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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. 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 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 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, 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](https://www.bioRx.org/content/early/2018/07/11/263401)) 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](https://arxiv.org))

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.

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-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 burning issue in global and national environmental discuss 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 green gas effect. Wallace Smith Broecker called this predicted increase in earth surface temperature global warming 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 expanded 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 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

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 (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 cause soil erosion while drought and heat depleted soil moisture and nutrients making land less productive.

Salinization resulting from rising sea level contaminate fresh water sources making irrigation difficulty 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 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 result 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 (Schwaab et al., 2020). Climate change pose survival threat to multitude of biodiversity leading to some species being threatened others endangered and some gone on extinction (Koll & Cronin, 2018).

Changes in the landcover 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

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)

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:

- 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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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 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 helps 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 though 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 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.
- **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.

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).

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).

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 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).

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 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).

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 a significant role in influencing the smallholder farmers in their adoption of CSA practices. There is a 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 a 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 a 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 are coming from.

The CSAF funds are provided by institutions and organizations that support and promote environmental sustainability through reduction in greenhouse gas emission and climate-smart agricultural practices. The 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 their 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 a reasonable profit margin.

Banks are more likely to fund CSA projects that the loan requests are supported with a business plan that contains 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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SAEREM/UNIABUJA2025 INTERNATIONAL CONFERENCE

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 Speaker1
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 Speaker2

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	UNIABU JA/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	UNIABU JA/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	UNIABU JA/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	UNIABU JA/004
SA250E	A Review Paper On Mechanism Of Host Plant Resistance To Pests & Diseases Augustine A. M ¹ , & Uzakah, R. P ²	UNIABU JA/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	UNIABU JA/006
*****	Machine Learning Evaluation of Irrigation Water Quality Indices Affecting Rice Performance in the Northern Guinea Savanna: Gani A.T.* and Awwal Y.A.	UNIABU JA/007
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	UNIABU JA/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.,	UNIABU JA/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 Rabiatsu, Y. A., and ¹ Hussaini, A.	UNIABU JA/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.	UNIABU JA/011
SA250L	Determinants of food expenditure among urban households in Bayelsa state, Nigeria Zelda A. Elum* and Tari Digitemie ²	UNIABU JA/010
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	UNIABU JA/012
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.	UNIABU JA/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 .	UNIABU JA/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	UNIABU JA/015
SA250Q	Fishery Value Chain in River Benue Valley Nigeria, A Livelihood Approach for Fishermen Economic Sustainability and Resources Management,	UNIABU JA/016

	¹ Modibbo U., ¹ Mohammad Hanafi Idris., ² Aliyu A ³ Sogbesan Olukayode Amos	
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	UNIABU JA/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	UNIABU JA/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	UNIABU JA/019
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	UNIABU JA/020
SA250U	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.	UNIABU JA/021
SA250U	Scaling up Climate-Smart Soil Management Practices among Smallholder Farmers in Imo State S. I. Ukwuaba	UNIABU JA/022
SA250U	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.	UNIABU JA/023
SA250U	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	UNIABU JA/024
SA250U	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.	UNIABU JA/025
SA250U	The Impact of Climate Change on Wildlife in Gashaka-Gumti National Park, Nigeria Bode, A. S., Mathias Ana'aticha, and Wadiamu Bello	UNIABU JA/026
SA250U	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	UNIABU JA/027
SA250U	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.	UNIABU JA/028
SA250U	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	UNIABU JA/029
SA250U	<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	UNIABU JA/030
SA250U	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.	UNIABU JA/031
SA250U	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.	UNIABU JA/032

SA250U	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.	UNIABU JA/033
SA250U	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.	UNIABU JA/034
SA250U	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.	UNIABU JA/035
SA250U	Evaluation of Soil Degradation Status in Selected Soil of Wukari, Taraba State Osujieke, D. N., Gani, A. T. and John, F. O	UNIABU JA/036
SA250U	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	UNIABU JA/037
SA250U	Do Farmers Derive Income from Yam Production? Novel Evidence from Imo State, Nigeria Esiobu, Nnaemeka Success ^{a*} ; Osuagwu, Chizoma Olivia ^a and Onyike, Rosita Chijioke ^b	UNIABU JA/038
SA250U	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	UNIABU JA/039
SA250U	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	UNIABU JA/040
SA250U	Population Ecology of Plants of Food and Medicinal Products in A Community-Managed Moist Rainforest in Akwa Ibom State, Nigeria: ¹ Ikpaetor, M. M. and ² *Olajide, O.	UNIABU JA/041
SA250U	Forestry Actions for Climate Change Mitigation and Environmental Sustainability in Nigeria Opeyemi OLAJIDE	UNIABU JA/042
SA250U	Species and Breed-Dependent Differences in Saturated and Unsaturated Fatty Acids of Ruminant Milk: Abubakar M.1* Tukur S. T. 2, Abba I. A. 1 and Karaye, S. I. 1	UNIABU JA/043
SA250U	Comparative Study of Biogas from Waste Akintola T	UNIABU JA/044
SA250U	Effect of Enzyme and Vitamin Supplementation on Physiohaematological Parameters of Turkey Broiler Birds: Gabi, R.A ^a , Harande, I. S. ^b , and Ibrahim, N.T ^b ,	UNIABU JA/045
SA250U	Effects of Fadama I11 Project on Livelihood Activities of Small-Holder Farmers in Kebbi State, Nigeria.: Aminu Yahaya Sanda ¹ Shehu Usman Hassan ² Jibril Muhammad Yelwa ³ and Yohanna J. Alhassan ⁴	UNIABU JA/046
SA250U	Assessment of Tomato (<i>Lycopersicon lycopersicum</i> L.) Varieties for Growth and Productivity in the Northern Guinea Savanna Region of Nigeria * ¹ Fakai. A U., Sanda H Y ² ., Khadija U.Z ³ and Harande I.S ⁴	UNIABU JA/047
SA250U	Effects of different rates of poultry manure and plant population on the yields of <i>Corchorus olitorious</i> : ¹ BELLO, Wasiu Babatunde and ² SALAMI, Taofeek Boladale	UNIABU JA/048
SA250U	Adoption of Climate-Smart Agricultural (CSA) practices and their Impact on Food Security among Smallholder Farmers in Kebbi State, Nigeria.: Manga T. A ¹ , Alhassan Y. J ² , Sanchi I.D ² and ³ U. S. Hassan	UNIABU JA/049
SA250U	Climate-Smart Agriculture as a Tool for Poverty Alleviation and Sustainable Livelihoods among Rural Households in Kebbi State: Manga T. A ¹ , Alhassan Y. J ² , Sanchi I. D ² and U. S. Hassan ³	UNIABU JA/050
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Relationships and Prediction of Organic Matter from Selected Soil Properties in the Nigerian Environment

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Abstract

In tropical soils, particularly those found in Nigeria, soil organic matter is an essential component. This is due to its function in fertility, production, and soil conservation. The objectives of this study were to: (1) access the relationship between organic matter and selected soil properties within the scope of the Nigerian environment; and (2) evaluate the role of this relationships in the prediction of organic matter levels. Primary soil data was obtained from 32 profiles dug in the Nigerian guinea savanna area. Soil properties investigated were organic matter levels, particle size distribution, cation exchange capacity, base saturation, and total nitrogen. Secondary data involving 1,176 soil profiles and 3, 299 soil samples across the ecological zones in the Nigerian environment were obtained from the African Soil Profiles Data Base (version 1.2). The secondary soil data were used for correlation and regression analysis whereas the primary soil data were used for validation studies. Correlation analysis indicated that the selected soil properties had weak or no linear relationship with organic matter. However, average soil depth had a highly significant ($p < 0.01$) slightly weak negative linear relationship ($r = -0.4$) with organic matter. On the other hand, organic matter had a highly significant strong positive linear relationship ($r = 0.8$) with total nitrogen. Regression equations was also tested, and validation results are included in the article and indicates great potential of the use of organic matter data in predicting total nitrogen levels in Nigerian soils.

Key words: Organic matter, Nigeria, Soil properties, Nitrogen, NDVI

Introduction: One of the most vital components of Nigerian soils, particularly in the tropical setting, is soil organic matter. According to Brady and Weil (1999), organic matter enhances soil tilth, decreases compaction and surface crusting, acts as a store of plant nutrients and water, and is crucial for the formation and stability of soil structure. This underscores the importance of organic matter on soil productivity, fertility, and conservation. Consequently, the proper management of soil organic matter is, therefore, important to food security and the protection of marginal lands (Martius et al, 2001). Furthermore, it was noted that appropriate management of soil organic matter in the tropics, still requires considerable research into the regional variability of soil organic matter quantity, quality and function; the importance of the quality of input material; the role of below-ground versus mulched organic matter; the role of recalcitrant materials such as biochar in building a stable soil organic matter fraction in the long-term; and how to balance the need for stable forms against the need for short-term nutrient availability. Reports by Conteh and Kamara (2020) indicates that under tropical climatical conditions, soil organic matter vary with vegetation (higher in forest than in savanna soils), climate (higher in mountain forests than in lowland forests), soil texture (increasing with increasing clay and silt content), minerology (higher in volcanic soils due to stabilizing effect of allophane on organic matter) and land use (higher in undisturbed soil than those under continuous cultivation). It was also noted that results of various studies indicate that a significant fraction of soil organic matter within soil aggregates and that associated with clay minerals is physically protected from decomposition. Much of this organic carbon is thought to comprise a pool with intermediate residence time (for example: 10 - 50 years), but which may decompose much faster upon soil disturbance

Field and Laboratory Studies: Primary soil data used for validation studies were obtained from 32 soil profiles dug at random within the Nigerian guinea savanna. Soil samples were obtained from genetic horizons using guideline described in the soil survey manual (Soil Survey Division Staff, 1993). Soil samples were subject to laboratory analysis: Particle size analysis was carried out using the hydrometer method as described by Gee and Bauder (1986). Cation Exchange Capacity (CEC) was determined at pH 7 by the NH₄OAc saturation method of Rhoades (1982). The effective cation exchange capacity (ECEC) was obtained by summation of the exchangeable bases and exchange acidity (Uehara and Gillman, 1981). Base saturation was determined from total exchangeable bases and CEC as described by Thomas (1982). Organic carbon was determined by the Walkley-Black dichromate wet oxidation method as described by Nelson and Sommers (1982). The Kjeldahl method was used for determination of total nitrogen.

Data Analysis: Correlation and regression analysis were performed on secondary soil data obtained from the African soil data base (version 1.2) as documented by Leenaars et al (2014). 1200 data points were identified retrieved from the database. One way analysis of variance was used to compare data predicted from regression equations and primary soil data obtained by laboratory analysis. Descriptive statistics were also performed on secondary soil data. Geographic information Systems was used to display precipitation, and secondary soil data obtained from Fick and Hijmans (2017), and Leenaars et al (2014) respectively. Normalized Difference Vegetation Index (NDVI) for Nigeria at a resolution of 250m for the month of January 2001 was obtained from the International Research Institute for Climate and Society (IRI), Moderate Resolution Imaging Spectroradiometer (MODIS) analysis tool. NDVI data for the year 2001 was used because most of the secondary soil data used for this study were obtained around that period

Relationships between Soil Characteristics and organic matter: Table I shows general soil characteristics across the Nigerian landscape. Extremely high variation was observed among soil properties. Coefficient of variation was highest for soil organic carbon (117.49). These high variation in soil organic carbon could be due to effects of the variable nature (across the Nigerian environment) of factors such as climate, vegetation land use, soil texture, depth, and minerology as was noted by Conteh and Kamara (2020). The relationship among these soil properties is presented in Table 2. In most cases no strong relationships were observed between soil organic carbon and soil properties and could also be due to factors earlier mentioned. However, there was a highly significant ($p < 0.01$) moderate negative correlation between soil organic carbon and average soil depth ($r = -0.404$). This is not unexpected as has been observed in various soil studies within the Nigerian environment. For example, in studies carried out by Ande, (2010), Eshett et al, (1990) and Aki et al, (2014); organic matter was observed to decrease with increasing soil depth. Also, a highly significant strong positive relationship was observed between soil organic carbon and total nitrogen ($r = 0.805$). This indicates that nitrogen contents in Nigerian soils is mainly in the organic form. Relationships between soil organic matter and total nitrogen has been the subject of various soil studies. For example, Brady and Weil (1999) proposed various relationships between soil organic carbon and total nitrogen which could be expressed mathematically as follows (equation 1 and 2):

$$TN = \frac{OM}{1.72} \times \frac{1}{12} \quad \dots\dots\dots \text{equation 1}$$

$$TN = \frac{OM}{1.72} \times \frac{1}{20} \quad \dots\dots\dots \text{equation 2}$$

$$TN = 0.1152 + 0.072182 \left(\frac{OM}{1.72} \right) \quad \dots\dots\dots \text{equation 3}$$

$$TN = 0.1707 - 0.000343 AD - 0.1245 GMWD + 0.07075 \left(\frac{OM}{1.72} \right) \quad \dots\dots\dots \text{equation 4}$$

Where:

TN = total nitrogen (%)

OM = organic matter (%)

AD = average soil depth

GMWD = geometric mean weight diameter

Equation 1 was proposed for most soil types (excluding soils of arid areas) whereas equation 2 was proposed for Histosols, humid and wetland soils. Furthermore, the linear regression equation between total nitrogen and organic matter (equation 3), and the multiple linear regression equation between nitrogen on one hand and organic matter, average soil depth and soil particle size distribution expressed as geometric mean weight diameter (equation 4) was highly significant however only 65% of the variation in the distribution of total nitrogen can be accounted for by the equations.

Table 1: General soil characteristics

Variable	Mean	StDev	CoefVar	Minimum	Maximum
Sand	58.178	24.030	41.30	0.000	100.000
Silt	16.343	12.379	75.75	0.000	89.000
Clay	25.483	18.567	72.86	0.000	88.100
ECEC	13.907	14.141	101.69	0.270	60.000
CEC Soil	11.694	11.913	101.88	0.100	87.700
B sat	62.424	30.183	48.35	0.000	100.000
Org C	6.171	7.250	117.49	0.000	111.000
Total N	0.6065	0.6958	114.72	0.0000	11.3000

StDev: standard deviation, CoefVar: coefficient of variation

Model Validation

The mathematical models (equation 1 – 4) were tested with an independent data set obtained from 32 soil profiles in selected areas of the Nigerian guinea savanna (Table 3) as a validation procedure to test whether models developed from the African soil data base and that obtained from Brady and Weil (1999) were not merely artifacts of the data. Soil data presented in Table 3 ranged from Entisols to Inceptisols; with particle size distribution having a geometric mean weight diameter ranging from 0.21 to 0.87. Mean organic matter content in soil was 1.44% with a standard deviation of 0.84 and a coefficient of variation of 58.32. On the other hand, mean total nitrogen contents was 0.042% with a standard deviation of 0.024 and a coefficient of variation of 56.42.

Variation in the distribution of total nitrogen and organic matter is much lower compared to that obtained from the African soil database most likely due to reduced variability in ecological conditions within the Nigerian guinea savanna. This was underscored by Foth (1990), who documented wide variations in soil organic matter distributions between forest and grassland ecosystems.

Table 2: Correlation analysis

	Av depth	Sand	Silt	Clay	ECEC	CEC-Soil	B-sat	Org-C
Sand	-0.077							
	0.000							
Silt	-0.070	-0.649						
	0.000	0.000						
Clay	0.145	-0.862	0.174					
	0.000	0.000	0.000					
ECEC	-0.031	-0.727	0.365	0.708				
	0.176	0.000	0.000	0.000				
CEC Soil	-0.015	-0.635	0.266	0.646	0.931			
	0.306	0.000	0.000	0.000	0.000			
B sat	-0.024	-0.086	0.085	0.054	0.422	0.189		

	0.101	0.000	0.000	0.000	0.000	0.000		
Org C	-0.404	-0.051	0.031	0.046	0.106	0.145	-0.094	
	0.000	0.001	0.059	0.004	0.000	0.000	0.000	
Total N	-0.338	-0.136	0.074	0.126	0.065	0.185	-0.116	0.805
	0.000	0.000	0.000	0.000	0.039	0.000	0.000	0.000

Cell Contents

Pearson correlation

P-Value

Summary statistics of soil nitrogen predicted by equations 1 to 4 is presented in Table 4. There was highly significant difference ($P < 0.01$) between soil nitrogen predicted by the equations and that observed in the laboratory. Further analysis using Fisher pairwise comparison indicated that means were in the order: Equation 4 > Equation 3 > Equation 1 > Equation 2 = Observed. Hence soil nitrogen contents obtained from laboratory analysis and that predicted by equation 2 were statistically similar ($P < 0.05$). The significant difference between soil nitrogen levels predicted by equations 3 to 4 and that observed from laboratory analysis could be due to great variation in ecological conditions, geology, land use, and consequently soil types across the Nigerian landscape. These factors have been noted by Foth, (1990) and Conteh and Kamara (2020).

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Table 3: The 32 soil profiles used to test models is presented here.

N	E	Profile No.	Horizon	average depth (cm)	GMWD	N (%)	OM (%)
9.150085	9.780018	1	A	6.00	0.64	0.051	1.73
			AC	21.00	0.72	0.038	1.30
			C1	42.50	0.71	0.025	0.87
9.141644	9.774425	2	A	7.50	0.35	0.095	3.29
			C1	32.50	0.35	0.059	1.68
			C2	57.50	0.35	0.022	0.07
9.13856	9.771327	3	A	20.00	0.29	0.062	2.08
			C1	65.00	0.29	0.042	1.46
9.771327	9.812774	4	A	22.50	0.37	0.007	0.23
			BA	47.50	0.37	0.014	0.41
			B	127.50	0.37	0.005	0.18
9.085832	9.809885	5	A	22.50	0.58	0.024	0.81
			BA	55.00	0.58	0.028	0.90
			B1	80.00	0.58	0.030	0.97
			BC	102.50	0.58	0.031	1.03
			C1	160.00	0.58	0.041	1.34
9.083862	9.816099	6	A1	12.50	0.74	0.024	0.76
			A2	32.50	0.74	0.047	1.72
			B1	60.00	0.74	0.038	1.31
			B2	95.00	0.74	0.028	0.90
			C1	120.00	0.74	0.026	0.82
9.09727	9.809663	7	A	15.00	0.72	0.055	1.83
			B1	42.50	0.72	0.020	0.65
			B2	67.50	0.72	0.027	0.87
			B3	120.00	0.72	0.033	1.09
			BC	180.00	0.72	0.012	0.37
9.114471	9.786592	8	A	11.00	0.53	0.056	1.86
			B	38.50	0.53	0.018	0.59
			C1	97.50	0.53	0.059	1.96
			C2	175.00	0.53	0.041	1.32
			C3	265.00	0.53	0.023	0.68
9.160063	9.781774	9	A	22.50	0.58	0.053	1.77
			C1	21.00	0.58	0.036	1.11
			C2	21.00	0.58	0.054	1.83
9.168299	9.765158	10	A	15.00	0.74	0.046	1.52
			C1	21.00	0.74	0.030	1.03

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Conclusion The relationships between organic matter and selected soil properties were investigated across the Nigerian environment. Weak relationships were observed in most cases. These relationships were most likely obscured by great variation among the various ecosystems. However moderate negative correlation and strong positive correlation were observed between organic matter and average soil depth and soil nitrogen, respectively. This study further underscored the potential of mathematical models in predicting nitrogen levels from soil organic matter data. For the soils studied, equation 2 was significantly effective in predicting soil nitrogen levels. Consequently, this study has shown that the relations between soil organic matter and soil nitrogen can be explored to develop pedo-transfer functions for the prediction of soil nitrogen. However, it is recommended that for future research, similar studies should be conducted for relatively homogeneous ecosystem for more reliable outcomes.

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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

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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 (Agbede, 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.

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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.

Objectives of the Study

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 climate change, banditry, and food security indicators.

2.0 EMPIRICAL RELATED LITERATURE OF THE STUDY

The study is anchored on a conceptual framework that positions climate change and armed banditry as the two primary stressors influencing food security in Mubi North LGA. Climate change indicators such as erratic rainfall, temperature rise, and drought, reduce agricultural productivity and natural resource quality. Armed banditry manifests through farmer displacement, crop destruction, and market disruption. These factors jointly or individually reduce food availability, accessibility, and stability.

Nnanguma et al. (2025) conducted a study focusing on soil erosion in Mubi North and South LGAs. Their findings revealed that factors such as steep slopes, intense rainfall, sandy soils, and unsustainable agricultural practices significantly contribute to soil erosion. This erosion leads to the loss of fertile topsoil, reduced crop yields, and increased farming costs, thereby threatening agricultural productivity and food security in the region. A report by the Associated Press highlighted the challenges faced by farmers in northern Nigeria, including Adamawa State, due to climate change. The study noted that long dry spells and extreme heat have led to the drying up of rivers, making irrigation difficult. In Adamawa State, water scarcity caused by higher temperatures and changing rain patterns has affected over 1,250 hectares of farmland, disrupting food supply and livelihoods. Garandi et al. (2025) explored the role of indigenous farming knowledge in enhancing food security and land conservation in Mubi North LGA. The study found that traditional practices, such as crop rotation and organic fertilization, have been effective in restoring

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soil fertility and improving food security. Farmers who adopted these indigenous methods reported better land conservation and agricultural sustainability.

Garandi (2024) analyzed maize production patterns in Mubi North before and after the Boko Haram insurgency. The study revealed a significant decline in maize production post-insurgency, with 63% of farmers producing less than one ton, compared to 44% producing 1–5 tons before the insurgency. Factors contributing to this decline included inaccessibility to farmlands, high costs of production inputs, and increased insecurity.

A report by Premium Researchers highlighted the impact of herdsmen banditry on food scarcity in Nigeria. The study noted that frequent attacks on farming communities have led to the displacement of farmers, abandonment of farmlands, and destruction of crops. These activities have resulted in persistent increases in food commodity prices and detrimental food scarcity/insecurity in the country.

Agbede (2024) discussed the broader implications of banditry on Nigeria's food security. The article emphasized that the escalation of food scarcity is due to the disruption of agricultural activities by bandit attacks, leading to the abandonment of farmlands and harvested crops. This situation has caused food production to plummet, resulting in acute shortages and soaring prices.

The combined effects of climate change and armed banditry have exacerbated food insecurity in Mubi North. While climate change leads to environmental degradation and reduced agricultural productivity, armed banditry disrupts farming activities and displaces communities. These intertwined challenges necessitate comprehensive strategies that address both environmental and security concerns to enhance food security in the region.

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 cain, suya 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 Janyi.

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

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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)

$$n = N / (1 + N(e)^2)$$

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.

Method 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.

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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

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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.

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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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Assessment of the Impact of Educational Interventions and Management on Prostate Cancer Screening Awareness and Attitude among Farmers who use Agro-Chemicals in Nigeria

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Abstract

This study investigated the impact of educational interventions in enhancing awareness of prostate cancer screening among farmers exposed to pesticides in rural communities in Benue State, Nigeria. Using quasi-experimental approach, a sample of 120 farmers who mixed or applied pesticides participated in pre- and post-intervention surveys following educational workshops focused on prostate cancer risks and screening importance. Results indicate a significant improvement in participants' awareness and attitudes towards prostate cancer screening post-intervention, with pre-intervention surveys revealing low awareness. The findings underscore the efficacy of tailored educational approaches in addressing knowledge gaps and promoting health-seeking behaviours among farmers. It is therefore suggested that public health programmes should incorporate targeted education on prostate cancer, using Health Belief Model constructs to improve knowledge and attitudes, while exploring digital platforms and community involvement for sustained behavior change.

Keywords: Educational interventions, Farmers, Benue, Arrest, Prostate cancer

Introduction: Educational interventions have long been recognized as a cornerstone in advancing public health awareness and shaping positive attitudes toward preventive health behaviours (Hahn & Truman, 2015; Raghupathi & Raghupathi, 2020). In the context of prostate cancer screening, education is crucial in increasing awareness, addressing misconceptions, and fostering proactive health-seeking behaviours globally (Abhar et al., 2020; benedict et al., 2023; Çapık, 2014; Çapık & Gözüm, 2011; Khalil et al., 2024; Molazem et al., 2018). Prostate cancer is a major health concern, especially among men aged 50 and above, and disease ranks as the second most prevalent cancer types among men and the fifth leading cause of cancer related mortality globally (Rawla, 2019). The disease is a malignant tumor in the prostate gland, affecting male reproductive health, often characterized by difficulty urinating and pelvic pain. Despite its prevalence and the benefits of early detection, prostate cancer screening rates remain low in many regions, particularly in low- and middle-income countries (Abila et al., 2022; Ugochukwu et al., 2019). Studies suggest that this low uptake can be attributed to a general lack of awareness, limited access to screening services, and prevalent negative or unclear attitudes about the disease, even among those aware of its risks (Adibe et al., 2017; Gift et al., 2020; Maladze et al., 2023; Mbugua et al., 2021; Yeboah-Asiamah et al., 2017; Rebbeck et al., 2013; Ugochukwu et al., 2019). Consequently, prostate cancer is often diagnosed at later stages, leading to higher mortality rates and reducing patients' chances for effective treatment (Sekhoacha et al., 2022). Educational interventions play a crucial role in improving screening rates by informing high-risk populations about the importance of early detection, thus potentially saving lives.

However, awareness initiatives often fail to reach high-risk populations in rural and resource-limited settings, where the need for targeted education is particularly acute (Adedeji et al., 2021; Mbugua et al., 2021). Among these populations, farmers who work with agrochemicals represent a group with an elevated risk of prostate cancer due to frequent exposure to potentially harmful substances (Alavanja & Bonner, 2012; Alves Pedroso et al., 2022; Parent et al., 2009; Settini et al., 2003). Numerous studies have shown a link between prolonged exposure to specific agrochemicals, such as organophosphates and certain pesticides, and an

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increased risk of prostate cancer (Cavalier et al., 2023; Pardo et al., 2020; Van Maele-Fabry & Willems, 2015). These chemicals are known to disrupt endocrine functions and may promote carcinogenic processes within the prostate, posing significant risks to individuals who handle them regularly without adequate protective measures (Parent et al., 2009). Farmers in agricultural communities are frequently exposed to these hazardous compounds as a result of direct application, inadequate protective equipment, and extended periods of time spent in treated fields. The occupational dangers they confront highlight the importance of addressing their health education needs, particularly in terms of prostate cancer awareness and prevention.

Educational outreach in rural Nigerian communities is not only crucial for enhancing prostate cancer awareness but also essential for addressing broader public health challenges that arise from the extensive use of agrochemicals. Farmers in these areas are often exposed to hazardous substances without adequate protective measures or knowledge of their potential long-term health effects (Moda et al., 2022; Sosan et al., 2013). By focusing on this high-risk group, the study seeks to provide insights into how targeted educational efforts can make a significant difference in preventive health behaviours among vulnerable populations. The findings from this research have the potential to inform future interventions aimed at improving screening uptake and reducing prostate cancer mortality rates in rural areas.

Methodology: Study Design: We adopted a quasi-experimental design with pre- and post-intervention study to evaluate the impact of educational interventions on prostate cancer screening awareness and attitudes among agrochemical-using farmers in rural Nigeria. The quasi-experimental design enabled the measurement of changes in participants' knowledge and attitudes after an intervention without randomisation to control or experimental groups (Creswell & Creswell, 2018; White & Sabarwal, 2014). This approach was chosen because it allows for the measurement of intervention success in a real-world setting while taking into account practical limitations in the research context, such as farmer accessibility and desire to participate.

Designation of Study Areas We conducted research in rural communities across Benue State, Nigeria, where agriculture and pesticide use are prominent. We selected these areas due to the high number of farmers who frequently mix and apply agrochemicals, increasing their risk of pesticide-related health issues, including cancer (Abakpa et al., 2024; Pii et al., 2019). The areas of focus were Owukpa, Ogbadibo LGA and Ogobia, Otukpo LGA, Zone C Senatorial District, Benue State. This targeted geographical focus enhanced the relevance of our educational intervention, as farmers in Benue often have limited access to healthcare information and resources (Adu et al., 2024). To refine our approach, we conducted field observations and preliminary surveys, identifying specific villages within Benue where farming and pesticide usage are most prevalent. This process allowed us to deliver a more effective intervention by addressing the unique needs of these farming communities (Marshall & Rossman, 2016).

Population and Samples: We purposively targeted farmers in Benue State who actively applied or handled agrochemicals in their farming practices as the study population. From this group, we selected a sample of 120 farmers (60 farmers per community – one in the experimental and the other in the control) based on specific criteria: participants were required to be over 18, regularly involved in pesticide application, and willing to complete both pre- and post-intervention surveys. Using purposive sampling, we ensured the inclusion of individuals directly exposed to pesticide use, a key factor for assessing the intervention's impact on this high-risk group (Etikan, Musa, & Alkassim, 2016). We determined the sample size to balance statistical power with logistical feasibility, aligning with established guidelines for quasi-experimental studies in rural health settings (Teddlie & Yu, 2007). Participants initially attended an interactive educational session focused on prostate cancer risks and screening practices. Following this, we conducted pre-intervention surveys to establish baseline awareness and attitudes. After the intervention, we surveyed the same participants again to measure any changes in their awareness and attitudes.

Research Instrument : We used two instruments to elicit data in the study. First, we developed a primary instrument, which was a 12-week educational intervention programme made to assess prostate cancer screening awareness and attitude among farmers who admitted to being frequently exposed to agrochemicals. The development of this intervention was informed key principles of the HBM. While the intervention was designed to focus only on the experimental group (i.e., those who resided in Owukpa, Ogbadibo LGA), the control group did not receive any intervention (i.e., those who resided in Ogobia, Otukpo LGA). Also, a 5 expert panel in the field of public health reviewed the actual content of the intervention, with the aim of ensuring validity. They found that an Item Objective Congruence (IOC) index of 1.00.

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In implementing the intervention, we developed an interactive teaching sessions, which we named: *Prostate Health: Raising Awareness and Improving Attitudes*. These teaching sessions were accessible to the experimental group only. The researchers and RAs (Research Assistants) facilitated the interactive sessions. We divided these sessions into four learning sections. The first section was about *Prostate Cancer Screening Education*—enveloping the symptoms, risk factors, screening and the need to act in response to a positive result. While the second section included *Information on Agrochemical Exposure and Health Risks*, *Knowledge-enhancing* dramas focused on prostate cancer screening benefits and pesticide-related risks dominated the third section. *Cartoon posters* which were obtained from the public domain, aimed at engaging farmers in prostate cancer preventative practices was the content of the fourth section.

The second instrument was a structured questionnaire designed to measure changes in prostate cancer screening awareness and attitudes among both the experimental and control groups, in alignment with the HBM constructs. To begin with, we elicited general information about the key basic socio-demographic characteristics of farmers, including age, farming practices, pesticide usage and general knowledge questions about whether they know about prostate cancer and the extent of their awareness concerning the disease and screening options. In order to elicit substantive data for the study, we created questions consisting of four components of the HBM. (perceived susceptibility to prostate cancer, perceived severity of the disease, perceived benefits of screening, and perceived barriers to screening). We developed 6 items or statement for each of the components of the model (24 items in total). Examples from each of the constructs are presented. As to perceived susceptibility, one of the items read: “I am of the view that frequent and uncontrolled exposure to agrochemicals increases my risk of prostate cancer.” To capture perceived severity, respondents responded to items such as: “A prostate cancer diagnosis would seriously affect my capacity to farm and support my family.” An example of items developed on the component of perceived benefits included, “prostate cancer screening will assist in identifying prostate issues or cancer early for effective treatment.” Lastly, one of the examples of the component about barriers was: “Screening is difficult due to costs and time away from farming.” Responses were scored on a 5-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree. Results from reliability analyses showed strong internal consistency, with the following Cronbach's alphas: perceived susceptibility ($\alpha = 0.81$), perceived severity ($\alpha = 0.84$), perceived benefits ($\alpha = 0.87$), and perceived barriers ($\alpha = 0.79$). The overall Cronbach's alpha for the instrument was 0.83, indicating reliable measurement across constructs.

Data Collection : The first phase of data collection happened prior to the educational intervention, when both the experimental and control groups filled out a baseline questionnaire. The purpose of this initial data collection was to examine individuals' current understanding of prostate cancer risks, attitudes towards screening, and exposure to agrochemicals. To guarantee comparability, the baseline survey was administered simultaneously to both groups. This initial survey lasted one week, during which experienced research assistants visited the selected areas and administered the questionnaires in person, assuring clarity and consistency in responses.

The final phase of data collecting included administering the post-intervention survey to both groups. This survey was administered immediately following the conclusion of the 12-week intervention, which marked the end of the data gathering period. The post-intervention survey was administered over the period of one week, with research assistants returning to participants to ensure complete data collection. The entire duration of data collection, including pre- and post-intervention questionnaires, was 14 weeks: one week for baseline data collection, 12 weeks for the educational intervention, and one week for post-intervention data collection. This structured timeline enabled the evaluation of both the immediate and long-term effects of the educational intervention on the experimental group, while controlling for any external influences by collecting data from both groups at the same time periods.

Data Analysis : We analysed data using descriptive and inferential statistical approaches to compare changes in prostate cancer screening awareness and attitudes between the experimental and control groups. First, we used descriptive statistics (means, standard deviations, and frequencies) to summarise participants' socio-demographic characteristics as well as baseline knowledge and attitudes about prostate cancer. Chi-square tests were conducted to compare the extent of knowledge and awareness regarding prostate cancer and its screening between the experimental and control groups. To evaluate the intervention's effectiveness, we used paired-sample t-tests to compare pre- and post-intervention scores within the experimental group, and independent-sample t-tests to analyse differences between groups. To assess the effects of the intervention, we reported effect sizes where necessary. To guarantee robust results, all analyses were undertaken at a significance level of $p < .05$ in SPSS.

Table 1: Participants' Demographics

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Demographic Characteristic	Experimental Group (N = 60)	Control Group (N = 60)
Age (years)		
20-29	12 (20%)	10 (16.7%)
30-39	15 (25%)	18 (30%)
40-49	18 (30%)	17 (28.3%)
50+	15 (25%)	15 (25%)
Farming Practices		
Mono Cropping	14 (23.3%)	10 (16.7%)
Mixed Cropping	46 (76.7%)	50 (83.3%)

The demographic characteristics of the participants are presented in two categories: the experimental and control groups. As to the age category of participants, the highest proportions belong to age 40 through to 49 years, with 30% in the experimental group and the 28.3% in the control group. Findings also reveal most participants in both groups practiced mixed cropping, with higher prevalence in the control group (83.3%) than in the experimental group (76.7%).

Impact of Educational Intervention on Knowledge

Table 2: Pre- and Post-Intervention Awareness and Knowledge of Prostate Cancer and Prostate Cancer Screening

Knowledge/Understanding Topic	Experimental Group Pre-Intervention (%)	Experimental Group Post-Intervention (%)	Control Group Pre-Intervention (%)	Control Group Post-Intervention (%)	χ^2 -value
Awareness of Prostate Cancer	40.0	85.0	45.0	50.0	23.62**
Awareness of Prostate Cancer Screening	35.0	82.5	40.0	45.0	22.42**
Understanding of Risk Factors for Prostate Cancer	38.3	78.3	30.0	40.0	20.15**
Knowledge of Screening Methods Available	40.0	80.0	35.0	42.5	21.73**
Perceived Importance of Regular Screening	47.5	85.0	35.0	47.5	24.15**

Note: ** = $p < .001$

In order to draw comparisons between groups of interests (experimental and control) in terms of their awareness and knowledge concerning prostate cancer and prostate cancer screening, a Chi-square test of independence was conducted. However, differences in proportions at different times were calculated before the Chi-square test was performed. As shown in Table 2, awareness and understanding of those in the experimental group reached statistical significance between time 1 and time 2 across all measures. As an example, there was a 45% increase in the experimental post intervention as compared to those in the control group who only recorded a 5% increase. Equally, knowledge about screening methods in the experimental group increased by 47.5%, relative to the very small percentages (5%) recorded among the control group. Similarly, the understanding of the risk factors of the disease was improved in the experimental group by 40%, compared to a smaller change in the control group (10%). The knowledge of the screening methods available was improved among experimental group by 40% relative to those who were in the control group showing minimal increase of 7.5%. Finally, perceived importance of regular screening was improved by 37.5% among the experimental group compared to those in the control group at 12.5%. All comparisons showed statistically significant differences ($p < .001$), indicating the effectiveness of the educational intervention in enhancing knowledge and awareness about prostate cancer and screening methods among the experimental group. Comparably, the control group showed minimal changes in awareness and knowledge, further emphasizing the impact of the intervention.

Impact of Educational Intervention on Attitude

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Table 3: Comparison of Pre-Intervention Scores Between Experimental and Control Groups

HBM Construct	Experimental Group Mean (SD)	Control Group Mean (SD)	t-value	p-value
Perceived Susceptibility	3.50 (0.82)	3.48 (0.80)	0.18	0.86
Perceived Severity	4.08 (0.85)	4.02 (0.83)	0.43	0.67
Perceived Benefits	4.25 (0.88)	4.18 (0.86)	0.39	0.70
Perceived Barriers	3.32 (0.78)	3.30 (0.79)	0.15	0.88
Overall HBM Constructs	3.79 (0.84)	3.75 (0.82)	0.24	0.81

In a bid to determine the impact of the intervention on attitude using the items developed in line with the HBM constructs, we performed independent-sample to compare pre-intervention scores between the experimental and control groups. Findings did not show significant differences between both groups at baseline, alluding to the fact that both groups had similar directions in terms of attitudes regarding prostate cancer screening (all p-values > 0.05).

Conclusion: The increasing amount of data demonstrating the beneficial effects of educational interventions on health outcomes is reinforced by this study. The results emphasise the value of knowledge-and attitude-based interventions in preventing prostate cancer and also show how they can be applied to public health campaigns in rural areas. Future initiatives should include these tactics into larger health promotion campaigns and keep using the HBM to improve attitudes towards screening. Public health systems should also give priority to health literacy and screening access in order to effectively combat prostate cancer, especially in rural and agricultural areas.

Recommendations: To improve prostate cancer awareness and screening knowledge, particularly among underprivileged populations, public health programs should include focused educational interventions. Furthermore, incorporating the concepts of the Health Belief Model into health education initiatives might enhance attitudes and boost screening participation for preventive care. To achieve long-lasting health benefits and reinforce behaviour change, future interventions should involve community leaders, incorporate digital platforms for a wider reach, and include long-term follow-ups

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