiaceae	Ekpa okpo	Monkey kola	Edible/Medicinal	Leaf, Fruit, Root
8	<i>Cnestis ferruginea</i> Dc	Clinaraceae	Utinewa	Velvetsunfruit	Edible/Medicinal	Fruit, Leaf, Root
9	<i>Garcinia manii</i> Oliv	Clusiaceae	Okok edi	Chewing stick	Medicinal	Leaf, Stem, Root
10	<i>Hannoa klaineana</i> Pierre &Engl	Simaroubaceae	Eto ibit		Medicinal	Leaf
11	<i>Harungana madagascariensis</i> Lam. ex Poiret	Hyperiaceae	Oton		Medicinal	Leaf, Root
12	<i>Heinsia crinata</i> (Afzel) G. Tayl	Rubiaceae	Atama		Edible/Medicinal	Leaf, Root
13	<i>Icacinia trichantha</i> Oliv.	Icacinaceae	Efikisong	Earth ball	Edible/Medicinal	Tuber, Leaf
14	<i>Laccosperma secundiflorum</i> (P. Beauv) O. Kize	Arecaceae	Nkara	Rattan palm	Medicinal	Leaf
15	<i>Lansianthera africana</i> P. Beauv.	Bignoniaceae	Editan		Edible/Medicinal	Leaf, Stem
16	<i>Longacarpus griffonianus</i> (Baill) Dum		Ududu		Medicinal	Leaf, Bark, Root
17	<i>Maesobotrya barteri</i> (Baill) Hutch	Euphorbiaceae	Nyanyated		Edible/Medicinal	Fruit, Leaf
18	<i>Mallotus oppositifolium</i> (Geiseler) Mull.Arg	Euphorbiaceae	Nwariwa	Fruiting branch	Medicinal	Leaf
19	<i>Melastomastrum capitatum</i> Vahl A.&R. Fernandes	Melastomataceae	Eyop inuen		Edible/Medicinal	Fruit, Leaf
20	<i>Microdesmis pubarula</i> Hook. F. ex Planch	Pandaceae	Ntabit		Edible/Medicinal	Leaf, Root
21	<i>Milleffia thoningii</i> (Schum & Thom) Bak	Leguminosae	Isara		Medicinal	Leaf, Root
22	<i>Sorindela mildbriedii</i>	Annacardiaceae	Adiahaidang		Edible/Medicinal	Fruit, Root
23	<i>Voacanya africana</i> Stapf	Apocynaceae			Medicinal	Leaf, Bark, Root

Table 5c: Plants of herb life- form producing edible and medicinal products

S/N	Plant Species	Family	Ibibio Name	Common/English Name	Uses	Parts Used
1	<i>Aframomum sceptrum</i> K. Schum	Zingiberaceae	Ikpod		Edible/Medicinal	Fruit, Leaf, Root
2	<i>Anchomanes difformis</i> (Bl.) Eng.	Araceae	Nkokot	Spiny arum	Medicinal	Bark, Root
3	<i>Argemone mexicana</i> L.	Papaveraceae	Mbaraekpe	Devil's fig	Medicinal	Leaf, Stem, Root
4	<i>Aspelia africana</i> Oliv.&Hiern	Asteraceae	Ndinuene	Compost weed	Medicinal	Leaf, Stem
5	<i>Asystasia gangetica</i> (L) T.Anderson	Acanthaceae	Eka meme	Chinese violet	Edible/Medicinal	Leaf, Stem
6	<i>Chromolaena odorata</i> (L) R M.King &H.Robinson	Asteraceae		Siam weed	Medicinal	Leaf, Stem
7	<i>Combratum racemosum</i> P. Beauv.	Combretaceae	Asaka		Medicinal	Leaf
8	<i>Costus afer</i> Ker-Gawl	Costaceae	Mbrirem	Bush cane	Medicinal	Leaf, Stem
9	<i>Hibiscus surattensis</i> L.	Malvaceae	Ifod ebót		Medicinal	Leaf, Stem, Root
10	<i>Justicia schimperiana</i> (Hochst) Danby	Acanthaceae	Meme	Hunter weed	Edible/Medicinal	Leaf, Root
11	<i>Laportea aestuans</i> (L.) Chew.	Urticaceae	Ntan	African stinging nettle	Edible/Medicinal	Leaf, Root
12	<i>Nephthylis constanta</i>		Nyarotong		Medicinal	Leaf, Root
13	<i>Palisota hirsuta</i> (Thumb) K. Schum	Commelinaceae	Edongebot	Goat knee	Medicinal	Leaf, Root
14	<i>Piper umbellacum</i> L.	Piperaceae		Wild pepper	Medicinal	Leaf, Stem
15	<i>Thaumatococcus daniellii</i> Benth	Marantaceae	Mfang aya	Moi-moi leaf	Medicinal	Leaf, Stem, Root
16	<i>Urena lobata</i> L.	Malvaceae	Ndidi	African jut fibre	medicinal	Leaf, Root

Table 5d: Plants of climber life- form producing edible and medicinal products

S/N	Plant Species	Family	Ibibio Names	Common/ English name	Uses	Parts Used
1	<i>Adenopus breviflorus</i> Benth	Vitaceae	Ndise ekpo	Wild colocynth	Medicinal	Leaf, Stem
2	<i>Cissus quadrangularis</i> L.	Vitaceae	Oboro	Stem vine	Medicinal	Fruit, Leaf
3	<i>Combretum micranthum</i> G.Don	Combretaceae	Asaka		Medicinal	Leaf, Root
4	<i>Gloriosa superba</i> L.	Colchicaceae		Flame lily	Medicinal	Leaf, Fruit
5	<i>Gnetum africanum</i> Welw.	Gnetaceae	Afang	African salad	Edible/Medicinal	Fruit, Leaf
6	<i>Gongronema latifolium</i> Benth	Asclepiadaceae	Utasi		Edible/Medicinal	Leaf, Stem, Root
7	<i>Ipomoea involucre</i> Beauv.	Convolvulaceae	Mkpaefiang	Morning glory	Medicinal	Leaf, Root
8	<i>Loranthus apyllus</i> L.	Cactaceae	Ndot enyong	African mistieto	Medicinal	Leaf, Root
9	<i>Physalis angulate</i> L.	Solanaceae	Flower ikot	Wild tomato	Medicinal	Leaf, Stem
10	<i>Selaginella myosurus</i> (Sw.) Alston	Selaginellaceae	Mkpatatat	Spike mosses	Medicinal	Leaf, Stem
11	<i>Smilax anceps</i> Willd.	Smilacaceae	Odufat	West sarsaparilla	African Edible/Medicinal	Tuber, Leaf

0.713

Discussion: The study revealed that plant species of edible and medicinal products encountered in Ikot Efre Itak Community owned rainforest belong to different life forms or habits. The very high population of *Nephtylis constanta* (5000 per/ha) in the herb life-form agreed with the observation of Udo *et al.* (2009) that the species was the most prevalent herb in a different study communal rainforest in Akwa Ibom state. The population densities of herbs are an indicator that the forest is a disturbed rainforest (Secondary rainforest). The findings of the study agree with the observation of Udo *et al.* (2009 and Olajide and Udo, (2014) that species like *Gentium africanum*, *Hensia crinata* and *Gongroema latifolium*, are important wild leafy vegetables. Moreover, the abundance or rarity of a plant species of edible and medicinal products in a rainforest also depends on the intensity and manner of its exploitation. The existence of high population of most individual shrub and herb species in the study can be ascribed to the availability of seeds and propagules and the favorable microclimate which included adequate sunlight created by the canopy-gaps occasioned by timber exploitation. Nath *et al.* (2005) reported higher population of undergrowth species compared with tree species in a disturbed tropical rainforest in Northeast India. The high population density of the undergrowth species might be ascribed to the large canopy-gaps that exist or occurred due to the disturbance or fragmentation of the forest. Offiong and Okon (2001) described forests as sources of traditional and conventional medicine such as alkaloids, hydrocortisone, quinine, digitalis, diosgenin and ipecae. The utilization involves the usage of different parts such as leaves, barks, seeds, roots and for some treatment, the whole plant. Destruction of vast areas of rainforest has been responsible for the disappearance of many wild edible and medicinal plant species (Offiong and Okon, 2001). Perhaps, due to dependence of many rural people in the adjoining communities, on these valued forest products, some of the edible and medicinal plant species seems to be over-exploited.

Conclusion: The study rainforest is a disturbed rainforest that contains many species of plant of food and medicinal products. The food and medicinal products enhance sustainable living of the adjoining communities. It also provides sources of income to the communities and render environmental protection service to the area. With most tree species having low population density, it is therefore proffered that the forest should be primarily managed for production of non-timber products of food and medicine, rather than timber or wood alone management that often leads to deforestation, and eventual loss of biodiversity.

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Forestry Actions for Climate Change Mitigation and Environmental Sustainability in Nigeria

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ABSTRACT

Forestry and forests have been recognized to be a critical factor in the mitigation of climate change and environmental sustainability. Thus, this paper discusses forestry actions that can enhance climate change mitigation and environmental conservation in Nigeria, which include conservation and preservation of remaining natural forests, massive reforestation and afforestation, use of eco-friendly technologies for logging and timber processing, promotion of systemic agroforestry production and promotion of urban forestry. Recommendations proffered include among others, participatory management approach should be adopted and emphasised in the management of forest resources by collaborating with communities adjoining gazetted and protected forests, waste-saving technologies should be introduced and adapted for logging and wood processing, government should promote and encourage the use of alternative products to wood by ensuring their availability and affordability to drastically reduce the high rates of cutting down the forests and trees for timber and firewood, and comprehensive review of forestry policies and laws across the country to stimulate, encourage and enable mass participatory in forest conservation and tree planting for the purpose of climate change mitigation and overall environmental sustainability.

Keywords: Forestry, forests, climate change, mitigation, environmental sustainability

INTRODUCTION: The invaluable environmental services render by forests to human include regulation and maintenance of benign climates, purification of atmosphere of pollutant gases, protection of soils against erosion, protection of water-bodies, such as rivers, perennial streams, lakes and aquifers against getting turbid, silted and dried-up. Not until recently, the invaluable environmental services provide by forests are not accorded due importance. Climate change refers to long-term changes of climatic parameters, such a temperature (UNFCCC, 2010). It is a prevailing global phenomenon that is threatening the well-being and existence of man on the planet earth. Climate change is evident in unfavourable extremes of climatic parameters such as temperature and rainfall. The most conspicuous expression of climate change is global warming which is the harmful increase in the earth's temperature. Excessive carbon dioxide (CO₂) in the atmosphere has been identified as the principal cause of global warming. Excessive CO₂ in the lower part of the atmosphere (troposphere) traps earth infra-red radiation (heat emitted from the earth surface) and prevent it from escaping into space, thereby raising global temperatures. The burning of fossil fuels (petroleum fuels) and deforestation are the major anthropogenic activities generating excessive CO₂ (UNFCCC, 2010). Burning of fossil fuels releases about 5 billion tonnes of CO₂ into the atmosphere yearly (Sato, 2008 and Sukhdev, 2010), while tropical deforestation releases 1.5 billion tonnes of carbon per annum into the atmosphere (ITTO, 2011 and Abad, 2015). Accordingly, forests and forestry are a critical factor in the mitigation of climate change and environmental sustainability as a whole. Forests, particularly tropical forests, have been adjudged the largest biological sink of CO₂ (ITTO, 2011 and FAO, 2020). It has also been reported that tropical forests are absorbing nearly five billion tonnes of CO₂ released yearly into the atmosphere through burning of fossil fuels and other sources, thereby substantially buffering the rate of climate change (Sukhdev, 2010 and ITTO, 2011). The total estimated carbon stock in the forests worldwide is 662 gigatonnes (FAO, 2020). Forests are a much cheaper, easier and efficient reservoir for storing carbon than industrial capture storage (Tewari *et al.*, 2008 and UNFCCC, 2010).

This paper, therefore, discusses forestry-based actions and technologies that can considerably enhance mitigation of climate change nay environmental sustainability in Nigeria.

Conservation and preservation of natural forests: Conservation of natural resources is a policy which seeks to ensure a balance between consumption, income demands, ecological and environmental imperatives in the exploitation of natural resources. Conservation of natural forests is the prudent exploitation of the needed produce or products from the forests without vitiating the resource base or impairing the renewability of the forests. The tropical rainforest, for example, is the most biologically diverse ecosystem on the earth and highly ecological robust in providing environmental services of soil protection, moderating climate and sequestering carbon. Research findings indicated that mangrove forests store exceptionally more carbon than most tropical forests, which implies that the rapid rate of their destruction along coastlines is causing significant emissions of greenhouse gases higher than was previously thought (CTA, 2011). The remaining areas of the natural forests should be brought under sustainable management particularly the gazetted forest reserves in order to enjoy their benefits in perpetuity. Accordingly, conservation of an appreciable area of remaining mangrove forest would enlarge carbon sinks and greatly complement climate change mitigation mechanisms. Preservation is prohibition of exploitation of any produce or products from an area of forest. The exclusive objective of natural forests' preservation is biodiversity and environmental conservation. A preserved forest is managed as strict nature reserve. The Rainforest National Parks, for examples, the Cross River and Okomu National Parks, are deemed as preserved forests or strict nature reserve. The management and protection of preserved forests against poachers, particularly, illegal loggers, is a herculean task, but its valuable ecological, environmental and climatic services to local, national and inter-continental territories are unquantifiable. Traditionally preserved forests, for example, patches of sacred forests, are equally important in this context. The effective management and protection of these forests is imperative more than hitherto as they serve as huge sinks of high volumes of pollutant gases being generated by the phenomena of economic growth, which include industrial, agricultural and ore mineral exploration and exploitation activities.

Massive Reforestation and Afforestation: One of the effective and efficient ways through which climate change can be prevented and mitigated is by increasing the biospheric sinks of carbon through reforestation, afforestation, arboriculture and other related practices (ITTO, 2024). The Nigerian forests have been widely degraded and destroyed. The agents of destruction include subsistence farming, logging, mining and infrastructural development. Firewood collection and charcoal production also play very prominent role in deforestation in Nigeria. Nigeria has the highest rate of deforestation in the world and this has resulted in the disappearance of the primary forests such that the relics remaining are insignificant (Akindele, 2012 and Olajide, 2018). Deforestation in Nigeria translates to loss of over 400,000 ha of forest land per year (Akpan-Ebe, 2015 and FAO, 2020). Deforestation endangers the environmental, economic, social and in fact entire wellbeing of the citizenry. According to Akindele (2012), a lot of damage is done to the land through increase soil erosion, siltation of water bodies, loss of biodiversity, habitat loss for wildlife and desertification. When one hectare of forest goes up in smoke, between 100 and 200 tons of carbon dioxide (principal gas causing global warming) are released into the atmosphere (CTA, 2007). The regeneration of forests by artificial planting of fast-growing tree species on the degraded and destroyed forest lands is a must in a fast-growing economy like Nigeria in order to ameliorate the concomitant adverse environmental effects of economic development activities.

The vast areas of the country that have been eaten up by human-induced savanna and desertification should be afforested by planting fast-growing, draught and fire resistant tree species. The principal object of intensive reforestation and afforestation activities should be the establishment of planted forests to provide ecological, environmental and favourable climatic services. In other words, the establishment of forests plantation should not entirely be for timber or wood production. Tropical forest trees are absorbing about 18 percent of the CO₂ added to the atmosphere each year from burning fossil fuels, substantially buffering the rate of climate change (Sato, 2008 and ITTO, 2011). Both government and private sector of the economy should be involved in intensive afforestation of the country to create a friendly and healthy environment for the citizenry as the economy grows. The denuded forest estates or reserves and other lands dedicated to forestry can be given out to organized private sectors on very simple terms to establish forest plantations, while government provides them with attractive and encouraging incentives and subsidies.

Use of Eco-Friendly Technologies for Logging and Wood Processing: Timber harvesting involves a number of operations, which include construction of roads and skidrides, cutting of associated plants around marked trees for harvesting, felling and cross-cutting of trunks to logs, loading and transportation of logs to sawmills and/or conversion of logs into flitches right at the stump site and transportation to resawing mills. All of the logging operations are often indiscriminately carried out, thereby culminating in a considerable damage and degradation of the ecosystem with the attendant loss of juvenile trees (regeneration) which are supposed to constitute the future forest stock. Wood is a raw material that can be processed into different valuable products. Every cubic metre of wood should be prudently utilized. This can only be accomplished by using efficient and integrated technologies and greatly minimize wastes. It has been reported that most of the wood processing machines in use in Nigeria generate huge waste at every stage of production (Molinos, 2011 and 2013). Waste generation starts right from the forest through the inefficiency of chainsaw operators (Udo, 1996). Crooked logs, off-cuts, large branches and sawdust are abandoned in the forests, while in the factories; wastes are generated in the forms of slabs, sawdust and half-processed materials. However, these wastes can be processed into other useful products, but this is not often the case. The use of reduced impact logging (RIL) technologies in timber harvesting will greatly reduce ecological and environmental impacts of timber exploitation and result in greater future productivity of the forests. The use of more efficient and integrated production technologies will lead to greater efficiency in processing, less waste generation in the forest and factory and provide room for the recycling of waste generated. Localization and establishment of integrated wood-based industries especially in the timber-rich areas, should be encouraged by the government. What this implies is that different wood-based industries are sited in a close range or a neighbourhood. An integrated wood-based industry is one with different components (factories) producing different wood products. These approaches, among others, foster interdependence of the wood-based industries/factories in the area of raw material supply, that is, the by-product or waste from one industry serving as raw material to another. It has been suggested that the peeler core from the plymill and slabs from sawmills should be used for the manufacture of small items such as floor tiles, blocks and machete handles, while sawdust should be recycled to power stations as fuel for the generation of steam (Oyagade, 1997 and Olajide, *et al.*, 2008). These suggestions would translate to drastic reduction in the number of wood-based industries that directly exploit the forests for their wood raw material and this would invariably enhance the capacity of the forests to mitigate climate change.

Institutionalised Urban Forestry: As a result of seemingly ever increasing rural-urban migration and coupled with recent policy actions of urban renewal and development across the length and breadth of Nigeria, vast areas of forest in many villages adjoining cities and towns have been cleared to give way for city expansion and infrastructural development in the forms of road network expansion, establishment of housing estates, markets, stadia, airports industrial estates etc. In other words, many villages have been completely engulfed by city expansion and eventually turned to urban areas. The Nigerian cities or urban areas are generally characterized by seas of cement pavement, coal-tarred and interlocked stones surfaces, which cause rise in ambient temperatures. The adverse environmental effects of widespread clearance of forests for urban expansion and development include aggravated soil erosion and flooding, loss of watersheds, increase incidence of damage of property (particularly houses) by storms, exacerbated air pollution, aggravated global warming and climate change. The practice of urban forestry is more imperative now than hitherto in order to appreciably mitigate the adverse environmental consequences of urban expansion and

development, thereby engendering sustainable healthy living in Nigerian towns and cities. Urban forestry is the art, science and technology of managing trees and forest resources in and around urban community ecosystems for environmental, sociological, economic and aesthetic benefits that trees provide in the society (Konijnandijk *et al.*, 2006). Furthermore, urban forestry practice involves planting of trees in green-belts, along major avenues or roads, recreational parks, botanical gardens in and around urban areas. It also encompasses planting and management of trees around the premises of residential and corporate buildings. The benefits of urban forestry practice include erosion control, purification of atmosphere air and stream water, reduction of wind speed, carbon sequestration, noise abatement, amelioration of ambient temperatures, improvement of property values and provision of food, fuelwood, herbal medicine and timber for urban dwellers (Vyas, 2006 and Larinde, 2010).

Adoption and Promotion of Systemic Agroforestry Systems: Agroforestry is the cultivation of forest crop, arable crop and/or rearing of animals on the same piece of land simultaneously on sustainable basis. The development of agroforestry is a contemporary prominent focus in agricultural and renewable natural resources management circles with the aim of exploiting its environmental, economic and social benefits. Shifting cultivation or slash-and-burn agricultural practice has caused widespread destruction of forests in West and Central Africa sub-regions. Shifting cultivation practice involves a process whereby a farmer clears an area of forest to cultivate a combination of arable crops for about two or three years and thereafter abandon the area, because of declined fertility of the soil and clear another expanse of forested land for cultivation. However, in the chains of shifting cultivation, farmers allow some forest tree and shrub species, which produce products of economic and social values to remain on their farms. In addition to the economic and social values, the standing trees and shrubs on the farms protect the soils against erosion and enrich the fertility of the soils. Moreover, the trees standing on the farms provide firewood, poles and in some cases, timber for the use of farming households and also, sources of income. It therefore implies that agroforestry has been a long time practice. Due to rapid increase in human population and increase demand for lands for economic development activities, land has become scarce for agricultural production and consequently, continuous cultivation of a piece of land year in and year out by a farmer using chemical fertilizers to enhance soil fertility becomes a prevalent practice. The production and use of chemical fertilizers generate a lot of greenhouse gases. IPPC (2007) attested to the fact that agriculture accounts for at least one quarter of all the world's greenhouse gas emissions. Agricultural activity plays a significant role in the issue of global warming nay climate change by producing methane (CH₄), the second most important greenhouse gas, though it is hard to assess these emissions with accuracy (Adedire, 2010). Optimal production of forest and agricultural products on the same area of land simultaneously and sustainably, would greatly reduce the rate of clearance of the remaining areas of forest for cultivation of arable crops. From research, a number of tree species that are capable of continual and steady maintenance of mineral nutrients' enrichment of soils have been identified and incorporated into agroecosystem. Organized agroforestry systems, like alley cropping and alley farming have been developed, but yet to be widely adopted and practiced by farmers across the country. Possibly because of poor extension service. In other words, deliberate and systemic planting of trees capable of continual renewing soil fertility and produce economically valued non-timber products, has not been widely adopted and practiced. In addition to the drastic reduction in the rate of deforestation and enhanced environmental services of the forests, organized agroforestry systems protect the soil against erosion, sequester carbon and create favourable micro-climate for high productivity of arable crops.

Conclusion and Recommendations: Forestry actions are undoubtedly imperative in sustaining friendly environment and mitigating the adverse effects of climate change as economic development activities is rapidly on the rise. For forestry to play the needed roles in greening the Nigerian growing economy, attention must be given to the following:

- i) community participatory management approach should be adopted and emphasised in the management of forest resources by mutually beneficially involving communities adjoining the gazetted and protected forests in all forest conservation actions.
- ii) comprehensive review of policies and laws pertaining to forestry across the country to enable and encourage private sector involvement in forest property ownership and practice of urban forestry.
- iii) provision of subsidies and incentives by government to individuals and organizations investing in forest plantations' establishment for the purpose of environmental protection.
- iv) forestry Directorates and Agricultural Extension Services of government should partner to spread the adoption and practice of organized or systemic agroforestry by farmers.
- v) Nigeria should modify and domesticate the international practice of carbon credit through enforceable legislation that will make it mandatory for big industries to commit a percentage of their profits before tax to afforestation for the purpose of climate change mitigation.
- vi) waste-saving technologies should be introduced and adapted for logging and wood processing
- vii) Government should promote and encourage the use of alternative products to wood by ensuring their availability and affordability to drastically reduce the high rates of cutting during the forests and trees for timber and firewood.

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Species and Breed-Dependent Differences in Saturated and Unsaturated Fatty Acids of Ruminant Milk

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ABSTRACT

This study investigated the effect of species and breed on the composition of saturated and unsaturated fatty acids in milk. The species examined were goats and cattle, with two breeds selected from each: Sokoto Red and Kano Brown for goats, and Bunaji and Rahaji for cattle. A 2×2 factorial experiment was conducted using a completely randomized design (CRD) with five replications. Ten fatty acids were analyzed—five saturated (lauric, myristic, palmitic, stearic, and arachidic acids) and five unsaturated (palmitoleic, oleic, linoleic, linolenic, and arachidonic acids). Data collected were subjected to analysis of variance (ANOVA) and Pearson's product-moment correlation (PPMC). The results revealed that species had a significant ($p < 0.05$) effect on the concentrations of palmitic and stearic acids (saturated) and palmitoleic, oleic, and linoleic acids (unsaturated). Cow milk contained higher levels of saturated fatty acids, while goat milk had higher levels of unsaturated fatty acids. Breed also significantly ($p < 0.05$) affected palmitic and linoleic acid concentrations, with milk from Sokoto Red goats showing the highest values, and the Rahaji breed the lowest. Correlation analysis indicated that most coefficients were negative and non-significant, ranging from -0.590 to -0.995 for goats and -0.436 to -0.994 for cattle. In conclusion, goat milk is recommended over cow milk due to its higher average content of unsaturated fatty acids, which are considered beneficial to human health.

Key words: Milk, Saturated fatty acids, Unsaturated fatty acids, Species and Breed

INTRODUCTION; Milk is a vital source of essential nutrients, including proteins, minerals, vitamins, and lipids. Among its constituents, milk fat plays a crucial role in human nutrition, not only as a dense energy source but also for its content of bioactive fatty acids that influence health outcomes (Parodi, 2004). Fatty acids in milk can be broadly categorized into saturated fatty acids (SFAs) and unsaturated fatty acids (UFAs), with the latter being particularly valued for their positive health implications, such as reducing cardiovascular risk and improving lipid metabolism (Jensen, 2002; Kratz et al., 2013). The composition of milk fatty acids varies significantly across animal species, breeds, feeding systems, and lactation stages (Chilliard et al., 2007). Species differences between goats and cattle, for example, are known to influence the lipid profile of milk, with goat milk generally containing higher proportions of short-chain and unsaturated fatty acids compared to cow milk (Park et al., 2007). These differences may be attributed to physiological variations in lipid metabolism between ruminant species. Furthermore, within species, breed variation can significantly impact milk composition. Genetic differences among breeds influence the biosynthesis and secretion of milk components, including fatty acids (Stoop et al., 2008). Understanding these breed-specific differences is essential for optimizing milk quality and selecting breeds for targeted nutritional or industrial purposes. Despite the growing interest in the nutritional benefits of ruminant milk, limited comparative studies have focused on the interactive effects of species and breed on both saturated and unsaturated fatty acid profiles. Therefore, this study aims to evaluate the effects of species (goats vs. cattle) and breed on the composition of saturated and unsaturated fatty acids in milk. The findings could guide dietary recommendations and breed selection strategies for enhanced milk quality and public health.

MATERIALS AND METHODS

Study area: The study was conducted at Danbatta Local Government, Kano State positioned on latitude $12^{\circ}20.260'N$ and longitude $8^{\circ}31.567'E$ (Ovimaps, 2018). The area possesses a tropical climate with mean annual rainfall of 600 mm which lasts for four months (May to September). The mean annual temperature is $38^{\circ}C$ with the highest occurring in April ($41^{\circ}C$) and lowest in January ($30^{\circ}C$). The relative humidity ranges from 22 to 52% (Ahmad, 2015). **Experimental Design and Animal Selection:** The study employed a 2×2 factorial arrangement in a Completely Randomized Design (CRD), with five replications per treatment group. Two ruminant species—goats and cattle—were selected, with two breeds chosen from each species. The goat breeds included Sokoto Red and Kano Brown, while the cattle breeds were Bunaji and Rahaji. All animals used in the study were healthy lactating females, maintained under similar management conditions to minimize environmental variation.

Feeding and Management: Animals were housed in well-ventilated pens and fed a standard diet consisting of a basal roughage component (grass hay) and a concentrate supplement formulated to meet maintenance and lactation requirements. Clean water was provided ad libitum. Feeding was done twice daily, and all animals were allowed a two-week acclimatization period prior to sample collection.

Milk Sampling: Milk samples were collected manually from each animal in the morning over five consecutive days to account for individual variation. Approximately 200 mL of milk was collected from each animal per sampling session. The samples were immediately cooled and transported to the laboratory under refrigerated conditions ($4^{\circ}C$) for fatty acid analysis.

Fatty Acid Analysis: Fat extraction was performed using the Folch method (Folch et al., 1957), with minor modifications. The extracted lipids were methylated to fatty acid methyl esters (FAMES) using methanolic potassium hydroxide (KOH), and analyzed using Gas Chromatography (GC) equipped with a flame ionization detector (FID). Ten fatty acids were quantified, comprising five saturated fatty acids (lauric, myristic, palmitic, stearic, and arachidic acids) and five unsaturated fatty acids (palmitoleic, oleic, linoleic, linolenic, and arachidonic acids). Identification was based on retention times compared with known standards.

Statistical Analysis: The data obtained were subjected to two-way Analysis of Variance (ANOVA) using statistical software (SAS, version 9). The main effects of species, breed, and their interaction were tested. Means were separated using the least significant difference (LSD) test at a significance level of $p < 0.05$. In addition, Pearson's Product-Moment Correlation (PPMC) was employed to determine the relationships between the concentrations of different fatty acids.

RESULTS AND DISCUSSIONS

Effect Species and Breed of Goats and Cattle on Fatty Acid Composition of Milk: Effect of species on saturated and unsaturated fatty acid composition of milk is presented in Table 1. Significant effect ($p < 0.05$) of species was observed on two saturated (palmitic and stearic) and three unsaturated (palmitoleic, oleic and linoleic) fatty acids. Milk from cows had higher saturated fatty acids than goats' milk, while for the unsaturated, the latter had higher values than the former. However, non-significant effect of species was noticed on lauric, myristic, arachidic, linolenic and arachidonic acids. Effect of breeds of goats and cattle on saturated and unsaturated fatty acid composition of milk is presented in Table 2. Significant effect ($p < 0.05$) of breed was observed on palmitic and linoleic acids. Milk from Sokoto Red goats had the highest for these fatty acids, while the least values were recorded in milk obtained from Rahaji breed. However, non-significant effect of breeds of goats and cattle was noticed on lauric, myristic, stearic, arachidic, palmitoleic, oleic, linolenic and arachidonic acids. Fatty acids play an important role in human health. It has been reported that polyunsaturated FA (PUFA) protect against heart attack risk, improve brain function, and reduce risk of dementia (Calder, 2015), and conjugated linoleic acids (CLA) inhibit the carcinogenesis and reduce the risk of atherosclerosis and diabetes (Walter *et al.*, 2008). The significant effect of livestock species observed on palmitic and stearic acid with the cattle having the highest values showed that milk from these animals (cattle) had higher saturated fatty acid which is detrimental to human health. This was similar reported by Boyazoglu and Morand-Fehr (2001) who estimated the percentages of about eight saturated fatty acid in lactating cows and goat and noticed that the values of these fatty acid reported in the former (cows) were significantly higher than the estimates recorded in the latter (goats). The authors attributed these variations to species differences. Among the species, variations were observed on myristics, palmitic and arachidic, they concluded that these differences could be as a results of management system since the milk samples were randomly selected from different farms. The work by Lordan *et al.* (2018) in the same species of livestock proved that milk from dairy cow had higher values on all the saturated fatty acids recorded and recommended the consumption goat milk health wisely. Jirillo *et al.* (2010) conducted a research on reconstituted yoghurts made from cow and goat milk powder and observed that yoghurt from cows had higher stearic acid (a saturated fatty acid) than that of goats. The author concluded that this could be reason why goat milk is cherished and priced high in most part of the world since it had more health benefit and now a days, people are very much conscious about health issues. Faye and Konuspayeva (2012) recommended butter fat from goats to individuals with high blood pressure due to low saturated fatty observed in their milk. The authors explained that saturated fatty acid triggers blood pressure and such compounds are very high in cow milk thereby unhealthy for hyperthetetic individuals. On the other hand, the work by Park (1994) on different breeds of dairy cows and goats showed that goat had higher value on most saturated fatty acid estimated. Similarly, Manuelian *et al.* (2017) review on milk fatty acid and composition of ruminants (cows, sheep and goats) observed that goats' milk had the highest mean on all saturated fatty acids recorded. Furthermore, Calder (2015) observed that yoghurt from goats' milk had higher saturated fatty acid than that of cows and buffaloes. The non-significant effect of species observed on lauric, myristic and arachidic acids is in line with the report by Walther *et al.* (2008) who noticed that cows' milk had higher for these acids but it is not statistically significant.

Table1: Effect of species on saturated and unsaturated fatty acid composition of milk

Fatty acid type	Parameters	Goat	Cattle	Level of significance
Saturated	Lauric acid	2.14±0.16	2.47±0.18	0.209
	Myristic acid	1.79±0.37	2.02±0.29	0.641
	Palmitic acid	2.22±0.36	30.74±10.94	0.040
	Stearic acid	2.73±0.26	8.72±2.50	0.046
	Arachidic acid	0.67±0.11	0.52±0.05	0.296
Unsaturated	Palmitoleic acid	1.75±0.11	0.66±0.22	0.005
	Oleic acid	38.33±7.57	12.99±1.93	0.018
	Linoleic acid	30.70±7.00	7.90±2.49	0.022

Linolenic acid	2.24±0.18	1.53±0.41	0.168
Arachidonic acid	2.67±0.46	2.14±0.20	0.338

Also, Poppitt *et al.* (2002) in some selected breeds of dairy goats and cows indicated the absence of significant variation on estimated fatty acids. The fact that goats' milk had higher unsaturated fatty (palmitoleic, oleic and linoleic acids) as reported in the present study is well documented (Schonfeld and Wojtczak, 2016). Similar observation was made by Van Schalkwijk *et al.* (2014) who reported that the unsaturated fatty acid found in goats' milk were higher than that of cows and noticed that they are antagonists to saturated fatty acid (even though not clearly understood). The fact that breeds of goat and cattle had effect on palmitic acid as reported in the current study agrees with the finding by Chilliard *et al.* (2000) who worked in different breed of both species and recorded higher myristic and arachidic values (both saturated fatty acid) in goats than cows. The work of Palmquist (2009) among different cattle breed showed that there was significant variation on palmitic acid. Benedet *et al.* (2019) reported that goats had higher percentage than cows on overall fatty acid profile recorded. Working on Saneen and other specialized dairy goat, Griinari *et al.* (1998) reported higher values of milk components and fatty acid profile in this breed (Saneen) and attributed the results obtained to specialization of this breed in milk production. Other factor that affected fatty acid composition includes feed and stage of lactation. For example, Strzalkowska *et al.* (2009) reported differences of FA profile in early, mid, and late lactation of Polish White Improved goats. Yurchenko *et al.* (2018) demonstrated that milk from Saanen and Landrace goat breeds fed the same ration differed from C4:0 to C14:0, C16:0, C16:1, and C18:1. Diets richer in concentrate than forage cause the reduction of the ruminal pH and the activity of cellulolytic bacteria; this leads to the increase of trans-10, cis-12 CLA synthesis in milk which could induce milk fat depression syndrome (Griinari *et al.*, 1998). However, the existing literature about FA profile characterization is limited to a restricted number of breeds and to our knowledge few studies have investigated the milk FA composition of older and endangered goat breeds.

Table1: Effect of Breed on saturated and unsaturated fatty acid composition of milk

Fatty acid type	Parameters	Sokoto Red	Kano Brown	Bunaji	Rahaji	LOS
Saturated	Lauric acid	2.38±0.13	1.90±0.13	2.64±0.24	2.30±0.27	0.218
	Myristic acid	1.30±0.30	2.28±0.51	1.71±0.31	2.33±0.46	0.342
	Palmitic acid	45.93±9.87 ^a	15.54±12.62 ^b	2.05±0.66 ^c	2.40±0.53 ^c	0.050
	Stearic acid	8.07±6.04	9.38±0.22	3.17±0.14	2.29±0.04	0.375
	Arachidic acid	0.55±0.10	0.49±0.05	0.48±0.08	0.85±0.08	0.081
Unsaturated	Palmitoleic acid	1.72±0.28	1.79±0.01	0.43±0.13	0.88±0.43	0.054
	Oleic acid	47.10±12.86	29.56±4.92	11.56±0.64	14.41±4.24	0.074
	Linoleic acid	40.90±9.10 ^a	20.50±1.85 ^b	11.07±0.17 ^c	4.72±4.13 ^d	0.026
	Linolenic acid	1.20±0.81	1.86±0.39	2.34±0.24	2.14±0.36	0.476
	Arachidonic acid	1.98±0.32	3.36±0.48	2.08±0.48	2.21±0.00	0.159

Phenotypic Correlation Coefficients of Fatty Acid Composition: The phenotypic correlation coefficients of fatty acid composition of both goats' and cows' milks are presented in Table 3 and 4, respectively. The results indicated that most of the coefficients recorded in both livestock species were negative and non-significant, with few having values ranging from – 0.590 to – 0.995 for goats and -0.436 and -0.994 for cattle. However, high, positive and significant values were observed between lauric and linoleic (0.878), myristic and linolenic (0.830), palmitic and oleic (0.917) and stearic and palmitoleic (0.929) acids in goats and between lauric and linolenic (0.959), myristic and oleic (0.787), palmitic and oleic (0.758), stearic and linoleic (0.749), arachidic and palmitoleic (0.808) and linoleic and linolenic (0.782) acids. The negative and mostly non-significant coefficients observed in both livestock species agrees with the finding of Gama *et al.* (2008) in the same livestock species. The work of Lordan *et al.* (2018) in milk obtained from dairy sheep and goats showed negative and non-significant correlation coefficients among both saturated and unsaturated fatty acid which indicates that these compounds did not share the same genes (no pleiotropic effect). However, some investigators (Popitto *et al.*, 2002) showed that significant relationship existed among the fat acid components of dairy cattle milk.

Table 3: Correlation matrix of milk fatty acid in goats

Parameter	1	2	3	4	5	6	7	8	9	10
Lauric acid (1)	1	- 0.590**	0.425*	0.203	-0.104 ^{ns}	0.161 ^{ns}	0.272 ^{ns}	0.878**	-0.540**	-0.995**
Myristic acid (2)		1	-0.755**	-0.186 ^{ns}	-0.232 ^{ns}	-0.195 ^{ns}	-0.434*	-0.875**	0.830**	0.516**
Palmitic acid (3)			1	-0.501**	0.789**	-0.496*	0.917**	0.530**	-0.261 ^{ns}	-0.392 ^{ns}

Stearic acid (4)	1	-0.894**	0.998**	-0.796**	0.393 ^{ns}	-0.703**	-0.160 ^{ns}
Arachidic acid (5)		1	-0.878**	0.929**	-0.100 ^{ns}	0.340 ^{ns}	0.102 ^{ns}
Palmitoleic acid (6)			1	-0.797**	0.375 ^{ns}	-0.708**	-0.114 ^{ns}
Oleic acid (7)				1	0.223 ^{ns}	0.139 ^{ns}	-0.273 ^{ns}
Linoleic acid (8)					1	-0.855**	-0.829**
Linolenic acid (9)						1	0.462*
Arachidonic acid (10)							1

** = p<0.01, * = p<0.05 and ns = non-significant

Table 4: Correlation matrix of milk fatty acid in cattle

Parameter	1	2	3	4	5	6	7	8	9	10
Lauric acid (1)	1	-0.515*	-0.943**	0.457*	-0.184 ^{ns}	0.302 ^{ns}	-0.872**	0.847**	0.959**	0.428*
Myristic acid (2)		1	0.240 ^{ns}	-0.737**	0.526**	-0.043 ^{ns}	0.787**	-0.887**	-0.482*	0.549**
Palmitic acid (3)			1	-0.150 ^{ns}	-0.114 ^{ns}	-0.482*	0.758**	-0.634**	-0.956**	-0.678**
Stearic acid (4)				1	-0.944**	-0.571**	-0.436*	0.749**	0.240 ^{ns}	-0.400*
Arachidic acid (5)					1	0.808**	0.114 ^{ns}	-0.488*	0.071 ^{ns}	0.461*
Palmitoleic acid (6)						1	-0.485*	0.110 ^{ns}	0.560**	0.345 ^{ns}
Oleic acid (7)							1	-0.922**	-0.913**	-0.049 ^{ns}
Linoleic acid (8)								1	0.782**	-0.118 ^{ns}
Linolenic acid (9)									1	0.451*
Arachidonic acid (10)										1

** = p<0.01, * = p<0.05 and ns = non-significant

CONCLUSIONS: Milk from cows had higher saturated fatty (palmitic and stearic) acids than goats' milk, while for the unsaturated ones (palmitoleic, oleic and linoleic), the latter had higher values than the former. Significant effect (p<0.05) of breed was observed on palmitic and linoleic acids. Milk from Sokoto Red goats had the highest for these fatty acids, while the least values were recorded in milk obtained from Rahaji breed. The phenotypic correlation of fatty acid composition of both goats' and cows' milks indicated that most of the coefficients recorded in both livestock species were negative and non-significant.

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Comparative Study of Biogas from Wastes

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ABSTRACT

Work was carried out on the comparative study of the production of biogas from biodegradable organic wastes: elephant grass, maize cub, maize chaff and saw dust in the presence of yeast at room temperature (25°C) and slurry condition of ratio 4g to 30cm³. Elephant grass, sawdust, maize cub and maize chaff were dried in the sun for about two weeks and ground to fine particles separately in different mortars. 4g of each sample was weighed separately and placed in different digesters. 0.6g of yeast and 30cm³ of water was added to the samples in the four different digesters which were connected to different devices for gas collection. The results showed that maize cub produced 245 cm³ of biogas, elephant grass produced 235 cm³ of biogas, sawdust and maize chaff produced 116 cm³ and 670 cm³ of biogas respectively. Maize chaff was found to produce the highest yield of biogas. Therefore, for maximum production of biogas, maize chaff is preferable above others. The graphs plotted show a similar pattern. It increases gradually for the first few days and a sudden rise as the days progress and finally reach a plateau (constant).

KEY WORD: Biodegradable, Slurry, organic waste, Biogas, yeast and digester.

INTRODUCTION: Society is today confronted with dwindling and depletion of fossil fuel and battling with the proliferation of wastes generated by municipalities, agriculture and industries. The conversion techniques of wastes to useful chemicals and fuels by microbial fermentation in a digester signifies a tremendous challenge for engineers in global technological stance and the future ahead with respect to energy demand. Biogas refers to a mixture of gases obtained from anaerobic digestion of agricultural wastes, organic wastes and animal dung (1). The gas is a mixture of methane (CH₄) 50 %-70%, carbon dioxide 30%-40%, hydrogen 5%-10%, nitrogen 1%-2%, hydrogen sulphide (trace) and water vapour 0.3%. The gas is useful as fuel substitute for fire wood, dung, agricultural waste, petrol, diesel and electricity. Biogas system also provides a residue organic waste after anaerobic digestion system that has superior nutrient qualities over the usual organic fertilizer (cattle dung) (2). Anaerobic digester also functions as waste disposal system, particularly for human waste and can therefore prevent potential sources of environmental contamination and the spread of pathogen (3). The generation of biogas from organic waste, refuse and food waste produces energy source (4). The search for energy such as biogas should be intensified so that ecological disaster like deforestation, desertification and erosion can be arrested (5). Biogas is practically produced as land fill gas or digested gas. A biogas plant is the name given to an anaerobic digester that treats farm wastes or energy crops (6).

MATERIAL AND METHOD: The materials used as biodegradable wastes are elephant grass, sawdust, maize cub and maize chaff. The apparatus used are measuring cylinder, delivering tube, retort stand, digester, rubber cork, weighing machine and water trough. The organic waste materials: elephant grass, sawdust, maize cub and maize chaff were dried in the sun for about two weeks and ground to fine particles separately in different mortars with pestle (7). 4g of each sample was weighed in a weighing machine and transferred to four different digesters (reacting vessels) of the same capacity of 100 cm³. 30cm³ of water and 0.6g of yeast were added to the contents of the four digesters which were connected by delivering tubes to measuring cylinders of 100cm³, emerged in a water trough (8). The biogas production was recorded daily for the different set up. Working temperature for the digesters is 25°C (room temperature).

RESULTS AND DISCUSSION

TABLE 1: CUMULATIVE DAILY BIOGAS PRODUCTION FROM MAIZE CUB

DAY	Cumulative Daily Biogas Production(Cm ³)

1	70
2	91
3-10	116
11	185
12-20	245

TABLE 2: CUMULATIVE DAILY BIOGAS PRODUCTION FOR ELEPHANT GRASS

DAY	cumulative Daily Biogas Production(Cm ³)
1	30
2	40
3-10	45
11	55
12	55
13	79
14	165
15	175
16-20	235

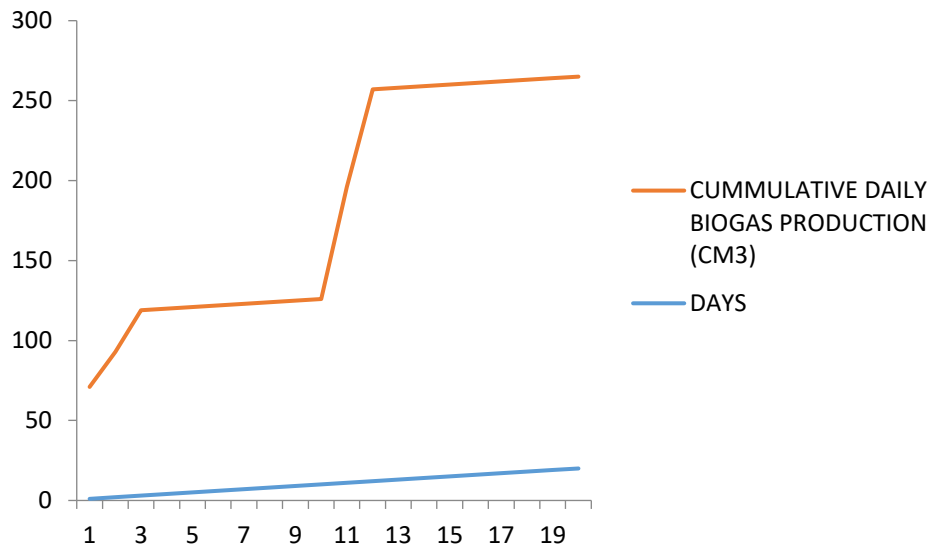
TABLE 3: CUMULATIVE DAILY BIOGAS PRODUCTION FROM SAW DUST

DAY	Cumulative Daily Biogas Production
1	10
2-9	15
10	30
11	35
12	35
13	35
14	35
15	35
16-20	116

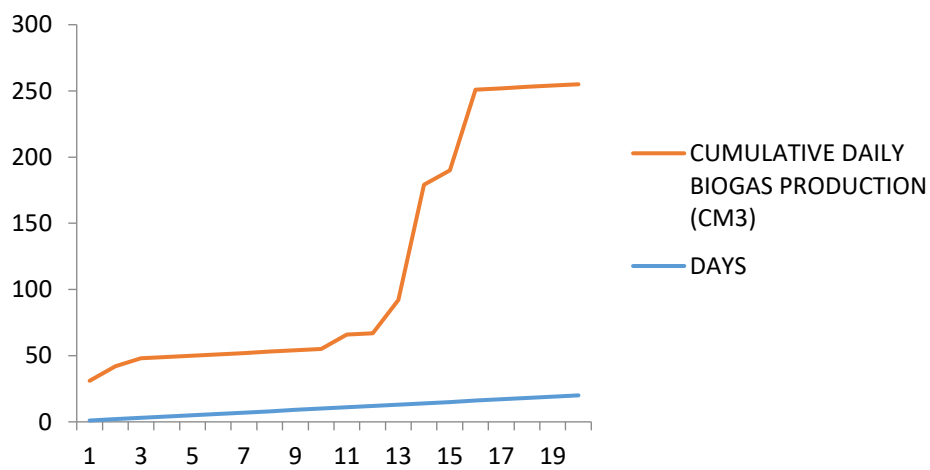
TABLE4: CUMULATIVE DAILY BIOGAS PRODUCTION FOR MAIZE CHAFF

DAY	Cumulative Production	DailyBiogas
1	120	
2	160	
3-8	200	
9	260	
10	320	
11	370	
12	545	
13-20	670	

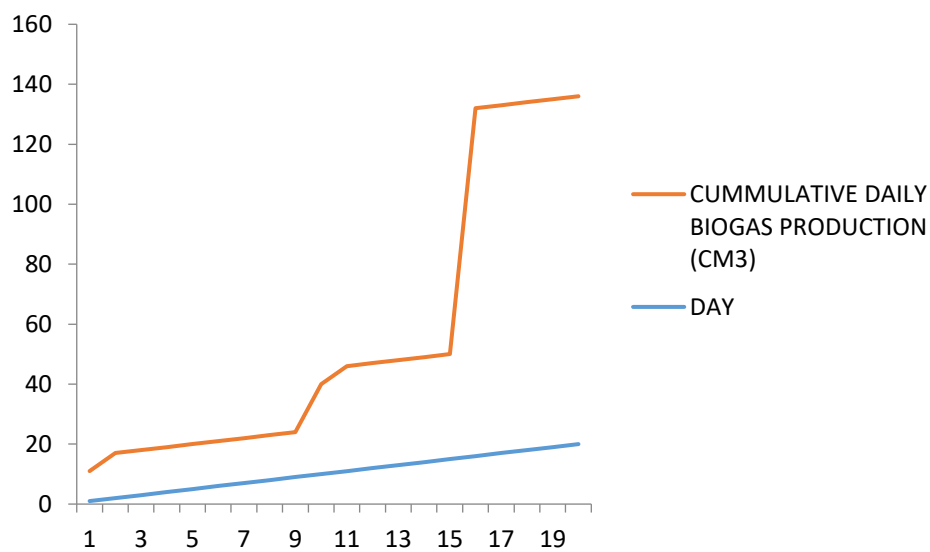
GRAPH1: MAIZE CUB



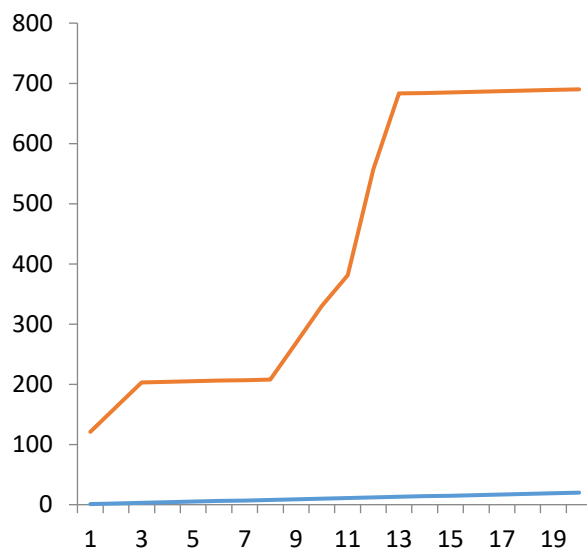
GRAPH2: ELEPHANT GRASS



Graph3: SAW DUST



Graph4: MAIZE CHAFF



RESULTS AND DISCUSSION: From the results shown in table 1-4, maize chaff produced a biogas yield of 245cm³, elephant grass produced 235 cm³, sawdust produced 116 cm³ and maize chaff produced 670 cm³. The graphs plotted above, show a similar pattern. It increases gradually for the first few days and a sudden rise as the days progress and finally reach a plateau(constant).

CONCLUSION: From the above results, the sample that produced the highest maximum yield of biogas production is maize chaff with value of 670 cm³. Therefore for maximum yield of biogas production, maize chaff is preferable above others.

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Effect of Enzyme and Vitamin Supplementation on Physiohaematological Parameters of Turkey Broiler Birds

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Abstract

This research was conducted to determine the effect of enzymes & vitamin on the physio- haematological parameters of broiler turkey birds (*Melliagris gallpavo gallopavo*) which were obtained from Big Brothers Farm (B &B) from Ilorin Kwara State. Sixty birds were used for the study. Same feed were given to the birds, the birds were grouped into four groups labeled as A, B, C and D, each group consists of fifteen (15) birds. Group A was maintained as control and placed on feed and drinking water throughout the experimental period. Group B was placed on enzymes at 1g/litter of water, group C was placed on vitamin at 0.5g/liter of drinking water and group D was placed on combination of enzymes and vitamin at the rate mentioned above. All the birds were fed the same commercial feed throughout the study. Initial body weight was recorded and subsequently, body weight was recorded at 7 days interval up to the end of experimental period and on the final day of the experiment blood sample were collected using 5ml syringe and 25 gauge needle via the wing vein for hematological haemoglobin (Hb), packed cell volume (PCV) red blood cell (RBC), white blood cell (WBC), study. The results revealed that mean value of WBC in all treated groups increased numerically with the highest value recorded in group D (242.96+15.35). However, statistically there was no significant increased ($P>0.05$) in all the treated groups. The mean value of RBC increased significantly ($P<0.05$) in all the treated groups and the highest value was recorded in group D (2.62+ 0.17) million/mm³. Similarly, the mean hemoglobin values increased significantly ($P<0.05$) in all the treated groups and the highest was recorded in group D (14.26 + 3.56) g/dl. The mean value of PVC similarly showed a significant increased ($P<0.05$) in all the treated groups with the highest value recorded in group D (42.66 + 0.21%). On platelets, no significant difference ($P<0.05$) was recorded in all the treated groups. On body weight there was an increased body weight gain numerically in all the treated groups than control group. The data showed that numerically on the 7th day there was an increase in body weight, however, statistically no significant difference ($P< 0.05$) was recorded in all the treated groups. Similarly, on day 14th, 21st, and 28th there was a numerical increase in body weight in the treated groups and the highest value was always recorded in group D in all the weeks. It is concluded that enzyme and vitamin has no negative effect on the turkey broiler birds, it rather enhance digestion utilization, performance and hematological parameter of turkey birds was not altered. Enzyme and vitamin should be used to enhance performance of the bird and a similar study should be carried out using the same enzyme and vitamin in turkey birds to see their effect in terms of egg production.

Keyword: Enzyme, Vitamin, Supplementation, Physiohaematological, Parameters, Turkey Broiler

INTRODUCTION: Turkey broilers are domestic birds raised for meat purpose. Turkey forms almost two percent of the total poultry production (Rajeshwara and Devishree, 2023). They are reared for meat only. Their meat is the leanest (having little fats) among other avian species. Turkey has nutritional and sensorial properties which makes it almost ideal raw material for rational and curative nutrition (Mahesh and Schulze, 2020). Turkey meat contains protein, fats, and the energy values of turkey meat are 240, 6.6%, 162 calories per 100gm of meat. Like potassium, calcium, magnesium, iron, selenium, zinc and sodium are present: it is also rich in essential amino-acids and vitamins like niacin, vitamin B6, B12. It is rich in unsaturated fatty acids and low in cholesterol (Rajeshwara and Devishree, 2023). Enzymes are proteins and are organic catalyst which take part in the rate of chemical reaction and increased the speed of chemical reaction without themselves undergoing any permanent changes or they are biological catalyst that accelerate a chemical reaction without altering its equilibrium (e.g. hydrogenase and carbohydrase's enzymes) (Mahesh and Schulze, 2020). Vitamins are organic compound which are needed in small quantities to sustain life, we get vitamins from the food we eat because the body of animals' either does not produce enough of them or none at all (Barton and Trabert, 2019). Both enzymes and vitamins has some effect but the adverse effect can be overcome by supplementation of exogenous carbohydrates (xyloses)enzymes which have been shown to lower viscosity of intestinal content and to improve digestibility of starch, proteins, fats and apparent metabolizable energy (AME) in broiler fed diet containing wheat (Annison and Choet, 2019; Bedford, 2019). The nutritive value of available feed stuffs such as wheat, maize, rice-polish, soya beans meal etc. contain more undigested part, so the feed utilization and digestibility is also poor. Exogenous enzymes should have the ability to breakdown plant cell wall materials and nutrient such as protein and starch (Singen, 2019), thereby feed utilization and digestibility is expected to get enhanced. Adding non starch polysaccharides (NSP) degrading enzymes in turkey diet has increased in recent years (Bedford and Shulze, 2019) (Bedford 2020; Acamovic, 2021). Therefore optimum enzyme and vitamin supplementation are required for turkey, poultry, and formulating premixes are necessary, Vitamins play an important role in both nutrition and production (Dowel, 2019).

MATERIALS AND METHODS

Experimental Site: This study was conducted in the Department of Animal Science, College of Agriculture, Federal University of Agriculture Zuru, Kebbi State, Nigeria. Zuru is located within latitude $11^{\circ} 45'$ and $5^{\circ} 25'$ East of the equator in the Northern Guinea savannah of the South Eastern part of Kebbi State (KBSG, 2003) it is also found in the extreme South Eastern part of Kebbi State on a hilly terrain and bounded to the North by Gummi Local Government Area North West by Yauri Local Government Area, North East by Bukkuyum Local Government Area of Zamfara State and South by Rijau Local Government Area of Niger State (Sakaba *et al.*, 2017).

Experimental Birds: A total number of sixty (60) broiler turkeys were used for the experiment the birds were sourced from B and B (Big Brother) poultry farm in Ilorin Kwara State.

Management of Experimental Birds: A week before the arrival of the birds the pen was thoroughly cleaned, washed and disinfected with detergent (Klin) and universal germicide (1ZAL) respectively, the pen stayed for three days to get rid of pathogens that may be harboring in the pen from previous stockings. Feeding and water trough were available, in addition to litter materials. The pen was partitioned into four (4) compartments which are treatment A, B, C and D respectively.

Experimental Diet: Commercial feed was given to turkey broiler from 0-4 weeks. Starter diets composition - 28% CP, lysine 1.70%, methionine 0.62, calcium 1.4%, phosphorus 0.7% sodium 0.18%, metabolizable energy (ME) 2900kcal/kg, Finisher Diet - 18% CP, lysine 1.15%, methionine 0.4%, calcium 0.90%, phosphorus 0.6%, sodium 0.17% metabolizable energy (ME) 3 100kcal/kg.

Experimental Design: The birds were randomly divided into four equal groups each group consisting of fifteen (15) birds and were numbered as group A, B, C and D) respectively. And each group was replicated three times with five birds per replicate. Group A was the control and was placed only on water without additives, then group B was placed on vitamin at 0.5g/liter of drinking water, group C was placed on enzyme at 1.0g/liter of drinking water and group D was placed on both enzymes and vitamins, at the above mentioned rate. The additives were measured using electronic weighing balance in the college laboratory. All the birds were fed with commercial feed throughout the experimental period.

Data Collection: Initial body weight of the birds was recorded and subsequently the weights were taken on weekly basis up to the end of experimental period. At the end of the experiment blood was collected for analysis at the end of the experiment or study for blood parameters (RBC, WBC, PCV, and HB).

Sample Collection: The blood was collected in the morning, by the use of 5ml syringe and 26 gauge needles, the area used for collection of blood was disinfected using spirit and cotton wool, the hand gloves used was properly disposed. 3ml was dispensed into the EDTA bottle for RBC, WBC, PCV and HB examination.

Data Analysis: Data generated from the study was expressed in mean and standard deviation and then subjected to analysis of variance (ANOVA).

RESULTS AND DISCUSSION: All the hematological values analyzed in the study are presented in table 1. The mean value of WBC in all treated groups increased numerically with the highest value recorded in group D (242.96 ± 15.35) however, statistically there was no significant increased ($P > 0.05$) in the body weight recorded in all the treated group. The mean value of RBC increased significantly ($P < 0.05$) in all he treated groups and the highest value was recorded in group D (2.62 ± 0.17) million/mm, Similarly, the mean hemoglobin values increased significantly ($P < 0.05$) in all the treated groups and the highest was recorded in group D (14.26 ± 3.56) g/dl. The mean value of PVC similarly showed a significant increased ($P < 0.01$) in all the treated groups with the highest value recorded in Group D (42.66 ± 0.210). On platelets, no significant difference ($P < 0.05$) was recorded in all the treated groups. The hematological parameter of present findings is in conformity with that of Dukes (1955) who reported that the number of erythrocytes and other component of blood may decrease or increased due to the influence of age, environment, exercise, nutritional status and climate.

Table 1: Effect of enzyme and vitamin supplementation on physiological parameters of turkey broiler birds

N = 5 groups	WBC	RBC	HGB	PCV	PLT
Control A	23.64 ± 4.17^a	2.47 ± 0.08^b	12.40 ± 0.16^b	37.20 ± 0.16^b	0.12 ± 0.44
Enzyme B	235.12 ± 0.59^a	2.47 ± 0.03^b	12.36 ± 0.11^b	37.40 ± 0.16^b	0.22 ± 0.44
Vitamin C	239.44 ± 5.31^a	2.62 ± 0.08^b	12.32 ± 0.19^b	36.80 ± 1.40^b	0.22 ± 0.44
Combination D	242.96 ± 15.35^a	2.62 ± 0.17^{ab}	14.26 ± 3.56^{ab}	42.26 ± 9.42^{ab}	0.21 ± 0.44

N=No of blood sample tested, values with different superscripts in the same column differ significantly ($P < 0.05$).

Values with different superscripts in the same column differ significantly ($P < 0.05$). Turkey treated with different treatments of enzymes and vitamin supplement showed an increased body weight gain numerically than control group. The data showed that numerically on the 7th day there was an increase in body weight, however statistically no significant difference ($P < 0.05$) was recorded in all the treated groups. Similarly, on day 14th, 21st, and 28th there was a numerical increase in the treated groups and the highest value was always recorded in group D in all the weeks. These research is in line with the earlier report of Ahmed *et al.* (2017), Meng *et al.* (2019); Saleh and Ward (2019); Wang *et al.* (2019); Silva and Smithard (2022) that birds placed on supplements such as vitamin and enzymes performed better. The decreased in body weight gain in most of the treated groups statistically may be due to environmental factor, and species of animal but grossly there was increase in body weight and this might not be unconnected with the feed intake, feed consumption, utilization, digestion, absorption and metabolism of supplied feed nutrients especially protein essential for their health and body weight gain. The increased body weight gain in group D is due to synergistic effect of combined treatment of enzyme and vitamin. This finding is not in agreement with the Carlier reports of Villar (2020) who reported that the weight gain and feed efficiency increased statistically with enzyme and vitamin supplementation.

CONCLUSION: The study was designed to establish the effect of enzymes and vitamin on the haematological indices of turkey birds raised in Department of Animal, Following this experiment, it is therefore concluded that the agents has no effect. It rather enhance feed digestibility, weight gain, and growth rate, and the haematological parameters of the turkey birds were not altered.

RECOMMENDATION: Based on the research findings, it is therefore recommended that; these agents (enzyme and vitamin) can be used to enhance feed intake, digestibility in poultry and turkey birds

1. Further study should be carried out using these agents on other species of birds to ascertain their performance.
2. Farmers should be encouraged to use the agents to enhance their production
3. A similar study should be carry out to assess whether these agents could influence egg production in turkeys

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Effects of Fadama iii Project on Livelihood Activities pf Small-Holder Farmers in Kebbi State, Nigeria.

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ABSTRACT

The study was conducted to examine the effects of Fadama III additional funding (AF) project on livelihood activities among smallholder farmers in Kebbi state, Nigeria. A multistage sampling procedure was used to randomly select 180 participant farmers to constitute the sampling size for the study. Primary data and secondary source of information were used and the data were collected with the aid of structured questionnaire. Descriptive statistic like frequency, percentage and mean score were used to analyze the data, food security score line tool was used to determine the farmer's food security status/level. The result revealed that 45.1% of farmers were within the age bracket of 31-50 years, with the mean years of 45.6. Majority of participant farmers representing 67.2% were males while 32.8 were females. A total of 43.9% of the participant farmers had 6-10 members in their household, and the average household size was 12.2 members. It was revealed in the result that greater proportion of 31.6% of participant farmers had 11-20 years of farming experience and the average farming experience of 22.1. About 86% have been involved in Fadama membership for 6-15 years, with average membership years of 10.9. The result also revealed that major livelihood activities engaged by respondents were crop production, animal rearing, poultry production, non-farm activities and agro- processing. However some problems were encountered by the respondents. The study recommended that there is need for Fadama participants to have access to credit as financial assistance from Fadama project cannot meet their demand for inputs, various stake holders including farmers should be involved in planning, execution, monitoring and evaluation of the programme, and the programme should be sustain.

KEYWORDS: Effects, Fadama III Project, Additional Funding, Livelihood Activities, Smallholder farmers, Kebbi state. Nigeria

INTRODUCTION: The National Fadama Development Project (NFDP) was established to guarantee all-year round growing of crops and promotion of simple and low-cost improved irrigation under a World Bank financing. Food crops grown on the Fadama include rice, leafy vegetables, okra, maize and other crops including root and tuber. Fadama projects aim at reducing poverty by increasing farm productivity and income of farmer participants (Bello, 2008). The projects so far (NFDP I and NFDP II) were adjudged successful by both national and international assessors culminating in Federal Government of Nigeria requesting the World Bank for implementation of the third National Fadama Development Project (NFDP III) (Ezeh, 2007 and Ike, 2012). The scope of the Third National Fadama Development Project (NFDP III) was extended to involve all 36 states in the federation and the Federal Capital Territory (FCT) as a tripartite funded intervention of the World Bank, the Federal Government of Nigeria and participating States. Funding is by World Bank contributing 55.6%, Federal Government of Nigeria, 5.1%; participating States and Local Governments contributing 17.1% and 8.9% respectively.

The World Bank had provided the sum of \$200m US Dollars for Nigeria Fadama III project as at August 2013 (World Bank, 2013). The NFDP III is aimed at sustainably increasing income of beneficiary groups such as Fadama Users Groups (FUGs) and Fadama Community Associations (FCAs) in all the states, by directly delivering resources to them, empowering them to take decisions collectively on how to effectively and efficiently allocate and manage resources for their livelihood activities (Osondu *et al.*, 2014). By doing this the project would help reduce rural poverty, increase food security and contribute to the achievement of a key millennium development goal. The project which started from July 2008 and has an end line to June 2013 has been extended to 2017, and ended in December 2017. The programme strategy included investing in public infrastructure, asset acquisition using matching grants and advisory services on best ways of improving group management mechanisms to avoid and resolve conflict(s) within participating groups (FMARD, 2003). In this regard facilitators had been deployed to Nigerian communities to provide training and technical support to all categories of Fadama resource users. To improve performance of the programme in each state and ensure welfare delivery, statutory and independent assessments need to be made with evidences gathered from farmers themselves (Mohammed *et al.*, 2014). It is worthy of note that the desire to harness the verse potentials of Fadama in Nigeria culminated in the design of National Fadama Development Projects I, II, III and then Fadama III – Additional Financing. Fadama III Additional Financing, which was an extension of Fadama III, aimed at sustaining an increase in the income of users of rural land and water resources (Agunloye, Fasina, and Akinagbe, 2017). The project was to scale up the impacts and the development effectiveness of a well-performing project by aligning it more closely with the new Agricultural Transformation Agenda, which was adopted by the Government of Nigeria in 2011. The project has been consistent with the development objective of the parent project and as such, no major changes were made to the Project Development Objective, design or implementation arrangements of the original project. Nevertheless, the main difference is that instead of national coverage as in the

case under the parent project, the AF had a narrow geographical focus on clusters of farmers in selected states with comparative advantage and high potential to increase production and productivity of cassava, rice, sorghum and horticulture value chains and link them to better-organised markets. (NFCO, 2018; Dayo, Olumuyiwa, Yarama, Malomo and Ekong, 2018)

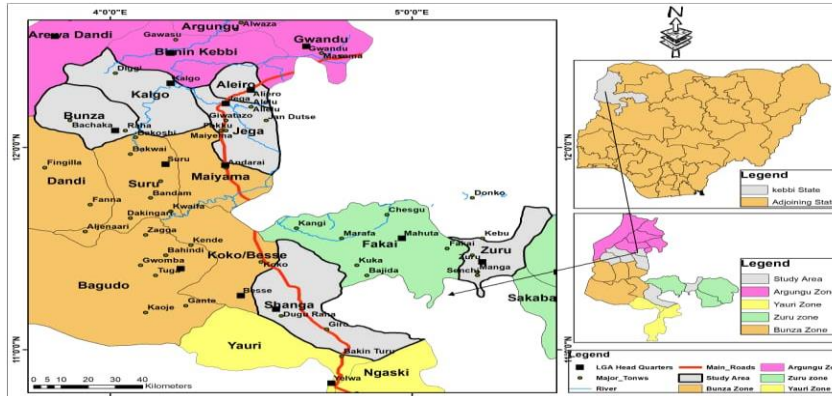
The concept of livelihood and sustainable livelihood framework has become an integral part of rural development and poverty reduction in recent times. Rural livelihoods are composed of the activities that provide the means of household survival and long-term well-being (Stephen and Lenihan 2010). The further stated that state that livelihood strategies may be classified into natural resources-based activities (e.g. collection and gathering, cultivation, livestock-keeping, etc) and non-natural resources based activities (e.g. trade, services, remittances). The livelihoods framework is founded on a belief that people require a range of assets to achieve positive livelihood outcomes. Assets require investments of time and money in order to be acquired or create livelihoods resources. Different households have different access to livelihood assets, which the sustainable livelihood approach aims to expand. Changes in the portfolio of assets, their productivity and the extent to which households have access to them are the attributes that are critical in determining livelihood diversification and ultimately household welfare (Dorward et al., 2003). Small scale farmers constituted 90% of Nigeria's agricultural output (Ayinde *et al*, 2020) while the majority of such farmers are not able to feed themselves and other relatives. The low productivity is mainly as a result of fragmented land holdings, over a reliance on rain-fed agriculture, climate change, low access to input and poor economic base. Small-holder agriculture involves about 95% of Nigerian farmers, while the corporate and government supported large-scale farms account for the 5 percent. However, efforts in promoting agriculture in the country prioritize the 5%, possibly due to their alliance and proximity to government agencies, thereby giving less attention to the greater percentage of the farming population. Small-holder farming system characterizes Nigeria's food production system. The system is operated on small farms, family-owned, rented, or leased as a dominant form of agriculture. Small-holder farmers constitute a significant proportion of farm holdings in Nigeria and have continued to feed the nation and its people, but the system receives inadequate support and improper attention from government (Sabo *et al.*, 2017). Although, concerted efforts have been made by past and present governments of Nigeria towards improving agricultural productivity and production efficiency and in alleviating poverty among the rural farmers, millions of people in Nigeria are still poor and hungry (Simonyan *et al.*, 2010). Studies have been carried out in different parts of Nigeria and on different aspect of the impact analysis of the National Fadama Development Project. For example, Bajoga *et al*, 2006, Adeoye *et al* 2011 and Ugwumba and Okechukwu, 2014) etc, showed that a lot of studies have been conducted on Fadama development project on the living standard of dry season farmers, small-scale farmer's income, poverty alleviation among farmers, rural infrastructure and profitability of farmers, FUGs mid-term performance of the programme, poverty and food security among rice farming beneficiaries in Nigeria. But majority of these studies were conducted on Fadama I and II while few of them were on Fadama III, and this create a gap. Thus, this current study is determined to fill the gap as it is focus to determine the effects of Fadama III on livelihood activities among small holder farmers in kebbi state. Therefore, the need to evaluate and validate this claim became necessary and this necessitated this study, Hence, the study seeks to provide answers to the following research questions;

1. What are the socio-economic characteristics of Fadama III AF participating farmers?
2. What are the livelihood activities engaged by the Fadama III AF participating farmers?
3. What are the problems faced by Fadama III AF programme participating farmers?

RESEARCH METHODOLOGY

Description of the Study Area: The research was conducted in Kebbi state. It lies in north western region of Nigeria with its capital in Birnin kebbi. Based on projection from 2006 census figure, kebbi state is estimated to have a population of 4, 629,880 (NPC, 2006: projected to 2017). Kebbi state is made up of 21 local government area (LGAs). It has four (4) emirate councils (Gwandu, Argungu, Yauri, and Zuru) and has four (4) agricultural zones namely Agungu, Bunza, Yauri and Zuru zones respectively, for ease of administration. Kebbi state falls between latitude 12 46N and 12 27N and longitude 4 19E and 4 11E. Agriculture is the main occupation of people of the state especially in the rural areas. Crops produced are mainly grains like rice, millet, sorghum etc. The weather of the state is often dry with lots of sunshine. The wet season last from May to October, while the dry season lasts for the remaining period of the year. Mean annual rainfall is about 800mm-1000mm. Temperature is generally high with mean annual temperature of about 26 C and above in all location of the state. This climatic peculiarity allows for meaningful investment in agriculture.

Figure 1 Map of the Study Area



Source: Cartography Lab Geography Department UDUS(2021)

Sampling Technique and Sample Size: The study sample was drawn from rural communities in Kebbi State. The population of this study comprises of Fadama III participating farmers in Kebbi State, Northwest of Nigeria. Kebbi State is divided into four (4) Agricultural Zones (Emirate Councils) namely: Gwandu (Bunza) Zone, Argungu Zone, Zuru Zone, and Yauri Zone. Selection of sample for the study was done using multi-stage sampling technique. At the first stage, Proportionate sampling was used in each of the agricultural zones to select a total of six (6) local government across the state using 30%, considering the variation and disparity in number of local governments in agricultural zones. (Number of local governments divided by 100 multiplied by 30 to arrive at number of local government). At the second stage, Purposive sampling was employed to reach out to the targeted Fadama participating farmers, where one cluster was randomly selected from each local government as sampling frame. At the third and final stage, a simple random selection of thirty (30) Fadama III participating farmers from each selected cluster was done, giving a sample size of one hundred and eighty (180) Fadama participating farmers.

Method of Data Collection: Both primary and secondary data was used for the study. The primary data for the study was gathered through field survey with the use of a structured questionnaire designed in line with the objectives of the study. The secondary information includes those sources from journals, bulletins and other literature materials from the internet etc. The questionnaire for the study was used to collect information on: socio-economic characteristics of Fadama III participating farmers, food security status of the farmers before and during Fadama III programme, Factors influencing food security status of Fadama III AF participating farmers in the study area, improved technologies provided by the Fadama III agency and adopted by the farmers, activities engaged in by the Fadama III participating farmers, and problems faced by Fadama III programme participating farmers.

Method of Data Analysis: Data analysis was carried out using descriptive and inferential statistics to analyse the data generated using SPSS version 20. Descriptive such as frequency distribution, percentages, mean as well as mean weight were used to analyse the data in the table, this was used to describe the socio-economic characteristics of the Fadama III AF participating farmers, livelihood activities engaged in by the Fadama III AF farmers as well as the problems faced by Fadama III AF farmers in the study which are objective 1, 2, and 3 respectively.

1.6 Research Hypotheses: In order to provide empirical bases for relationship that exist between the variables of this study, the following hypothesis were set in null form.

Ho1 Fadama III AF programme farmer's socio economic characteristics has no significant effect on livelihood activities of participants in the study area.

RESULTS AND DISCUSSION

Socio-economic Characteristics of Respondents: This section described the socio-economic characteristics of the Fadama III AF Farmers in the study area. These characteristics include age, gender, marital Status, household size, level of education, farming experience, farm size, years of FUG membership, secondary occupation and income. The result of the study shows that the minimum age of the participant farmers in the study area was 25 years and the maximum age was 72 years with the mean age of 45.75 years. Majority of the participants farmers 67.2% were male, and 84.4% of the participants were married. All farmers had one form of formal education. The mean household size was found to be 12.2 person per household. The minimum and maximum farming experience of participants farmers were 4 and 52 years with mean of 22 years farming experience. The result shows that the minimum and maximum years of membership involvement to Fadama III user groups were 2 and 15 years, with the mean years of 10.9. The minimum and maximum hectares cultivated by the participant farmers before and during the programme were 1 and 5 hectares with mean of 2.6 hectares, and during the programme the minimum and maximum hectares were 1 and 5 with mean of 3.5 hectares. The distribution according to farm size indicate that the Fadama III farmers were made up of small and medium scale farmers. The minimum and maximum of farm income of farmers before the programme was N50,000 and N4,500,000 with mean of N689,794.4, also during the programme the minimum and maximum farm income was N50,000 and N10,000,000 respectively, with the mean of N1,560,816.7. The result indicated that the Fadama III participants had higher income during the programme than before in the study area.

The major secondary occupation apart from farming among the participants farmers in the study were trading 42.2%, livestock rearing 26.1%, and civil service 13.9%.

Table 1a : Socio-economic characteristics of Fadama III AF participating farers (N=180).

Source: Field Survey 2022

Table.1b: Socio-economic characteristics of Fadama III AF participating farmers (N=180). Cont.

Variables	Frequency	Percentage	Mean	S.D
Age				
20-30	31	17.3	45.75	12.34
31-40	40	22.2		
41-50	41	22.9		
51 years and above	68	37.9		
Total	180	100		
Gender				
Male	121	67.2		
Female	59	32.8		
Total	180	100		
Marital Status				
Single	12	6.7		
Married	152	84.4		
Divorced	10	5.6		
Widow	6	3.3		
Total	180	100		
Level of Education				
Arabic Education	31	17.2		
Adult Education	24	13.3		
Primary Education	21	11.7		
Secondary Education	54	30.0		
Tertiary Education	50	27.8		
Total	180	100		
Household Size				
1-5	27	14.9	12.2	7.54
6-10	79	43.9		
11-15	23	12.7		
16-20	21	11.7		
21 and above	30	16.8		
Total	180	100		
Variables	Frequency	Percentage	Mean	S.D
Farming Experience				
1-10	36	20	22.1	11.4
11-20	57	31.6		
21-30	46	25.7		
31-40	37	20.7		
41 and above	4	2		
Total	180	100		
Years of FUG Membership				
1-5	24	13.4	10.9	3.84
6-10	62	34.4		
11-15	94	52.2		
Total	180	100		
Secondary Occupation				
Crop farming	26	14.4		
Livestock rearing	47	26		
Civil servant	25	13.9		
Trading	76	42.2		
Artisan	5	2.8		
Others	1	0.7		
Total	180	100		

Source: Field Survey 2022

Table.1c: Socio-economic characteristics of Fadama III AF participating farmers

(N=180). Cont.

	Before Fadama III AF		After Fadama III AF	
Income	Frequency	Percentage	Frequency	Percentage
50,000-1,000,000	149	83	114	62.7
1,000,001-2,000,000	25	13.4	24	13.6
2,000,001-3,000,000	3	1.8	16	9
3,000,001-4,000,000	2	1.2	11	6.2
4,000,001 and above	1	0.6	15	8.5
Total	180	100	180	100
	Before Fadama III AF, Mean 689,794.4		After Fadama III AF, Mean 1,560,816.7	
Farm size (hectares)	Frequency	Percentage	Frequency	Percentage
0-1.0	56	31.1	9	5.0
1.1-2.0	46	26.2	43	23.9
2.1-3.0	15	8.3	40	22.2
3.1-4.0	30	16.3	13	7.2
4.1 and above	33	18.1	75	41.7
Total	180	100	180	100
	Before Fadama III AF, Mean 2.6556		After Fadama III AF, Mean 3.5667	

Source: Field Survey 2022.

Distribution of Respondents Based on Livelihood Activities: The result presented in Table 4.5 which was recorded in multiple response revealed that all the participating farmers were engaged in one form of livelihood activity or the other with very few engaging in agro forestry (9.4%) and fishing (31.1%). The commonly observed livelihood activities in which the participating farmers were engaged include crop production, animal rearing, poultry production, agro-processing and non-farm activities. The result indicates that (100%) of the participating farmers were engaged in crop production which was ranked first, (93.9%) were found to engage in animal rearing and it was ranked second, (87.2%) were involved in poultry production and it was ranked third, (86.7%) were engaged in non-farm activities due to capital provided to them by the project and it was ranked fourth, and (41.1%) were into agro-processing which was ranked fifth. The result of the study implies that most of the participating farmers were engaged in agricultural related activities (crop production, animal rearing, poultry etc) and non-farm activities (civil servant, trading, tailoring, artisan etc). According to CTA (2004), diversifying income sources helps to minimize risk among farmers, and one single activity does not provide the income needed as such agricultural activities needs to be incorporated with non-farm income-generating activities that require relatively working capital.

Table 2. Distribution of Respondents Based on livelihood Activities.

Variable	Frequency	Percentage	Ranking
Crop production	180	100	1 st
Animal rearing	159	93.9	2 nd
Fishing	56	31.1	6 th
Poultry	157	87.2	3 rd
Agro-processing	74	41.1	5 th
Agro-forestry	17	9.4	7 th
Non-farm Activities	156	86.7	4 th

Multiple Response Recorded*

Distribution of Respondents Based on Problems Faced by Fadama III AF Participating Farmers: The result in Table 4.6 shows that the responses of Fadama III programme participating farmers were analyzed on a 5 point scale with weighted mean of 3.0, where any variable ≥ 3.0 was considered as a problem while variables < 3.0 were considered as not a problem. The most challenging problems faced by Fadama III participants farmers in the study area were the problems of high cost of farm inputs (50.6%), late arrival farm of farm inputs (95.0%), inadequate information dissemination (60.8%), high risk and uncertainties (87.8%), non-availability of credit facilities (88.9%), incidence of pests and diseases (84.4%), late disbursement of credit facilities (91.7%) and inadequate extension staff (75.0%). The implication is that these problems had negative effects on the productivity and food security status of the respondents. These problems could affect farmer's level of commitments and the adoption of new technology being provided to them through Fadama III programme in the study area.

The problem of high cost of farm inputs and late arrival of farm input could discourage many farmers from participation in the programme. Farm inputs supply to the farmers serves as an incentive to the farmers, farmers will engage more when they are sure of being supplied with farm inputs while participating in the programme. Also, inadequate extension staff/personal alongside inadequate information dissemination when the need arise will limit the ability of a farmer to tackle his immediate challenges so as to increase the level of production. According to Onyemauwa (2005), shortage of Fadama staff will affect the rate of response of farmers to any challenge they face

in trying to adopt new farming technologies introduced to them through the Fadama III programme and these will translate into low productivity on the part of farmers. Inadequate information dissemination will affect the easiness with which a farmer would relate his/her problems to the Fadama personnel/extension staff and get the expected feedback as quickly as possible. The inability of farmers to communicate their problem effectively will translate to low productivity, and also will affect the ability of the farmers to learn new technologies and to brainstorm for solution for these most pressing needs. According to Ibeagwa (2011), irregular meeting of farmers with Fadama III personnel affects the rate of exchange of ideas among the farmers and between the farmers and the programme personnel for increasing the productivity of the farmers.

Non-availability and late disbursement of credit facilities will hinder most farmers from making huge investments in their farming business or adopting costly technologies. It will also affect most farmers from purchasing sufficient farm inputs and to finance their farming business. Ogbu, (2009) noted that the larger the size of farm the larger the scale of farming operation and hence the higher the demand for funds to meet up the scale of operation. This assertion was supported by Nnamerenwa (2012) who noted that lack of funds affect the willingness of an individual to make investment and set up any enterprise. This will hinder the participating farmers from expanding their farm business away from subsistence level. High risks and uncertainties are inevitable situations. Farming is risky, farmers in the area live with risks and make decision every day that affect their farming operations. Many of the factors that affects farmer's decision cannot be predicted with 100 percent accuracy, weather conditions changes, price and the time of harvest could drop, hired labour may not be available at peak times, machinery and equipment could break down when most needed, government policy can change overnight. All these changes are example of risks that farmers face in managing their farms business, which affect their farm profitability.,FAO, (2013)

Also from the table it was revealed that inadequate capital (57.8%) , problem of marketing farm produce (61.2%), non-involvement of farmers in decision making (74.2%) , non-involvement of farmers in the planning of the programme (55.6%), non-involvement of farmers in programme evaluation (74.4%) , inadequate monitoring and evaluation of the programme (78.4%), weak institution and inadequate logistics (73.4%) strongly disagree with these challenges. Investigation during the study revealed that the participants were given financial grants, input support and infrastructural development by the Fadama programme. Inputs such as seeds, fertilizers, chemicals etc; assets such as sprayers, power tillers grinding machines, oil extraction machine etc. and met infrastructural development such as market stalls, stores, feeder roads, culverts, and even guest houses were provided,(NFDO, 2007). Rural infrastructure support the creation of economic infrastructure and local public goods to improve the productivity of Fadama user households. Investigation from the result revealed that the participating farmers were involved in every milestone of the programme and were adequately coordinated with the resources to the desired direction.

Table 3 : Distribution of Respondents Based on Problems Faced. (N = 180)

SN	Problems	Strongly agree freq. %	Agree freq. %	Undecided freq. %	Strongly disagree freq. %	Disagree freq. %	Mean score	Std. dev.	Rank
1	Inadequate capital	70(38.9)	6(3.3)	-	4(2.2)	100(55.6)	2.6778	1.93658	9 th
2	High cost of farm inputs	91(50.6)	2(1.1)	3(1.7)	5(2.8)	79(43.9)	3.1167	1.95558	8 th
3	Late arrival of farm inputs	171(95.0)	5(2.8)	-	1(06)	3(1.7)	4.8889	.57789	2 nd
4	Inadequate information dissemination	78(43.3)	30(16.7)	13(7.2)	10(1.1)	49(27.2)	3.4333	1.69488	7 th
5	High risk and uncertainties	158(87.8)	14(7.8)	3(1.7)	4(2.2)	1(.6)	4.8000	.62891	4 th
6	Non availability of credit facilities	160(88.9)	14(7.8)	4(2.2)	1(.6)	1(.6)	4.8389	.53025	3 rd
7	Late disbursement of credit facilities	165(91.7)	11(6.1)	-	2(1.1)	1(.6)	4.9389	.48150	1 st
8	Incidence of pest and diseases	152(84.4)	19(10.6)	2(1.1)	1(.6)	6(3.3)	4.7222	.81230	5 th
9	Problem of marketing farm produce	54(30.0)	14(7.8)	2(1.1)	19(10.6)	91(50.6)	2.5611	1.79747	11 th
10	Inadequate extension staff	32(17.8)	103(57.2)	6(3.3)	10(5.6)	29(16.1)	3.55000	1.30069	6 th
11	Non-involvement of farmers in decision making	24(13.3)	7(3.9)	-	15(8.3)	134(74.4)	1.7333	1.42836	14 th
12	Non-involvement of farmers in planning of the programme	32(17.8)	47(26.1)	1(.6)	16(8.9)	84(46.7)	2.5944	.66696	10 th

13	Non-involvement of farmers in programme evaluation	20(11.1)	9(5.0)	-	17(9.4)	134(74.4)	1.6889	1.36308	15
14	Inadequate monitoring and evaluation of the programme	15(8.3)	14(7.8)	10(5.6)	14(7.8)	127(70.6)	1.7556	1.33128	13
15	Weak institution and inadequate logistics	15(8.3)	15(8.3)	18(10.6)	12(6.7)	120(66.7)	1.8500	1.35562	12
Grand mean (x)				3.27					
Source: Field survey 2022				Agree					

Test of Research Hypothesis: Based on result of descriptive statistics on testing the stated hypothesis, the result indicated significant relationship between Fadama III AF project and crop production, animal rearing, poultry production, non-farm activities and agro- processing. Therefore the null hypothesis was rejected Fadama III AF project has no significant effect on livelihood activities of participants in the study area

CONCLUSION: The study evaluates the effect of Fadama III AF project on food security among small holder farmers in Kebbi State. The study concludes that the majority of the participants farmers were food secured. The age, educational level, income, household size, farm size, membership to FUG, year of farming experience were major factors (socio-economic characteristics of the farmers) that influence their food security status. The livelihood activities engage in by participants farmers, identified were crop production, animal rearing, and poultry production, agro-processing and non-agricultural activities.

In the same vein majority of the challenging problems faced by the Fadama III participating farmers were found to include:- late arrival of farm inputs, non availability of credit facilities, late disbursement of credit facilities, high risk and uncertainties, incidence of pest and diseases, inadequate extension staff and inadequate information dissemination,

RECOMMENDATION: Based on the findings of this research, the following recommendations are made to improve the food security status in the study area.

1. Government should provide adequate funds for the projects, timely disbursement of farm inputs as well as providing quality extension service delivery to further strengthen the existing positive attitude of the farmers towards Fadama project. This will enhance the adoption of policies and programmes among farmers.
2. There is need for Fadama III participants to have access to credit as financial assistance from Fadama project cannot meet their demand for inputs.
3. All stakeholders including farmers should be involved in planning execution, monitoring and evaluation of the programme.

CONTRIBUTION TO KNOWLEDGE

1. This work also established that late arrival farm of farm inputs 95.0% inadequate information dissemination 60.8% high risk and uncertainties 87.8% non-availability of credit facilities (88.9%), incidence of pests and diseases 84.4% late disbursement of credit facilities 91.7% and inadequate extension staff 75.0% posed a major challenge to Fadama III Farmers toward attaining food security. Finally, the study will suggest solutions to the problems encountered by participating farmers.
2. The model for the study of food security has been revealed from the study for adoption or modification

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Assessment of Tomato (*lycopersicon lycopersicum* L.) Varieties for Growth and Productivity in the Northern Guinea Savanna Region of Nigeria

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Abstract

Field trials were conducted during the 2020 and 2021 rainy seasons at the Teaching and Research Farm of the Federal University of Agriculture, Zuru. The purpose was to assess the performance of four tomato varieties—Roma-VF, Tima, UC82B, and Rio-grande—under the Sudan savanna conditions. A randomized complete block design with three replications was used. Among the tested varieties, Roma-VF exhibited superior agronomic traits, including the tallest plants (101.87 cm at 10 weeks after transplanting), highest leaf count (103), greatest fruit weight per plant (1.10 kg), largest fruit diameter (3.25 cm), and highest fresh fruit yield (55.41 t/ha). Tima followed closely, showing comparable growth and yield traits such as plant height (92.64 cm), leaf number (83.92), and average fruit weight (57.87 g). Both Roma-VF and Tima outperformed UC82B and Rio-grande in terms of fruit weight. The data indicate that Roma-VF and Tima are the most productive varieties for cultivation in this ecological zone.

Introduction: Tomatoes, originally native to Central and South America and later domesticated in Europe, have become globally significant vegetables. In Nigeria, tomatoes are predominantly cultivated during the wet season in the Guinea savanna and during the dry season with irrigation in the Sudan savanna. Despite being a key vegetable in Nigerian diets, local yields are still low compared to global standards. This discrepancy is largely due to climatic factors, poor-quality varieties, and inadequate agronomic practices like insufficient fertilizer application. Due to the tomato plant's shallow roots and its need for early fruiting, nutrient availability is essential for high productivity. Previous studies have demonstrated varietal differences in growth and yield responses to fertilization. This study aims to evaluate selected tomato varieties to identify those most suited for the Sudan savanna zone.

Materials and Methods: The research was conducted during the 2020 and 2021 wet seasons in Zuru, Nigeria (Lat: 11°35'N; Long: 4°45'E; 394 m a.s.l.). The site experiences rainfall between 690–885 mm annually, with temperature ranges of 18–38°C. Four tomato varieties were tested using a randomized complete block design with three replications. Plots were prepared with sunken nursery beds and transplanted into the field after hardening. Fertilization was carried out with 300 kg/ha NPK 15:15:15. Transplant spacing was 40x50 cm. Irrigation and staking were managed systematically. Pest control involved cypermethrin applications, and weeding occurred at regular intervals. Data collected included plant height, number of leaves, fruit count, fruit weight, fruit diameter, and fresh yield. ANOVA was conducted using SAS (2003), and differences among means were assessed via Duncan's Multiple Range Test.

Results: Roma-VF consistently showed the highest plant height and leaf count across all sampling intervals. It also produced the heaviest and largest fruits per plant, with the highest yield. Although UC82B had a high number of fruits, its mean fruit weight was lower compared to Roma-VF and Tima. Roma-VF and Tima significantly outperformed UC82B and Rio-grande in fruit diameter and weight, demonstrating better adaptability and productivity under local conditions.

Discussion: Roma-VF's superior performance in growth and yield parameters may be attributed to its genetic traits, such as upright leaf orientation conducive to efficient photosynthesis. This aligns with findings from Enujeke (2013), who linked plant morphology and canopy structure to photosynthetic efficiency. UC82B showed a high leaf area index and fruit count, suggesting effective photosynthetic capacity, although it lagged in fruit weight and size. The yield advantage of Roma-VF and Tima is likely due to more efficient partitioning of assimilates towards reproductive structures. Differences observed among the varieties are thus largely genetically driven, in agreement with studies by Olaniyi et al. (2010) and others who reported similar genotype-based performance variability in tomatoes.

Conclusion: The study concluded that Roma-VF and Tima are the most promising tomato varieties for growth and productivity under the Sudan savanna agroecological conditions. These varieties are therefore recommended for commercial tomato production in this region.

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Table 1: Plant height and number of leaves as evaluated by tomato variety for growth and yield during 2020 and 2021 Growing season

Treatment	Plant Height (cm) 8WAT		Number of leaves 8WAT	
	2020	2021	2020	2021
Varieties				
Roma – VF	88.36a	40.16a	99.25a	37.35a
Tima	78.03ab	32.44bc	78.08b	24.66b
UC82B	76.82ab	28.33c	68.33bc	27.20ab
Rio-grande	74.55b	36.22ab	53.00c	27.37ab
SE±	4.17	2.32	6.33	3.65

Means followed by the same letter (s) in a treatment group are not significantly different at 5%

Table 2: Number and Weight of Fruits per Plant as evaluated by tomato variety for growth and yield during 2020 and 2021 Growing season.

Treatment	Number of Fruits per Plant		Weight of Fruits per Plant (kg)	
	2020	2021	2020	2021
Varieties				
Roma-VF	22.15a	24.58a	1.10a	0.79a
Tima	15.73b	13.58c	0.85a	0.78a
UC82B	24.20a	25.33a	0.92a	0.76a
Rio-grande	14.00b	19.88b	0.42b	0.31b
SE±	2.090	1.530	0.211	0.130

Means followed by the same letter (s) in a treatment group are not significantly different at 5% using DMRT.

Table 3: Mean fruit weight (g), mean fruit diameter (cm) and fresh fruit yield (t ha⁻¹) as evaluated by tomato variety for growth and yield during 2020/2021 Growing season.

Treatment	Mean Fruit Weight (g)		Mean Fruit Diameter (cm)		Yield (t ha ⁻¹)	
	2020	2021	2020	2021	2020	2021
Varieties						
Roma – VF	52.28a	50.04a	2.83a	3.07ab	45.95a	55.41a
Tima	57.87a	54.15a	2.94a	3.25a	39.29ab	42.58b
UC82B	28.41c	38.27b	2.40b	2.87b	35.98b	46.30b
Rio-grande	20.09d	30.03c	2.90a	2.92b	19.96c	21.02c
SE±	2.030	2.203	0.080	0.130	3.313	3.432

Means followed by the same letter (s) in a treatment group are not significantly different at 5% using DMRT

Effects of Different Rates of Poultry Manure and Plant Population on The Yields of *Corchorus Olitorious*

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Abstract

Field experiment was conducted from June to September, 2024 to determine the effects of different rates of poultry manure and plant population on yields of *C. olitorius* at Igboora, Oyo State. Three rates of poultry manure were applied; 00, 300 and 400kg/ha combined with three population density of *C. olitorius*. The seven treatments which were done in triplicates includes; 20,000 + 00kg/ha, 10,000 + 300kg/ha, 10,000 + 400kg/ha, 20,000 + 300kg/ha, 20,000 + 400kg/ha, 30,000 + 300kg/ha, 30,000 + 400kg/ha. It was arranged in a randomized complete block experimental design. *Corchorus olitorius* sown on the same day in all the plots was nurtured for eight weeks and data taken were dry matter and herbage yield (g stand⁻¹). Data were subjected to analysis of variance and treatment means separated by DMRT at 5% probability level. The treatments significantly enhanced the yield of *Corchorus olitorius*. The results revealed that higher rates of poultry manure, particularly at 400 kg/ha, combined with moderate plant population density (20,000 plants/ha), produced the highest response from all the characters considered. Also, the plant population of density of 20,000stands ha⁻¹ yielded better results than other populations. Thus, the use of 400 kg/ha of poultry manure rate of application and a plant population of 20,000 plants/ha is recommended for optimal production of *C. olitorius* in the region of investigation.

Key words: poultry manure, plant population, Yield and *Corchorus olitorius*.

INTRODUCTION: The yield of *Corchorus olitorius*, is dependent on soil fertility and plant density. However, most soils in humid tropics are intensely weathered, leached and intensively cultivated leading to impoverished soil (Akanbi and Togun, 2002). Hence, it lacks the capacity to support plant growth to produce optimally. The inherently low fertility status of the soil had resulted in poor crop performance in the field. However, low plant population without soil amendment among other husbandry activities employed in the cultivation of *C. olitorius* had resulted in low yield per unit area. These constraints necessitated the need for appropriate management techniques to improve soil fertility and utilize appropriate plant population in order to increase crop yield. There is an important need to increase yield per unit area through the application of organic and / or inorganic fertilizer. Leafy vegetables responded positively to plots that received NPK fertilizer giving rise to better yields than non-fertilized plots. However, the limited use of inorganic fertilizer by farmers is attributed to scarcity, high cost, it does not improve soil tilt and its long-term usage has resulted in soil nutrient imbalance. This necessitates research on the use of organic fertilizers that are cheap, readily available and environmentally friendly (Ayeni, 2010). Unlike chemical fertilizers, poultry manure improves the organic matter content, soil structure, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Ferhad *et al.*, 2009). Moreover, poultry manure can increase the dry grain yield of maize (Ayoola and Makinde, 2006). Ali *et al.*, (2003) had reported that the use of poultry manure increased the height of maize because of the presence of macro and micronutrients than other organic manure sources. Thus, it is adjudged as the most valuable of all forms of livestock manure (Omisore *et al.*, 2009). For poultry manure to be beneficial to crops, optimum plant population is important.

Plant spacing is an agronomic management strategy used by farmers to optimize the husbandry of plant ecosystem from sowing to harvest with the goal of boosting the production of crops and determining plant population density (Sharratt and McWilliams, 2005). High population density heightens intra-specific competition among the plants, each production system should have a population density that maximizes the utilization of available resources and allows expression of maximum attainable yield in that environment (Sangoi *et al.*, 2000). Appropriate plant population optimized light interception to favour higher yield production. Generally, increase in plant population has resulted in increased yield per unit area up to certain limit. Crop yield per stand decreased with increasing plant population. This is attributable to inter- and intra-specific plant competition for growth resources. Information on the usage of different fertilizer sources for *C. olitorius* and appropriate plant population to maximize yield is not well documented. Therefore, this project aimed to evaluate the response of *Corchorus olitorius* to different plant population and fertilizer types.

Materials and Methods

Study Area: Field trials were conducted at Oyo State College of Agriculture Igbo-ora spanning from June – September, 2024 cropping seasons. Igbo-Ora, is in Ibarapa zone; the Northern part and derived Savannah Zone of South Western Nigeria. It is located between 7°15' - 7°33' North, and 3°56' - 3°57' East.

Sample Collection: Prior to Land preparation, soil samples were collected randomly from 120 spots at 0-15 cm depth of the soil, at the experimental site with the use of an auger. Samples were bulked, air dried and ground to pass through a 2mm sieve. The soil samples were analysed for physico-chemical properties as follows: soil particle size were evaluated by Bouyoucos method, 1962). Soil pH in H₂O (1:1) was determined using the standard laboratory

apparatus as specified (I.I.T.A, 1982). Soil organic carbon was determined by Walkley black modified method (Black, 1965). Available phosphorus and total nitrogen were determined separately by Technicon method while exchangeable Ca, Mg, K, Na and effective C.E.C in soils by use of atomic absorption spectrophotometer (Tel and Hargerty, 1984).

The Poultry manure (PM) was the droppings from broilers raised by deep litter system that had been left to decompose for about five months on College farm and deposited outside.

Land Preparation and Planting: The poultry manure fertilizer was applied two weeks before planting. The manure rates of application are; 0, 2.5, 5, 7.5 and 10t/ha. The treatments are; (population density + poultry manure rate); 20,000 + 00kg/ha, 10,000 + 300kg/ha, 10,000 + 400kg/ha, 20,000 + 300kg/ha, 20,000 + 400kg/ha, 30,000 +300kg/ha, 30,000 +400kg/ha and replicated three times. The experiment was arranged in Randomized Complete Block Design (RCBD) and the treatments were replicated three times. The blocks were 1m apart and 0.5m between plot and furrow and each plot was measured 1 m×3 m. Viable seeds of *C. olitorius* seeds (variety NHCO-2) were obtained from National Horticultural Research Institute, Ibadan. Before sowing, the seeds were steeped into boiling water for 10 seconds to break dormancy and air-dried for 24 hours. The planting was done on the plots by broadcasting the seed on the bed. Each plot was irrigated with equal volume of fresh water every day. Regular weeding was done manually by hand picking. At 8 weeks after planting (WAP), plant samples were carefully uprooted and the fresh herbage yields as well as the total dry matter were obtained using the ISTA, (1993) procedure

Data collection and Analysis: Harvesting was done by cutting the plant at 10cm above soil surface at 5 weeks after planting. The fresh shoot and leaves were weighed using digital weigh balance. Data collected were subjected to Analysis of Variance (ANOVA) and the sample means separated using Duncan Multiple Range Test at 5% level of significance.

Results and Discussion: The results of the analysis of soil and poultry manure used are presented in Tables 1 and 2 respectively. The soil was a slightly acidic, sandy loam with low organic carbon content, exchangeable cations while total N and available P content were 0.09% and 3.53mg kg⁻¹. The total N and available P were very low compared with the critical levels of 0.1% for N and 10-12mg kg⁻¹ for available P (Adeoye, and Agboola, 1985) obtained for soil in South-West, Nigeria (FMANR., 1990). Using the critical levels of 0.16-0.20cmol kg⁻¹, exchangeable K was also low (Agboola and Obigbesan, 1974).

Result from Table 2, revealed the chemical properties of the poultry manure. The result showed that poultry manure is rich in nutrients and this may definitely influence the result of the experiment. Poultry manure should be expected to provide the soil and plant with higher quantity of nutrients especially N, compared with those treatments without it. The application of poultry manure at varying rates and plant population densities significantly influenced the yield of *Corchorus olitorius*.

From the results, 30,000plants /ha + 400 kg/ha plots had reduced growth, with a dry matter yield of 317.00 g/m², emphasizing the adverse effects of overcrowding and competition for resources. This result further confirm the work of Akpan and Udeagbara, (2020) where it was observed that optimization of plant population is a major agronomic practice that could be used in the manipulation of growth and yield indices of any crop. The herbage yield of *Corchorus olitorius* varied significantly with the application rates of poultry manure and plant population density. The plots with 20,000 plants/ha + 400 kg/ha of poultry manure produced the highest herbage yield (156.00 g per stand and 25.50 t/ha). The plots with 20,000 plants/ha + 400 kg/ha gave the best performance, indicating a balanced nutrient supply with a moderate plant population density that produced optimal growth and yield. Also, the plots with 20,000 plants/ha + 0.0 kg/ha poultry manure recorded the lowest herbage yield, (50.00 g per stand and 10.60 t/ha).

Plots with 10,000 plants per hectare + 300 kg/ha of poultry manure produced moderate yield (142.00 g per stand and 20.00 t/ha), while 10,000 plant/ha + 400kg/ha poultry manure plots gave 98.00 g per stand and 18.90 t/ha yield. The lower yield observed with higher manure rates and lower plant density suggested a potential imbalance in resource utilization. Similarly, plots with 30,000 plants per hectare + 300 kg/ha poultry manure gave 92.00 g per stand and 16.30 t/ha yield, while the 30,000 +400kg/ha poultry manure plots recorded 114.00 g per stand and 19.90 t/ha yield. This observation is in-line with the findings of Olsantan (2001), who reported that yield per unit area increases with increase crop density, up to a certain limit, beyond which yield reduces as a result of insufficient environmental resources required for plant growth. From the experiments conducted, the application of poultry manure significantly enhanced the growth and yield of *Corchorus olitorius* while the plant population density of 20,000stands ha⁻¹ and a poultry manure rate of 400kg/ha were optimal for plant growth.

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Result

Table 1: Physico-chemical properties of soil used for the experiment

Element	Value
pH (H ₂ O) 1:2	6.30
Total Organic C (%)	0.90
Total Nitrogen (%)	0.09
C/N ratio	10
Available P (mg kg ⁻¹)	3.53
Exchangeable base (cmolkg ⁻¹)	
Ca (cmol/kg)	5.34
Mg (cmol/kg)	1.20
K (cmol/kg)	0.30
Na (cmol/kg)	0.37
Exchangeable Acidity (cmolkg ⁻¹)	
H ⁺	0.4
(ECEC)	7.33
Mn (mg/kg)	69.70
Fe	10.05
Cu (mg/kg)	0.60
Zn (mg/kg)	6.90
Particle Size	
Sand(%)	91.20
Silt (%)	4.60
Clay (%)	4.20

Textural class of this soil is sandy loam

Table 2: Chemical properties of poultry manure used

Nutrient element (Units)	Poultry manure
Total N (%)	1.67
Available P (g/kg)	0.35
K (g/kg)	0.07
Ca (g/kg)	0.07

Na (g/kg)	0.05
Mg (g/kg)	0.34
pH	9.32
Temperature (°C)	27.1

Table 3: Effect of poultry manure application rates and different plant population on the yield of *C. olitorious* at 8WAP

TREATMENTS	Herbage yield (g stand ⁻¹)	Herbage yield (tha ⁻¹)
Pop + Pm rates		
20,000 + 0.0kg/ha	50.00e	10.60f
10,000+ 300kg/ha	142.00b	20.00c
10,000 + 400kg/ha	98.00cd	18.90cd
20,000 + 300kg/ha	146.00ab	22.80ab
20,000 + 400kg/ha	156.00a	25.50a
30,000 +300kg/ha	92.00d	16.30e
30,000 +400kg/ha	114.00c	19.90cd

Means followed by the same letters in the same columns are not significantly different at 5% level of probability by DMRT

Adoption of Climate-Smart Agricultural (CSA) practices and their Impact on Food Security among Smallholder Farmers in Kebbi State, Nigeria.

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ABSTRACT

This study examined the adoption of Climate-Smart Agricultural (CSA) practices and their impact on food security among smallholder farmers in Kebbi State, Nigeria. A multistage sampling technique was employed to select **343 respondents** across the three senatorial zones of the state. Structured questionnaires and interviews were used for data collection. Data were analyzed using descriptive statistics, and Likert-scale analysis, logistic regression, and food security indices. The major objective was to assess how CSA adoption influences food security and sustainable livelihoods. Results revealed that **81.6%** of respondents were aware of CSA, and **65.9%** had adopted one or more CSA practices. Regarding income and poverty alleviation, **68.5%** reported increased household income following CSA adoption. In terms of food security and livelihood sustainability, **70.6%** of adopters experienced improved food availability and dietary diversity. Key constraints to CSA adoption included lack of inputs (**78.2%**), limited access to credit (**72.9%**), and inadequate information (**69.4%**). Furthermore, **83.9%** of respondents acknowledged that agricultural extension services played a critical role in promoting CSA through awareness creation and technical support. The study concludes that CSA adoption significantly enhances food security, income generation, and livelihood resilience among smallholder farmers. However, barriers such as poor access to credit and limited technical support hinder widespread adoption. Based on the above, it is therefore recommended that: The government and stakeholders should strengthen extension services and input delivery systems to scale up CSA adoption and improve rural households' resilience to climate change.

KEY WORDS: Climate-Smart Agriculture, Food Security, Smallholder Farmers, Livelihood Sustainability

Introduction: Climate-Smart Agriculture (CSA) has emerged as a strategic approach to addressing food insecurity, poverty alleviation, and sustainable livelihood enhancement in developing economies (Lipper *et al.*, 2014). With climate change posing a significant threat to agriculture, The agricultural sector plays a significant role in the economic development of Nigeria, contributing approximately 25% to the Gross Domestic Product (GDP) and providing employment for about 70% of the population, particularly in rural areas (World Bank, 2021). However, climate change has exacerbated challenges such as desertification, flooding, and unpredictable rainfall patterns, leading to decreased agricultural productivity and worsening poverty levels. Consequently, CSA has been recognized as a vital strategy for ensuring agricultural sustainability, as it encompasses three main pillars: increasing productivity, enhancing resilience (adaptation), and reducing greenhouse gas emissions (mitigation) (FAO, 2010). Research indicates that CSA practices such as conservation agriculture, agroforestry, drought-resistant crop varieties, and improved irrigation techniques have the potential to enhance food security and promote sustainable livelihoods (Lal, 2015). Despite these benefits, smallholder farmers in Nigeria often face constraints in adopting CSA due to limited access to information, high costs of inputs, weak extension services, and inadequate institutional support (Pretty *et al.*, 2018). Therefore, understanding the level of awareness and adoption of CSA among rural households is crucial in designing policies and interventions that can foster greater uptake of climate-smart practices. Several studies have examined the relationship between CSA and poverty alleviation in sub-Saharan Africa. For instance, Mbow *et al.* (2014) highlighted that smallholder farmers who adopted CSA practices experienced increased productivity and household income, leading to improved welfare. Similarly, Kassie *et al.* (2015) found that farmers implementing CSA techniques in Ethiopia achieved better resilience against climate variability compared to non-adopters. However, there is a lack of empirical studies focusing specifically on Kebbi State, where agricultural activities are vital for rural households' survival. Moreover, sustainable livelihoods are closely linked to the successful adoption of CSA practices. Despite the potential benefits of CSA, its adoption in Kebbi State remains low, primarily due to socio-economic and institutional barriers. Farmers' reluctance to adopt CSA practices may stem from a lack of awareness, inadequate training, high input costs, and limited access to credit facilities (Adesina & Zinnah, 1993).

Statement of the Research Problem: Despite the growing advocacy for CSA, smallholder farmers in Kebbi State continue to struggle with low productivity, poverty, and climate-related risks. Previous studies (e.g., Adesina & Zinnah, 1993; Deressa *et al.*, 2009) highlight low adoption rates due to factors such as limited access to information, poor extension services, and financial constraints. This study seeks to explore the extent of CSA adoption and its effectiveness in alleviating poverty and promoting sustainable livelihoods.

Objectives of the Study: To assess the level of awareness and adoption of CSA practices among rural households in Kebbi State; To assess the level of awareness and adoption of Climate-Smart Agriculture (CSA) practices among rural households in Kebbi State; To examine the impact of CSA practices on household income and poverty

alleviation in the study area; To analyze the effects of CSA on food security and livelihood sustainability among rural farmers; To identify the major constraints affecting the adoption of CSA practices in Kebbi State; To evaluate the role of agricultural extension services in promoting CSA for improved livelihoods.

METHODOLOGY

Description of the Study Area: Kebbi State is located in North Western Nigeria. Its approximate geographical coordinates are **Latitude:** 12.5° N and **Longitude:** 4.2° E. As of the latest estimates, Kebbi State has a population of approximately **4 million people**. The population is predominantly rural, with a significant portion engaged in agricultural activities. The demographic composition includes various ethnic groups, with the Hausa and Fulani being the most prominent. The state has a youthful population, which poses both opportunities and challenges for development. Kebbi State is characterized by its diverse agricultural landscape. The state is predominantly rural, with agriculture serving as the primary source of livelihood for a majority of the population. The climatic conditions and soil fertility vary across the region, providing a unique environment for different crops. However, the adoption of modern agricultural practices remains uneven among farmers.

Sampling Procedure and Sample Size: A multistage sampling technique was employed. First, three agricultural zones were purposively selected. Second, Local Government Areas (LGAs) were randomly selected within these zones. Finally, 343 respondents were proportionally selected from farming households using simple random sampling.

Method of Data Collection: Primary data were collected through structured questionnaires and interviews. Secondary data were obtained from agricultural reports, research articles, and government publications.

Method of Data Analysis: Objective 1 and 4: Assessment of CSA Awareness and Adoption, and Constraints to CSA Adoption were analysed using descriptive statistics (percentages, mean scores, and frequency distributions). Objective 2: Impact of CSA on Household Income and Poverty Alleviation was analysed by comparing the impact on the income and poverty rate of adopters and non-adopters. Objective 3: CSA Effects on Food Security and Livelihood Sustainability was analysed using descriptive statistics (percentages) and Food Security Index. Objective 5: Role of Extension Services in Promoting CSA was analysed using

RESULTS AND DISCUSSION

Table 1: Distribution of the Respondents Based on Level of Awareness and Adoption of CSA Practices among Rural Households in Kebbi State.

CSA Practice	Aware (%)	Not Aware (%)	Adopted (%)	Not Adopted (%)
Conservation Agriculture	75.2	24.8	58.3	41.7
Agroforestry	68.9	31.1	50.4	49.6
Improved Crop Varieties	82.7	17.3	67.1	32.9
Soil Management	71.5	28.5	55.8	44.2
Water Conservation	65.3	34.7	47.6	52.4

Source: Field Survey, 2025

The results in Table 1 indicate that a high percentage of respondents are aware of CSA practices, with improved crop varieties (82.7%) and conservation agriculture (75.2%) having the highest awareness levels. This finding aligns with previous studies by **Deressa et al. (2009)**, who reported that smallholder farmers in Africa generally have high awareness of improved agricultural technologies. However, awareness does not necessarily translate into adoption, as only 67.1% of those aware of improved crop varieties have adopted them. The adoption rate for conservation agriculture (58.3%) is relatively high, similar to the findings of **Kassie et al. (2015)**, who reported that conservation agriculture adoption rates in Ethiopia were around 60% due to perceived soil fertility benefits. On the other hand, agroforestry adoption remains relatively low (50.4%), which aligns with **Mbow et al. (2014)**, who found that agroforestry adoption faces challenges such as long-term investment requirements and limited extension services. Water conservation techniques had the lowest adoption rate (47.6%), suggesting that farmers in Kebbi State may have limited access to irrigation facilities or perceive these practices as costly.

Table 2: Impact of CSA Practices on Household Income and Poverty Alleviation

CSA Practice	Avg. Annual Income of Adopters (₦)	Avg. Annual Income of Non-Adopters (₦)	Poverty Rate Among Adopters (%)	Poverty Rate Among Non-Adopters (%)
Conservation Agriculture	750,000	450,000	42.5	67.8
Agroforestry	720,000	460,000	44.3	65.2
Improved Crop Varieties	800,000	470,000	40.7	66.1
Soil Management	730,000	455,000	43.1	64.8
Water Conservation	690,000	440,000	45.9	68.3

The results in Table 2 indicate that households adopting Climate-Smart Agriculture (CSA) practices have significantly higher incomes and lower poverty rates compared to non-adopters. For instance, the average annual income of farmers adopting improved crop varieties is **₦800,000**, while non-adopters earn **₦470,000**, representing a 70% increase. Similarly, the poverty rate among adopters of improved crop varieties is **40.7%**, whereas it is **66.1%** among non-adopters, confirming the positive impact of CSA adoption on income and poverty alleviation. These

findings align with the work of **Kassie et al. (2015)**, who reported that CSA adoption in Ethiopia led to significant improvements in household income and food security. Similarly, **Mbow et al. (2014)** found that agroforestry and conservation agriculture enhanced farmers' financial stability and resilience against climate shocks in sub-Saharan Africa. Among the CSA practices analyzed, improved crop varieties had the most substantial impact on income and poverty reduction. This is consistent with **Deressa et al. (2009)**, who found that farmers using drought-resistant and high-yield crop varieties in Ethiopia earned significantly higher incomes than those relying on traditional farming methods. Conversely, water conservation had the lowest impact on income and poverty reduction, with an average income increase of **₦250,000** and a poverty rate of **45.9%** among adopters compared to **68.3%** among non-adopters.

Table 3: Effects of CSA on Food Security and Livelihood Sustainability among Rural Farmers

CSA Practice	% Households with Improved Food Availability	% Households with Improved Dietary Diversity	% Households with Sustainable Livelihoods
Conservation Agriculture	75.4	68.2	71.5
Agroforestry	72.1	64.5	69.3
Improved Crop Varieties	80.6	71.3	74.8
Soil Management	73.8	66.1	70.2
Water Conservation	69.2	62.7	67.4

The results on **Table 3** reveal that Climate-Smart Agriculture (CSA) practices have a **positive impact on food security and livelihood sustainability** among rural farmers in Kebbi State. As shown in the tabulated results, households that adopted CSA practices such as improved crop varieties, conservation agriculture, agroforestry, soil management, and water conservation reported higher levels of food availability, dietary diversity, and sustainable livelihood outcomes. Among the practices examined, **improved crop varieties** had the **strongest impact**, with **80.6%** of households reporting improved food availability, **71.3%** indicating better dietary diversity, and **74.8%** enjoying more sustainable livelihoods. Similarly, **conservation agriculture** contributed substantially to food security (75.4%) and livelihood sustainability (71.5%), primarily due to its capacity to improve soil fertility, reduce erosion, and increase yield stability over time. According to **Pretty et al. (2018)**, conservation agriculture can build long-term resilience in farming systems, especially under erratic climate conditions. **Agroforestry** and **soil management practices** also played vital roles in improving both food access and livelihood security. Farmers practicing agroforestry benefited from diversified food sources (e.g., fruits, nuts, medicinal plants) and additional income from tree products. This supports **Mbow et al. (2014)**, who reported that agroforestry enhances household nutrition and income diversification in rural African communities. Similarly, **Ajayi et al. (2011)** emphasized the contribution of agroforestry to both food stability and ecological sustainability.

Water conservation practices, though effective, had a slightly lower impact compared to other CSA strategies. While **69.2%** of adopters reported improved food availability, the dietary diversity and livelihood indices were modest. This may be attributed to **limited access to irrigation technologies**, infrastructure challenges, and higher initial investment costs. **Mwongera et al. (2017)** also observed similar limitations in their study on East African farmers, highlighting that water-based CSA interventions tend to be underutilized without institutional support.

Table 4: Major Constraints Affecting the Adoption of CSA Practices in Kebbi State.

Constraint	Frequency (n = 343)	Percentage (%)
Inadequate access to credit/finance	282	82.2
Limited extension services	265	77.3
High cost of CSA technologies/inputs	248	72.3
Poor access to information/awareness	232	67.6
Lack of training and technical knowledge	221	64.4
Poor infrastructure (e.g., irrigation, roads)	196	57.1
Land tenure insecurity	173	50.4
Cultural and traditional beliefs	145	42.3
Climate variability and unpredictability	128	37.3

The results in **Table 4** reveal that rural farmers in Kebbi State face several significant constraints in adopting Climate-Smart Agriculture (CSA) practices. The most frequently cited challenges include **inadequate access to credit or finance (82.2%)**, **limited extension services (77.3%)**, and the **high cost of CSA technologies or inputs (72.3%)**. **Inadequate Access to Credit/Finance:** Access to financial resources is crucial for adopting new and improved agricultural technologies. The lack of affordable credit was reported by over **82%** of respondents. This aligns with findings by **FAO (2013)** and **Kassie et al. (2015)**, who emphasized that limited financial capital remains a primary barrier to CSA adoption across sub-Saharan Africa. **Deressa et al. (2009)** also observed that many smallholder farmers are risk-averse due to lack of insurance or credit options, making them hesitant to invest in new technologies. **Limited Extension Services:** A total of **77.3%** of farmers identified inadequate extension services as a key challenge. CSA technologies are knowledge-intensive, and farmers require regular guidance and training for successful implementation. This result is consistent with **Mwangi and Kariuki (2015)**, who noted that weak extension support hinders the diffusion of climate-resilient technologies. Similarly, **Akinyemi et al. (2019)** found that the limited presence of trained extension agents restricts awareness and uptake of CSA practices in Nigeria.

High Cost of Inputs: The **high cost of CSA technologies**, including drought-resistant seeds, irrigation kits, and fertilizers, was a concern for 72.3% of the farmers. This aligns with the work of *Giller et al. (2009)*, who stressed that input affordability is a major constraint to CSA adoption, especially for resource-poor farmers. Without subsidies or cost-sharing mechanisms, these innovations remain inaccessible to most smallholder farmers. **Poor Access to Information and Training:** About 67.6% of the respondents pointed to limited access to information, while 64.4% cited lack of training and technical knowledge as barriers. CSA requires context-specific knowledge and adaptation skills. According to *Mugi-Ngenga et al. (2016)*, the lack of targeted training sessions reduces farmers' confidence in experimenting with new practices. Information asymmetry also impedes technology scaling, as suggested by *Arslan et al. (2017)*. **Infrastructure and Land Tenure Issues:** Over half of the respondents (57.1%) reported poor infrastructure as a constraint especially regarding irrigation and road access. Additionally, 50.4% highlighted **land tenure insecurity**, which discourages long-term investments in land-enhancing CSA practices. These findings are echoed in *Place et al. (2014)*, who argued that secure land tenure is essential for sustainable agriculture. Farmers are less likely to plant trees, adopt conservation techniques, or invest in irrigation without legal assurance over their land. **Cultural Beliefs and Climate Variability:** Cultural and traditional beliefs (42.3%) and climate unpredictability (37.3%) were also mentioned as minor but relevant challenges. In some communities, conservative attitudes and resistance to innovation limit farmers' willingness to change.

Table 5: Role of Agricultural Extension Services in Promoting CSA for Improved Livelihoods

Extension Role	Frequency (n = 343)	Percentage (%)
Creation of awareness on CSA practices	288	83.9%
Training and capacity building on CSA technologies	265	77.3%
Technical support during implementation of CSA practices	247	72.0%
Dissemination of climate-related information	231	67.3%
Linkage with inputs and service providers	216	62.9%
Mobilization and organization of farmers into groups/cooperatives	198	57.7%
Monitoring and evaluation of CSA adoption outcomes	176	51.3%

The findings in Table 5 highlight that **agricultural extension services play a critical role** in promoting CSA practices and supporting improved rural livelihoods in Kebbi State. The most prominent functions mentioned by farmers include **creating awareness (83.9%)**, **providing training (77.3%)**, and **offering technical support (72.0%)**. **Creation of Awareness on CSA Practices:** A significant majority (83.9%) of respondents acknowledged that extension agents help create awareness about CSA. This is in line with the findings of *Adekoya et al. (2018)*, who reported that extension services serve as the primary channel for informing smallholder farmers about climate-resilient innovations. Awareness is the first step toward adoption, and the regular presence of extension workers increases farmer confidence in these practices. Similarly, *Ajayi (2016)* emphasized the importance of farmer education in CSA adoption, arguing that awareness drives curiosity, experimentation, and eventual integration of new practices into farming routines. **Training and Capacity Building:** About 77.3% of farmers affirmed that extension agents offer training on CSA technologies such as conservation tillage, drought-tolerant crops, agroforestry, and water management. This supports the view of *Meijer et al. (2015)* that extension services must go beyond information sharing to hands-on capacity building. *Mwangi and Kariuki (2015)* also argued that proper training enables farmers to understand not just the "what" but the "how" of implementing CSA practices, thereby enhancing adoption rates and long-term impacts. **Technical Support for Implementation:** Roughly 72% of farmers stated that extension agents provided technical guidance during the adoption of CSA practices. This on-site assistance helps farmers overcome knowledge and skill gaps, especially when integrating new or unfamiliar methods. *Mugi-Ngenga et al. (2016)* pointed out that technical support ensures that CSA practices are correctly implemented, thereby increasing their effectiveness and sustainability.

Dissemination of Climate-Related Information: About 67.3% of the respondents received timely information on weather forecasts, seasonal patterns, and adaptive strategies from extension agents. This aligns with *Hansen et al. (2011)*, who stressed that climate information services are vital for agricultural planning and risk management under uncertain climate conditions. However, some farmers indicated delays or irregular access to such information, showing a need for improved systems for real-time dissemination. **Linking Farmers to Inputs and Services:** Nearly 63% of respondents indicated that extension services helped them connect with suppliers of improved seeds, fertilizers, and CSA tools. About 57.7% of the farmers credited extension agents for mobilizing them into cooperatives. These groups facilitate shared learning, resource pooling, and better access to government or NGO programs. Only 51.3% of the farmers mentioned that extension agents engaged in monitoring their CSA adoption and livelihood progress. This relatively lower percentage reflects the well-known challenges of staffing, transport, and operational budgets faced by most public extension systems in Nigeria (FAO, 2013).

Conclusion/ Recommendation

The study concludes that CSA practices play a pivotal role in enhancing food security, income generation, and livelihood sustainability among smallholder farmers in Kebbi State. Despite their potential, the adoption of CSA practices is hindered by structural and institutional challenges such as poor access to inputs, inadequate funding, and weak extension support. The following recommendations were made: **Kebbi State Ministry of Agriculture and Natural Resources, Agricultural Development Programmes (ADPs), and National Agricultural Extension and Research Liaison Services (NAERLS)** should increase the number and training of extension agents to enhance farmer awareness, training, and technical support for CSA. **Central Bank of Nigeria (CBN)** (through schemes like Anchor Borrowers Programme), **Bank of Agriculture (BOA)**, **Private Agro-dealers and Microfinance Institutions (MFIs)**, and **Non-Governmental Organizations (NGOs)** involved in agricultural finance should

provide subsidized inputs and facilitate affordable credit schemes tailored to smallholder farmers to encourage wider adoption. **Orientation Agency (NOA), Non-Governmental Organizations (NGOs)** like IFAD, Oxfam, etc., and **Community-Based Organizations (CBOs)** should organize regular workshops, field demonstrations, and radio programs to improve farmer understanding and skills in CSA practices.

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Climate-Smart Agriculture as a Tool for Poverty Alleviation and Sustainable Livelihoods among Rural Households in Kebbi State

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ABSTRACT

This study investigated Climate-Smart Agriculture as a tool for poverty Alleviation and Sustainable Livelihoods among Rural Households in Kebbi State, Nigeria. The study's major objective was to evaluate how CSA practices influence household food availability, accessibility, and stability. A multistage sampling procedure was used to select 346 respondents across different agro-ecological zones in Kebbi State. Primary data were collected using a structured questionnaire administered through face-to-face interviews. Data analysis involved descriptive statistics, and regression models to assess relationships and impacts. Findings revealed that the most commonly adopted CSA practices include agroforestry (68.2%), crop rotation (61.0%), drought-tolerant varieties (57.5%), and water harvesting techniques (54.9%). Awareness of CSA practices was moderate, with 41.9% of respondents having high awareness levels, and the primary sources of information were extension agents (65.6%) and fellow farmers (58.4%). The extent of CSA adoption varied significantly across agro-ecological zones. Regression analysis identified key influencing factors such as access to extension services ($p < 0.01$), education level ($p < 0.05$), credit availability ($p < 0.01$), and farm size ($p < 0.05$). The study found that CSA practices had a positive and significant impact on food security: food availability (mean difference = 1.11, $p < 0.01$), accessibility (1.06, $p < 0.01$), and stability (1.01, $p < 0.01$). Major challenges identified include high input costs (80.3%), limited credit access (70.2%), and inadequate extension services (65.3%). In conclusion, the adoption of CSA practices significantly improves food security among smallholder farmers. It is recommended that, government and NGOs provide subsidized CSA inputs, and strengthen extension services to improve CSA awareness and capacity building.

Keywords: Climate-Smart Agriculture, Food Security, Smallholder Farmers, Agricultural Innovation

INTRODUCTION: Agriculture in Nigeria is increasingly threatened by climate change, particularly in the northern regions where rainfall is erratic and desertification is accelerating. Climate-Smart Agriculture (CSA) has emerged as a critical strategy to promote sustainable food systems, enhance farmers' resilience, and mitigate climate-related risks. The Food and Agriculture Organization (FAO, 2013) defines CSA as agricultural practices that sustainably increase productivity, enhance resilience (adaptation), reduce or remove greenhouse gases (mitigation), and enhance achievement of national food security and development goals. In recent years, CSA practices such as conservation agriculture, agroforestry, improved seed varieties, water harvesting techniques, integrated soil fertility management, and crop-livestock integration have been promoted across sub-Saharan Africa (Meybeck et al., 2012; Khatri-Chhetri et al., 2017). These practices aim to reduce vulnerability to climate shocks while ensuring food availability, accessibility, and stability. In Nigeria, smallholder farmers constitute about 70% of the agricultural workforce (NBS, 2020). These farmers are particularly vulnerable to climate-related risks due to limited access to resources, technology, and information (Akinbile et al., 2021). In Kebbi State, a predominantly agrarian region, climate variability has already begun to affect crop yields, reduce arable land, and threaten household food security (Usman et al., 2022). The impacts of climate change on agriculture are multifaceted, encompassing both biophysical and socio-economic dimensions. Rising temperatures, erratic rainfall, prolonged dry seasons, and increased incidence of pests and diseases negatively affect farm productivity, income stability, and nutrition levels. Consequently, smallholder farmers are compelled to adopt adaptive strategies to mitigate these adverse effects. CSA offers a holistic approach that integrates adaptation and mitigation into agricultural development planning and practice, ensuring that productivity and food security are not compromised (FAO, 2013). Furthermore, CSA is context-specific and knowledge-intensive. Its successful adoption depends on various factors, including access to climate information, availability of credit and inputs, extension services, education, land tenure security, and socio-cultural norms. According to Khatri-Chhetri et al. (2017), when CSA interventions are aligned with local needs and capacities, they can transform rural livelihoods and contribute significantly to poverty reduction and sustainable development.

Statement of the Research Problem: Climate change continues to pose a significant threat to agricultural productivity and food security in Kebbi State. Despite government and non-governmental efforts to promote CSA, its uptake remains low among rural farmers, partly due to knowledge gaps, cultural practices, and infrastructural limitations. The specific types of CSA practices being adopted, the level of awareness among farmers, and the tangible impact on household food security are not well documented. There is also insufficient understanding of the socio-economic and institutional factors that influence adoption. Without this information, policy interventions risk being ineffective or misdirected.

Objectives of the Study: The general objective of this research was Adoption of Climate-Smart Agricultural Practices and their Impact on Food Security among Smallholder Farmers in Kebbi State, Nigeria, and the specific objectives were:

1. To identify the types of climate-smart agricultural (CSA) practices adopted by smallholder farmers in Kebbi State.
2. To examine the level of awareness and sources of information on CSA practices among rural farmers.
3. To assess the extent of adoption of CSA practices across different agro-ecological zones in Kebbi State.
4. To analyze the factors influencing the adoption of CSA practices among smallholder farmers.
5. To evaluate the impact of CSA practices on household food availability, accessibility, and stability.
6. To determine the challenges faced by farmers in adopting and sustaining CSA practices.

Description of the Study Area: Kebbi State is located in NorthWestern Nigeria, sharing international borders with Niger Republic and internal boundaries with Sokoto, Zamfara, and Niger States. The state lies within the Sudan and Sahel Savanna zones and experiences a tropical climate characterized by distinct wet and dry seasons. Agriculture is the mainstay of the economy, with crops such as rice, millet, maize, and groundnut being widely cultivated. The major rivers include the Rima and Niger, supporting irrigation activities.

Sampling Procedure and Sample Size: A multistage sampling technique was employed. First, Kebbi State was stratified into its major agro-ecological zones. From each zone, two LGAs were purposively selected based on the intensity of agricultural activity. Within each LGA, four farming communities were randomly selected. From each community, respondents were selected proportional to their population sizes, thus a total sample size of 346 respondents made up the sample size from the population of 2400 farmers.

Method of Data Collection: Primary data will be collected through the administration of structured questionnaires, focus group discussions, and key informant interviews. Secondary data were obtained from extension offices, government reports, and previous research publications.

Method of Data Analysis and Model Specification: Objective 1 & 2 and 6: were analysed using descriptive statistics (frequencies, percentages, means) Objective 3: Adoption Index Score (AIS) will be calculated and compared across zones using ANOVA, Objective 4: Binary Logistic Regression Model

Model: where = probability of CSA adoption; = socio-economic and institutional variables.

Objective 5: Food Security Index (FSI) and Multiple Regression Model was used to estimate the relationship between CSA and food security.

RESULTS AND DISCUSSION

Table 1: Types of Climate-Smart Agricultural (CSA) Practices Adopted by Smallholder Farmers in Kebbi State (n = 346)

CSA Practice	Frequency	Percentage (%)
Use of improved drought-resistant seeds	291	84.1
Water harvesting techniques	204	59.0
Agroforestry	117	33.8
Conservation agriculture	165	47.7
Integrated crop-livestock system	139	40.2
Soil fertility improvement (compost/manure use)	187	54.0
Crop diversification	238	68.8
Early planting and timely harvesting	276	79.8

Source: Field Survey, 2025

The results in Table 1 reveal that the most widely adopted CSA practices among smallholder farmers in Kebbi State are the use of improved drought-resistant seeds (84.1%), early planting and timely harvesting (79.8%), and crop diversification (68.8%). These practices are likely preferred due to their direct influence on yield stability and food production in the face of erratic rainfall patterns. Water harvesting (59.0%) and soil fertility improvement techniques (54.0%) are also fairly common, indicating farmers' increasing awareness of soil and water conservation strategies. Conversely, agroforestry (33.8%) and integrated crop-livestock systems (40.2%) are among the less adopted CSA strategies. These practices may require more technical knowledge, longer-term investment, and land availability, which may not be accessible to all farmers. The relatively low adoption of conservation agriculture (47.7%) also reflects findings by Arslan et al. (2015), who noted that conservation techniques are often constrained by labor demands and lack of mechanized support.

These findings align with previous studies such as Khatri-Chhetri et al. (2017), who found that the adoption of CSA practices is often influenced by farmers' perception of climate risks, socio-economic status, and access to advisory services. Similarly, Yusuf et al. (2021) reported that CSA uptake in northern Nigeria is highest for low-cost, labor-efficient practices such as improved seeds and early planting. On the other hand, Ojo & Adebayo (2020) emphasized that adoption levels vary depending on the effectiveness of extension services and the suitability of practices to local contexts. The widespread use of drought-resistant seeds and early planting techniques indicates a responsive adaptation to rainfall variability and dry spells key characteristics of the climate in Kebbi State. The moderate

adoption of water harvesting and soil fertility practices also highlights farmers' efforts to build resilience through moisture retention and enhanced soil productivity.

Table 2: Level of Awareness of CSA Practices among Smallholder Farmers (n = 346)

Level of Awareness	Frequency	Percentage (%)
Highly aware	108	31.2
Moderately aware	153	44.2
Slightly aware	62	17.9
Not aware	23	6.6

Source: Field Survey, 2025

Table 3: Sources of Information on CSA Practices (Multiple Responses Allowed)

Source of Information	Frequency	Percentage (%)
Extension agents	202	58.4
Radio/TV	179	51.7
Fellow farmers	164	47.4
NGOs	123	35.5
Agricultural input dealers	98	28.3
Mobile phones/Social media	76	22.0

Source: Field Survey, 2025

The data from Table 2 indicate that a significant proportion of smallholder farmers in Kebbi State were aware of climate-smart agriculture (CSA) practices, with 31.2% being highly aware and 44.2% moderately aware. Only 6.6% reported no awareness of CSA practices. This relatively high level of awareness suggests successful sensitization efforts through various communication channels. Table 3 shows that extension agents (58.4%) were the most common source of information, followed by radio/TV (51.7%) and peer learning from fellow farmers (47.4%). These results align with the findings of Khatri-Chhetri *et al.* (2017), who emphasized the importance of extension services and local networks in disseminating CSA knowledge. Similarly, Akinbile *et al.* (2021) found that media platforms and interpersonal communication play complementary roles in promoting climate-resilient practices. The lower frequency of mobile phone/social media (22.0%) as an information source suggests a digital divide in rural areas, possibly due to limited internet connectivity or digital literacy. This supports the observations by Yusuf *et al.* (2021), who noted infrastructural and socio-economic limitations in using ICT tools among farmers in Northern Nigeria. On the contrary, studies in more urbanized areas like those by Ojo and Adebayo (2020) showed higher reliance on digital platforms for agricultural information.

Table 4: Extent of CSA Practice Adoption across Agro-Ecological Zones in Kebbi State (n = 346)

Agro-Ecological Zone	High Adoption (%)	Moderate Adoption (%)	Low Adoption (%)
Sudan Savannah	42.1	38.2	19.7
Northern Guinea Savannah	56.4	29.5	14.1
Sahel Region	34.7	41.2	24.1

Source: Field Survey, 2025

The results in Table 4 reveal a notable variation in the extent of CSA practice adoption across agro-ecological zones in Kebbi State. The Northern Guinea Savannah zone showed the highest proportion of high adoption (56.4%), likely due to more favorable climatic conditions and better access to extension services. The Sudan Savannah recorded 42.1% high adoption, while the Sahel region lagged behind with only 34.7% reporting high adoption. These findings align with Khatri-Chhetri *et al.* (2017), who emphasized that regional and agro-ecological differences significantly influence the adoption of climate-smart practices. Factors such as soil type, rainfall patterns, and access to resources can either enable or constrain adoption. Yusuf *et al.* (2021) similarly found that agro-ecological suitability plays a major role in shaping farmers' willingness and capacity to adopt CSA interventions. The relatively low adoption in the Sahel region may be attributed to harsher environmental conditions, limited infrastructure, and fewer support services, corroborating the findings of Arslan *et al.* (2015), who reported that adoption rates are often lowest in ecologically fragile and resource-poor areas. Additionally, socio-economic barriers such as poverty, insecurity, and limited land tenure rights may further hinder widespread adoption in the Sahel. The data underscore the need for agro-ecologically tailored strategies in promoting CSA adoption. This means prioritizing locally suitable technologies and increasing investment in extension and support services, particularly in underperforming regions like the Sahel. Development programs should also consider context-specific constraints and leverage local knowledge systems to improve the adoption rate of CSA technologies.

Table 5: Factors Influencing Adoption of CSA Practices (Binary Logistic Regression Result)

Variable	Coefficient (B)	Std. Error	Wald	p-value	Exp (B)	Decision
Age	-0.014	0.021	0.444	0.505	0.986	Not Significant
Education level	0.347	0.102	11.589	0.001	1.415	Significant
Farm size	0.298	0.089	11.225	0.001	1.347	Significant
Access to credit	0.624	0.133	22.103	0.000	1.866	Significant
Extension contact	0.578	0.129	20.135	0.000	1.782	Significant
Access to climate info	0.452	0.117	14.984	0.000	1.571	Significant

Household size	0.092	0.065	1.994	0.158	1.096	Not Significant
Farming experience	0.175	0.070	6.250	0.012	1.191	Significant

Source: Field Survey, 2025

The logistic regression analysis in Table 5 highlights several key determinants of CSA adoption among smallholder farmers in Kebbi State. Education level, farm size, access to credit, extension contact, access to climate information, and farming experience were statistically significant at $p < 0.05$, indicating their strong influence on the likelihood of adopting CSA practices. Education significantly increased the likelihood of CSA adoption, consistent with findings by Khatri-Chhetri et al. (2017), who noted that educated farmers are more likely to understand and apply climate-resilient technologies. Similarly, access to credit emerged as a major enabler, supporting the work of Arslan et al. (2015), who found that financial empowerment facilitates technology adoption. Farm size also positively influenced CSA adoption. Larger farms may offer more flexibility in experimenting with new practices and absorbing risks, aligning with Yusuf et al. (2021), who reported a similar trend in northern Nigeria. Extension contact and access to climate information were strongly significant, highlighting the importance of institutional support and information dissemination in promoting adoption. This finding agrees with Akinbile et al. (2021), who emphasized the role of extension services in knowledge transfer and decision-making. Farming experience was also positively correlated with adoption, possibly due to better problem-solving skills and exposure to climate variations. However, age and household size were not significant predictors in this study, suggesting that demographic factors may be less relevant than access to enabling resources and services.

Table 6: Impact of CSA Practices on Household Food Security Dimensions

Food Security Dimension	Mean Score (CSA Adopters)	Mean Score (Non-Adopters)	Mean Difference	t-value	p-value	z-value	Decision
Food Availability	4.23	3.12	1.11	7.85	0.000	7.13	Significant
Food Accessibility	4.01	2.95	1.06	8.10	0.000	7.43	Significant
Food Stability	3.89	2.88	1.01	7.54	0.000	6.89	Significant

Source: Field Survey, 2025

The results in Table 6 show a statistically significant difference between CSA adopters and non-adopters across all three dimensions of household food security: availability, accessibility, and stability. CSA adopters reported a mean score of 4.23 for food availability, compared to 3.12 for non-adopters. This result confirms that adopting CSA practices can improve household food supply throughout the year. This aligns with the findings of Thierfelder and Wall (2012), who reported that conservation agriculture enhances food availability through improved yields and soil fertility. In terms of food accessibility, CSA adopters had a mean score of 4.01, significantly higher than the 2.95 reported by non-adopters. Improved accessibility may stem from increased income due to better yields, enabling households to purchase diverse food items. This agrees with the observations of Khatri-Chhetri et al. (2017), who emphasized the role of CSA in improving household income and reducing vulnerability to food insecurity. For food stability, adopters again outperformed non-adopters with a mean score of 3.89 versus 2.88. This suggests that CSA practices help buffer households against seasonal food shortages and climatic shocks. Similar conclusions were drawn by FAO (2013), which highlighted the stabilizing effect of CSA on food supply by reducing exposure to weather extremes. These findings demonstrate that CSA adoption not only enhances food availability but also contributes to better access and year-round food stability. This is especially critical in Kebbi State, where climate variability is increasingly disrupting agricultural cycles. However, this finding is at odds with Usman et al. (2022), who found only marginal food security improvements from CSA in some northern Nigerian regions, suggesting that local adaptation strategies and implementation quality may moderate outcomes.

Table 7: Challenges Faced by Farmers in Adopting and Sustaining CSA Practices

Challenges	Frequency	Percentage (%)	Rank
High cost of inputs	278	80.3	1
Limited access to credit	243	70.2	2
Inadequate extension services	226	65.3	3
Lack of awareness and technical knowledge	204	59.0	4
Poor access to CSA technologies	188	54.3	5
Land tenure insecurity	165	47.7	6
Labour shortage	143	41.3	7
Climate variability	128	37.0	8

Source: Field Survey, 2025

Table 7 presents the major challenges hindering the adoption and sustainability of CSA practices among smallholder farmers in Kebbi State. The most frequently cited constraint was the high cost of inputs (80.3%), indicating that the financial burden of acquiring improved seeds, fertilizers, and irrigation technologies poses a major barrier. This supports the findings of Mwongera et al. (2017), who identified input cost as a critical constraint to CSA adoption in East African farming systems. Limited access to credit (70.2%) emerged as another significant challenge, reflecting structural issues in rural finance and the inability of farmers to obtain loans for CSA investments. Similar

observations were made by Fagariba et al. (2018), who noted that lack of financial support prevents resource-poor farmers from transitioning to climate-smart practices. Inadequate extension services (65.3%) and lack of technical knowledge (59.0%) further underscore the role of institutional support and capacity building. Farmers who are not properly informed or trained on CSA techniques are less likely to adopt and sustain such practices. This aligns with findings by Asfaw et al. (2016), who emphasized the importance of extension in facilitating climate-smart innovations. Challenges such as poor access to CSA technologies (54.3%) and land tenure insecurity (47.7%) also reflect structural and policy limitations. Farmers are hesitant to adopt long-term practices like agroforestry or soil rehabilitation when land ownership is uncertain.

Conclusion/ Recommendations: The adoption of Climate-Smart Agricultural (CSA) practices has a significant impact on enhancing food security among smallholder farmers in Kebbi State, Nigeria. The study findings reveal that CSA practices improve food availability, accessibility, and stability, making them crucial in ensuring household resilience to climate change. Despite the benefits, adoption levels remain hindered by challenges such as high input costs, limited access to credit, inadequate extension services, and poor infrastructure. Addressing these barriers through targeted interventions will enhance the adoption of CSA practices, leading to increased agricultural productivity and long-term food security. **From the results of the above research, the following major recommendations were arrived at:** High input costs remain a significant barrier to CSA adoption. Government agencies and NGOs should implement targeted subsidy programs for essential CSA inputs, such as drought-resistant seeds, organic fertilizers, and water conservation equipment. Limited access to credit prevents farmers from investing in CSA technologies. Financial institutions such as: *Central Bank of Nigeria (CBN)*, *Bank of Agriculture (BOA)*, *Microfinance Banks*, and *Cooperative Societies*, should introduce flexible, low-interest credit schemes specifically tailored for smallholder farmers.

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Benefit Cost Ratio of used of Compost Enriched Biochar in Sesame Cultivation

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Abstract

Biochar is an organic soil amendment that improves highly weathered or degraded soils through sustainable technology. The benefit cost ratio of biochar as related to conventional inorganic fertilizers was determined in the study. Compost (5 t/ha); Biochar (2 t/ha); four levels of Compost -enriched biochar, (B₂C - biochar 2 t/ha with 5 t/ha compost; B₄C - biochar 4 t/ha with 5 t/ha; B₆C - biochar 6 t/ha with 5 t/ha compost; B₈C - biochar 8 t/ha with 5 t/ha compost) N-S fertilizer and control using 2x8x4 factorial arrangement fitted in completely randomized design using two sesame varieties (NCRIBEN 01M and E8). Data were taking on growth and yield parameters and were subjected to analysis of variance (ANOVA) using GenStat (Discovery edition) with treatment mean values separated using Duncan Multiple Range Test (DMRT) at 5% probability level. Application of B₄C - biochar 4 t/ha was found to record 87.69 % and 86.99 % Harvest Index for E8 and NCRIBEN 01M respectively while highly profitable to use compost, B₄C - biochar 4 t/ha and B₈C - biochar 8 t/ha for sesame production using E8 variety.

Keywords: Soil amendment, yield, B/C

Introduction: Decline in soil fertility and low soil nutrient status are inevitable in the tropic due to nutrient losses through leaching, erosion, run-off, crop nutrient depletion, nutrient fixation, salinization and water logging. Use of organic soil amendments are therefore a prerequisite for continuous cultivation of crops that enhances better soil condition, good crop production and sustain soil fertility. Biochar is an organic soil amendment that is gaining popularity in modern horticulture in recent time. Biochar can be defined simply as charcoal produced with plant or animal residues used for agricultural purposes. It is deliberately addition of char on soils as a soil amendment or soil conditioner. It was reported to improve the physio-chemical properties of soils thus contributing to increased crop productivity (Yamato et al., 2006). It was reported to improve highly weathered or degraded soils through sustainable technology (Lehmann et. al., 2006). Biochar's specific and unique properties as well as its micro porous nature with extensive surface area (12m²g⁻¹) make it stand out among other organic soil amendments. However, sole application of biochar to poor soils may have little benefit to growing plants. Application in combination with other organic and inorganic fertilizer materials can dramatically improve plant growth. The extensive surface of biochar is exploited as substrate to adsorb nutrients and slowly release them for plant use. Crop yields are usually increased when biochar is fortified or mixed with other organic or mineral fertilizers (Steiner et al., 2007). Therefore, the objective of this study is to evaluate the benefit cost ratio of compost-enriched biochar compare to conventional fertilizers; N and S fertilizer sources.

Methodology: A field was carried out using eight treatments combination; B₂ - biochar 2 t/ha; B₂C - biochar 2 t/ha with 5 t/ha compost; B₄C - biochar 4 t/ha with 5 t/ha; B₆C - biochar 6 t/ha with 5 t/ha compost; B₈C - biochar 8 t/ha with 5 t/ha compost. These treatments were in factorial arrangements in completely randomized design (r=6). Further investigation was carried to evaluate residual effect of these treatment combinations in a 2 x 8 CRD in three replicates. Data were taken on growth and yield parameters analyzed using descriptive statistics and ANOVA at α_{0.05}. The benefit cost ratio of compost – enriched biochar in respect to inorganic fertilizers used was calculated using the formula below.

$$B/C = \frac{\sum_{t=1}^n \frac{B_t}{(1+i)^t}}{\sum_{t=1}^n \frac{C_t}{(1+i)^t}} \geq 1 \quad (\text{FAO, 1995})$$

B_t, C_t, n, t, i as defined for NPV

ANOVA was used to test the statistical significance of the differences in the profit.

Results and Discussions: The results on Table 1 showed the effect of treatments on the growth of sesame varieties. The effect of treatment on sesame plant height was highly significant. Application of CB₈ had the highest plant height (96.8 cm) which is statistical similar to compost (95.3), followed by CB₄, (86.5); NPKS (81.9) and CB₆ (81.5)

while control and B₂ recorded the least mean values of 69.5 cm and 68.0 cm respectively. It was recorded that NPKS has the high mean value (3.9 cm) for stem diameter which was statistically higher than the other treatments that are at par except for control (2.6 cm) and B₆C (2.1 cm) that are significantly lower while B₆C recording the least mean value. However, number of leaves recorded by B₈C is statistically higher (61.0) and at par with NPKS (56.5) followed by Compost (50.8) that is statistically similar to B₄C (46.3) while Control recorded statistically lowest number of leaf (24.8). The trend of the treatment on number of leaves shows thus; B₈C > NPKS > Compost > B₄C > B₆C > B₂ > B₂C > Control. Application of biochar has significant effect on the leaf area with B₆C recording 13.8 cm² while Control (11.5 cm²) had the lowest mean value. Statistically, all treatments have statistically similar values except B₆C that is significantly higher. The mean values of leaf area follow this trend: B₆C > NPKS > Compost > B₈C > B₂ > B₂C > B₄C > Control.

A positive response to addition of biochar to soil as soil amendment has been reported for a wide range of crops. As reported by Dalila, et al., 2012 and Solaiman, 2010, maize was said to increase by 98 -150%; lettuce, Arabidopsis biomass increased by 111% (Viger, 2015), wheat grain yield increased by 18% (Solaiman, 2012) and tomato yield by 30%. It was reported that biochar is highly efficient in increases crop production and yield (Rehman and Razzaq, 2017) as a result of its effect on nutrient transformation and microbial community. This study confirmed these claims that either sole application of biochar and compost-enriched biochar as soil amendments induced positive effect on sesame as reported by Dalila et al., 2017 on lettuce growth. Similarly, Azu (2023); Biederman and Harpole (2013) reported that biochar enhances the growth and vegetative yield of vegetables. An average of 25 – 50% increase in yield of sesame was obtained in this study with B₄C and B₂C largely enhancing yield parameters in the screen house, field experiments and residual evaluations. As reported by Abdulkadir, 2024 long term effect of biochar on nutrients availability was due to an increase in surface oxidation and cation exchange capacity. This is further corroborated with Ammu, et al., 2017 report that biochar has long term benefits in crop performance.

Benefit cost of the soil amendments: Decision of benefit cost (B/C) accept projects with a ratio above one i.e. B/C > 1. It is the percentage of return on capital invested in a project. The field experiment at first season evaluates effects of these treatments on sesame performance in term of seed yield. The residual effect of these treatments was investigated at second season The B/C at second year (residual evaluation) is higher across all the treatments used compared to first year. The benefit cost ratio was less than 1 (B/C < 1) for compost at year 1 for both varieties (NCRIBEN 01M and E8) and this is similar to what was obtained at CB₄, CB₆ and CB₈ for the two varieties at year 1. B/C at first year is low to second year where B/C is above 1 across all the treatments. CB₄ recorded highest B/C at second year with value of 19.28 followed by compost with (19.00) while least was observed NPKS with 4.49. Most of the soil amendments under this study should be accepted because their benefit cost (B/C) are greater than one (B/C>1) particularly for residual evaluation. They have economic returns particularly on degraded soil. These results corroborate the finding of Dalila et. al., 2017 that reported that addition of compost solely as amendments showed the best and positive effects on plant growth. This was also supported by Diacono and Montemurro, 2011 that reported that compost amended soil increased the total biomass accumulation of lettuce, further confirmed by Scotti, 2015 and Khan, 2012 that use of several composted materials as soil amendment are sustainable high source of available nutrients that could enhance plant growth, ameliorating soil physicochemical characteristics and microbiological activities. This equally enhances the activities of enzymes involved in phosphorus and nitrogen cycling and has higher benefit cost ratio. Application of biochar (CB₄) was observed to significantly have higher economic return value compared to other levels of biochar in combination with compost while nitrogen and sulphur based fertilizers has the least. This however corroborates the report of Joseph, 2021 that said that combination of biochar with organic fertilizers has high nutrient-use efficiency and the most cost-effective.

Table 1: Effect of compost-enriched biochar on sesame performance

Treatments	Plant height (cm)	Stem diameter (cm)	Number of leaves	Leaf area (cm ²)
Control	69.5d	2.6d	24.8d	11.5b
NPKS	81.9b	3.9a	56.5a	12.6b
B ₂	68.0d	3.3b	42.3c	11.9b
Compost	95.3a	3.1b	50.8b	12.2b
B ₂ C	81.5bc	3.4b	39.5c	11.9b
B ₄ C	86.5b	3.3b	46.3bc	11.6cb
B ₆ C	76.5c	2.1e	42.8c	13.8a
B ₈ C	96.8a	3.5b	61.0a	12.2b

Mean values with the same *letters* in the column are statistically the same at 5% probability level

B₂ - biochar 2 t/ha, B₂C- biochar 2 t/ha with 5 t/ha compost, B₄C - biochar 4 t/ha with 5 t/ha, B₆C - biochar 6 t/ha with 5 t/ha compost, B₈C - biochar 8 t/ha with 5 t/ha compost

Table.2: Residual evaluation of compost-enriched biochar on sesame yield

Treatment	E8			NCRIBEN 01M		
	No of Pod	Seed	Harvest Index	No of Pod	Seed Yield/ha	Harvest Index
		Yield/ha	(%)			(%)
Control	10	8.88	83.62*	11	9.74	84.31*
B ₂	10	9.23	83.36*	11	10.58	86.38*
Compost	9	8.18	82.21*	11	9.88	85.29*
NPKS	7	5.98	76.59	9	8.08	82.67*
Com+ B4	15	11.83	87.69*	13	10.26	86.99*
Com+ B6	8	7.46	80.67	9	8.91	81.69
Com+ B8	8	7.31	80.13	12	10.74	86.33*

S.e.d	0.0	0.0036	0.006	0.0	0.0036	0.006
L.s.d	NS	0.007	0.012	NS	0.007	0.012

Table 3: Cost benefit of the treatments used

Treatment	Variety	Season	Input (₦)	Price	Output (₦)	Price	Discount factor 13.25%	Discounted Cost	Discounted Benefit (₦)	Benefit Cost	Ratio	Inference
Control	NCRIBEN 01M	1	50,000		587,348		1	50,000	587,348	11.75		P
Control	NCRIBEN 01M	2	50,000		583,008		0.883	44,150	514,796	11.66		P
Control	E8	1	50,000		510,216		1	50,000	510,216	10.20		P
Control	E8	2	50,000		501,399		0.883	44,150	442,735	10.03		P
NPKS	NCRIBEN 01M	1	193,629		467,656		1	193,629	467,656	2.42		P
NPKS	NCRIBEN 01M	2	50,000		467,151		0.883	44,150	412,494	9.34		P
NPKS	E8	1	193,629		230,328		1	193,629	230,328	1.19		P
NPKS	E8	2	50,000		224,493		0.883	44,150	198,227	4.49		P
B ₂	NCRIBEN 01M	1	184,224		686,504		1	184,224	686,504	3.73		P
B ₂	NCRIBEN 01M	2	50,000		665,948		0.883	44,150	588,032	13.32		P
B ₂	E8	1	184,224		423,136		1	184,224	423,136	2.29		P
B ₂	E8	2	50,000		546,998		0.883	44,150	482,999	10.94		P
Compost	NCRIBEN 01M	1	644,784		626,808		1	644,784	626,808	0.97		N
Compost	NCRIBEN 01M	2	50,000		971,595		0.883	44,150	857,918	19.43		P
Compost	E8	1	644,784		418,824		1	644,784	418,824	0.65		N
Compost	E8	2	50,000		644,238		0.883	44,150	568,862	12.88		P

B ₂ C	NCRIBEN 01M	1	460,560	976,920	1	460,560	976,920	2.12	P
B ₂ C	NCRIBEN 01M	2	50,000	623,369	0.883	44,150	550,435	12.47	P
B ₂ C	E8	1	460,560	644,224	1	460,560	644,224	1.39	P
B ₂ C	E8	2	50,000	419,271	0.883	44,150	370,216	8.39	P
B ₄ C	NCRIBEN 01M	1	829,009	744,296	1	829,009	744,296	0.89	N
B ₄ C	NCRIBEN 01M	2	50,000	735,329	0.883	44,150	649,296	14.71	P
B ₄ C	E8	1	829,009	1,004,360	1	829,009	1,004,360	1.21	P
B ₄ C	E8	2	50,000	963,908	0.883	44,150	851,131	19.28	P
B ₆ C	NCRIBEN 01M	1	1,013,232	416,696	1	1,013,232	416,696	0.41	N
B ₆ C	NCRIBEN 01M	2	50,000	404,869	0.883	44,150	357,499	8.09	P
B ₆ C	E8	1	1,013,232	360,248	1	1,013,232	360,248	0.36	N
B ₆ C	E8	2	50,000	352,798	0.883	44,150	311,521	7.06	P
B ₈ C	NCRIBEN 01M	1	1,197,008	723,632	1	1,197,008	723,632	0.61	N
B ₈ C	NCRIBEN 01M	2	50,000	720,340	0.883	44,150	636,060	14.41	P
B ₈ C	E8	1	1,197,008	331,688	1	1,197,008	331,688	0.28	N
B ₈ C	E8	2	50,000	325,832	0.883	44,150	287,710	6.52	P

B₂ - biochar 2 t/ha low dose biochar); B₂+C- biochar 2 t/ha with 5 t/ha compost (low dose biochar); B₄+C - biochar 4 t/ha with 5 t/ha compost (medium dose biochar); B₆+C - biochar 6 t/ha with 5 t/ha compost (high dose biochar); B₈+C - biochar 8 t/ha with 5 t/ha compost over dose biochar)

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Biochemical Parameters of Broiler Birds Fed *Vernonia amygdalina* and *Guiera senegalensis* Leaf as Phyto-genic Feed Additive

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Abstract

This research was carried out in the Department of Animal Science, College of Agriculture, Federal University of Agriculture Zuru, Kebbi State. To determine some biochemical parameters of broiler birds fed *Vernonia amygdalina* and *Guiera senegalensis* leaf as phyto-genic feed additive. Two hundred (200) broilers were used for this study, they were randomly allocated into four (4) dietary treatments (T₁, T₂, T₃ and T₄) replicated five with ten birds per replicate. They were fed *Vernonia amygdalina* and *Guiera senegalensis* leaf (T₁) 0%, *Vernonia amygdalina* leaf (T₂) 0.1%, *Guiera senegalensis* leaf (T₃) 0.1% *Vernonia amygdalina* leaf and T₄ *Vernonia amygdalina* and *Guiera senegalensis* leaf 0.1%. At the end of the feeding trial the result for biochemical parameters measured revealed that there were significant differences ($P < 0.05$) in URE, CRT, AST, ALT and ALB and there was no significant difference ($P > 0.05$) in TP and ALP. The best URE numerical value was recorded in T₂ (2.70 g/dl) followed by T₃ (1.90 g/dl), T₁ (1.76 g/dl) and the lowest value was observed in T₄ (1.0 g/dl). The CRT value recorded were (0.43 mg/dl), (1.90 mg/dl) and (1.21 mg/dl) for T₁, T₂, T₃ and T₄ respectively. The largest ALT numerical value was observed in T₃ (59.63 g/dl) and the lowest in T₃ and T₄ (55.33 g/dl). T₃ recorded the highest AST values (6.66 μ /l) and lowest was seen in T₃ (3.33 μ /l). The best TP value was recorded in T₂ and T₄ (59.66 g/dl) and the lowest value in T₁ (58.66 g/dl). The ALB values were (33.66 g/dl), (35.60 g/dl), (33.33 g/dl) and (32.66 g/dl) for T₁, T₂, T₃ and T₄ respectively. From the results obtained in this study it could be concluded that feeding broilers with *Vernonia amygdalina* and *Guiera senegalensis* leaf as phyto-genic feed additive had no adverse effect on biochemical parameters of broilers. Therefore, from the findings of this study, it is recommended that antibiotic growth promoters can be replaced with *Vernonia amygdalina* and *Guiera senegalensis* leaf in broilers diets. It is also recommended that haematological parameters and carcass analysis should be carried out on birds fed *Vernonia amygdalina* and *Guiera senegalensis* leaf.

INTRODUCTION

Background of the Study: In Nigeria, broilers provide much of protein, vitamin and minerals in human diet (Mapiye et al., 2008). And they are source of cash for small and large scale farmers (Mapiye et al., 2008). Feed is essential part of livestock production which has great effect in their growth and quantity of their production. (Dairo, 2005). Biochemistry is the study of chemical reaction in living organism (Jezek and Klinkon, 2006). The study of biochemical parameters can provide valuable information as relating to nutrition, sex, age and physiological status of the animal (Jezek and Klinkon, 2006). Biochemical analysis of blood serum is very useful to get insight in the metabolism and the health status of animals, during diagnostic procedure it is very useful to compare the value obtained from a mill animal with normal healthy animal (Jezek and Klinkon, 2006). Biochemical parameters responsible for various body functions induce structural and physiological abnormalities (Jezek and Klinkon, 2006).

Guiera senegalensis is commonly known as "Sabara" in Hausa, a shrub of the savannah region of west and central Africa. It is widely being used in traditional medicine for the remedy of many ailments/disease. Its leaves extract is being used against dysentery, diarrhea, gastrointestinal pain and disorder, rheumatism and fever (Sule and Mohammed 2006). The astringent property of this plant was reported to be due to its tannin content (Koumare et al., 1968).

Vernonia amygdalina is a medium sized shrub with abundant bitter principle in every part of it. It belongs to the family composite or asteraceae. The plant is known as "ewuro" or "ologhu" or "shuwaka" in Yoruba, western, Igbo southern, Hausa Northern Nigerian for both therapeutic and nutritional purpose. Bitter leaf decoction of plant is aethnomedicinally employed as an anti-diabetic remedy (Okafor, 2002).

MATERIALS AND METHODS

Experimental Site and Location: The research was conducted at Poultry Unit of the Department of Animal Science College of Agriculture Federal University of Agriculture Zuru, Kebbi State Nigeria. Zuru is located at latitude 4°15'N to latitude 11°25'N and longitude 4°14'E to 4°14'E covering an area of about 461,884 square kilometers, and the area is at extreme South Eastern part of Kebbi State. Geographically Zuru falls within a region of crystalline rocks which form part of basement complex rocks of African shield. The climate of the area is a tropical savannah climate with average annual rainfall of about 1300 to 1500 mm and mean temperature of about 27°C. The soil of the area is a well-drained sandy-loam soil which supports many crops production. The vegetation of the area is tropical savannah woodland and tall scattered grasses which are greenish in the rainy season, but dried and dumped in the dry season. The area falls within the Northern Guinea Savannah Agro-Ecological Zone of Nigeria. (Sakaba, 2017).

Management of Experimental Birds: The birds were managed in the brooder house for four weeks and after the brooding, they were transferred to individual pen feed and water was provided *ad libitum* with appropriate routine medication and vaccination on the basis of maize, soyabean, wheat offal, fish meal, bone meal, Premix, salt, lysine, methionine, *Guiera senegalensis*, and *Vernonia amygdalina* Leaves

Experimental Diets: Four (4) experimental diets were formulated as follows: Treatment one (T₁) contained only the feeding ingredient, treatment two (T₂) contains *Vernonia amygdalina* 0.1 kg, treatment three (T₃) contains *Guiera senegalensis* 0.1 kg, treatment four (T₄) contains mixture of *Vernonia amygdalina* and *Guiera senegalensis* leaves.

Table 1: Basal diets for starter phase.

Ingredients	T ₁ (0% VA/GS)	T ₂ (0.1% VA)	T ₃ (0.1% GS)	T ₄ (0.1% VA&GS)
Maize	43.0	43.0	43.0	43.0
SBM	40.0	40.0	40.0	40.0
Wheat Offal	10.0	10.0	10.0	10.0
Fish Meal	2.00	2.00	2.00	2.00
Bone Meal	4.00	4.00	4.00	4.00
Premix	0.30	0.30	0.30	0.30
Salt	0.20	0.20	0.20	0.20
Lysine	0.20	0.20	0.20	0.20
Methionine	0.30	0.30	0.30	0.30
Total	100	100	100	100
Calculated Chemical Composition				
Energy (kcal/kg)	3869 MEKcal/kg			
Crude Protein (%)	24%			
Calcium (%)	1.7%			
Phosphorus (%)	1.0%			

Table 2: Basal diets for finisher phase.

Ingredients	T ₁ (0% VA/GS)	T ₂ (0.1% VA)	T ₃ (0.1% GS)	T ₄ (0.1% VA&GS)
Maize	59.00	59.00	59.00	59.00
SBM	22.0	22.0	22.0	22.0
Wheat Offal	10.0	10.0	10.0	10.0
Fish Meal	2.6	2.6	2.6	2.6
Bone Meal	3.04	3.04	3.04	3.04
Blood Meal	2.00	2.00	2.00	2.00
Premix	3.04	3.04	3.04	3.04
Salt	0.03	0.03	0.03	0.03
Lysine	0.02	0.02	0.02	0.02
Methionine	0.03	0.03	0.03	0.03
Total	100	100	100	100

Calculated Chemical Composition

Energy(kcal/kg)	3032MEKca/kg
Crude Protein(%)	19.8%
Calcium(%)	1.50%
Phosphorus(%)	0.50%

Experimental Design

A total of 200 broiler birds were used for the experiment. The birds were randomly allocated into four (4) treatment groups. Each treatment was replicated five times. Each replicate was consisted of 10 birds and four treatment was performed for the experimental diets for the period of eight (8) weeks.

Sample Collection

Approximately 2 ml of blood sample was taken from the wing vein of the birds and disposed into a plain tube using a 2 ml syringe and 23 gauge needle. All blood collected tube was kept in ice pack container to avoid denaturation of protein before taking to laboratory for analysis.

Procedure to Determination of Biochemical Parameters

The following parameters were analyzed in the sera: Aspartate Aminotransferase (AST), Albumin, Total protein (Dumas, 2005).

Aspartate Amino Transferase (AST)

Principle: L-oxyglutarate + L-aspartate $\xrightarrow{\text{AST}}$ L-Glucose + Oxaloacetate.

Aspartate aminotransferase activity was measured by monitoring the concentration of oxaloacetate hydrazine formed with 2,4-dinitrophenylhydrazine.

Reagents: Areagent kit containing phosphate buffer (10 mmol, pH 7.7), L-aspartate (100 mmol/l), L-oxoglutarate (2 mmol/l), 2,4-dinitrophenylhydrazine (2 mmol/l) and sodium hydroxide (NaOH) 0.4 M was used.

Procedure: Two (2) clean test tubes were labeled as 'test' and 'blank', then each of the test tubes contain 0.5 ml of substrate buffer solution which was placed and incubated at 37°C for 5 min, then 0.1 ml of the serum was added to the 'test' tube and further incubated at a aliquot of serum which was beaded to the test tube labeled 'blank'. The mixture was shaken and allowed to stand at room temperature for 20 min after which 5 ml of 0.4 M NaOH was added to each tube and allowed to stand for 5 min. The absorbance was measured at 546 nm after zeroing the instrument using the blank.

Into Test Tube	Test (ml)	Blank
Substrate buffer solution was indicated at 37°C for 5 min	0.5	0.5
Serum was mixed and incubated at 37°C for 30 min	0.1	--
2,4-dinitrophenylhydrazine	0.5	0.5
Serum was mixed and allowed to stand at room temperature for 20 min	--	0.1
0.4 M NaOH was mixed and absorbance of test was read at 546 nm against blank after 5 min	5.0	5.0

Determination of Total Serum Protein

Principle: Alkaline copper solution reacts with peptide bond in the protein molecule producing a violet color which is directly proportional to the amount of protein present in the sample.

Procedure: Three (3) clean test tubes were labeled as 'test', 'standard' and 'blank', then 2 ml of Biuret reagent was beaded to each of them, thereafter, 0.02 ml of serum was added to the tube labeled 'test' and 0.02 ml of standard (multi standard protein solution) was added to the tube labeled 'standard'. The 0.02 ml of distilled water was added to the blank. The mixture in each test tube was then incubated at 37°C for 10 min and the absorbance was read at 550 nm.

Into Test Tube	Test (ml)	Standard (ml)	Blank (ml)
Biuret Reagent	2.0	2.0	2.0
Serum	0.02	--	--
Standard Protein Solution	--	0.02	--
Distilled water was mixed and incubated at 37°C for 10 min. Absorbance of test was read at 550 nm against blank after 10 min	--	--	0.02

Calculation: Total Protein conc. (g/l) = (Absorbance test / Absorbance of standard) * Std conc.

Determination of Serum Albumin

Principle: The measurement of serum albumin is based on its quantitative binding to the indicator 3,3',5,5'-tetrabromo-m-cresol sulphonephthalein (Bromocresol Green, BCG). The albumin-BCG complex absorbs maximally at 578 nm and the absorbance is directly proportional to the concentration of albumin in the sample.

Reagent: Areagent kit containing succinate buffer (75 mmol/l; pH 4.2), bromocresol green (0.15 g), Tris buffer (100 mmol/l; pH 7.3) was used.

Procedure: Three (3) clean test tubes were labeled as 'test', 'standard' and 'blank', then 0.01 ml each of distilled water, standard solution and serum sample was added to the tubes labeled 'blank', 'standard' and 'test' respectively. After that, 3 ml of BCG reagent was added to each of the test tubes and then mixed properly. Each of the mixtures was incubated for 5 min at room temperature. The absorbance of the test and standard was read against the reagent blank at 630 nm using a spectrophotometer.

Into Test Tube	Test (ml)	Standard (ml)	Blank (ml)
Serum	0.01	--	--
Standard Solution	--	0.01	--
Distilled water	--	--	0.01
BCG Reagent	3.0	3.0	3.0

was bemixed and incubated at room temperature for 5 min. Absorbance of test was beread at 630 nm against blank after 5 min

Data Analysis

Data Analysis was generated and expressed as means and standard deviation (SD). Significance difference was considered as ($P > 0.05$) and SPSS package was used to separate the mean by Duncan multiple range test.

RESULTS AND DISCUSSION

The chapter reveals the result of biochemical parameters of Broiler fed *Vernonia amygdalina* and *Guiera senegalensis* leaves as phyto-genic feed additive.

Table 3: Biochemical parameters of broilers fed *Vernonia amygdalina* and *Guiera senegalensis* as phyto-genic feed additive.

Parameter	T ₁ (0% VAL/GSL)	T ₂ (0.1% VAL)	T ₃ (0.1% GSL)	T ₄ (0.1% VAL/GSL)	SEM ±
URA (g/dl)	1.76	2.70	1.90	1.50	0.16
CRT (mg/dl)	0.43	0.63	1.90	1.21	0.20
ALP (g/dl)	57.66	55.33	59.63	55.33	0.82
AST (I μ /l)	5.33	6.66	3.33	4.66	0.46
ALT (I μ /l)	7.33	9.00	5.33	8.00	0.46
TP (g/dl)	58.66	59.66	59.00	59.66	0.27
ALB (g/dl)	33.66	35.60	33.33	32.66	0.33

Key:

AST: Aspartate Amino Transferase

TP: Total Protein

ALB: Albumin

The biochemical parameters investigated showed that the result for URE was significantly different ($P < 0.05$) between T₂ (2.70 g/dl) and T₄ (1.50 g/dl). Contrarily, the result of creatinine (CRT) shows that there was significant difference ($P < 0.05$) in the values recorded across the treatments. The values for Alkaline phosphatase (ALP) show that there were no significant difference ($P > 0.05$) among the treatments. The result for Aspartate amino transferase (AST) shows that there was significant difference ($P < 0.05$) between T₂ (6.66 I μ /l) and T₃ (3.33 I μ /l). Alanine Amino Transferase (ALT) also shows that there was significant difference ($P < 0.05$) between the T₂ (9.00 I μ /l) and T₃ (5.33 I μ /l).

The value obtained for (URE) in this study were higher than the finding of Maidala, and Abdullahi, (2017) who reported (0.01-0.00 g/d) for (URE) for broilers fed neem and *Guiera senegalensis* leaf. However, the values for (URE) obtained in this present study were within the range reported by Iyayi, (2001). High level of urea is associated with kidney impairment and high protein breakdown. (Emadi and Kermanshahi, 2007).

The value of creatinine (CRT) in this study was higher than the value 0.42-0.83 mg/dl reported by Aikpanyi and Egweh (2020) for broilers fed neem and *Guiera senegalensis* leaf. Although the value obtained in the present study were within the range reported by Maidala and Abdullahi, (2017). The high value obtained in this study may be attributed to the fact that protein level is maintained by critical homeostatic mechanisms that depend on the stage of growth, feed consumption, productivity, and environmental change (Plateland and Crivivasan, 2004).

The value for Alkaline phosphatase (ALP) in this study were lower than the finding of Aikpanyi and Egweh (2020) who reported 137.7-309.00 I μ /l for the Alkaline phosphatase (ALP) for broilers fed ginger and black pepper. However, the value for Alkaline phosphatase (ALP) in all the treatments obtained in this research were within the range (10.20 I μ /l) reported by (Lumeij, 2008). Higher serum level of Alkaline phosphatase (ALP) are observed when there is increased osteoblastic activity involving the formation of mineralization of bone associated skeletal growth (Lumeij, 2008).

The value for Aspartate Amino Transferase (ALT) in this study were lower than the finding of Maidala and Abdullahi (2017) who reported 21.40-

27.52 µl/l for Aspartate Amino Transferase of broiler birds fed ginger and *Guierasengalensis* leaf. However, the value for Aspartate Amino Transferase obtained in this research were within the range reported by Osho *et al.* (2016) for broiler chickens. The activities of aspartate amino transferase (AST) in the blood are both indicator of liver function and damage. Increased levels of these enzymes are associated with liver or muscle stress (Lumeij, 2008).

The value obtained for Alanine amino transferase (ALT) in this research were lower than the finding of Aikpitanyi and Egweh (2020) who reported 65.084.13 µl/l for Alanine amino transferase (ALT) for broilers fed ginger and black pepper. However, the value obtained were within the range reported by Aidin and Navid (2015). The reduction in Alanine amino transferase (ALT) is an indication of better liver function. This is however contrary to the finding of a study of effect of turmeric rhizome powder on activity of some blood enzymes in broiler chicken (Emadi and Kermanshahi, 2007). The value for Total protein (TP) in this study is higher than the findings of Adewale *et al.* (2018) who reported 3.07-3.40 g/dl for total protein (TP) of broilers fed varying level of biscuit waste meal.

However the level for total protein obtained in this study were within the normal range 3.00-21.2 reported by Maidala and Abdullahi, (2017) the increase in the total protein (TP) is an indication of nutritional adequacy of the dietary protein in this experiment. The value for Albumin (ALB) in this research were higher than the findings of Aikpitanyi and Egweh who reported 1.45-1.4 g/dl for Albumin (ALB) for broiler birds fed ginger and black pepper. However, the values for albumin (ALB) obtained were within the normal range as reported by Farugia, (2010) serum Albumin produced from liver and forms a proportion of plasma protein low Albumin may be caused by liver disease, malnutrition, late pregnancy, genetic variation. High Albumin is caused by dehydration (Farugia, 2010).

CONCLUSION AND RECOMMENDATION: Based on the result obtained using *Vernonia amygdalina* and *Guierasenegalensis* leaf as phytogenic feed additives had no adverse effect on biochemical parameters of broilers. Therefore from the finding of this study, it is recommended that antibiotic growth promoters can be replaced with *Vernonia amygdalina* and *Guierasenegalensis* leaf in broiler diets without any effects on their biochemical parameters. It is also recommended that the hematological parameters and carcass analysis should be carried out on birds fed *Vernonia amygdalina* and *Guierasenegalensis* leaf.

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Reconcile Healthcare Service and Agricultural Productivity: Pathway for Rural Development in Nigeria

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Abstract

Agriculture remains a fundamental pillar of Nigeria's economy, with rural households heavily reliant on farming for sustenance and income. However, poor health outcomes and limited access to healthcare services significantly hinder agricultural productivity. This study investigates the synergy between access to healthcare services and agricultural productivity among farming households in Nigeria. A multistage sampling technique was adopted to select 720 farming households in Southwest, Nigeria. Using a two-stage least squares (2SLS) regression model, the study examines how access to healthcare services influences farm productivity, employing distance to healthcare facilities as an instrumental variable. The findings reveal that farmers who utilize healthcare services exhibit higher productivity levels than those who do not. Specifically, the treatment group (households accessing healthcare services) reported a significantly higher value of farm produce sales (₦141,775.90) compared to the control group (₦102,430.11). Notable, major determinants of agricultural productivity include farm size, farming experience, cooperative membership, and access to health extension services, while distance to healthcare facilities negatively impacts healthcare utilization. The study highlights that frequent health-related incapacitation leads to labour loss and reduced efficiency, reinforcing the importance of an integrated approach to health and agriculture. Policy interventions such as mobile health clinics, community-based health insurance, and agricultural-health synergies could mitigate the adverse effects of poor health on agricultural output. Bridging the healthcare-agriculture divide is imperative for sustainable economic growth, improved food security, and poverty reduction in Nigeria.

Keywords: Productivity; Extension service; Healthcare access; Health-capital transition; Rural development

Introduction: In sub-Saharan Africa, agriculture is the predominant economic activity, with more than half of the population engaged directly or indirectly (FAO, 2021; Omotoso et al., 2023). It employs more than 60% of the economically active labour force and contributes nearly 40% to total productivity in the Nigerian economy (Omotoso & Omotayo, 2024b; Outhwaite et al., 2022). Consequently, growth in agricultural productivity is essential for improving welfare, especially among rural households and achieving sustainable economic growth for poverty reduction (Outhwaite et al., 2022). It is noted that no country has been able to sustain a rapid transition out of hunger and poverty without raising productivity in its agricultural sector. Notably, agricultural productivity in Nigeria is dependent on physical strength and stamina, and therefore, health shocks are more likely to directly and indirectly affect workers' productivity (Outhwaite et al., 2022). Directly, ill health affects physical strength and work days/hours available for farm work while indirectly, ill health involving high medical expenditures tends to deprive farming households of resources to invest in experimentation on improved practices and the adoption of new technology. Notably, poor health reduces farmers' ability to innovate, experiment, and operationalize changes in agricultural systems (Omotoso & Omotayo, 2024c; Outhwaite et al., 2022). Serious health conditions resulting in catastrophic expenditures may also result in the depletion of productive assets such as the sale of draught animals and the sale of cultivable land (Outhwaite et al., 2022). The consequences of these actions include a reduction in farm sizes, cultivation of less-intensive crops, and reduction in livestock numbers resulting in poor livelihoods. The intersection of healthcare services, agricultural productivity, and rural development is critical to fostering sustainable economic growth and improving the well-being of rural populations (Outhwaite et al., 2022).

In Nigeria, majority of rural households depend on agriculture for their livelihoods, yet they face significant health challenges that hinder productivity (Outhwaite et al., 2022). Poor access to quality healthcare services, high disease prevalence, and inadequate health infrastructure reduce the labour efficiency of farmers, ultimately affecting agricultural output and rural development (Outhwaite et al., 2022). The health-capital transition, which refers to the shift in economic productivity due to improved health conditions, is essential for breaking the cycle of poverty and underdevelopment in rural areas where agriculture remains the backbone of the economy, contributing significantly to employment and food security. However, poor health conditions among farmers, including malnutrition, waterborne diseases, and occupational hazards, lead to reduced labour productivity and lower farm yields (FAO, 2021). Without proper healthcare services, rural communities struggle with high morbidity rates, limiting their ability to engage in productive agricultural activities. Despite extensive research on the individual aspects of healthcare services, agricultural productivity, and rural development, there remains a significant gap in understanding how these three domains intersect to drive economic transformation in Nigeria. Existing studies (Omotoso & Omotayo, 2024c; Outhwaite et al., 2022) have primarily focused on the health-productivity nexus, emphasizing how poor health conditions reduce labour efficiency in agriculture. However, there is limited empirical evidence on how integrated healthcare and agricultural policies can create a sustainable health-capital transition in rural communities. Additionally, most studies (Omotoso & Omotayo, 2024c; Outhwaite et al., 2022) on agriculture and rural development tend to overlook the critical role of healthcare services in enhancing farmers' productivity and resilience. The link between rural health interventions and agricultural performance remains underexplored, particularly in the Nigerian context, where rural communities face both poor healthcare access and low agricultural yields.

Furthermore, there is a lack of comprehensive studies that analyze policy frameworks addressing the simultaneous improvement of healthcare infrastructure and agricultural productivity in Nigeria. While various government initiatives aim to boost agricultural development, there is little integration of healthcare policies that address the well-being of the farming population. Bridging the

gap between healthcare and agricultural productivity requires a holistic approach that integrates health interventions, agricultural innovations, and rural development policies. Investments in rural health facilities, mobile health services, and agricultural extension programs can enhance farmers' well-being and improve their economic resilience. Additionally, strengthening health education, nutrition programs, and access to affordable healthcare services will ensure that rural populations remain healthy enough to sustain agricultural production.

Methodology

Study Area: The study was carried out in rural Southwest Nigeria, encompassing the states of Osun, Ogun, Ekiti, Ondo, Lagos, and Oyo. Agriculture is the primary livelihood activity in the geopolitical zone, with commercial production of maize, cassava, yam, oil palm, cocoa, and timber. The predominant households in this area depend mostly on subsistence farming, supplemented by income from trading, hunting, foraging, and handicrafts (Omotoso & Omotayo, 2024a). The natural vegetation of the geopolitical zone consists of tropical rainforest in the south and guinea savannah in the north, with soil conducive to subsistence cultivation.

Sampling Procedures and Data Analysis: The study utilized primary data collected through an interview schedule. The study population is composed of rural farm households in the zone who primarily engage in subsistence farming. Additionally, 720 agricultural households across six (6) states in Southwestern, Nigeria were conducted using a multistage sampling procedure. The initial phase involved the deliberate selection of Ekiti, Ogun, and Oyo from the states that comprised the southwest geopolitical zone of Nigeria. The three states were selected due to their prominence in small-scale agricultural cultivation and their status as the food hub of the geopolitical zone. The second stage entails the selection of three zones from each state, resulting in a total of nine zones. In the third stage, a total of 2 blocks were randomly selected from nine zones in the area (18 blocks). In the fourth stage, four cells from each of the 18 blocks (a total of 72 cells) were randomly selected. The final stage entails the random selection of 10 rural farming households from each of the cells. Consequently, a sample size of 720 rural farming households was employed in the study. Data about socio-economic characteristics, usage of health services, labour utilization patterns, and output value were gathered from the sampled households. The data were analyzed using descriptive statistics such as means, and standard deviation, two-sample t-test, and IV regression model.

Results

Description of variable used in the analysis: The findings from Table 1 underscore the significance of healthcare access in shaping the agricultural productivity and socioeconomic well-being of farming households. The treatment group—comprising households that accessed healthcare facilities—exhibited significantly higher agricultural productivity (₦141,775.90) compared to the control group (₦102,430.11), with a mean difference of ₦39,345.79 ($p < 0.001$). This suggests that improved health conditions, facilitated by healthcare access, enhance the efficiency and productivity of farm labour. Healthier farmers are more capable of performing labour-intensive activities, thereby improving yields and farm income (Combary, 2016; Daud et al., 2018). The observed difference aligns with prior studies (Allen & Ulimwengu, 2015; Combary & Traore, 2021), which emphasize the role of health in ensuring a stable and productive agricultural workforce.

Consistently, farm size also varied significantly between the two groups, with the treatment group cultivating an average of 7.16 hectares compared to 5.74 hectares in the control group. Admittedly, larger farm sizes often require greater physical labour, which may be more effectively managed by healthier households with fewer incapacitating illnesses. Additionally, the treatment group had longer farming experience (16.89 years) than the control group (9.02 years), implying that households that prioritize health may have better agricultural knowledge and resilience against productivity shocks. Access to healthcare services was also associated with a higher likelihood of engagement with agricultural extension health services, cooperative membership and access to potable water suggesting broader positive spillover effects (Balogun, 2021). Conversely, the control group reported a significantly greater average distance to healthcare facilities, reinforcing the role of physical accessibility in determining healthcare service accessibility. The control group also experienced higher days of incapacitation due to illness (50.74 days) compared to the treatment group which might indicate underreporting of illness or reliance on traditional healing methods rather than formal healthcare. These results emphasize the critical interplay between health and labour efficiency in agricultural systems. Investing in healthcare infrastructure in rural farming communities could thus serve as a viable strategy for improving agricultural productivity and sustainable rural development.

Table 1. Variable description and descriptive statistic of treatment and control group (n=720)

Variables	Description	Treatment group (n=292)		Control group (n=428)		Difference	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Test of diff.
Productivity	Value of sale of farm produce (₦)	141775.90	53092.11	102430.11	62003.72	39345.79	0.001***
Farm size	Area cultivated (hectares)	7.16	3.08	5.74	2.99	1.42	0.035**
Age	Age of the HH in years	48.17	23.84	51.62	31.07	-3.45	0.002***
Sex	Gender of HH (1=male, 0=otherwise)	0.682	0.241	0.661	0.302	0.021	0.103
Marital status	Marital status of HH (1=married, 0=otherwise)	0.705	0.511	0.600	0.337	0.105	0.216
Off income	Off-farm income (1=yes, 0=otherwise)	0.578	0.225	0.616	0.377	-0.038	0.021**
Experience	Farming experience (years)	16.89	8.44	9.02	3.85	7.87	0.012***
Cooperative	Membership of cooperative society (1=yes, 0=otherwise)	0.725	0.302	0.890	0.418	-0.165	0.000***
Hh size	Number of household members	8.61	3.17	10.01	4.96	-1.4	0.027**
Health	Contact with health extension works (1=yes, 0=otherwise)	0.821	0.461	0.402	0.228	0.419	0.003***
Water	Access to potable water (1=yes, 0=otherwise)	0.501	0.272	0.337	0.186	0.164	0.061*
Incapacitation	Incapacitation due to illness, injury (days)	50.74	37.01	72.15	24.22	-21.41	0.000***
Distance	Distance to healthcare facilities (Km)	6.11	2.95	14.47	6.92	-8.36	0.000***

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.1$

3.2. Healthcare access and Agricultural productivity – Two stage least squares estimation: The results presented in Table 2 from Two-Stage Least Squares (2SLS) regression estimate highlight the determinants of healthcare access among farming households and the impact of healthcare access on agricultural productivity. The first stage of the regression estimates the likelihood of accessing healthcare services, while the second stage examines how healthcare access influences productivity. The findings from 2SLS regression provide compelling evidence on the link between healthcare access and agricultural productivity.

Stage 1 – Determinants of access to healthcare services: The first-stage 2SLS regression identifies key factors influencing access to healthcare services among farming households. The significant and negative effect of distance to healthcare facilities ($\beta = -0.3391$, $p < 0.01$) corroborates previous studies (Allen & Ulimwengu, 2015; Combarry, 2016) that have highlighted distance as a major barrier to healthcare utilization in rural settings. Long distances increase travel costs and reduce the likelihood of timely medical attention, leading to worsening health conditions (Combarry & Traore, 2021). Furthermore, the positive effect of access to health extension workers ($\beta = 0.0261$, $p < 0.01$) on healthcare access is consistent with (Oyekale, 2017; Rufai et al., 2021), who emphasized the role of community-based health interventions in improving healthcare utilization. The role of incapacitation due to illness ($\beta = 0.1741$, $p < 0.01$) is also notable, suggesting that severe health challenges push households to seek medical attention. Interestingly, age ($\beta = -0.0223$, $p < 0.01$) negatively affects healthcare access, a result that supports previous studies (Otekunrin, 2022; Rutledge et al., 2023) indicating that older individuals, particularly in rural areas, may face mobility and financial constraints when seeking medical care.

Stage 2 – Effect of healthcare service access on agricultural productivity: The second-stage regression establishes a significant positive relationship between healthcare access ($\beta = 0.1554$, $p < 0.01$) and agricultural productivity, reinforcing the argument that health is a critical determinant of labour efficiency and farm productivity. Farmers who utilize healthcare services are more productive, as they experience fewer workdays lost to illness and maintain higher energy levels to perform physically demanding agricultural activities (Rutledge et al., 2023; WHO, 2021). This finding aligns with studies by (Liu et al., 2024; Oloruntoba et al., 2021), who reported that health investments significantly enhance labor productivity and agricultural output. Moreover, incapacitation due to illness ($\beta = -0.3015$, $p < 0.01$) significantly reduces productivity, highlighting the negative economic consequences of poor health in rural areas. This finding resonates with (Otekunrin, 2022; WHO, 2021), who demonstrated that malaria prevalence among farmers in Northern Nigeria led to reduced farm output and technical efficiency. The impact of health-related labor losses was also documented by (Omotoso & Omotayo, 2024b; Otekunrin, 2022), who found that each day of illness among agricultural workers resulted in more than a day of lost labour. Other productivity-enhancing factors identified include farm size ($\beta = 0.1074$, $p < 0.01$) and farming experience ($\beta = 0.2302$, $p < 0.01$), both of which have been widely acknowledged in agricultural economic literature as critical determinants of farm efficiency (Kehinde et al., 2021; Liu et al., 2024).

The positive role of cooperative membership ($\beta = 0.1045$, $p < 0.1$) and household size ($\beta = 0.1099$, $p < 0.1$) suggests that access to social capital and a larger labour pool improve farm productivity. Noteworthy, significant evidence supporting the positive impact of healthcare access on agricultural productivity suggests the need for rural health policy interventions that reduce barriers to healthcare utilization. The findings reinforce the bidirectional relationship between health and agriculture. Strengthening healthcare access not only enhances individual well-being but also serves as a key driver of rural economic development, supporting Nigeria's broader goals of food security and poverty reduction.

Table 2. Instrumental variable – Two stage least square regression estimate (n=720)

Variable	Stage 1 (access to healthcare services)		Stage 1 (Productivity)	
	Coefficient	Robust SE	Coefficient	Robust SE
Farm size	0.0031**	0.0015	0.1074***	0.0043
Age	-0.0223***	0.0011	0.1244**	0.0622
Sex	0.0512	0.1062	-0.1893	0.7819
Marital status	0.1142	0.0997	0.4526	0.6210
Off income	0.2041	0.2133	0.0156***	0.0027
Experience	0.0041	0.0511	0.2302***	0.0931
Cooperative	0.2915	0.4114	0.1045*	0.0510
Hh size	0.1127	0.2041	0.1099*	0.0600

Health extension	0.0261***	0.0017	0.0024**	0.0010
Water	0.2291	0.7410	0.1185	0.1399
Incapacitation	0.1741***	0.0053	0.3015***	0.0061
Distance	-0.3391***	0.0110	-	-
Healthcare	-	-	0.1554***	0.0094
Constant	0.0013***	0.0001	0.2890	0.0442
Diagnostic statistics				
Wald chi ²	48.15***		-	
Prob> chi ²	0.0001***		-	
R-square	0.6512		0.7114	
Adj R-square			0.6809	

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.1$

4. Conclusion and recommendation: Access to healthcare services is essential for maintaining a healthy workforce, yet many rural farmers face challenges such as long distances to healthcare facilities, high costs, and inadequate medical infrastructure. This study examines the impact of access to healthcare services on agricultural productivity among farming households in Nigeria. Using the Instrumental Variable Two-Stage Least Squares (2SLS) regression approach, the findings reveal that households with better healthcare access exhibit higher agricultural productivity compared to those that do not seek medical care. Distance to healthcare facilities is a major determinant of healthcare utilization, negatively impacting farm productivity due to increased health-related incapacitation. The results underscore the critical role of healthcare in enhancing agricultural labor efficiency, reinforcing the argument that poor health is a major constraint to rural development and food security. Key factors influencing healthcare access include proximity to health facilities, health extension services, farm size, and off-farm income. Productivity is significantly driven by farm size, farming experience, cooperative membership, and household size, emphasizing the need for economic and social resources to enhance agricultural outcomes. Health-related incapacitation negatively affects productivity, highlighting the economic burden of untreated illnesses on farming households. The study recommends expanding rural healthcare infrastructure, strengthening health extension services, and implementing affordable health insurance schemes for farmers. Integrating health interventions into agricultural policies is essential for achieving sustainable food security and rural development.

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Assessment of the Level of Awareness on Improved Postharvest Practices among Smallholder Rice Farmers in Kano State, Nigeria

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ABSTRACT

The study examined the level of awareness on improved postharvest practices among smallholder rice farmers in Kano state, Nigeria. A multistage sampling procedure was used in selecting 400 respondents for the study and data were collected using questionnaire and analysed using both descriptive and inferential statistical tools. The mean age of the respondents is 48 years, farm-size of 1.3 ha, household-size of 10 persons and farming-experience of 14 years. Majority (80.0%) are males, married (72.5%), with either primary, secondary or tertiary education (72.5%) status respectively. Available postharvest rice practices are drying (35.0%), threshing (27.3%) and storage (14.0%) among others. Majority (84.5%) were having high awareness level of improved rice postharvest practices. The ridge-regression analysis shows significant determinant socioeconomic factors with respect to age, sex, educational-level, household-size, farming-experience among others at 5% level of probability. Main constraints to awareness of improved postharvest rice practices are lack of capital (95.8%), poor access to credits (91.5%) and high cost of equipment (78.8%) among other. It was concluded that the respondents have high awareness and perception of improved rice postharvest practices. It was recommended that with the high awareness level other sources of awareness of IPRPs should be incorporated to sustain awareness and improve food security as well as strengthening those positive determinants of awareness.

Keywords: Awareness, Postharvest, Smallholder, Rice, Level, Improved

INTRODUCTION: Rice is one of the world's most cultivated crops (Minh et al., 2019). It is an important component of diets consumed in many developing countries, and also a staple food in many African countries. Much emphasis has been placed on promoting rice production in Nigeria through improved technology which has not resulted in increased production (Abubakar et al., 2023). Proper postharvest practices are important in maintaining grain quality and safety while being brought to consumers for storage, sales and consumption respectively. However, lack of awareness and knowledge among the smallholder farmers as well as other key factors along the value chains remains a major challenge to reducing postharvest loss in Sub-Saharan African (SSA). Through awareness of best postharvest rice practices needed among key players in rice production due to continuous improvement in technologies and climate change events (Kachapulula et al., 2017). Weather conditions and poor postharvest management practices have been reported as the major factors influencing more harvest in rice as well as other crops (Suleiman et al., 2017). However, as the consumption level of rice increases, the level of production of rice in Nigeria has not met up with consumption, due to myriad of factors among which are postharvest losses, low utilization and adoption of improved production practices as well as lack of awareness of the best practices among rice production players (Massomo, 2020). Postharvest management practices can be seen as the phase of rice production immediately following harvesting hence its awareness among farmers is pivotal. Postharvest management practices in rice are the various handling, packaging, threshing, bagging, parboiling and treatment that the rice grain undergoes before consumption. However, each stage is equipped with innovation or combination of same to improve productivity and income of farmers. Postharvest operations in rice begin when the separation of panicle from the rice plant at harvest, harvesting is often considered the starting point of the postharvest management process including; harvesting, storage, by-products generation, drying and milling as an inclusion to the aforementioned (Egwuonwu, 2020). Postharvest management in rice is of necessity because it will affect the total production of rice in a country and this will reduce the losses in both quality and quantity thus farmers' awareness is key. Rice postharvest losses are largely caused by factors such as insect pests, poor logistics, fungal and bacterial diseases, poor management practices and inadequate storage facilities as well as mechanical damage. Proper postharvest management system awareness will reduce losses in both rice quantity and quality leading to increase in income of the smallholder farmer and food security. It is at this premise that the study was conceived to assess the level of awareness on improved postharvest practices among smallholder rice farmers in Kano State, Nigeria. The specific objectives are to;

1. identify the available improved postharvest rice practices among respondents;
2. determine the level of awareness of the respondents on improved rice postharvest practices;
3. identify the respondents' constraints to utilization of improved postharvest rice practices.

Hypothesis:

H₀₁: What are the socioeconomic factors prompting farmers' utilization of improved postharvest rice practices in the study area

METHODOLOGY

Study Area: Kano state is located in the North-west geopolitical zone of Nigeria between latitudes 13°N and 11°S and longitudes 8°N and 10°E, with a land mass of 20,760 km². The state has a projected population of 16 million as of 2023. The average annual rainfall is 700 mm, with 35 °C and 19 °C as the mean daily maximum and minimum temperature, respectively. Major crops

cultivated by farmers in the State include rice, maize, millet, cowpea, groundnut and vegetables. The Kano State Agricultural and Rural Development Authority (KNARDA) is the government agency with the primary mandate to provide agricultural extension services in the State. Kano state is also one of the Nigeria's most important rice-producing areas, with more than 200,000 rice farmers involved in rice production. This is largely due to more than 22,000 ha of irrigated schemes of the Hadejia Jama'are River Basin Development Authority (HJRBD), the vast Fadama areas that were further developed under the erstwhile National Fadama Development Project and the upland production area of Tudun Wada and Rogo towns. The Kura-Kano Rice Corridor is an important rice production and processing cluster in the State, and the corridor processes more rice than is being produced in the immediate surroundings. Therefore, the State has a significant number of producers, processors and quality-oriented retail markets for paddy and milled local rice located along the Kura – Kano Rice Corridor (Inuwa et al., 2011).

Sampling Procedure and Sample Size: A 4-stage sampling procedure was used in selecting 400 respondents within the sample frame (2147) of rice farmers in Kano state. The first stage was a purposive selection of kano state out of the seven states in the Northwest zone of Nigeria due to high concentration of rice farming households. The second stage involved the purposive selection of four (4) out of the 44 Local Government Areas (LGAs) in Kano state. The choice of the selected Local Government Areas was based on the high concentration rice farmers in those local government areas. The four selected LGAs are Garun Malam, Bunkure, Kura and Tudunwada based on their significant involvement in rice production as being important in the State's rice production and processing areas. In the third stage, purposive sampling procedure was used in selecting four (4) communities from each of the four LGAs based on their high rice farming activity, making sixteen (16) communities. The fourth stage was a proportionate selection of 20 percent (20%) of the respondents from each of the communities in the selected local government via the list of registered rice farmers obtained from Kano Agricultural Development Programme Office and the rice farmers' association in the state to give a sample size of 400 respondents for the study. Questionnaire was validated by experts in the field of Agricultural Extension and Rural Development and administered to 20 respondents entirely different from the sample size. This was repeated two weeks after and the coefficient of 0.89 was obtained which ascertained the questionnaire as reliable for data collection. Data were analysed using descriptive and inferential statistical tools.

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Rice Farmers: The socioeconomic variables considered in this study are presented in Table 2 in the following order: age, sex, marital status, rice farm size, level of education, household size, membership of association, year of rice farming experience, primary occupation and sources of labour. The mean age of the respondents is 48 years which implies that the respondents are in their active and productive age range. This is in line with the work of Oyewole et al., (2023). Mean rice farm size of 1.3ha, household size of 11 persons and farming experience of 14 years. This is a mirror of Yusuf *et al.*, (2023) Majority are males (80.5%), married (71.5%) with significant proportion (71.2%) having either primary, secondary or tertiary education respectively. These findings corroborated that of Bose, Danwanka and Asani (2020).

Table 2: Distribution of respondents based on socioeconomic characteristics (n=400)

Variables	Frequency		Percentage		Mean±SD
Age (years)					
≤ 25		20		5.0	48.0±4.1
26-35		79		19.8	
36-45		121		30.3	
46-55		113		29.3	
56-65	49	12.3			
≥ 66	18	4.5			
Sex					
Male		320		80.0	
Female		80		20.0	
Marital Status					
Single		80		20.0	
Married		290	72.5		
Divorced		20	5.0		
Widowed	10	2.5			
Rice Farm Size					
≤ 2.0		120		30.0	1.3±1.1
2.1-5.0	254	63.5			
5.1-10.0	22	5.5			
≥ 11	4	1.0			
Level of Education					
No Formal Education		110		27.5	
Primary education	80	20.0			
Secondary Education		120		30.0	
Tertiary Education		90		22.5	
Household Size (No)					
≥ 5		77		19.3	10.1±2.3
6-10		225		56.3	
≥ 11	98	24.5			
Years of Rice Farming					
≤ 5		23		5.8	14.0±3.2
5-10		105		26.3	
11-15		91		22.8	
16-20		47	11.8		

≥ 21

134

33.5

Source: Field Survey, 2024

The Available Improved Postharvest Rice Practices among Respondents: The available postharvest rice practices among the respondents in the study area is depicted in Table 1. This was measured on a binomial scale of Yes or No. The result shows that the types of postharvest practices seen among the respondents are Drying (35.0%). This was serially followed by threshing (27.3%) as well as Storage (14.0%), Packaging (7.8%), Grading (5.5%), and weighing (3.8%), Cleaning practices (3.5%), milling (2.8%) and lastly others (1.0%). The findings indicate that majority (76.3%) engaged in drying, threshing, storage respectively as the postharvest practice mostly prevalent or available among smallholder rice farmers in the study area. These activities play a crucial role in ensuring the quality and preservation of rice after harvesting. This finding agreed with the position of Aremu, *et al.*, (2022).

Table 1: Distribution of the respondents based on available postharvest rice practices (n=400)

Variables (Practice)	Frequency	Percentage	Rank
Drying	140	35.0	1
Threshing	109	27.3	2
Storage	56	14.0	3
Packaging	31	7.8	4
Grading	22	5.5	5
Weighing	15	3.8	6
Cleaning	14	3.5	7
Milling	9	2.3	8
Others (polishing)	4	1.0	9

Source: Field Survey (2024)

Level of Awareness of the Respondents on Improved Rice Postharvest Practices: Table 2 shows the distribution of the respondents based on awareness of IRPP. This was measured on a scale of Aware and Not Aware. The result shows that majority of farmers have high awareness of the various IPRPs (with awareness percentages practices range of 52.3% to 99.8%). Among the IPRPs, the practices with the highest awareness among respondents include threshing on a mat or tarpaulin over a clean concrete floor and the removal of floating immature grains, dirt, and stones (99.8%). Harvesting mature grains at the right moment (99.5%), keeping paddy from hitting the ground during heaping, threshing, winnowing, drying, and packing (98.5%). There are also storage practices (98.0%) as well as Soaking rice overnight in boiled water and drying it to a safe moisture content of 13-14°C (96.8%). There is also improved milling of rice and polishing (95.8%), cleaning paddy with clean water when wet (94.5%), destoning practices (85.3%), use of a mechanical thresher/winnowing (81.5%) while use of a mechanical drier has the lowest awareness level (52.3%) probably because most rice farmers in the study area use sun drying methods since it is almost at no cost. These agreed with position of Aremu, *et al.*, (2022) and Orifah *et al.*, (2020). These findings highlight the need for increased efforts to raise awareness and enhance knowledge about certain practices among rice farmers in the study area.

Table 2: Distribution of the respondents' based on awareness of IPRPs (n=400)

Variables	Awareness	
	%	Rank
Threshing on a mat or tarpaulin over a clean concrete floor rather than on the ground or along roadsides	99.8	1
Removal of floating immature grains, dirt, and stones	99.8	1
Harvesting of mature grains at the right moment	99.5	3
Keep a paddy from hitting the ground during heaping, threshing, winnowing, drying, and packing	98.5	4
Storage	98.0	5
Soaking rice overnight in boiled water and then drying to a safe moisture content of 13-14 °C	96.8	6
Improved milling of rice	95.8	7
Polishing	95.8	7
Cleaning paddy with clean water when wet	94.5	9

Destoning	85.3	10
Use of mechanical thresher/winnower	81.5	11
Use of mechanical drier	52.3	12

Source: Field Survey (2024)

Categorization of the Awareness of the Respondents on IPRPs: The result of the categorization of the respondents' awareness of the improved postharvest rice practices (IPRPs) is shown in Table 3. The categorization was classified into high awareness and low awareness respectively. As shown in the table 3, majority (84.5%) of the respondents have high awareness of the improved postharvest rice practices while only small proportion (15.5%) of the respondents have low awareness of the improved postharvest practices. This finding agreed with the study done by Adisa, Micheal and Kolawole (2020); Bose, Danwanka and Asani (2020); Aremu et al., (2022); Orifah *et al.*, (2020).

Table 3: Categorization of Awareness of the Respondents on Improved Postharvest Rice Practices (IPRPs) (n=400)

Level of Awareness	Frequency	Percentage
Low	62	15.5
High	338	84.5

Source: Field Survey, 2024

The Result of Regression Analysis between the Socioeconomic Characteristics of the Respondents and their Awareness of Improved Postharvest Rice Practices-IPRPs

The result in Table 4 shows the ridge regression analysis between the socioeconomic characteristics of the rice farmers and their awareness of improved postharvest rice practices. The result from the ridge regression analysis showed that age, sex, educational level, membership of association, household size, farming experience, farm-size, marital status, sources of farm land, main occupation, sources of labor and availability of information were found to have significant influences (both positive and negative) on the awareness of improved rice postharvest practiced by farmers. The coefficient of ridge determination (R^2) was found to be 91.70% and was statistically significant at 5% level of probability. Among the socioeconomic indicators examined under the ridge age had a slightly negative influence on awareness of improved rice postharvest practices ($\beta = -0.0022$, $p < 0.05$). This implies that younger farmers may be more inclined to rice postharvest awareness of IPRPs because they are very much in their active stage. Farming experience positively influenced awareness of IPRPs ($\beta = 0.0020$, $p < 0.05$) also signifying that experienced farmers were more likely to aware of the rice improved practices because of their familiarity with postharvest challenges and losses incurred all year round. Educational level had a minimal positive effect ($\beta = 0.0007$, $p < 0.05$), implying that higher education may marginally enhance the likelihood of awareness because higher educational attainment would pave way for proper confirmation of the postharvest rice practices before it will be used. Sex and marital status had negligible effects, with coefficients of $\beta = -0.0215$ and $\beta = -0.0157$ respectively. Suggesting that these factors did not significantly influence awareness of improved postharvest rice practices. The size and source of farmland had weak negative effects ($\beta = -0.0036$ and $\beta = -0.0059$), indicating that larger farm sizes or specific land sources may not necessarily drive awareness of improved postharvest rice practices. So also considering marital status ($\beta = 0.0157$) with a positive coefficient implies that married individuals have more awareness of IPRPs that single individuals because of the family responsibility tied to marital life since they need to be food secured as well as income. Main occupation ($\beta = 0.0079$) has positive and direct relationship with awareness. It implies that with high income from primary occupation respondents would be more inclined on awareness of best improved rice postharvest practices. Similar to membership of association ($\beta = 0.0108$). The above findings are in congruent with the position of Egwuonwu (2020).

Table 4: Ridge Regression Coefficients of Socioeconomic Factors Influencing the awareness of improved postharvest rice practices-IPRPs

Independent Variable	Regression Coefficient	Standard Error	Standardized Regression Coefficient	VIF
Intercept	0.03905981			
Socio-economic factors				
Age	-0.002153192	0.001043077	-0.051	2.7851
Gender	-0.02153434	0.02375713	-0.017	1.6386
Size of Household	-0.0003682672	0.00186681	0.004	1.5645
Rice farming experience 0.002046668	0.001089973	0.041	2.2250	
Level of education	0.0007460905	0.001785815	0.006	1.0930
Farm-Size	-0.0035596	0.00305208	-0.018	1.1258
Marital-Status	0.0157183	0.01601278	0.019	1.6493
Source-Farmland	-0.005854075	0.00581082	-0.016	1.1339
Main Occupation	0.007979072	0.006103987	0.020	1.0878
Labor source	-0.01071782	0.01186728	-0.015	1.2437
Availability of Infor	-0.006285923	0.01761713	-0.005	1.0763
Membership-Group	0.01081661	0.01587934	0.010	1.0574
R ²	91.70			
Sigma	14.70			

Source: Field Survey, 2024. k = 0.005000, Probability level=5%

Constraints to Utilization of Improved Postharvest Rice Practices among Farmers

Table 5 provides an overview of the constraints of farmers on awareness of rice postharvest practices. The most severe constraint is lack of capital to purchase necessary inputs and machines (95.8%). The was followed by poor access to institutional credits (91.5%). High cost of equipment and machinery is another one (78.8%) as well as complexity of some components of the technology (77.8%). Late delivery of improved technologies was next (75.3%) and labour intensiveness (66.5%) The unfavourable market situation affecting respondents is another (57.8%) There is communication gap between farmers and extension personnel (52.8%). Inadequate skills and knowledge (50.0%) were not an exception Finally, poor extension services (30.5%) was not really identified as constraint by the respondents. The is in support of Elum and Enemali (2023); Abubakar et al. (2016).

Table 7: Distribution of the respondents according to constraints to utilization of improved postharvest rice practices-IPRPs (n=400)

Variables (Constraints)	Severity score		
	Freq	Percent (%)	Ranking (n th)
Lack of capital to purchase the necessary inputs and machines	383	95.8	1
Poor access to institutional credits	366	91.5	2
High cost of equipment/machinery	315	78.8	3
Complexity of some components of the technology	311	77.8	4
Late delivery of improved technologies	301	75.3	5
Labour intensiveness	266	66.5	6
Unfavourable market situation	231	57.8	7
Communication gap between farmers and extension personnel	211	52.8	8
Inadequate skills and knowledge	200	50.0	9
Poor extension services	122	30.5	10

Source: Field Survey (2024)

CONCLUSIONS AND RECOMMENDATION: The study concluded that majority of the respondents shows the respondents have very high awareness of the improved rice postharvest practices with quiet a number of constraints to awareness of the improved rice postharvest practices. Also, there are numerous determinant factors of awareness of the improved practices such as age, marital status, educational level, household size amongst others. It was recommended that with the high awareness level other sources of awareness of rice postharvest practices should be incorporated to sustain awareness and improve food security as well as those positive determinants of awareness.

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Value Chain Analysis of Cassava in Iseyin Local Government Area, Oyo State

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Abstract

This study investigated the value chain of cassava in Iseyin Local government, Oyo State. Data were collected using a structured questionnaire. Purposive, random and snow balling sampling techniques were used to select 215 respondents for this study. The data were analyzed using frequencies, percentages, and gross margin analysis. The study focused on cost and return of each stakeholders in cassava value chain in the study area. The study revealed that the mean age of producers 44, 48, 42 and 41 years respectively years, The mean of household size is 5.8 for producers, 5.7 processors, 5 marketers and 5.2 for consumers, the study also revealed that majority 84.35 percent of the processors and 100 percent of the marketers were female, while majority 70 percent of the producers were male. Cassava value chain was profitable with a gross margin of ₦680949.1, ₦130,788.902, ₦34,655 for the producers, processors, marketers respectfully. Herdsmen/cattle, lack of capital, scarcity of labour, increase in farm input, high cost of processing, identified high cost of produce, lack of access to market, irregular supply of raw materials, irregular products, inadequate management, inadequate equipment, lack of access to loan, high interest on loan, and inadequate supply of firewood were the major constraints faced by stakeholders in cassava value chain. Government should provide credit facilities to the farmers to help overcome financial constraints facing cassava value chain and subsidize farm input to help reduce problems of high cost of input facing the cassava stakeholders.

Keywords: Cassava, value chain, producer, processor, marketer, gross margin

Introduction: Cassava (*Manihot esculentus*) is an important staple, basic food for millions of people in the world. Cassava is occupying number 4th among the major important food crops across the whole world. Cassava comes after maize (grain), wheat (grain), and rice (grain). It is grown majorly in sub-Saharan Africa. Nigeria is observed to be the largest producer of cassava in the world. The quantity of cassava produced in Nigeria in 2018 was about 53.0 million metric tonnes (CBN, 2019). The area used for harvesting of cassava in 2017 was 6.79 million hectares in Nigeria. It was estimated that the average yield of cassava in Nigeria was 87.5 metric tonnes per hectare (FAO, 2019). The major secondary products from cassava processing which has high market and industrial values were chips, garri, flour or lafun, starch, pellets, adhesives, alcohol. The industries that utilize cassava products include amongst others: livestock, alcohol and or ethanol, textile, food, wood, soft drink, confectionary, pharmaceuticals industries. The cassava products can be of high value tradable both in local and international markets (Knipscheer et al, 2007). Most farmers preferred cassava firstly, it requires low input, secondly, it is tolerance to small amount of rainfall, thirdly, it can survive in poor soils, and fourthly, it can be propagated with ease using the stem called vegetative cuttings. Cassava is observed to be grown in about 105 countries across the whole world, and it is grown in about 24 million hectares of land (CBN, 2019). Cassava tubers consist of 60–70% water and have a shelf life of 2–3 days. Once harvested, the tubers have to be processed or consumed immediately otherwise the tubers begin to deteriorate. In addition, it is very necessary that the processing commence as early as possible because it influences the market value. Processing of cassava roots before consumption is also essential because it helps to eliminate its cyanide content. Cassava can be processed into Garri, high quality cassava flour, odorless fufu, fermented cassava flour, tapioca, and cassava chips. Despite this role of cassava in the Nigerian economy, there is need to increase the value addition mechanism by improving the quality of cassava products in Nigeria. Processing predominantly at small scale, employing little or no mechanization, resulting in an inability to meet the quality and quantity demand of the industry and other users of the product. Prominent among other factors are high postharvest losses and low export of cassava products, (Onwulalu, 2007).

Value chain activities of cassava products begins with the processing activities which includes Gari; harvesting, transportation, peeling, washing, fetching, grating mill, sieving, toasting, and packaging. Fufu; harvesting, transportation, peeling, washing, fetching, soaking, sieving and packaging. Lafun; harvesting, transportation, peeling, washing, fetching, soaking, slicing, grating mill, sieving, drying and packaging. The marketing activities includes transportation, bagging, storage for future sales (Elegbede, et al., 2018). All various forms of activities that are involved from the start which is called conception through different stages or phases in bringing a product, services to final consumers are called value chain. Value chain involves various activities, producers, transformations of physical products, actors, processors, marketers, transporters, consumers. Utilities were created in different forms, different times, and different places. Processing of cassava is labour intensive, and the fresh tubers are highly perishable in nature. The actors or processors are further faced with challenges of using technology that are poor, they could not access the markets easily, the actors had low productivity, the transport cost is very high, they had poor infrastructures, they utilized traditional methods of processing. Actors do not have efficient machine called dryers. In sub-Saharan Africa, all efforts made to get maximum potentials coming from agriculture including cassava processing would leads to reduction in poverty in the region., It can be used in industries (CBN, 2019). Bakery and pasta products can use cassava flour as partial replacement. Cassava can be used to feed poultry, pigs and ruminants. Non-food industries which include corrugated cardboard, furniture, paper and or plywood use dextrin as high-quality adhesives. Fruit canning and jam industry can also be added to use dextrose. Most sweetening agents involve glucose and dextrose. The cyanogens which are contained in cassava are removed through processing. Processing of cassava in Nigeria are small-scale in nature, the products may not be for commercial purpose and may also not be of high standard for international markets yet, processing methods are inefficient, therefore, to address these challenges and improve the standard of

cassava processing, a lot of problems or challenges needs to be addressed. Through processing, values are added to cassava, market values are increased through processing, and employment opportunities were created. In sub-Saharan Africa, cassava products were perceived to be both food security crop, and also for raw materials for our industries (Nang'ayo et al, 2005).

The economic inefficiency in the cassava value chain, characterized by low productivity, significant post-harvest lost, limited processing capability, and inadequate market access, hinder the crop's potential to significantly contribute to economic development and poverty alleviation in many developing countries (Ezedinma et al., 2007). The cassava value chain encompasses various stages, from production, processing, distribution, marketing, and consumption. Each stage presents distinct economy challenges that impact the overall efficiency and profitability of the chain. The cassava value chain is hindered by high production costs, which significantly reduced the profitability for farmers and other stakeholders. The broad objective is to examine the cassava value chain in Iseyin local government area, Oyo state with the following specific objectives, examine the socio-economic characteristics of each stakeholder in cassava value chain, analyze the cost and return of each stakeholder in cassava value chain, identify the constraints facing each stakeholder in cassava value chain and to identify the factors influencing each stakeholder scale of production in cassava value chain.

Methodology: This study was conducted in Iseyin Local government of Oyo state. The Local Government Area is characterized by two main seasons (wet and dry seasons). The rainy season is established around late march to early April and get to the peak in August and September while dry season begin in November up to late February. The crop grown included both annual and perennial crop such as yam, cassava, oranges, cocoa, cashew etc. The vegetation consists of the savannah wood land and the forest land savannah woodland cover over half of the land area of Iseyin local government According to (Opeyemi 2015). The population of the study comprises of all the stake holders in cassava value chain in Iseyin Local Government Area of Oyo State. Purposive, random and snow balling sampling techniques was used to select the respondents for this study.

A multistage sampling technique was used to select the respondent for this study. Agricultural Development Programme (ADP) structure was used. Iseyin Local Government Area of Oyo State falls under a block in ADP structure. There are five active cells among the eight-existing cell in the study area. 50% of the active cells were randomly selected to have 3 cells namely Iseyin, Ado-awaye and Akinwunmi/Osoogun. Purposive selection of 25 cassava farmers from Ado-awaye and Akinwunmi/Osoogun making 50, Also 115 processors was purposefully selected from Iseyin, Ado-awaye and Akinwunmi/Osoogun and 40 consumers from Iseyin. respectively. Snow balling was used to select 10 marketers from the selected villages. Descriptive statistics were used which include measures of central tendencies such as mean, frequency distribution. Gross Margin (GM) analysis was used

$$\text{Gross Margin} = TR - TVC$$

Where GM = Gross Margin (₦)

TR = Total Revenue (₦)

TVC = Total Variable Cost (₦)

Results and Discussion: The study revealed that the mean age of producers 44, 48, 42 and 41 years respectively years, The mean of household size is 5.8 for producers, 5.7 processors, 5 marketers and 5.2 for consumers, the study also revealed that majority 84.35 percent of the processors and 100 percent of the marketers were female, while majority 70 percent of the producers were male. The education level of respondents indicated that 10 percent of the producers, 6.09 processors, and 2.50 percent of the consumers had primary school education, while 60 percent of the producers, 84.35 percent of the processors, 100 percent of the marketers and 87.50 percent of the consumers had secondary education while few of them had tertiary education. Accessibility to source of finance differed from one actor to others, few of the actors got their finance from commercial bank while majority was from personal saving and cooperative The cost and return in table below show that cassava a value chain is profitable among actors

Cassava value chain was profitable with a gross margin of ₦680949.1, ₦130,788.902, ₦34,655 for the producers, processors, marketers respectfully. The result shows that Total Variable Cost of producers was estimated at ₦326,580.9, total variable cost of processors was estimated at ₦420,155.472 and total variable cost of marketers was estimated at ₦75,905, total fixed cost of processors was estimated at ₦3648.438. The total revenue generated by the producers was ₦1007530, total revenue generated by the processors was ₦550,944.374 and total revenue generated by the marketer was ₦110560, the gross margin for the producer was ₦ 680949.1, gross margin for the processor was ₦130,788.902 while the gross margin for the marketer was ₦34,655. This implies that value chain of cassava is profitable with cassava production with the highest rate of return on investment

TABLE 1. SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENTS IN THE STUDY AREA.

Variable	Producer F (%)	Mean	S/D	Processor F (%)	mean	S/D	Marketer F (%)	Mean	S/D	Consumer F (%)

Age (years)								
<30				1 (0.87)				
30 – 40	6 (12)			26 (22.61)	47.608	8.233112	3(30)	42.6
41 – 50	16 (32)	44.3	12.69782	49(42.61)			7(70)	
51 – 60	13(26)			33 (28.70)				
Above 60	8(16)			6 (5.22)				
Total	7(14)			115			10	
Sex								
Female	50							
Male	15(30)			18			10(100)	
Total	35(70)			97			10	
Religion								
Christian	50			115				
Islamic	28 (56)			63(54.78)			5(50)	
Traditional	21(42)			52(45.22)			5(50)	
Marital status								
Divorced	1 (2)							
Married				106(92.98)				
Single	1(2)			1(0.88)			10(100)	
Widow	43(86)			7(6.14)				
Household size								
1-4	2(4)	5.82	1.304466					
5-7	4(8)							
Above 7		7.18	5.385885	18(15.65)	5.7	8.23	3(30)	5
Farm size	9(18)			88(76.52)			7(70)	
1-5	36(72)			9(7.83)			0	
6-10	5(10)							
11-15								
16-20	25(50)							
Above 20	16(32)							
Monthly income								
<50,000	5(10)							
50,000-100,000	3(6)							
100,001-150,000	1(2)							
150,001-200,000								
Above 200,000	33(66)	110300						
Edu/level								
Primary	17(34)		57555.74					
Secondary				109(95.65)			9(90)	
Tertiary	1(2)			5(4.35)			1(10)	
Source/finance								
C/bank	32(64)				79600	17486.24		96,000
Coop	8(16)							
Personal								
	5(10)			7(6.09)				
				97(84.35)			10(100)	
	4(8)			11(9.57)				

COST AND RETURN OF STAKEHOLDERS IN CASSAVA VALUE CHAIN: The result of cost and return of stake holder in cassava value chain in the study area was presented in Table .2. The result shows that Total Variable Cost of producers was estimated at ₦326,580.9, total variable cost of processors was estimated at ₦420,155.472 and total variable cost of marketers was estimated at ₦75,905, total fixed cost of processors was estimated at ₦3648.438. The total revenue generated by the producers was ₦1007530, total revenue generated by the processors was ₦550,944.374 and total revenue generated by the marketer was ₦110560, the gross margin for the producer was ₦680949.1, gross margin for the processor was ₦130,788.902 while the gross margin for the marketer was ₦34,655. This implies that value chain of cassava is profitable with cassava production with the highest rate of return on investment

TABLE 2. COST AND RETURN OF CASSAVA PROCESSING

S/N	Producer Variables	Producer Amount (₦)	Processor variables	Processor Amount(₦)	Marketer Amount(₦)	Marketer Amount(₦)

1.	Cost of land preparation	29957.43	Cost of cassava tuber	322320	Cost of product	66250
2	Cost of rent on Land	11472.67	Cost of transportation	19690.29	Cost of packaging	770
3.	Cost of cassava stem	8735.286	Cost of offloading	1164.261	Cost of loading	195
4.	Cost of labour for planting	9527.738	Cost of peeling	7930	Cost of transportation	4305
5.	Cost of herbicides	18127.76	Cost of milling	6888.594	Cost of offloading	185
6	Cost of spraying	14180.75	Cost of dehydrating	3336.735	Miscellaneous cost	4200
7	Cost of weeding	31076.39	Cost of frying	17000		
8.	Cost of harvesting	48536.17	Cost of firewood	22306.12		
9.	Cost transportation	154966.7	Cost of equipment	3648.438		
10.			Cost of sun drying	5539.216		
11			Cost packaging	8016.372		
12			Cost of labour	3508.182		
13			Miscellaneous cost	2455.702		
	Total variable cost	326,580.9	Total variable cost	420,155.472	Total variable cost	75,905
			Total fixed cost	3648.438		
			Total cost	423,803.91		
	Revenue from sales	1007530	Revenue from sales	550,944.374	Revenue from sales	110560
	Gross margin	680949.1	Gross margin	130,788.902	Gross margin	34,655

Source: Field Survey, 2024

The distribution of respondents according to constraints in cassava value chain were presented in Table 3. The respondents faced various constraints in cassava value chain which where herdsmen/cattle, and were extreme, lack of capital was high while 80% of the marketers viewed it as extreme. Also identified high cost of processing as high constraints acknowledged Inadequate management, inadequate equipment, lack of access to loan, high interest on loan, and inadequate supply of firewood respectively were all regarded as extreme constraints. The producers identified high interest on loan, farm security respectively as high constraints.

TABLE 3 CONSAINTS FACED BY STAKEHOLDERS IN CASSAVA VALUE CHAIN

Variables	producer Extreme F(%)	Producer High F(%)	Producer Mild F(%)	Processor Extreme F(%)	Processor High F(%)	Processor Mild F(%)	Marketer Extreme F(%)	Marketer High F(%)	Marketer Mild F(%)
*Herdsmen/cattle	29(58)	19(38)	2(4)						
Scarcity of labour	19(38)	25(50)	6(12)	29 (25.2)	70(60.87)	16(13.91)			
*Access to land	22(44)	18(36)	10(20)						
*Lack of access to market	3(6)	10(20)	37(74)	6 (5.22)	32(27.83)	77(66.96)	4 (40)	6 (60)	
*Increase in farm input	24(48)	21(42)	5(10)						
*Absence of buyer from neighboring state		13(26)	37(74)						
*Low price of farm produce	4(8)	36(72)	10(20)						
*Pest and diseases	1(2)	23(46)	26(52)						
*Climate change	5(10)	26(52)	19(38)						
*Lack of access to loan	7(14)	36(72)	7(14)	21 (18.42)	88(77.19)	5 (4.39)	2 (20)	8 (80)	
*High interest on loan	4(8)	36(72)	10(20)	15 (13.04)	94(81.74)	6(5.22)		10 (100)	
*Farm security	10(20)	38(76)	2(4)						
*High cost of processing				12(10.53)	63(55.26)	39(34.21)			
*High cost of produce							4 (40)	6 (60)	
*Irregular supply of raw materials				53 (46.09)	61(53.04)	1(0.87)			
*Irregular supply of product/ produce							6 (60)	4 (40)	
*Inadequate management				5 (4.35)	77(66.96)	33 (28.70)			
*Inadequate equipment									
Seasonality				8 (6.96)	84(73.04)	23(20.00)			
*Inadequate supply of fire wood				36 (31.30)	77(66.96)	2 (1.74)			
*Scarcity of produce/product				21 (42.86)	28(57.14)		1 (10)	9 (90)	
*Poor transportation							1 (10)	9 (90)	
*Irregular supply of quality							3 (30)	6 (60)	1 (10)

*Lack of standard measurement	(20)	8 (80)
Source: Field Survey, 2024		

FACTORS INFLUENCING SCALE OF PRODUCTION STAKEHOLDERS IN CASSAVA VALUE CHAIN: The distribution of respondents based on the factor influencing scale of production of stakeholders in the study area were presented in table 4. The producers agreed that availability of land, availability of labour, access to finance, access to market, and technology respectively influenced the scale of production of producers in the study area, while 100% of the processors agreed that availability of raw materials, availability of labour, access to finance, access to market and technology influenced the scale of cassava processing, Marketer opined that access to finance, access to market, access to good vehicle for transportation, availability of labour and access to loan influence the scale of production of the marketers in the study area.

TABLE 4 FACTORS INFLUENCING SCALE OF PRODUCTION OF STAKEHOLDERS IN THE STUD AREA

S/N	Variables	Producer Yes F(%)	Producer No F(%)	Processor Yes F(%)	Processor No F(%)	Marketer Yes F(%)
1	Availability of land	50(100)	0			10 (100)
2	Availability of labour	49(98)	1(2)	115 (100)		
3	Access to finance	48(96)	2(4)	115 (100)	10 (100)	
4	Access to market	49(98)	1(2)	115 (100)	10 (100)	
5	Technology	50(100)	0	115 (100)		
6	Adequate farm security	48 (96)	2 (4)	115 (100)		
7	Access to loan	47 (94)	3 (6)	115 (100)	10 (100)	
8	High quality farm input	50 (100)	0			
9	Low cost of farm input	49 (98)	1 (2)			
10	Low interest rate	47 (94)	3 (6)	115 (100)	10 (100)	
11	Low cost of raw materials			115 (100)		
12	High quality raw materials			115 (100)		
13	Supply of durable firewood			48 (100)		
14	Farm security			114 (100)		
15	Access to high quality product/produce					10 (100)
16	Adequate supply of product/produce					9(90)
17	Access to good vehicle for transportation					10(100)
18	Low cost of product/produce					10 (10)
19	High quality raw materials					10 (100)
20	Adequate payment by buyer					10 (100)
21	Perfect market information					10 (100)

Source: Field Survey, 2024

Conclusion: It was therefore concluded that cassava value chain is profitable venture that farmers need to learn to utilize to increase their farm profit. Based on this study it is therefore recommended that government should provide credit facilities to the farmers to help farmers to overcome financial constraint facing them in cassava value chain, and government should subsidize farm input to help reduce problem of high cost of inputs facing the cassava stakeholders. Farmers should adopt technology that can boost in their operation efficiency so to increase their output and minimize their cost of production

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Comparative Analysis of Compost and Phosphorus Fertilizers in Enhancing Nutritional Content of Pigeon Pea

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Abstract

Pigeon pea (*Cajanus cajan*) is important leguminous crop, especially in tropical and subtropical regions, based on its high protein content and contribution to soil fertility. A field experiment was conducted at the Oyo State College of Agriculture and Technology, Igboora, to assess the comparative effects of compost and phosphorus (P) fertilizers on the nutritional composition of four pigeon pea varieties (NSWCC29A, NSWCC24, NSWCC34D and Otili). A Randomized Complete Block Design (RCBD) with treatments comprising compost, phosphorus fertilizer, and a control, each applied at varying rates was used. Harvested seeds were analysed for major nutritional parameters, including crude protein (CP), crude fat (CFAT), crude fiber (C.Fibre), Total ash (T.Ash), moisture content (MC), dry matter (DM), and nitrogen-free extract (NFE). All the data collected were subjected to analysis of variance (ANOVA) and means separated using Duncan Multiple Range Test at 5% level of probability. Results showed that compost application significantly enhanced seed quality, with increases in CP (24.39%), CFAT (2.62%), and NFE (51.49%) compared to phosphorus fertilizer (23.31% CP, 2.50% CFAT) and the control (21.17% CP, 2.21% CFAT). Compost also improved MC (8.09%) and T.Ash (5.36%), contributing to better overall crop quality. Statistical analysis revealed significant interactions among variety, fertilizer type, and application rate, indicating the importance of context-specific nutrient management. Application of 15 t/ha compost significantly improved the nutrition composition of NSWCC24. Integrating organic and inorganic fertilizers is recommended to optimize crop performance and support food security, particularly in regions where legumes are a dietary staple.

Key word: Compost, Nutritional composition, Pigeon pea (*Cajanus cajan*), Grain yield and Soil fertility

Introduction: Pigeon pea (*Cajanus cajan*) is an important leguminous crop cultivated extensively in tropical and subtropical regions, prized for its high protein content and ability to enhance soil fertility through nitrogen fixation. It serves as a staple food source for millions, providing essential nutrients and contributing to food security in many developing countries. The nutritional quality of pigeon pea is significantly influenced by soil fertility management practices, particularly the application of fertilizers. Effective nutrient management is vital for optimizing crop yields and improving the nutritional profile of legumes. Among the various fertilizers used, compost and phosphorus (P) fertilizers are widely recognized for their potential to enhance soil nutrient availability and improve crop performance. Compost, derived from organic waste materials, not only supplies essential nutrients but also improves soil structure, increases water retention, and promotes beneficial microbial activity. This organic amendment plays a significant role in sustainable agriculture by reducing dependency on chemical fertilizers and enhancing soil health. Phosphorus, on the other hand, is a critical macronutrient that influences various physiological processes in plants, including energy transfer, photosynthesis, and root development. Phosphorus deficiency is a common limitation in many soils, adversely affecting crop yield and nutritional quality. The application of phosphorus fertilizers can mitigate these deficiencies, leading to improved growth and higher nutritional content in crops, particularly in phosphorus-deficient soils.

The application of compost as an organic amendment has been shown to improve soil health and enhance the nutritional quality of crops. Compost enriches the soil with essential nutrients, such as nitrogen, phosphorus, potassium, and various micronutrients, which are critical for plant growth. Additionally, it improves soil structure by increasing organic matter content, leading to better aeration and water retention. This enhanced soil environment increases microbial activity, which plays a crucial role in nutrient cycling and availability. Collectively, these factors contribute to better nutrient uptake by plants, resulting in healthier and more productive crops (Zhao *et al.*, 2022). Recent studies indicate that compost application can significantly increase the protein and micronutrient content in legumes, including pigeon pea, by enhancing the bioavailability of nutrients in the soil. This is particularly important in regions where soil fertility is declining due to intensive agricultural practices, as compost serves as a sustainable solution for improving soil health and crop quality (Singh *et al.*, 2023). Phosphorus is a vital macronutrient that plays a critical role in various physiological processes in plants, including energy transfer, photosynthesis, and root development. It is essential for the formation of ATP (adenosine triphosphate), which is necessary for energy transfer in biochemical reactions (Ali *et al.*, 2023). The application of phosphorus fertilizers has been found to improve the yield and nutritional quality of pigeon pea, particularly in phosphorus-deficient soils where natural availability is low. Research has shown that appropriate phosphorus fertilization can lead to increased root biomass and enhanced flower and pod development, ultimately resulting in higher seed yields and improved nutritional content (Kumar *et al.*, 2023). However, the effectiveness of phosphorus fertilizers can vary based on factors such as soil type, pigeon pea variety, and environmental conditions, necessitating a tailored approach to fertilization practices (Babu *et al.*, 2023). Several studies have explored the combined effects of compost and phosphorus fertilizers on crop performance. For instance, Verma *et al.*, (2023) demonstrated that the integrated application of compost and phosphorus not only enhanced the yield of pigeon pea but also improved its nutritional profile, suggesting that such practices could be beneficial for sustainable agriculture. The synergistic effects of these amendments can lead to improved nutrient cycling and enhanced soil fertility, ultimately benefiting

crop production. By combining organic and inorganic fertilizers, farmers can optimize their nutrient management strategies, promoting both environmental sustainability and agricultural productivity (Kumar *et al.*, 2023).

MATERIALS AND METHODS: A field experiment was conducted at Experimental field and Central Laboratory of Oyo state College of Agriculture, Igboora, This was located on latitude 72612.57"N and 317'18.77"E, attitude of 140m above the sea level. It has an average annual rainfall of 1,278mm with average annual temperature of 27°C to 32°C. The experiment was arranged in a randomized complete block design (RCBD) with three replications. The treatments consisted of different pigeon pea varieties, amendments (compost and phosphorus), and varying rates of compost application 5 t/ha, 10 t/ha and 15 t/ha and Phosphorus 18 kg/ha, 36 kg/ha, and 72 kg/ha and control to assess the comparative effects of compost and phosphorus (P) fertilizers on the nutritional composition of four pigeon pea varieties (NSWCC29A, NSWCC24, NSWCC34D and Otili). At maturity, the pigeon pea seed were harvested, and samples were collected from each treatment for nutritional analysis. The following parameters were measured:

Crude Protein (CP): Determined using the Kjeldahl method.

Crude Fat (CFAT): Measured through the Soxhlet extraction method.

Crude Fiber (CFibre): Analyzed using the Van Soest method.

Total Ash (T.Ash): Measured by incinerating the samples at high temperatures.

Moisture Content (MC): Determined by drying the samples to a constant weight.

Dry Matter (DM): Calculated as the difference between the fresh weight and moisture content.

Nitrogen-Free Extract (NFE): Calculated using the formula: $NFE = 100 - (CP + CFAT + CFibre + T.Ash + MC)$.

Data collected from the experiment were subjected to analysis of variance (ANOVA) using statistical software. Mean comparisons were performed using the least significant difference (LSD) test at a significance level of 0.05. The interaction effects of variety, amendment, and rate were also analyzed to determine their influence on the nutritional composition of pigeon pea.

RESULTS AND DISCUSSION

Nutritional composition of the Pigeon pea varieties: NSWCC29A, NSWCC24, NSWCC34D, and Otili shows a significant differences across most parameters ($p < 0.05$), as shown in the table.

The crude protein content ranged from 23.11% to 23.30%, with no significant differences among the varieties. Significant differences were observed in crude fat content ($p < 0.05$). NSWCC34D had the highest fat content (2.73%), followed by NSWCC24 (2.57%), NSWCC29A (2.53%), and Otili (2.47%), which recorded the lowest. NSWCC29A, NSWCC24, and NSWCC34D had significantly higher crude fibre content compared to Otili, which had the lowest (4.81%). Ash content, representing total mineral content, also varied significantly ($p < 0.05$), with NSWCC29A (5.37%) and NSWCC24 (5.31%) showing higher values compared to NSWCC34D and Otili. Moisture content did not vary significantly among the improved varieties (ranging from 5.04% to 5.18%), except for Otili, which had a significantly lower moisture level (4.81%). Dry matter content was relatively consistent across all varieties, with values ranging between 91.60% and 91.70%, NFE, which includes digestible carbohydrates, varied significantly among varieties. NSWCC24 recorded the highest NFE (65.21%), followed by NSWCC34D (63.53%) and NSWCC29A (60.21%), while Otili had the lowest (41.78%).

Effects of Fertilizer Nutritional composition of the Pigeon pea varieties

Crude Protein (CP): The data indicate that compost significantly enhances the CP content of pigeon pea, with the highest value recorded at 24.39% in the compost treatment. This improvement can be attributed to the higher nitrogen content typically found in compost, which contributes to protein synthesis in plants.

Crude Fat (CFAT): The CFAT content was highest in the variety NSWCC34D (2.73%), with the compost treatment yielding a CFAT of 2.62%.

Crude Fiber (CFibre): All pigeon pea varieties exhibited similar fiber levels, reinforcing the idea that compost can maintain or slightly enhance fiber content.

Total Ash (T.Ash): The T.Ash content, which reflects the mineral content of the crop, was highest in the compost treatment (5.36%).

Moisture Content (MC): The compost treatment showed a significantly higher moisture content (8.09%) compared to the control.

Dry Matter (DM): The DM content remained consistent across treatments, indicating that neither compost nor phosphorus adversely affected the overall biomass of the pigeon pea.

Nitrogen-Free Extract (NFE): The NFE, representing the carbohydrate content, was significantly higher in the compost treatment (51.49%) compared to the control (34.56%).

COMPARATIVE ANALYSIS OF COMPOST AND PHOSPHORUS FERTILIZERS IN ENHANCING NUTRITIONAL CONTENT OF PIGEON PEA

Variety	CP	CFAT	CFibre	T.Ash	MC	DM	NFE
NSWCC29A	23.13a	2.53bc	5.07a	5.37a	5.04a	91.60a	60.21a
NSWCC24	23.30a	2.57b	5.18a	5.31ab	5.18a	91.70a	65.21a
NSWCC34D	23.11a	2.73a	5.04a	5.17b	5.07a	91.65a	63.53a
Otili	23.19a	2.47c	4.81b	5.15b	4.81b	91.60a	41.78b
LSD	0.16	1.97	0.17	1.98	0.16	0.32	5.45
<u>Amendments</u>							
Compost	24.39a	2.62b	5.22a	5.36a	8.09a	88.13a	51.49a
Phosphorous	23.31b	2.50a	4.93b	5.25a	7.68a	88.12a	48.94a
Control	21.17c	2.21b	4.87b	5.04b	5.78b	56.76b	34.56b
LSD	0.84	0.52	0.14	0.17	0.79	7.42	3.96
<u>Rates</u>							
Compost 5 t/ha	22.78bc	2.58a	5.23a	5.25ab	8.56b	91.64a	56.83a
Compost 10 t/ha	23.05abc	2.57ab	5.27a	5.38ab	9.12b	91.59a	56.90a
Compost 15 t/ha	24.11ab	2.62a	5.16ab	5.45a	10.28a	91.72a	56.68a
Phosphorous 18 kg/ha	24.40ab	2.61a	4.87b	5.25ab	8.50b	91.64a	56.69a
Phosphorous 36 kg/ha	24.89a	2.61a	4.95ab	5.25ab	9.01b	91.69a	56.55a
Phosphorous 72kg/ha	23.89a	2.61a	4.99ab	5.25ab	9.56ab	91.66a	56.60a
Control	21.17c	2.51b	4.87b	5.04b	6.03c	91.58a	56.57
SE	1.41	0.06	0.22	0.21	1.31	0.15	0.15
<u>Interaction</u>							
V	*	*	*	*	*	*	*
F	**	**	*	**	*	*	*
R	**	*	*	*	*	**	*
V*F*R	*	*	*	*	*	*	*

Means followed by the same letter within a column are not significantly different

Significant 0.05 = *: 0.01= **

NS: Non-Significant

Conclusion and Recommendation: Crude Protein (CP): The results align with previous studies of (Zhang *et al.*, 2014). That have shown organic amendments can improve nitrogen availability in soils, leading to better protein content in crops (Reichel *et al.*, 2018). The ability of compost to enhance protein levels is especially important in regions where dietary protein intake is crucial for addressing malnutrition. The ability of compost to increase fat content, albeit modestly, indicates its role in improving the overall energy density of pigeon pea. Higher fat content can enhance the nutritional value of legumes, making them more suitable as a staple food in energy-deficient diets (Thomas *et al.*, 2019). This is particularly relevant in developing countries where energy intake from food sources is a critical concern. All pigeon pea varieties exhibited similar fiber levels, reinforcing the idea that compost can maintain or slightly enhance fiber content. The importance of fiber in human diets cannot be overstated, as it plays a crucial role in digestive health and aids in preventing chronic diseases (Li *et al.*, 2017). The fiber content observed in this study aligns with expectations, as legumes are generally known for their high fiber levels, which are beneficial for gut health. The T.Ash content, which reflects the mineral content of the crop, was highest in the compost treatment. This finding suggests that compost not only improves the organic matter of the soil but also contributes to a higher mineral content in the harvested produce. Minerals are essential for various physiological functions in humans, and their presence in adequate amounts in food crops is vital for nutritional adequacy (White and Brown, 2010). The compost treatment showed a significantly higher moisture content compared to the control. This improvement in moisture retention is crucial for crop sustainability, especially in regions facing water scarcity. Compost can enhance soil structure and porosity, leading to better water retention and reduced irrigation needs (Alvarenga *et al.*, 2017). The ability to retain moisture is particularly beneficial for pigeon pea, which is often grown in dryland farming systems. The DM content remained consistent across treatments, indicating that neither compost nor phosphorus adversely affected the overall biomass of

the pigeon pea. This stability in dry matter is essential for yield assessments and suggests that nutritional enhancements do not come at the expense of crop productivity. The NFE, representing the carbohydrate content, was significantly higher in the compost treatment compared to the control this increase in carbohydrates is vital for energy provision in diets, especially in regions where legumes serve as a primary food source. The findings reflect the role of compost in enhancing the overall caloric density of pigeon pea, which can be beneficial for populations relying heavily on plant-based diet. The improved varieties (NSWCC29A, NSWCC24, NSWCC34D) generally outperformed the local check (Otili) in most nutritional parameters, particularly in NFE, crude fibre, and ash content. Among them, NSWCC24 stood out for its balanced nutritional content, especially high NFE and moderate values in other traits. These findings support the potential adoption of improved cowpea varieties for enhanced nutritional quality.

Recommendation: Based on the findings of the comparative analysis of compost and phosphorus fertilizers on the nutritional content of pigeon pea (*Cajanus cajan*), it is recommended that farmers prioritize the use of compost as a primary amendment. The significant enhancement in nutritional parameters such as crude protein, fat, and nitrogen-free extract with compost application underscores its importance in improving both crop quality and soil health. Selection of pigeon pea varieties should focus on those that exhibit superior nutritional performance, such as NSWCC24, which demonstrated high protein and carbohydrate content.

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Comparative Study of the Effects of Npk and Urea Fertilizers on Okra (*abelmoschus esculentus*) Performance and Weed Density

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ABSTRACT

A pot experiment was conducted at Ogbomoso Farm Settlement, Ogbomoso to determine the effects of NPK and Urea fertilizers on okra performance and weed density. Okra seeds were planted at the rate of 2 seeds per pot in 27 experimental pots containing 5 kg top soil. Treatments which included NPK and Urea fertilizers were applied at 2 weeks after planting. The control was not treated with any fertilizer. The treatments were laid out in randomized complete block design and replicated 3 times. The data collected were plant height, stem diameter, number of leaves and leaf area, number of days to flowering, number of days to 50% flowering, number of pods, weight of pods and weed density, and were subjected to analysis of variance, while means were compared using Duncan's Multiple Range Test at 5% probability level. The effect of Urea produced significant number of leaves (39.00) and leaf area (555.82 cm²) respectively. Also, Urea produced the highest pod weight (45.33 g) and highest weed density (8.33 g) at 9 weeks after planting.

Keywords: Comparative, NPK, Urea, Performance and Weed density

Introduction: Okra (*Abelmoschus esculentus*), also known as lady's finger or gumbo, is a flowering plant in the mallow family, valued for its edible green seed pods. Native to the African and South Asian regions, okra is now cultivated in tropical, subtropical, and warm temperate regions around the world. The plant is a significant source of dietary fiber, vitamins (particularly vitamin C and K), folate, and antioxidants, making it a valuable component in nutritional diets (Gemede *et al.*, 2015). Botanically, okra is an annual or perennial plant that thrives in warm climates and is known for its characteristic mucilage, a thick, gel-like substance that is often used to thicken soups and stews (Kumar *et al.*, 2010). In addition to culinary use, okra has gained attention in pharmaceutical and industrial applications due to its mucilage, seed oil, and polysaccharides, which show potential in drug delivery and biodegradable packaging materials (Adelakun Adelakun, Oyelade, Ade-Omowaye, Adeyemi and Van De Venter, 2009). As both a food and functional crop, okra plays a growing role in sustainable agriculture and food security, especially in regions affected by climate change and soil degradation due to its resilience and low-input requirements. Phosphorus is a key element in the formation of high energy compounds, such as AMP, ADP and ATP, which play essential role in photosynthesis and respiration. It is a vital component of nucleic acids and phospholipids. Plants take up phosphorus in the inorganic form, mainly as the orthophosphate H₂PO₄ ion. Phosphorus supports early phase of crop development, synchronizes the germination process and leading to enhance the final yield, especially in P deficient soil (Arif *et al.*, 2015). Phosphorus increases crop resistance to diseases. In contrast to N, deficiency symptoms of P most often, occur in seedlings and young plants. Since P is mobile within the plant, symptoms appear on the lower leaves/parts of the plants (Khalil, 2006). Vegetable seed production is unique from most agronomic crops as they must develop sufficient vegetative growth prior to cool temperature exposure in order that vernalization may successfully induce flower formation in the following season such as that in Okra.

Okra (*Abelmoschus esculentus* L.) is grown for fresh fruits in the tropical and sub tropical regions and ranks first in terms of calorie for human consumption (Babatunde, Omotosho and Shatotan, 2007). The output constituted about 4.6 percent of the total staple food production in Nigeria between 1970 and 2003. Inadequate weed management, infertile soils, cultivation of low-yielding varieties and suboptimal planting densities are some of the major constraints to high okra yield and production in Nigeria (Iyagba, Onuegbu and Ibe, 2013) which necessitated the development of various agronomic practices the farmer can adopt to improve okra growth and fresh pod yield. The soil in Nigeria is inherently poor in fertility on account of low available nutrients and organic matter content such that the application of organic and inorganic fertilizers would be rule for high crop production.

However, with the increasing civilization and present day crave for modern education and white collar job, getting labour for manual job on the farm, including weeding has remained problematic. Another problem to crop production in the tropics is that of dwindling crop performance due to reducing soil fertility for adequate growth and fruit production. Hence, there is the need for enhanced soil fertility if good crop is expressed. It is in the light of this that this experiment was set-up to evaluate different types of fertilizer for Okra production.

Therefore, the objectives of this experiment were:

1. To determine the effects of NPK and Urea fertilizers on Okra performance.
2. To determine the effects of NPK and Urea fertilizers on weed density.

Materials and methods: The experiment was carried out at Ogbomoso Farm Settlement, Ogbomoso, Oyo State. The climate of Ogbomoso is mostly influenced by the North-East trade wind which is characterized with cold and with a drying effect starting from November till March and characterized by bimodal rainfall distribution with two peaks (between 1150mm and 1250mm) in late July/early August and October/November. The soil is a moderately well drained, ferruginous tropical soil with a sandy loam texture. The soil lies over metamorphic rocks. Okra seeds obtained at a farmers center, Ogbomoso were sown at three seeds per pots, after seed treatment with fungicides (Apron plus) to prevent fungi attack. After one week, the pots were thinned down to 1 plant per pot. The treatments were: Control, NPK 15:15:15 and Urea. The treatments were laid out in Randomized Complete Block

Design (RCBD) and replicated nine (9) times. Each treatment were represented by three pots to give a total of twenty-seven (27) pots. The treatment pots were arranged at 0.3 m distance from one another within replicate. There was 1 m spacing between replicate. NPK was applied at the rate of 7.14 g per plant (i.e. 1:1:1) and Urea was applied at the rate of 2.40 g per plant (i.e. 1:0:0). All pots on the experimental plot were subjected to similar activities such as supplying of missing stand, thinning, spraying of insecticides, weeding and regular watering. Thinning was carried out after ten (10) days of planting. Each pot was sprayed with insecticides at 5 days intervals from 10 days after planting to prevent insect pests attack. Weeding was done at three weeks intervals to reduce competition. Appropriate fertilizers according to treatments were applied at two weeks after sowing by ring method. Data collection commenced after eight days of sowing. The data were collected as follows: plant survival at 2, 4, 6, 8 weeks after planting by visual observation, Stem diameter of each surviving plant was recorded using Vernier caliper, number of leaves from the base of the plant to the top was counted by visual observation. Only fully opened leaves were counted, plant height obtained by taking a full measurement of the length of the plant from the ground level to its apex at 2, 4, 6, 8 weeks after sowing, weight of fruits was estimated by weighting each fruit on a digital sensitive scale, all measurements was taken in grams, leaf area of Okra at flowering was estimated following the formular $Y = 115x - 1050$ (Asif, 1977).

Where: Y = Leaf Area, X = Leaf length.

Number of days to flowering was counted and recorded, number of days to 50% flowering was recorded when observed and number of fruits per plant was counted and recorded. The data collected were subjected to analysis of variance (ANOVA) and significant means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability level (SAS, 2009).

Results and discussion: The effect of fertilizer types on Okra plant was not significantly different from the control ($P = 0.05$) with respect to plant height, and stem diameter. The tallest height (33.42 cm) was produced by Urea treated plants while the shortest (31.36 cm) was produced under control. The number of leaves of Okra was also not significantly affected by fertilizer types though the treated plants were superior to the control. Highest number of leaves (39) was produced by Urea, while the least 26.33 was produced under control.

The leaf area of Okra was significantly affected by fertilizer types throughout the experiment. At 6 WAP, the largest leaves (555.82 cm²) were produced from the Urea treated plant. These were superior only to the control.

Table 1: Effects of NPK and Urea on growth parameters of Okra

Fertilizer	Plant height (cm)			
	2 WAT	4 WAP	6 WAP	8 WAP
No fertilizer	6.10a	26.03a	29.39a	31.36a
NPK 15:15:15	5.06a	25.38a	29.67a	32.58a
Urea (46% N)	4.83a	25.95a	31.48a	33.42a
Fertilizer	Stem diameter (cm)			
	2 WAT	4 WAP	6 WAP	8 WAP
No fertilizer	0.35a	0.40a	0.43a	0.59a
NPK 15:15:15	0.40a	0.45a	0.47a	0.66a
Urea (46% N)	0.56a	0.65a	0.66a	0.79a
Fertilizer	Number of leaves			
	2 WAT	4 WAP	6 WAP	8 WAP
No fertilizer	23.33a	25.33b	26.00b	26.33b
NPK 15:15:15	35.67a	36.67a	37.33a	38.33a
Urea (46% N)	36.00a	37.00a	38.00a	39.00a
Fertilizer	Leaf area (cm ²)			
	2 WAT	4 WAP	6 WAP	8 WAP
No fertilizer	285.22b	313.00b	326.11b	338.94b

NPK 15:15:15	298.54b	299.75b	312.00b	327.45b
Urea (46% N)	536.27ab	536.33ab	548.84ab	555.82a

Means followed by same letter on the same column are not significantly different at 5% probability level using Duncan's Multiple Range Test.

The control produced the shortest number of days to flowering and number of days to 50% flowering (30.33 and 35.33 days), but were not significantly lower than NPK and Urea fertilizers (Table 2).

There was no significant difference in the crop yield. The highest number of pods (2.00) was produced with NPK which were similar to those of zero fertilizer (2.00) and urea (1.67) (Table 3). Similarly, urea produced the heaviest pods (45.33 g) which was also not significantly higher to those of NPK (44.33 g) and zero fertilizer (43.00 g). The weed density in Okra is presented in Table 4. Higher number of weeds occurred under Urea treated pot (10.67) at 6 WAP.

Table 2: Effects of NPK and Urea fertilizers on the number of days to flowering and days to 50% flowering of Okra

Fertilizer	Number of days to 50% flowering	Number of days to flowering
No fertilizer	35.33a	30.33a
NPK 15:15:15	35.67a	30.67a
Urea	36.00a	31.00a

Means followed by same letter on the same column are not significantly different at 5% probability level using Duncan's Multiple Range Test.

Table 3: Effects of NPK and Urea on the number and weight of pods per plant

Fertilizer	Number of pods per plant	Pod weight (g)
No fertilizer	1.67a	43.00a
NPK 15:15:15	2.00a	44.33a
Urea	2.00a	45.33a

Means followed by same letter on the same column are not significantly different at 5% probability level using Duncan's Multiple Range Test.

Table 4: Effects of NPK and Urea fertilizers on the weed density of Okra

Fertilizer	Weed Density		
	3 WAP	6 WAP	9 WAP
No fertilizer	22.67a	6.00ab	5.00a
NPK 15:15:15	11.00b	5.67b	5.67a
Urea (46% N)	9.67b	10.67a	8.33a

Means followed by same letter on the same column are not significantly different at 5% probability level using Duncan's Multiple Range Test.

Discussion: The application of fertilizer produced significant ($P \leq 0.05$) effect on number of leaves and leaf area of Okra. Urea produced the highest significant values with respect to number of leaves and leaf area when compared to NPK 15:15:15 and the Control. This may be due to high nitrogen content in the Urea fertilizer compared to NPK fertilizer. Urea contains a higher nitrogen content (46%) compared to NPK, which is essential for okra's growth and development. Also, Urea fertilizer increased soil chemical properties, such as pH, organic matter, and nutrient availability, which favored okra growth (Okoro, Uyovbisere and Okolie, 2017). This results corroborated the findings of Aiyelari, Obasi and Ano (2013) who reported that Urea fertilizer applied at 60 kg/ha

increased okra growth parameters, including plant height, leaf area, and stem girth, compared to NPK. Also, Urea fertilizer produced higher okra yields, with a recorded increase of 93.3% compared to the control. In contrast, NPK fertilizer, although providing a balanced nutrient supply, may not have been as effective due to its lower nitrogen content and potential soil acidity issues. The highest weed density (10.67/pot) at 6WAP obtained under Urea is attributable to higher nitrogen supply by the Urea fertilizer.

Conclusion and recommendation: The application of fertilizer had varying effects on the growth and yield of Okra. Urea produced significant effect on number of leaves and leaf area. Also, the effect of Urea increased the weed density compared to NPK and control.

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Effects of Toposequence on Some Selected Soil Properties at the Oyo State College of Agriculture and Technology, Igboora

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Abstract

The impact of toposequence on the pH, organic carbon (OC) and the particle size analysis was undertaken along the sloping portion of the land within the Oyo State College of Agriculture and Technology, Igboora, Nigeria. Three profile pits were sunk using physiographic position (upper slope, mid-slope and valley bottom) and the soil samples were collected based on the genetic horizon differentiation, which is at 0-10cm, 10-35cm, 35-45cm, 45-60cm and 60-75cm, making a total of 15 samples. All the samples were replicated three times. The samples were air dried and passed through a 2mm sieve before laboratory analysis. All the data collected were subjected to analysis of variance (ANOVA) and means separated using Duncan Multiple Range Test at 5% level of probability. The results showed that the pH in water of the soil ranged from 5.87 to 7.61. The pH in water decreased down the profile in all the three profiles. The OC was highest in the A horizon of the mid-slope with a value of 26.9 g kg⁻¹ while the lowest value (1.3 g kg⁻¹) was recorded in the Bt2 horizon of the upper slope. The OC content also decreased down the slope. The highest sand fraction (910 g kg⁻¹) was recorded in the A horizon of the lower slope while the lowest value (445 g kg⁻¹) was observed in the Bt of the upper slope. The highest silt fraction of 230 g kg⁻¹ was observed in the A horizon of the mid-slope while the lowest value of 30 g kg⁻¹ was observed in the A horizon of the lower slope. The clay fraction was highest (435 g kg⁻¹) in the Bt horizon of the upper slope while the lowest value of 567 g kg⁻¹ was recorded in the A horizon of the mid-slope. All these values varied significantly at 5% level of probability. Therefore the studies has indicated that toposequence has a great effect on the variability of the pH, OC and the physical parameters in the study area. Similarly, parameters particularly the pH and OC revealed the soil along the toposequence will be suitable for crop production because the values fall within the optimum range for most Nigerian soils.

Key words: Organic carbon, horizon, soil properties, Toposequence

Introduction: African soils are characterized by rolling topography and soil properties changes due to the factor of slope which plays a vital role in influencing soil properties as one moves from crest position down to the valley bottom (Egbochus, 2014). Apart from parent material and climate, topography is another important factor that plays important roles in the distribution of soil minerals. Topography/relief determines the drainage and depth of a soil profile; for instance, soils on higher elevation are usually well-drained whereas soil on the lower slope is usually poorly drained and of fine texture (Atofarati *et al.*, 2012). Further, topography influences drainage, soil erosion, textural composition and other soil properties that affect crop development and productivity (Atofarati *et al.*, 2012). Soils on a hill or steep slope are usually very shallow and gravelly due to minimal rate of weathering and removal of soil by erosion while soil on a gentle slope allows ample infiltration of water and develops into deep profile (Esu, 2010). Topography of a landscape can influence soil physicochemical properties biomass production, incoming solar radiation, precipitation and affect crop production. As topography gradually increases down the slope, there is a significant increase in soil moisture, soil organic carbon while bulk density, pH and soil temperature would be significantly lower at the higher elevations (Nalusenay and Kibebew, 2016). Glassman *et al.* (1980), as cited in Lawal *et al.* (2014) states that water velocity on a slope affects the deposition of materials in suspension, sand drops out of suspension first, while clay size particles can be carried further away from the upland before they are deposited on the floodplains. This process of geological sorting of suspended soil materials as they travel along a slope brings about variations in soil texture as we move from upland to lowland. Normally, topography influences morphological, chemical and physical properties of soil. In essence, topography affects the pattern of soil distribution over landscape even when the soils are derived from the same parent material (Esu *et al.*, 2008). This gives rise to a succession of soil types, known as a catena from the hilltop to the valley bottom (Milne, 1935 cited in Ewato and Enaruvbe, 2010). The catenary differentiation of soils is of pivotal importance to the management of soils in different topographic positions in the landscape. Consequently, understanding the roles of topography in a landscape will help in assessing productive values of soils and most importantly, in developing strategies for its conservation and reducing uniform soil management which could result to uneven distribution of input in an agricultural field situated on a topography (Oku *et al.*, 2010). The physical features around Ibarapa axis of Oyo State, Nigeria, consist mainly of gently undulating high plains developed on basement complex rocks. Predominantly, soils developed on basement complex rocks of Tharapa, have impervious subsurface horizons due to plinthization processes (Odunze and Kurch, 2009; Jimoh *et al.*, 2016). The plinthites do limit vertical water flow and encourage the horizontal flow of water in soils.

Information from soil maps is usually low resolution and the values of soil attributes are assumed to be uniform although there is often great variation within soil units (Zhu *et al.*, 1997). Thus, there is much interest in relating different properties of the soil and habitat to readily available data such as elevation data. Elevation data can then be used to generate digital maps of soil properties or soil types (Behrens *et al.*, 2005). Together with parent material, climate, biota, and time, topography is one of the five fundamental elements of the soil forming factor theory (Amundsen *et al.*, 1994; Jenny, 1941). Likewise, topography is central to the catena concept for soil development (Hook and Burke, 2000), which is characterized by leaching and redistribution of elements and soil material along hill slopes. Therefore, the objective of the study was to evaluate the impact of toposequence on pH, organic carbon (OC) and particle size analysis of the soil within Oyo State College of Agriculture and Technology Igboora, Nigeria.

MATERIALS AND METHODS

Location: The study was carried out at Igboora of Oyo State, Nigeria. Two towns; Igboora and Idere were purposely selected based on their peculiarity. This was located on latitude 72612.57"N and 317°18.77"E, attitude of 140m above the sea level. It has an average annual rainfall of 1,278mm with average annual temperature of 27°C to 32°C.

Field work: In this study, a sloping portion of land, adjoining Oyo State College of Agriculture and Technology, Igboora River pass-by, was selected for the purpose of evaluating the impact of topography on soil physical and chemical properties. Differentiation of soils along a catena is most marked along transects running from the crest of the interfluvies to the valley bottom (Gerrard, 1981). Along the dominant slope, the study site was partitioned into three, designated as the upper, middle slope and valley bottom. In each segment, a representative profile pit was dug and described according to Food and Agriculture Organization (FAO) guidelines for soil profile descriptions (FAO, 2014). Soil samples were collected five horizons/depth at 0-10cm, 10-35cm, 35-45cm, 45-60cm and 60-75cm. A total number of fifteen samples were collected for physical and chemical analysis

Soil Analysis: The sample soils were air-dried, ground and sieved through a 2mm sieve, less than 2mm fractions was used for laboratory analysis. Soil pH (1:2) in water was determined by glass electrode pH meter (IITA, 1982). Organic carbon was determined by chromic acid oxidation method (Walkley and Black, 1934). Particle size analysis was by the use of hydrometer method (Bouyoucos, 1951). The percentage of sand, silt and clay of the soil were used to determine the textural class using USDA textural triangle.

Statistical analysis: All the data collected were subjected to analysis of variance (ANOVA) and means separated using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effects of Topo-sequence on soil pH and soil organic carbon: The influence of topo-sequence on the soil pH is presented on Table 1. The pH along the topo-sequence ranged from 5.87 to 7.61. The depth of 0 – 10cm at the lower slope had the highest pH of 7.61 while the lowest slop of 5.87 was observed at the middle slop of 35 – 45cm. The pH along the topo-sequence therefore ranged from slightly acidic to slightly alkaline. The pH of the upper layer of the soil along the topo-sequence will therefore support crop production. It is important to note that the pH in water decreased down the profile. This observation is similar to that of Imadojemu *et al.* (2022) who reported an increase in pH down the profile along a topo-sequence. All the value reported were significantly different at 5% level of probability.

The results showed that the topo-sequence greatly ($p \leq 0.05$) (Table 1) influence the OC content of the three profiles along the topo-sequence. The highest OC of 26.90 g kg⁻¹ was observed in the A horizon of the mid-slope while the lowest value of 1.3 g kg⁻¹ was recorded in the Bt2 horizon of the upper slope. This observation may be as a result of the fact that the OC tend to accumulate at the bottom of the valley than the upper part of the slope because of erosion and run off. The amount of the OC also decreased down the profile. This may be due to the presence of litters in the lower slop of the soil profile. The amount of OC recorded ranged from very low to very high according to FDALR, 2012 fertility rating for most Nigerian soils.

Table 1: Effects of topo-sequence on soil pH and soil organic carbon

Sample location	Igboora pH	Organic carbon (g kg ⁻¹)
Lower Slope/cm		
0 – 10	7.61a	13.1b
10 – 35	7.11ab	4.7de
35 – 45	6.99abc	3.8ef
45 – 60	6.78bcd	2.8fgh
60 – 75	6.18dc	2.1hi
Middle Slope/cm		
0 – 10	6.30cde	26.9a
10 – 35	6.49bcde	13.8c
35 – 45	5.87e	4.8de
45 – 60	5.93e	5.1d

60 – 75	6.07de	15.1a
Upper Slope/cm		
0 – 10	6.10de	3.5b
10 – 35	6.10de	3.2fg
35 – 45	6.09de	2.2ghi
45 – 60	5.91e	7.8c
60 – 75	6.01de	1.3i

Means with the same letter are not significantly different using Durcan Multiple Range Test at 5% probability level.

Effects of topo-sequence on particle size distribution of the Soil: The influence of topo-sequence on the particle size analysis of the three profiles along the topo-sequence is presented in Table 2. The results showed that the topo-sequence greatly ($p \leq 0.05$) influenced the sand, silt and clay fractions of the soil. The highest percentage of sand fraction (910 g kg^{-1}) was recorded in the A horizon of the lower slope while the lowest value of 445 g kg^{-1} was recorded in the Bt horizon of the upper slope. The sand fraction was noted to reduce down the profile except in the mid-slope. The silt fraction was highest (230 g kg^{-1}) in the A horizon of the mid-slope while the lowest value of 30 g kg^{-1} was observed in the A horizon of the lower slope. The silt fraction increased than the profile in both the lower and upper slope while it reduced down the profile in the mid-slope. The clay fraction was highest (435 g kg^{-1}) in the Bt horizon of the upper slope while the lowest value of 567 g kg^{-1} was recorded in the A horizon of the mid-slope. Expectedly, the clay fraction was observed to increase down the profile in all the three profiles.

Table 2: Effects of topo-sequence on soil particle size distribution

Sample location	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Textural Class
Lower Slope				
0 - 10	910a	30g	60h	Sand
10 – 35	850b	86.7f	63.3h	Loamy Sand
35 – 45	716.7c	120de	163.3e	Sandy Loam
45 – 60	613.3e	103.4e	283.3d	Sandy Clay loam
60 – 75	543.3f	93.4e	363.3bc	Sandy Clay
Middle Slope				
0 – 10	713.3c	230a	567h	Sandy Loam
10 – 35	683.3d	200b	116.7g	Sandy Loam
35 – 45	730.0c	113.3de	156.7e	Sandy Loam
45 – 60	706.0cd	140cd	154.0e	Sandy Loam
60 – 75	722.7c	143.3cd	134.0f	Sandy Loam
Upper Slop				
0 – 10	852.7b	76.6f	70.7h	Loamy Sand
10 – 35	624.7e	100e	275.3d	Sandy Clay Loam
35 – 45	504.7g	119.9de	375.3b	Sandy Clay
45 – 60	444.7h	120de	435.3a	Clay
60 – 75	484.7g	160c	355.3c	Sandy Clay

Means with the same letter are not significantly different using Durcan Multiple Range Test at 5% probability level.

CONCLUSION AND RECOMMENDATION: The results of the pH, OC and fractions of the sand, silt and clay varied greatly along the topo-sequence. The pH of the soil ranged from moderately acidic to slightly alkaline. The pH was also observed to decrease down the profile. Organic carbon ranged from very low to very high (only a depth at middle slope) and similarly decreased down the profile like pH. The sand and silt fraction of the soil were highest in the A horizon of the profile while the clay fraction was observed to be the highest in the Bt horizon. The study has indicated the hat toposquence could greatly impact the variability of soil properties in this area. It is therefore observed that the soil in the study area will be suitable for crop production based on the pH and OC content which falls within the optimum range for most Nigerian soil.

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Effects of Staking and Npk Fertilizer on Growth and Biomass Yield of Cowpea (*vigna unguiculata* L. Walp.) in Igboora, Oyo State, Nigeria

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Abstract

Staking and fertilizer application are important cultural practices in crop production. A pot trial was conducted to investigate the effects of staking and NPK 15:15:15 fertilizer (NPK) on growth and biomass yield of cowpea. The 2 x 4 factorial experiment comprised of 2 levels of staking (staked and unstaked) and 4 levels of NPK (0, 20, 30 and 40 Kg N per ha). The 8 treatment combinations were arranged in complete randomize design and replicated 5 times. Data collected were plant height, number of leaves, leaf area, number of peduncles, fresh shoot weight, fresh root weight, dry root weight and dry root weight). The data were subjected to analysis of variance and significant means were separated using Duncan's Multiple Range Test at a 5% probability level. Application of NPK at 30 kg N per ha produced the highest significant plant height (79.80 cm), number of leaves (50.60), leaf area (108.4 cm²) and number of peduncles (9.60). However, the effect of NPK was not significant on biomass yield (fresh shoot weight, fresh root weight, dry shoot weight and dry root weight). The effect of interaction of staking and NPK was significant on plant height, number of leaves, leaf area, number of peduncles, fresh shoot weight and dry shoot weight. NPK at 30 kg N per ha was recommended to cowpea farmers in the study area.

Keywords: Staking, NPK, Growth, Biomass, Cowpea

Introduction: Cowpea (*Vigna unguiculata*) is an annual herbaceous legume cultivated for its edible seeds or for fodder and cultivated cowpeas are herbaceous annuals that are either erect, prostrate or climbing annuals with a tap root and virtually all are glabrous. Cowpea is a multipurpose grain legume; in which the entire plant can be used for either human or livestock consumption (Boukar, Abberton, Oyatomi, Togola and Fatokun, 2021). It is one of the most important food and forage legumes in the semi- arid tropics that include parts of Asia, Africa, Southern Europe, Southern United States, and Central and South America (Rahim, Hossain, Ara and Islam, 2024).

It is one of the most important native food and forage legumes, and it is grown in Sub- Saharan Africa and some temperate regions of the world (Tswanya, Abubakar and Garba, 2024). The young leaves, green pods and green grains are used as vegetables, and the dry grains are used in various preparations for both human food and livestock feed (Owade, Abong, Okoth and Mwang'ombe, 2020). The cowpea grain is highly nutritious and contains about 22.8 - 28.9% protein with an average of 25.6% (Adegbite and Olanrewaju, 2022). According to **Islam, Adhikary, Mostafa, and Hossain (2024)**, all parts of the plant are used as food, which is nutritious, providing protein and vitamins. Immature pods and seeds are used as cooked vegetables while several snacks and main dishes are prepared from the grains (Atoyebi, Ade-Omowaye and Osundahunsi, 2021). In addition to its importance in human food and animal feed, cowpea is also useful for soil fertilization through symbiotic nitrogen fixation.

Cowpea does not require too much nitrogen fertilizer because it fixes its own nitrogen from the air using the nodules in its roots. However, in areas where soils are poor in nitrogen, there is a need to apply a small quantity of nitrogen as a starter dose for a good crop. If too much nitrogen fertilizer is used, the plant will grow luxuriantly with poor grain yield. About 30 kg of P/ha in the form of single super phosphate is recommended for cowpea production to help the crop to nodulate well and fix its own nitrogen from the air (Mohammed and Dakora, 2024). Most root growth usually occurs within the topsoil layer, but in times of drought cowpea can grow a taproot as long as 8 ft to reach moisture deeper in the soil profile (**Ahmed, Khatun, Sarkar, Era, Islam and Anwar, 2022**). Among the factors responsible for low yields are the use of local varieties and low soil fertility, as most tropical soils are deficient in essential nutrients particularly N and P (**Pradhan, Datta, Lal and Kumar, 2025**). Tropical soils are inherently low in nutrients particularly nitrogen and phosphorus (Silva and Edwards, 2020), hence, there is need to improve the growth and yield of cowpea by adding fertilizers. Also, staking is a cultural practice, and it has significantly influenced the yield of some crops. In view of this, it is important to investigate the effects of NPK fertilizer and staking on the performance of cowpea in the study area. Hence, the objective of the study was to evaluate the growth and biomass yield of cowpea as influenced by staking and NPK fertilizer.

Materials and methods: The experiment was conducted at the Teaching and Research Farm of Department of Crop Production Technology, Oyo State College of Agriculture and Technology, Igboora. Igboora is situated in the derived savanna zone, southwest, Nigeria (Latitude 7° 26'1"N and Longitude 3°17'16"E), and its shares boundaries with Abeokuta, Ibadan and Oke-Ogun regions. There are two distinct seasons; the dry season (from November to March) and wet season (April to October). The average high temperature of the region is 33 °C, while the average low temperature is 22 °C.

A soil auger (3 cm depth) was used to collect composite soil samples. The samples were subjected to analyses for physical and chemical properties. The soil samples were air dried for 21 days, crushed and sieved to remove debris. The hydrometer method was used to determine sample particle size (Bouyoucos, 1962). The total nitrogen of the substrates was assessed using the macro-Kjeldahl method (Jackson, 1958). The pH was determined with pH meter, while available phosphorus was estimated using the Bray 1 method (Bray and Kurtz, 1945).

Two seeds of cowpea were planted per hole at a depth of 2 cm and later thinned to one plant per stand at two (2) weeks after planting. Forty (40) experimental pots, each containing 8 kg top soil were used for planting. NPK 15:15:15 fertilizer was applied by side placement method at 2 weeks after planting at 0 (F1), 20 (F2), 30 (F3) and 40 (F4) kg N/ha, while staking (S1) was done

by tying rope at the tip of the stem to a wooden support. The unstaked plants (S2) were also treated with fertilizer as the staked plants. Weeds were manually controlled all through the experimental period.

The 2 x 4 factorial experiments comprised of 2 levels of staking (staked and un-staked) and 4 levels of NPK 15:15:15 fertilizer application (0, 20, 30 and 40 kg N/ha). The eight (8) treatment combinations were laid out in a Randomized Complete Block Design (RCBD) with five (5) replications making forty (40) experimental units.

Data collection commenced at three (3) weeks after planting on growth and biomass yield parameters such as plant height, number of leaves, number of peduncles, stem diameter, leaf area and biomass yield. Plant height was measured using measuring tape and recorded in centimeters (cm). Number of leaves was physically counted; stem diameter was measured with the aid of Vernier caliper and recorded in millimeter (mm). The leaf area was calculated using the formula of Osei-Yeboah *et al.*, 1983, $LA = LW \times C$ (L – leaf length, W – leaf width C – leaf area factor = 2.325). Yield parameters taken were fresh shoot weight, fresh root weight, dry shoot weight and dry root weight. This was done by weighing the respective shoot and root samples using S. Mettler Electronic Compact Balance measuring scale recorded in gram (g). Data collected were subjected to analysis of variance (ANOVA) and significant means were compared using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

Results and discussion

Pre-planting soil analysis: The results from the chemical and physical properties of the soil showed that the experimental soil had a pH value of 6.47 (Table 1). Hence, the experimental soil is moderately acidic. The soil is low in essential plant nutrients like nitrogen, phosphorus and potassium with values of 1.7%, 9.97mg/kg and 0.36cmol/kg respectively. The particle size analysis of the soil is 89.4% sand, 5.80% silt and 4.80% clay, therefore the soil textural class is sandy loam.

Table 1: Physical and chemical properties of experimental soil

Elements	Value
pH (H₂O)	6.47
Exchangeable base (Cmol/kg)	
Ca	3.65
Mg	0.76
K	0.36
Na	0.54
Total N (g/kg)	1.70
Total Org. C (g/kg)	8.70
Available P (mg/kg)	9.97
Particle size analysis	
Sand (g/kg)	89.4
Silt (g/kg)	5.8
Clay (g/kg)	4.8
Textural class:	Sandy loam

Effect of staking and fertilizer application on plant height (cm) of Cowpea: Staking produced the highest plant height (76.50 cm), but was not significantly higher than unstaking (63.80 cm) plant height at 8 weeks after planting. However, the effect of NPK fertilizer was significant ($P \leq 0.05$) all through the sampling period except at 3 weeks after planting. The application of NPK fertilizer at 30 kg N per ha produced highest significant plant height (63.70 cm, 73.00 cm, 79.80 cm, 87.60 cm and 95.10 cm) at 4, 5, 6, 7 and 8 weeks after planting respectively. These values were significantly higher than NPK fertilizer application 0, 20 and 40 kg N per ha. Also, the application of NPK fertilizer at 20 kg N per ha was significantly ($P \leq 0.05$) higher than application than 30 kg N per ha all through the sampling period. The control (0 kg N per ha) produced the lowest significant ($P \leq 0.05$) plant height (29.40 cm, 34.70 cm, 42.20 cm, 46.50 cm and 52.20 cm) at 4, 5, 6, 7 and 8 weeks after planting respectively. The effect of interaction between staking and fertilizer application was significant ($P \leq 0.05$) at 3 and 8 weeks after planting (Table 2).

Table 2: Effect of staking and fertilizer application on plant height (cm) of Cowpea in Igboora

Treatment	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Staking						
S1	27.85a	47.50a	54.70a	63.00a	69.50a	76.40a
S2	24.70a	44.60a	50.10a	55.30a	60.20a	63.80a

LSD (5%)	4.67	3.65	5.86	8.25	10.30	15.24
Significance	NS	NS	NS	NS	NS	NS
Fertilizer						
F1	20.90a	29.40c	34.70c	42.20c	46.80c	52.20c
F2	28.90a	52.60ab	57.90ab	65.00ab	70.30b	75.00b
F3	31.60a	63.70a	73.00a	79.80a	87.60a	95.10a
F4	23.70a	38.40bc	43.90bc	49.50bc	54.60bc	58.10bc
LSD	12.76	9.92	15.13	12.45	15.95	18.32
Significance	NS	*	*	*	*	*
Interaction						
S X F						
LSD	13.86	17.34	17.25	17.97	17.38	21.89
Significance	*	NS	NS	NS	NS	*

Means with the same letter along the column are not significant ($P \leq 0.05$) different. LSD: Least significant different, WAP: weeks after planting, S1: Staking, S2: Un-staking, F1: Control, F1: 20 kg N per ha, F2: 30 kg N per ha, F3: 30 kg N per ha, F4: 30 kg N per ha.

Effect of staking and fertilizer application on number of leaves of Cowpea: Also, staking produced 35.30 number of leaves which was not significantly higher to un-staking (30.60) at 8 weeks after planting. Similar trend was observed throughout the sampling period. The effect of fertilizer was significant all through the sampling period. Application of NPK fertilizer at 30 kg N per ha produced the highest number of leaves which was significantly ($P \leq 0.05$) higher than other application rates and the control. This trend was similar all through the sampling period. Application of NPK fertilizer at 30 kg N per ha produced the highest significant number of leaves (31.30, 36.90, 39.90, 43.80, 46.90 and 50.60) at 3, 4, 5, 6, 7 and 8 weeks after planting. These values were significantly higher than other application rates and the control. However, NPK application at 20 kg N per ha and 40 kg N per ha produced similar effect on the number of leaves of cowpea. The control (0 kg N per ha) produced the lowest significant ($P \leq 0.05$) number of leaves all through the sampling period. The interactive effect of staking and NPK fertilizer was significant ($P \leq 0.05$) all through the sampling period (Table 3).

Table 3: Effect of staking and fertilizer application on number of leaves of Cowpea in Igboora

Treatment	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Staking						
S1	21.25a	25.60a	27.15a	30.40a	33.00a	35.30a
S2	18.45a	23.70a	26.10a	27.50a	30.45a	30.60a
LSD (5%)	3.50	2.35	1.97	3.86	3.98	6.67
Significance	NS	NS	NS	NS	NS	NS
Fertilizer						
F1	7.20c	10.20c	13.20c	16.20c	19.20c	19.20c
F2	28.10b	29.80b	29.80b	33.10b	35.50b	35.40b
F3	31.30a	36.90a	39.90a	43.80a	46.90a	50.60a
F4	22.80b	29.50b	29.70b	32.70b	35.20b	36.50b
LSD	2.89	6.24	8.87	9.24	10.23	13.42
Significance	*	*	*	*	*	*
Interaction						
S X F						
LSD	8.51	9.05	8.73	9.01	8.65	8.44

Significance	*	*	*	*	*	*

Effect of staking and fertilizer application on leaf area (cm²) of Cowpea: The staking effect was not significant on leaf area of cowpea all through the sampling period. At 8 weeks after planting, staking effect produced 91.10 cm² leaf area, while un-staking produced 90.20 cm². The effect of NPK fertilizer was significant ($P \leq 0.05$) for leaf area of cowpea all through the sampling period. However, similar effect was observed for NPK fertilizer at 20, 30 and 40 kg N per ha at 3, 4, 5, 6 and 7 weeks after planting. At 8 weeks after planting, NPK at 20 kg N per ha (102.10 cm²) and 30 kg N per ha (108.40 cm²) produced similar effect for leaf area. These values were significantly ($P \leq 0.05$) higher than NPK application at 40 kg N per ha (87.20 cm²). The control produced the lowest significant ($P \leq 0.05$) leaf area of 30.50 cm², 63.30 cm², 55.20 cm², 64.70 cm², 65.50 cm² and 70.40 cm². The interaction between staking and NPK fertilizer was significant ($P \leq 0.05$) all through the sampling period (Table 4).

Table 4: Effect of staking and fertilizer application on leaf area (cm²) of Cowpea in Igboora

Treatment	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Staking						
S1	53.30a	84.50a	82.50a	85.10a	85.90a	91.10a
S2	40.10a	63.40a	74.50a	76.60a	84.40a	90.20a
LSD (5%)	15.21	28.10	10.42	10.21	2.54	2.12
Significance	NS	NS	NS	NS	NS	NS
Fertilizer						
F1	30.50c	55.20b	63.30b	64.70c	65.50b	70.40c
F2	63.40a	81.70a	83.90a	88.60a	89.50a	102.10a
F3	70.00a	80.40a	86.90a	90.60a	94.00a	108.40a
F4	62.90a	80.20a	82.20a	84.90a	86.80a	87.20b
LSD	5.67	0.75	2.19	1.26	3.43	4.98
Significance	*	*	*	*	*	*
Interaction						
S X F						
LSD	11.72	13.05	14.00	17.56	13.93	9.97
Significance	*	*	*	*	*	*

Effect of staking and fertilizer application on number of peduncles of Cowpea: Staking had no significant effect on the number of peduncle of cowpea. The highest number of peduncle (6.00) was observed at 8 weeks after planting, while the lowest was 5.20. These values were not significantly different. Similar trend was observed all through the sampling period. Also, the effect of NPK fertilizer was not significant for number of peduncle of the crop at 3 and 4 weeks after planting, but was significant at 5, 6, 7 and 8 weeks after planting. From 5 to 8 weeks after planting, NPK at 30 kg N per ha produced the highest significant ($P \leq 0.05$) number of peduncles 6.70, 7.70, 9.00 and 9.60 respectively, while the control had similar effect on number of peduncle with 20 kg N per ha, 30 kg N per ha and 40 kg N per ha. The interaction between staking and NPK fertilizer was significant ($P \leq 0.05$) all through the sampling period (Table 5).

Table 5: Effect of staking and fertilizer application on number of peduncles of Cowpea

Treatment	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Staking						
S1	2.50a	3.40a	4.15a	5.00a	5.60a	6.00a
S2	1.60a	2.40a	3.25a	3.80a	4.40a	5.20a
LSD (5%)	1.40	2.56	2.15	3.27	3.20	1.94
Significance	NS	NS	NS	NS	NS	NS
Fertilizer						
F1	1.20a	1.80a	2.40b	3.00b	3.10b	3.30b

F2	1.40a	2.30a	2.70b	3.40b	3.90b	4.30b
F3	3.80a	5.20a	6.70a	7.70a	9.00a	9.60a
F4	1.80a	2.20a	3.00b	3.80b	4.00b	5.00b
LSD	4.87	6.86	1.95	2.15	3.31	2.57
Significance	NS	NS	*	*	*	*
Interaction						
S X F						
LSD	1.11	1.30	1.59	1.52	1.61	1.56
Significance	*	*	*	*	*	*

Effect of staking and fertilizer application on biomass yield of Cowpea: Staking produced the highest fresh shoot weight (40.46 g) of cowpea, but was not significantly higher than un-staking (35.04 g). Also, the effect of NPK fertilizer was not significant with respect to fresh shoot weight of cowpea. NPK application rate of 40 kg N per ha produced the highest fresh shoot weight (40.23 g), but was not significantly higher than other NPK application rates including the control (38.19 g). However, the interaction between staking effect and NPK effect was significant ($P \leq 0.05$) with respect to fresh shoot weight (Table 6).

There was no significant effect of staking, NPK and interactive effect of staking and NPK fertilizer on fresh root weight of cowpea. Staking produced 9.15 g fresh root weight while un-staking produced 8.88 g. The highest fresh root weight was produced by NPK at 40 kg N per ha (9.25 g), but was not significantly higher than other treatments including the control (8.95 g). Also the effect of interaction between staking and NPK was not significant ($P > 0.05$) with respect to fresh root weight (Table 6).

The effect of staking (8.09 g) was higher than the un-staking (7.01 g), but not significant with respect to dry shoot weight of cowpea. The application of NPK fertilizer was not significant on dry shoot weight. NPK application at 40 kg N per ha produced the highest dry shoot weight (8.12 g), while the lowest dry shoot weight was produced by NPK at 30 kg N per ha. The interactive effect of staking and NPK fertilizer was significant with respect to dry shoot weight (Table 6).

Moreover, staking (1.15 g) produced similar effect with un-staking (1.11 g) on dry root weight of cowpea. Also, the effect of NPK fertilizer was not significant. NPK application at 40 kg N per ha produced 1.15 g dry root weight, while NPK application rates of 30, 20 and 0 produced 1.10 g, 1.13 g and 1.12 g dry root weights respectively. These values were not significantly different. Also, the interactive effect of staking and NPK fertilizer was not significant (Table 6).

Table 6: Effect of staking and fertilizer application on biomass yield of Cowpea in Igboora

Treatment	FSW (g)	FRW (g)	DSW (g)	DRW (g)
Staking				
S1	40.46a	9.15a	8.09a	1.15a
S2	35.04a	8.88a	7.01a	1.11a
LSD (5%)	7.73	2.15	1.97	1.02
Significance	NS	NS	NS	NS
Fertilizer				
F1	38.19a	8.95a	7.62a	1.12a
F2	36.57a	9.04a	7.27a	1.13a
F3	36.35a	8.84a	7.20a	1.10a
F4	40.23a	9.25a	8.12a	1.15a
LSD	5.36	1.12	1.34	1.01
Significance	NS	NS	NS	NS
Interaction				
S X F				
LSD	2.54	0.57	0.51	0.38
Significance	*	NS	*	NS

Means with the same letter along the column are not significantly ($P \leq 0.05$) different. LSD: Least significant different, WAP: weeks after planting, S1: Staking, S2: Un-staking, F1: Control, F1: 20 kg N per ha, F2: 30 kg N per ha, F3: 30 kg N per ha, F4: 30 kg N per ha. FSW- Fresh Shoot Weight, FRW – Fresh Root Weight, DSW- Dry Shoot Weight, DRW- Dry Root Weight.

Discussion: Generally, it was observed that the staking had no significant effect on all the growth parameters (plant height, number of leaves, leaf area) and yield parameters (number of peduncles, fresh shoot weight, fresh root weight, dry shoot weight and dry root weight) studied. However, the application of NPK 15:15:15 fertilizer enhanced the growth and biomass yield of cowpea. This can be attributed to the fact that nitrogen promoted vegetative growth (Ouattara and Kouhoude, 2025). The application of NPK fertilizer at 30 kg N per ha produced significant effect compared to other application rates and the control.

The importance of N in leaf production is well known in plants (Wang, Chen and Zhang, 2023). Results from (Dreccer, Schapendonk, Slafer and Rabbinge, 2000) suggest an increase in leaf area as well as number of branches following the availability of N in crop production. The report from Ali, Khan and Abbas (2023) also showed increasing number of leaves and branches due to availability of nitrogen fertilizer. The application of NPK at 30 kg N per ha recorded significantly increased biomass yield (fresh and dry shoot weights and fresh and dry root weights). This increase might be due to better nutritional status of the crop in the soil (Patel, Sharma and Kumar, 2023). The increased supply of nitrogen and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters. These results are in close conformity with the findings of Nasar, Wang, Ahmad, Muhammad, Zhao, Khan, Gul and Gitari (2023).

Conclusion and recommendation: The effect of staking cowpea plant is not significant with respect to growth and yield parameters. However, staking produced higher growth and yield parameters than unstaked cowpea plants. Moreover, the application of NPK fertilizer enhanced all the growth and yield parameters of cowpea compared to the control. The best growth and yield parameters observed was due to the application of NPK 15:15:15 fertilizer at 30 kg N per ha. The interactive effect of staking and NPK fertilizer was significant on plant height, number of leaves, leaf area, number of peduncles, fresh shoot weight and dry shoot weight. For optimal growth and biomass yield of cowpea, NPK 15:15:15 at 30 kg N per ha is recommended to cowpea farmers in the study area. Also, the effect of staking on growth and biomass yield of cowpea should be examined on the field for proper assessment.

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Determinants of Water Accessibility among Farming Households in Yobe State, Nigeria

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Abstract

This paper focused on analyzing water accessibility among farming households in Yobe State, Nigeria. The study specifically identified the water sources accessible to the farming households, determined the factors affecting water accessibility for these households, examined the patterns of water utilization, and identified the constraints faced by the respondents. A multistage random sampling technique was adopted in selecting 110 respondents, and data were analyzed using descriptive and multiple regression analysis. The results indicated that 40.9% of the respondents depend on vendor water supply, 22.7% rely on commercial borehole, while a small proportion of 7.3% source water from untreated and polluted dug wells. Furthermore, multiple regression estimates revealed that time to the main water source ($p < 0.1$), monthly income ($p < 0.01$), time taken to fill a container ($p < 0.01$), number of trips to the main water source ($p < 0.05$), and household size ($p < 0.05$) were positively and significantly related to water accessibility in the study area. This implies that an increase in any of these variables will increase water accessibility in the study area, while the cost (CST) of accessible water was negative, indicating that an increase in this variable will decrease water accessibility. Based on the pattern of water utilization, 45.5% of respondents mostly use water for sanitation purposes, followed by cooking meals at 34.5%, and drinking purposes at 20%. The study concluded that given the important role of water for quality life and sustainable living conditions, the identified barriers to water accessibility should be given appropriate attention. We recommend that concerted efforts should be made to improve households' water accessibility through the provision of new infrastructure and the rehabilitation of existing facilities in the study area.

Keywords: water, access, resources, policy, sustainable, Nigeria.

Introduction: The importance of water supply has been a subject of serious debate globally, and its significance is reflected in the measurement of the Human Development Index and embedded in Sustainable Development Goal 6: "Clean Water and Sanitation" (Obaideen et al., 2022). This concern follows several reports estimating the burden of the lack of access to drinking water supply and other uses (Lee et al., 2023; Greco et al., 2019; Hutton, 2013). The predominant use of unimproved water sources is mostly associated with people living in Sub-Saharan Africa, and Eastern and Southern Asia, with about 75% of the inhabitants experiencing inadequate water availability (Wandiga, 2015). This situation demonstrates that a lack of clean water supply can cause significant hazards. The consequences may include illnesses, morbidity, and death arising from complications due to poor water hygiene and sanitation. Recent reports indicate that some countries, particularly those in developing categories, are making steady progress in addressing water supply challenges. However, Sub-Saharan African countries have not made significant progress in this regard, as only about 40% of the population is estimated to have access to clean and affordable water supply to date (Emenike et al., 2017). Nigeria is the most populous African nation and holds a significant position in Sub-Saharan Africa. However, the citizens lament the unexpectedly poor record of water supply and facilities (Adeniran et al., 2021). Settlements in Nigerian states, particularly in the northern regions, are characterized by overpopulation, unplanned settlements, overcrowded living conditions, climate change vagaries, dilapidated water disposal and drainage systems, air and water pollution, poor road networks, and inadequate water services. This situation is observed and persistent in the arid region of the northeastern state of Nigeria. It can, therefore be inferred that overpopulation, rapid urbanization, and poor town and regional planning are some of the critical problems leading to water supply bottlenecks (Akoteyon, 2019). Apart from these identified challenges, low budget allocation, poor investment in water access, uneven policy implementation, and more importantly, a lack of political will by the government at different levels to intervene in the current low access to safe and clean water supply in the country. The provision of affordable and potable water is essential for meaningful living conditions, according to Sustainable Development Goals (SDG 6) and SDG 10, which aim at reducing inequality and improving inclusiveness. Therefore, it is expected that efforts geared towards the provision of adequate water should be a special priority for the government in Nigeria. Government investment in the water sector is still low compared to infrastructure facilities such as road networks, which consistently enjoy large budgetary allocations year after year. Some scholars opine that low investment, poor government political will, and weak water policy are major problems leading to poor performance in providing safe and clean water to achieve 75% coverage of the citizenry in the country (Adeniran et al., 2021; Oyeboode & Oyeboode, 2021). Recent data reveal that only about 65% and 30% have access to a safe and affordable water supply in urban and rural areas of the country, respectively (WHO & UNICEF, 2014).

Despite the multifaceted approach by individuals, groups, cooperative societies in cities and urban centers, as well as government efforts at different tiers (Federal, State, and Local Government Areas) and international donor agencies towards improving water conditions in Nigeria, a vast number of the population still experience unsatisfactory services due to poor access to safe and drinkable water. The current water supply in the country is about 48%, representing 90 million people. It is estimated that over 100 million people still lack access to safe water for drinking and other uses (Adeniran et al., 2021; Akoteyon, 2019). This issue is particularly concerning and prevalent in the northern region of Nigeria, especially Yobe State, due to severe climate change, weather conditions, and poor governance.

This research examines water accessibility among farming households in the Bade Local Government Area, Yobe State, Nigeria. The specific objectives are to:

- i. Identify the sources of water available to farming households in the study area.
- ii. Determine the factors affecting water accessibility for farming households in the study area.
- iii. Examine the patterns of water utilization by farming households in the study area.

Methodology

The Study Area: The study was conducted in Bade L.G.A, Yobe State, Nigeria. Yobe is located in the Northeast zone of Nigeria and is mainly an agrarian state with its headquarters in Damaturu. It was created on August 27th, 1991, with a total of seventeen Local Government Areas (LGAs). It lies between latitude 12°00'N and longitude 11.30°E, covering a land area of about 45,502 square kilometers, with an estimated population of three million six hundred forty-nine thousand six hundred (3,649,600) people (NPC, 2006). The projected population of the state for 2014, using an annual growth rate of 3%, is 2,914,184. The state shares boundaries with Borno State to the east, Bauchi to the south, and Jigawa to the west. It also shares international borders with the Republic of Niger to the north. Yobe State lies mainly in the dry savannah belt; it is therefore, dry, and hot for most of the year, except in the southern part of the state, which has a milder climate. The soil type is generally sandy, and the annual temperature ranges between 39°C and 40°C. The rainy season begins in June, with mean annual rainfall between 900mm and 1500mm, spreading up to October, depending on the year. The hot season is from February to May. The climate favors the production of a wide variety of crops, including legumes (groundnuts and beans), cereals (maize, millet, sorghum, and rice), and vegetable crops (peppers, tomatoes, and garden eggs). The state is said to have one of the largest cattle markets in West Africa. Animals such as camels, sheep, goats, and poultry are also kept. Apart from its agricultural orientation, Yobe has rich fishing grounds and mineral deposits of gypsum, kaolin, and quartz. The major ethnic group living in the state is the Fulani, with other ethnic communities including Kanuri, Kare-Kare, Bolewa, Ngizim, Bade, Hausa, Ngamo, and Shuwa.

Method of Data Collection: The study utilized primary data collected through a well-structured questionnaire administered to respondents (farming households). Specific information collected included socio-economic characteristics of the respondents, water accessibility and utilization indices, and variables related to consumption and constraints mapping. Trained enumerators and experts administered the questionnaires to the respondents.

Sampling Procedure and Sample Size: The targeted population for the study was farming households in Bade L.G.A. The sampling selection was based on accessibility to the researcher. The study purposively selected three wards out of the ten total wards in Bade L.G.A. The selected wards are those with the highest number of farming households based on the available sampling frame. The selected wards were Lawan Fannami Ward, Zango, and Gwiokura Ward. A two-stage random sampling technique was employed to select the respondents. In the first stage, one village was selected in each ward, making a total of three villages. These were Yan Budu in Lawan Fannami Ward, Dankalawa Village in Zango Ward, and Gwio-Dino Village in Gwio-Kura Ward. The selection was based on easy accessibility, familiarity, and spread. In the second stage, a simple random sampling technique was used to select a total of 110 respondents for the study.

Methods of Data Analyses: Descriptive statistics and inferential statistics were utilized to capture the stated objectives of the study. Descriptive statistics such as frequency table, percentages, means, etc were used to address objective (i), (iii) and (iv). Multiple Regression analysis following Akoteyon, (2019) was used to address and achieve objective (ii). Specifically, the implicit form of the equation can be stated thus,

$$Y=f(x_i) \dots\dots\dots (1)$$

Where

Y= water accessibility and utilization in litres

X_i = independent variables

Explicitly,

$$Y= b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + \mu \dots\dots\dots (2)$$

Where;

Y = water accessibility and utilization in liters.

b_0 = constant

X_1 = Time to main water source (TSMWS) in minutes

X_2 = Distance to main water source DMWS in meter

X_3 = monthly income (MIN) in Naira (₦)

X_4 = Time taken to fill container (TTFC) in minutes

X_5 = Main water source (MWS)

X_6 = Number of trips to main water source (NTMWS)

X_7 = Household size (HHS) in number

X_8 = Cost (CST) of available water (₦)

X_9 = Daily water consumption (DWC) in Kg

μ = error term

The three functional forms were run, and the best-fitted equation was chosen based on the lead criterion.

Results & Discussion: Sources of water accessibility to farming households in the study area

The available sources of water for farming households and inhabitants in the study area are presented in Table 1. The results reveal that the dominant water source is vendor providers, representing 40.9%, while dug wells are the least source of water supply at about 7.3%. Other sources include boreholes, rainwater storage, and piped household water connections. The observed dominance of vendor providers, popularly referred to as "mai ruwa," and commercial borehole supply in the area indicates a lack of government water infrastructure or a moribund water supply system where it exists. This is a serious problem because the water quality and hygiene of the vendors and their jerry cans used for water supply cannot be guaranteed. This may lead to serious health implications

for consumers. Similarly, the majority of the inhabitants are low-income earners. Therefore, regular exposure to purchasing water will erode their income and impair the living conditions of households. This result aligns with the findings of Mahama *et al.*, (2014) and Tadesse *et al.*, (2013). They argued that improved water accessibility affects low-income earners in Ghana, as well as rural water management and sustainability in Ethiopia, where the studies were conducted.

Table 1: Sources of water in the study area

Water sources	Frequency	Percent
Dug well	8	7.3
Vendor supply	45	40.9
Rainwater storage	22	20.0
Commercial boreholes	25	22.7
Piped HH water connection	10	9.1
Total	110	100.0

Source: Field Survey, 2024.

Factors affecting water accessibility of farming households in the study area

The semi-log functional form was chosen as the lead equation, as presented in Table 2. The choice was based on the number of significant variables, the magnitude of the coefficient of multiple determination (R^2), the conformity of variable signs with a priori expectations, and the significance of the F-ratio. The coefficient of multiple determination was 0.909, implying that 90.9% of the variation in the dependent variable was explained by the explanatory variables included in the model. Time to the main water source ($p < 0.1$), monthly income ($p < 0.01$), time taken to fill a container ($p < 0.01$), number of trips to the main water source ($p < 0.05$), household size ($p < 0.05$), and cost of available water (CST) ($p < 0.05$) were the significant variables affecting water availability in the study area.

The results in Table 2 revealed that the coefficients for time to the main water source ($p < 0.1$), monthly income ($p < 0.01$), time taken to fill a container ($p < 0.01$), number of trips to the main water source ($p < 0.05$), and household size ($p < 0.05$) were positive and significantly related to water availability in the study area. This implies that an increase in any of these variables will increase water availability in the study area, while the cost of available water was negative, indicating that an increase in this variable will decrease water availability in the study area. The finding aligns with Akoteyon (2019) in his study on access to water supply in residential areas of the Lagos metropolis.

Table 2: Multiple regression estimates on factors affecting water accessibility of farming households in the study area

Variables	Linear	Exponential	Semi log+	Double log
Intercept	-46269.52 (-0.526)	11.694 (46.555)***	-2537760.059 (-6.886)	3.917 (6.236)***
Time to main water source	2042.094 (1.903)*	0.002 (0.797)	64040.940 (1.721)*	0.048 (0.758)
Distance to main water source	2114.380 (0.749)	0.006 (0.752)	5072.356 (0.234)	0.017 (0.454)
Monthly income	6.821 (8.361)***	1.740E-5 (7.468)***	251574.170 (7.706)***	0.809 (14.538)***
Time taken to fill container	34312.906 (3.359)***	0.070 (2.387)**	156374.414 (3.398)***	0.205 (2.609)***
Main water source	4912.327 (1.404)	0.019 (1.918)*	10516.816 (0.582)	0.067 (2.161)**
Number of trips to main water source	57383.473 (3.082)***	0.148 (2.775)***	38297.846 (2.089)**	0.094 (2.997)***
Household size	37917.770 (1.638)*	0.012 (0.180)	52166.960 (2.276)**	0.024 (0.622)
Cost (CST) of available water	-4257.459 (-1.899)*	-0.004 (-0.589)	-47440.623 (-2.575)**	-0.040 (-1.285)
Daily water consumption	5963.984 (0.190)	0.88 (0.983)	-24872.742 (-0.808)	0.022 (0.414)
R^2	0.810	0.720	0.909	0.825
R^{-2}	0.772	0.663	0.890	0.789
F-ratio	20.948***	12.589***	47.795***	22.630***

Source: Field survey (2024)

Patterns of water utilization by farming households in the study area

The distribution of respondents based on water usage, as presented in Table 3, indicated that the majority, representing 45.5%, used water for sanitation. This was followed by water for cooking, representing about 34.5%, while water consumption (drinking) accounted for 20%. Sanitation here refers to water provisions for personal hygiene, household cleaning, hand and clothes washing, sewage, disinfection, and other environmental cleaning. The result aligns with the findings of Angoua et al. (2018), who inferred in their studies that there is a significant relationship between access to water and sanitation.

Table 3: Patterns of water utilization by farming households

Variable	Frequency	Percent
Sanitation	50	45.5
Cooking	38	34.5
Drinking	22	20.0
Total	110	100.0

Source: Field Survey, 2024.

Conclusion: The study examined the determinants of water accessibility among farming households in the Bade Local Government Area, Yobe State, Nigeria. Based on the major findings, the study concluded that time to the main water source ($p < 0.1$), monthly income ($p < 0.01$), time taken to fill a container ($p < 0.01$), number of trips to the main water source ($p < 0.05$), and household size ($p < 0.05$) were positively and significantly related to water accessibility, while the cost of available water was negatively related to water accessibility. The mentioned factors were significant variables influencing adequate water accessibility and affordability in the study area. The study recommends that policymakers, relevant agencies, and stakeholders improve water infrastructure facilities in the study area to enhance the quality and quantity of water for farming households and other inhabitants, thereby improving their living conditions.

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