SOCIETY FOR AGRICULTURE, ENVIRONMENTAL RESOURCES AND MANAGEMENT (SAEREM)

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BOOK OF CONFERENCE PROCEEDINGS

THEME: Effects of Fuel Subsidy removal on Climate Action, Agricultural Production and Agro Allied Industries, Food Security, Sustainable Fisheries, Biodiversity/Soil Conservation and Agricultural Resources.

DATE: 11th- 15th November, 2024

VENUE: Federal College of Forestry, Jos Plateau State, Nigeria

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Ladies and gentlemen, I welcome you all to this conference holding in the tourism town of Jos. The theme of this year's conference 'Climate Action, Effects of Fuel subsidy removal on agricultural production and Agro-allied industries, food security, sustainable fisheries, biodiversity/Soil conservation and agricultural resources" addresses so many aspects of Agriculture and food security. I have therefore decided to title my address thus:

IMPACT OF CLIMATE CHANGE ON FOOD SECURITY

The reality of climate change and frequency of its unpleasant consequences constitute significant threats to human lives across different regions of the world. The adverse outcome of climate change has necessitated global concerns and efforts at mitigating its effects as well as advocacy for measures that would restrict human actions that induce climate change. Climate change refers to changes in the mean variability properties of the climate, which persists over an extended period of time, typically within decades or longer. Climate refers to the atmospheric condition of a particular location over a longer period. The climatic condition is the long-term summation of the atmospheric elements such as solar radiation, temperature, relative humidity and precipitation and their variations over a long period. A persistent departure from the mean or/and variability properties of the climate is referred to as climate change. The main cause of the climate change experienced in the present time is the human expansion of greenhouse effect (IPCC, 2014). Human beings progressively utter the concentration of greenhouse gases and aerosols, both of which influence the climate (Enete, 2000). The greenhouse gasses produce greenhouse effects and global warming that follows it.

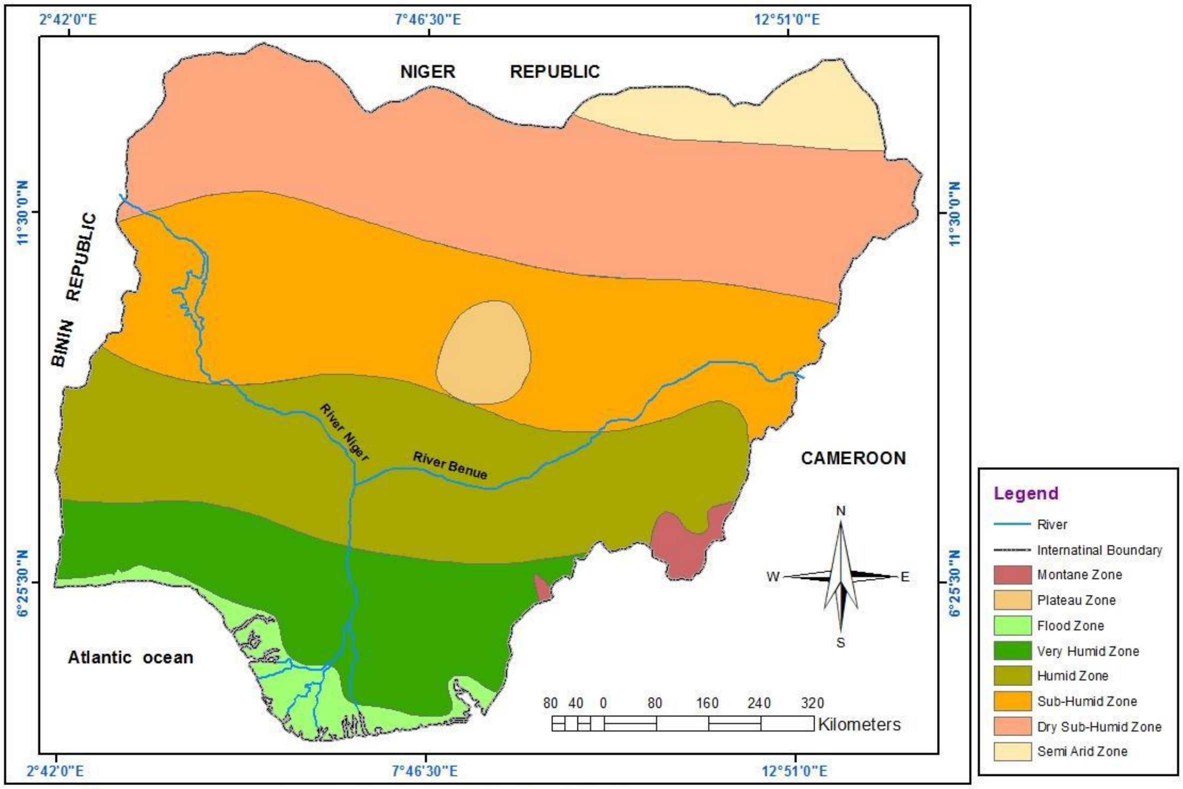
Global warming which has been a persistent manifestation of climate change is caused by the trapping of heat radiated from earth towards the space by greenhouse gases such as nitrous oxide (N_2O), Carbon dioxide (CO_2), methane (CH_4) and chlorofluorocarbons (CFCs). These greenhouse gases in their natural occurrences serve to keep the earth's atmosphere warm enough for living organism including plants and animals. However, human industrial and agricultural activities have led to expanded emissions of these gases into the atmosphere thereby resulting to an expanded greenhouse effect which brings about increase in mean atmospheric temperature otherwise known as global warming. Human activities such as burning of fossil fuels, coal and oil have led to high concentration of carbon dioxide in the atmosphere. Also, clearing of land for agriculture and industrial processes have to a lesser extent contributed to greenhouse effect. The emissions of chlorofluorocarbons (CFCs), which are synthetic compounds that have industrial origin have contributed to the destruction of the ozone layer thereby contributing to global warming.

Similarly, the changes in the natural composition of the greenhouse gases expand the greenhouse effects thereby making the earth to become warmer. The warmer condition of the earth's atmosphere results in increases evaporation and precipitation that varies across the regions. The greenhouse effect also brings about the warming of the oceans resulting to partial melting of glaciers and ice sheets which results to rising sea level. Research has shown that high concentration of atmospheric carbon dioxide has positive and negative effects on crop yield. Some category of crops according to findings does well under this condition while others do not. Climatic conditions such as floods, droughts and extreme temperature are some of the consequences of climate change. These conditions have led to crop loses and has threatened the livelihood of farmers as well as poses food security challenges overtime, to some states, especially in developing countries. The threats posed by climate change on human security have generated global concerns leading to some global initiatives and measures aimed at regulating human activities that induce global warming. The Kyoto protocol for instance was aimed at regulating the emissions of greenhouse gases through industrial processes in the countries of the world.

Nigeria is not shielded from the rest of the world in terms of the effect of climate change. The outcomes of climate change have been felt across the vegetative regions of the Nigeria. Research has shown that climate change is increasingly becoming a major threat to agricultural productivity in Nigeria. Some previously well drained agricultural plains have become flooded in recent times, also the increasing aridity of the Sahel and Sudan savannah belts have adverse effects on agricultural activities in the region (Ojo and Adebayo, 2012). Other outcomes of climate change such as heavy precipitation, abnormal onset and cessation of rainfall, rising temperature and alteration in relative humidity have negative consequences on agricultural activities and food systems in Nigeria. This alteration has led to disruption in the seasonal pattern of food production and distribution, thereby creating shortfall in supplies which bring rising food prices and limited access to food (Oyinloye et al., 2018).

Evidences of Climate Change in Nigeria

Nigeria, with a vast land space of 923,768 sq km, spanning across different climatic regions (see Figure 1) is understood to be highly vulnerable to climate change. There is no gain saying the fact that the country is threatened with extinction by a myriad of environmental problems, especially those triggered by climate change. Indeed, each of the 36 States and the Federal Capital is beset by one climate change problem or the other.



Source: ODNRI

Fig: 1. Nigeria' Agroclimatological Zones

There is desert encroachment and extreme droughts in the northern states as well as serious problems of flooding and erosion in the littoral southern states which are mingling to threaten Nigeria with shrinkage and collapse. Increasing climate uncertainties, sheet erosion, gully erosion, periodic flooding, biodiversity depletion, agricultural land degradation and general decline in yields of agricultural produce are now common norms in the country. All of these are both direct and indirect consequences of climate change and affects the entire 220m population whose major occupation is agriculture, which, before the discovery of oil, accounts for about 80% of the country's GDP and currently accounts for 90% of the non oil export earnings and climate dependent.

In northern Nigeria today, drought in April and May, which is accepted as normal, prevents timely land preparation and tillage. It further delays sowing and broadcasting of seeds as well as affects the transplanting of other crops. As drought extends into early June, it destroys all crops and harvests become very poor. Inadequate rains through July to October cause severe hardship to the entire country. This trend is further compounded by the fact that most of the large-scale irrigation projects are moribund. Increasing climatic uncertainties are additional threats in these drought-prone areas and also some of the major factors in risk averseness. It forces farmers to depend on low-input and low-risk technologies. Shunning new technologies to derive maximum gains during favourable seasons delays recovery after disasters. Even government investments made for poverty reduction are often lost within these high risk areas of northern Nigeria due to the persisting impacts of climate change, thus, further undermining development efforts and aggravating poverty. For subsistent farmers, who constitute more than 75% of the farming population and who find adjustments to climate change as a costly option due to the required investments, they resort to disposing or mortgaging their assets and eventually emigrating. High intense rainfall as forecasted in the southern part of the country has resulted in increased flooding and sedimentation of floodplains, making them less productive. The encroaching salinity due to sea level rise has further degraded the meagre agricultural areas. Other array of threats by the adverse impacts of climate change in Nigeria include those evident in water resources and supplies (dwindling), health (unpredictable), energy (erratic), transportation (unreliable), education (in distress), recreation and tourism (in shambles), geographical boundaries of agro-ecosystems as well as species composition and performance (changing).

Other non-economic resources such as biodiversity, air and water quality are also affected by adverse impacts of climate change. For example, many of the country's plant resources are diminishing as traditional herbalists now have to do with inferior alternatives. Migratory pattern of fish stocks have changed markedly, just as the catch has declined. Prominent animal species such as rodents, reptiles, birds and fishes and other marine organisms that were a primary source of protein for millions of citizens especially in the south are being endangered.

FOOD SECURITY: The World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. The USDA opined that "food security for a household means access by all members at all times to enough food for active, healthy life. Food security includes at a minimum, i. The ready availability of nutritionally adequate and safe foods, and ii. An assured ability to acquire acceptable foods in socially acceptable ways (i.e. without resorting to emergency food supplies, scavenging, stealing, or coping strategies)". Food security is built on three pillars: Food availability: sufficient quantities of food available on a consistent basis.

Food access: having sufficient resources to obtain appropriate foods for a nutritious diet. Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation. Food security is a complex sustainable development issue, linked to health through malnutrition, but also to sustainable economic development, environment, and trade. There is a great deal of debate around food security with some arguing that: There is enough food in the world to feed everyone adequately; the problem is distribution. Future food needs can – or cannot – be met by current levels of production. National food security is paramount but no longer necessary because of global trade. Globalization may – or may not – lead to the persistence of food insecurity and poverty in rural communities. Notwithstanding the above, the number of people without enough food to eat on a regular basis remains stubbornly high throughout the world. The figure is put around >800 million people and is not falling. More than 60% of the world's undernourished people live in Asia, while 25% live in Africa. The population of those who are hungry, however, is higher in Africa (35%). In Nigeria, the Ministry of Agriculture has estimated that 65% population is food insecure despite the fact that more than half of all employments depend on agriculture, reason being that, 90% of the produce comes from small rain-fed farms of few hectares, constrained by poor infrastructure, drought/flooding, pests and little access to credit. Many of the farmers are unable to meet their subsistence .

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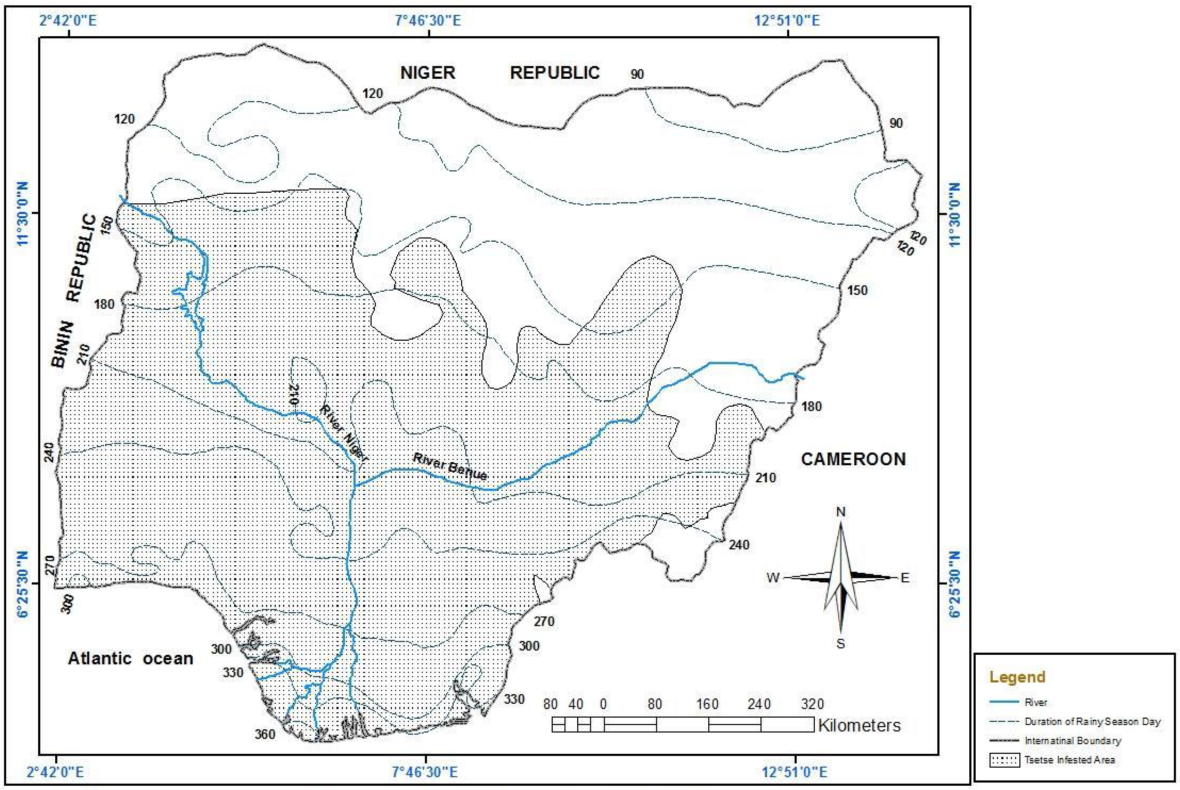


Source: ODNRI

Fig: 2. Nigeria' Profile of Agricultural Potentials

Climate change has a profound impact on food security, affecting it through various interconnected channels:

1. **Crop Yields**: Changes in temperature, precipitation patterns, and the frequency of extreme weather events can reduce crop yields. For instance, heat stress can impair the growth of staple crops like wheat, rice, and maize. Increased CO2 levels might boost plant growth in some cases, but this effect is often outweighed by negative impacts such as droughts and heatwaves.
2. **Soil Quality**: Climate change can lead to soil degradation through increased erosion, reduced fertility, and changes in soil moisture levels. This can make it more difficult to grow crops and maintain healthy agricultural lands.
3. **Pests and Diseases**: Warmer temperatures and shifting weather patterns can expand the range and increase the number of pests and plant diseases. This can lead to greater crop losses and increased use of pesticides, which can have further environmental and health impacts.
4. **Water Resources**: Changes in precipitation and increased evaporation due to higher temperatures can affect water availability for irrigation. Regions that depend heavily on irrigation may face shortages, leading to reduced agricultural productivity.
5. **Livestock**: Heat stress and changes in feed availability can negatively affect livestock health and productivity. This can lead to reduced meat, milk, and egg production, impacting food supply and prices.
6. **Fisheries**: Ocean warming, acidification, and changing currents can impact fish populations and marine ecosystems. This can affect the availability of seafood, which is a crucial protein source for many people around the world.

7. **Food Prices**: Reduced agricultural productivity and increased demand due to population growth can drive up food prices. This can make food less affordable for many people, particularly in developing countries.
8. **Economic and Social Impacts**: Food insecurity can lead to economic instability and social unrest, particularly in regions where people are heavily reliant on agriculture. Displacement due to climate impacts can also exacerbate food security issues as people move to areas with more favorable conditions.

Addressing these impacts involves a combination of mitigation strategies to reduce greenhouse gas emissions and adaptation measures to build resilience in food systems. This might include developing drought-resistant crop varieties, improving water management practices, and supporting sustainable agricultural practices. Considering the huge agricultural potentials in Nigeria government has embarked on a lot of mitigation programmes

The government on its part, as counter measures, through policy formulations have been responding to the challenges via mobilization and sensitization campaigns, enhancing small irrigation schemes, subsidies in inputs etc. The Academics have also been contributing to these counter measures through relevant research efforts and innovations in the fields of aquaculture, apiculture, livestock management/breeding/nutrition, crop improvement, water resources conservation, soil conservation etc.

. Climate Change Mitigation Measures for Improved Crop Production

Climate change mitigation involves measures that reduce the amount of emission or enhance the absorption ca- pacity of greenhouse gases. Measures which could enhance the mitigation of climate change and encourage the crop production include; carbon sequestration, use of bio-energy, farm level mitigation approaches.

P. Carbon Sequestration

Sequestration activities enhance and preserve carbon sinks and include practices that store carbon through crop

Linkages between crop production and climate change. Land management "best practices" such as no-till agriculture, or slow the amount of stored carbon released into the atmosphere through burning, tillage and soil erosion. Sequestered carbon is stored in soils, resulting in increases in soil organic carbon (SOC). There is a report that sequestration accounts for 89 percent of the technical mitigation potential in agriculture compared to 11 percent for emission abatement. The "best" management practices in agriculture such as reducing the amount of bare fallow, restoring degraded soils, improving pastures and grazing land, irrigation, crop and forage rotation, and no tillage practices can raise SOC. Sequestration of carbon thus, addresses the build of GHG in the atmosphere that contributes to climate change.

2. Bio-Energy

The production of liquid fuels from dedicated energy crop, such as grains and oilseed is to be re-examined in response to concerns over the environmental sustainability of continued fossil fuel dependence. The potential of bio-fuels to reduce carbon emissions, however, is highly dependent upon the nature of the production process through which they are manufactured and cultivated. A shift in this direction is capable of reducing the emission of carbon thereby keeping climate change problem low to support the production of food crops in Nigeria.

3. Farm Level Mitigation Approaches

Improved management practices that reduce on-farm emissions and enhance crop production include livestock manure management, fertilizer management, avoidance of bush burning, minimum tillage among others.

4. Livestock and Manure Management

Methods to reduce methane emissions from enteric fermentation include enhancing the efficiency of digestion with improved feeding practices and dietary additives. The efficacy of these methods depends on the quality of feeds, livestock breeds and age, and whether the livestock is grazing or stall-fed. A study observed that developing countries provide lower quality feed to livestock, which raises the emission rate per animal over that for developed country herds.

In livestock manure management, cooling and using solid covers for solid tanks and lagoons, separating solid from slurry, and capturing the methane emitted are relevant techniques. In developing countries in general and Nigeria in particular, applying this sort of manure management may be difficult as animal excretion happens in the field. Composting manure should be alternatives to reduce emissions.

5. Fertilizer Management

Improving the efficiency of fertilizer application or switching to organic production can decrease the amount of nutrient load and N_2O emissions. However, overall benefits would need to be weighed against the potential impact on yield. It was also revealed that fertilizer reductions of 90 percent in rain-fed maize field have been shown to reduce yield by 8.4% and 10.5% over the baseline in Brazil and China respectively. Furthermore, lack of access to soil nutrients needed for improving the quality of degraded soils is a hindrance to achieving food security is many parts of the developing world. Adequate consideration should be given to food security index in efficiency of fertilizers application or organic manure usage to ensure that the technique does not add to the national food insecurity question.

6. Avoidance of Bush Burning

Bush burning as a traditional practice of clearing the farm land contributes to the emission of GHGs such as CO_2 and CH_4 which adds to the atmospheric stock of gases thus, increasing global climate change. There is need to abolish the practice of bush burning and the emission of gases that result from the process. This could be achieved through clearing and raking of the grasses with the use of farm tools or alternatively allowing the grasses to decompose and increase the fertility of the soil. A soil that is fertile would ensure the release of nutrients for better production of crops. Equally, prohibition and punishment of defaulting farmers could serve as a deterrent to others in the habit of bush burning thus, reducing the atmospheric stock of CO_2 and CH_4.

7. Avoidance of Deforestation

Deforestation is the cutting down of tress without replacement for urban development, or erection of buildings causes disequilibrium in the carbon-oxygen balance in nature. This imbalance leaves substantial amount of CO_2 in the atmosphere which adds to the global stock of GHGs that fuel climate change problems affecting crop production. A shift from this practice through legislation and enlightenment can improve the carbon-oxygen balance thus reducing the stock of CO_2 in the atmosphere. Low emission of CO_2 reduces global climate change and its attendant effects on crop production. In addition the new business of charcoal export has heightened deforestation and at the same time increasing CO_2 emission in the process of converting the felled wood to charcoal.

P. Adoption of Appropriate Tillage Practices: Tillage operations of farmers speed up the release of stored soil organic carbon into the atmosphere that contribute to global climate change. The adoption of appropriate tillage operations such as zero or minimum tillage can sequester soil organic carbon and reduce its release to the atmosphere to add to the existing stock of gases. Good tillage practices further check soil erosion and associated dangers thereby conserving soil nutrients for greater yields of crops which would in turn address the food insecurity of the nation

THANKS FOR YOUR ATTENTION

KEYNOTE SPEAKER

Keynote Speech presented at the 7th International Annual Conference of Society for Agriculture, Environmental Resources and Management- (SAEREM) holding at Forestry Research Institute, Jos, Plateau State, Nigeria 11-15th November, 2024.

Addressing the Naira's Free-fall in the Wake of Energy Subsidy Removal: A Policy Roadmap for Nigeria's Agricultural development under democracy.

MUHAMMAD AHMAD MAKARFI, *PhD*

PROFESSOR OF AGRICULTURAL ECONOMICS

(*Former Nigerian Ambassador to the Federative Republic of Brazil*)

Protocols

Distinguished Guests, Esteemed Colleagues, Ladies and Gentlemen,

1. It is an honour for me to be invited to address you today at **the 7th International Annual Conference of Society for Agriculture, Environmental Resources and Management (SAEREM) holding at the Forestry Research Institute, Jos, Plateau State**, on a topic of great significance to our nation's future: "Addressing the Naira's Free-fall in the Wake of Energy Subsidy Removal: A Policy Roadmap for Nigeria's Agricultural development`.
2. The topic of the day, anchored by SAEREM with clear objectives on agriculture and environmental resources utilization and management, at Forestry Research Institute, is most timely and apt. This is attested by the attendance of highly knowledgeable, skilled professionals and students to the conference.
3. Personally, it the conference reminds of two events in my life. The first is my appointment at Institute of Agricultural Research, A. B. U. Zaria where I started my academic career as Assistant Research Fellow and Lecturer with the Department of Agricultural Research, Rural Sociology and Extension. The scope, depth and outputs generated by the research Programmes in Farming Systems, Cereals, Irrigation, Agricultural Engineering and so forth captures the essence of research and development enabled me appreciate the critical role agriculture plays in shaping the future of our nation. The second experience is when I led Africa Group of Ambassadors, on behalf the Dean, to the Amazon Cooperation Treaty Organization (ACTO) headquarters in Brasilia. ACTO is an intergovernmental organization formed by the eight Amazonian countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela, which signed the Amazon Cooperation Treaty (ACT), becoming the only socio-environmental block in Latin America. It aims to intensify collaboration and share knowledge on the main issues confronting the planet: Climate Change, Biodiversity loss and gain and Pollution. To seek and establish collaboration between ACTO and African countries in order to build capacity to deal with the challenges of biodiversity and climate change facing South America, Caribbean and Africa countries. Their enviable desire to seek and establish collaboration between ACTO and African countries in order to build capacity to deal with the challenges of biodiversity and climate change in the spirit of South- South cooperation touched the minds of all those present. It encouraged many of us to seek for linkages and collaborative research to advance the conservation of environmental resources.
4. It is my pleasure to note that the lead paper at this conference is going to be presented by erudite Dr Zacharia Buba Yaduma Ph D, who doubles up as the Chief Host of the Conference. An erudite Speaker, celebrated administrator and professional. I am confident he will do justice to themes, running through agriculture, climate

action, effects of fuel subsidy on agriculture, agro-allied industries, food security, sustainable fisheries, biodiversity, conservation and agricultural resources.

5. I therefore, praise the organisers for providing yet another platform for the promotion of dialogue amongst academics, professionals, experts, NGOs, business and corporate executives, public affairs managers etc. on contemporary development issues in Nigeria, Africa and beyond. As we navigate the complexities of the 21st century, it is imperative that we keep abreast with developments around us so that Nigeria's economy and security landscape could be timely, monitored, evaluated and appropriate actions taken to ensure sustainable growth and better livelihoods for the citizens.
6. Today, I will discuss how free fall of the Naira interlinked in a complex relationship removal of energy subsidies is impacting of the livelihoods of Nigeria's and the urgent need to address them, given the quantum of the victims. Proposed solutions revolve around understanding the nature of the relationship and the innovative agricultural practices that are suitable to bolster our resilience; and support policy shifts along desired directions for a prosperous and secure future for Nigerians.
7. Meanwhile, please join me to specially 11ubterran the struggle of the victims of terrorism, *kidnappings, abductions, banditry around Nigeria where the insecurity is assuming serious dimensions. Similarly,* for survival of the *Indigenous guardians of our Forests, in the Congo Basin of Africa, The Amazons of South America and all over the planet. Wildfires, oil drilling, and illegal mining are pushing the the forest dwellers, especially in the Amazon to the very edge of survival.* ***Scientists warn that if 20-25% of the forest is lost, the entire ecosystem could collapse into a dry savanna****. Indigenous guardians are the forest's last line of defence, and together we can help keep them safe. Bear in mind, life matters.*

11 | P a g e

P.2 Introduction

8. My respected colleagues, Ladies and gentlemen, permit me to share some thoughts on the pronouncements made by our President His Excellency Bola Ahmed Tinubu during his inauguration as the new President on the 29th May, 2023.
9. These pronouncements, namely the removal of energy subsidies and the floating of the Naira are major policy reversals that have profound effects on the state of Nigerian economy especially, the agricultural sector and the citizenry. These two factors affect every aspect of Nigerian life and, as students and stakeholders in the Nigerian state, it is necessary for us to understand the full implications.
10. As farmers, the specific effect on the agricultural sector is worrisome since it affects our livelihoods and that of future generations. It is in this context that we review the state of agricultural sector, some developmental changes going on as a result of the new policies to help unravel the rather, complex relationships between them. We can identify opportunities and threats that spring up, the accompanying adjustments needed to achieve intended outcomes for our survival and continuity. Actions and suggestions to relevant stakeholders for the way forward will be offered.

P.2 **Theoretical Framework**

Ladies and Gentlemen let us first, understand the implications of energy subsidy removal and the depreciation of the naira. It is essential to ground the analysis in relevant economic theories. Two key theories provide the foundation for this discussion: the theory of subsidies and the theory of exchange rates.

P.2.2 Theory of exchange rates

The theory of exchange rates is central to understanding the depreciation of the naira in the context of subsidy removal. According to the Purchasing Power Parity (PPP) theory, exchange rates between two countries should adjust to reflect changes in price levels, with currencies of countries experiencing inflation, depreciating relative to others. Nigeria's overreliance on oil exports and the mismanagement of foreign exchange reserves have contributed to a decline in the value of the naira, particularly as global oil prices have fluctuated.

1.1.2. Theory of subsidies

The economic theory of subsidies suggests that government intervention in the form of financial aid to producers or consumers is intended to lower the cost of goods or services. In the context of energy subsidies, governments typically provide financial support to energy companies, allowing them to offer products like fuel or electricity at below-market prices. This intervention is often justified by the need to ensure affordability for the population, particularly in developing economies where energy poverty is prevalent and the desire for industrialisation and growth is high. Though, this also happens in most developed economies. (Koutsoyiannis,1979)

However, subsidies can lead to inefficiencies in the market by distorting price signals. In the case of Nigeria, the government's long-standing fuel subsidy program has led to a situation where energy prices do not reflect the true cost of production, leading to overconsumption, inefficiency, and waste. Furthermore, subsidies represent a significant fiscal burden on the government, diverting resources away from other critical areas of the economy. The removal of subsidies is thus seen as a necessary corrective measure to restore market efficiency and reduce fiscal deficits.

The removal of energy subsidies, while necessary for fiscal discipline, can lead to inflationary pressures as fuel prices rise. This inflation can further weaken the naira, creating a vicious cycle where the currency's depreciation drives up import costs, leading to more inflation. In the context of Nigeria, where many goods, including fuel, are imported, the depreciation of the naira has compounded the negative effects of subsidy removal on the cost of living.

1.3 Historical context of energy subsidies in Nigeria

This review examines the historical context of energy subsidies in Nigeria, their impact on the economy, and the theoretical and conceptual frameworks that explain the interaction between subsidy removal and currency depreciation. It also delves into the current administration's policies on subsidy removal, the challenges posed by the free fall of the naira, and potential strategies for mitigating these issues. The paper concludes with recommendations for sustainable economic reform, focusing on balancing fiscal responsibility with social equity in a democratic context.

Energy subsidies have long been a point of contention in Nigeria, with successive governments grappling with the economic, social, and political implications of their removal. The removal of energy subsidies, touted as a necessary measure to free up government revenue for development projects, has triggered inflation, diminishing purchasing power, social unrest, and a free fall of the naira in the foreign exchange market.

1.4 Conceptual Framework

The conceptual framework for this research review integrates the relationship between energy subsidies, fiscal policy, inflation, and exchange rate depreciation. At the center of this framework is the idea that energy subsidies represent a distortionary fiscal policy that creates inefficiencies in the economy. These inefficiencies, in turn, lead to a misallocation of resources, reduced competitiveness, and a strain on government finances.

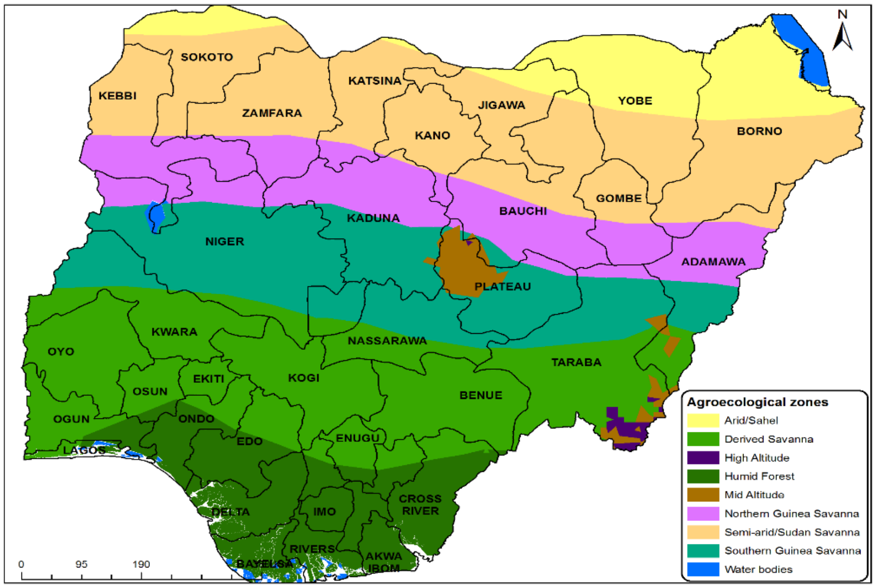
The removal of energy subsidies is conceptualized as a corrective fiscal policy aimed at restoring market efficiency and reducing the fiscal deficit. However, this policy comes with significant short-term costs, including inflation and currency depreciation, as prices adjust to market levels. The free fall of the naira, driven by both structural weaknesses in the economy and the inflationary effects of subsidy removal, exacerbates these challenges by increasing the cost of imports and reducing the purchasing power of Nigerians.

The conceptual framework also highlights the role of the democratic government in managing this transition. In a democratic context, where public opinion and social welfare are critical considerations, the government faces the challenge of balancing economic reform with the need to maintain social stability. The framework thus integrates fiscal policy, monetary policy, and political economy considerations, emphasizing the need for a coordinated response that addresses both the economic and social dimensions of subsidy removal and currency depreciation.

2.0 **Role of the agricultural sector in Nigeria's socio-economic development**

11. The roles, performances and capacities of the agricultural sector are well documented (World Bank, 2023, Idachaba, 2004) It has been the key driver of the Nigerian economy: provides food, feeds and fibre as well employment for over 70% of the active population and raw materials for local industries. It also contributes over 24.7% of the GDP. Further, the sector is key to reducing unemployment, alleviating poverty, and supporting Nigeria's broader developmental goals. The Nigerian government has increasingly emphasized agriculture in an effort to diversify the economy away from oil dependency, with limited success as, Nigeria's food import figures continue to increase, to meet up with domestic demand. For Instance, between 2016 and 2019, the country's cumulative agricultural imports stood at N3.35 trillion, which is four times higher than the agricultural export of N803 billion within the same period (World Bank, 2023).This is in spite of the abundant natural endowments , resourceful people ,favourable weather conditions Nigeria enjoys. Historically, at Independence in 1960 it relies on domestic food production for all its food needs. See Figure 1

Figures 1: Agroecological zones of Nigeria



12. Through agribusiness promotion and value-added production, agriculture drives industrial development. It is also essential for food security, with staple crops like maize, cassava, rice, and yams being widely produced and consumed locally, reducing reliance on food imports and creating opportunities for agro allied industries. A study reveals a glimpse at the 10 most cultivated food crops of each geopolitical zones reveal good potential for drastic improvements in productivity and total output if few techniques, access finance and infrastructure is improved by 25-50% across board. See Table 7 for selected five crops as at 2022 and projection to 2030.

1 Presents Table 7 Production and consumption of major food commodities per capita

Table 7: Current (2022) and Forecasted (2030) Production and Consumption per Capita Kg business as usual

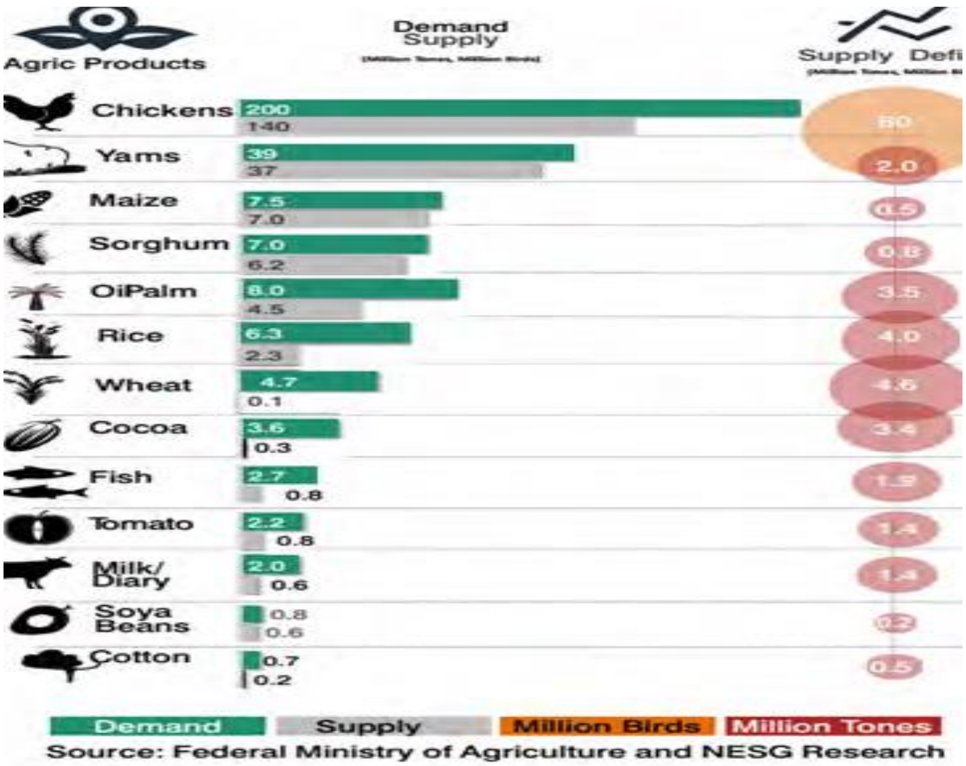
2022	Rice	Maize	Groundnut	Tomato	Cassava
Nigeria Population	219,000,000	219,000,000	219,000,000	219,000,000	219,000,000
Current production (tons)	9,444,920	13,624,990	4,760,000	3,698,170	58,955,080
Current consumption per capita (kg)	43.13	76.90	21.74	16.89	269.20
Land used HA	4,666,380	6,271,970	3,970,180	1,817,880	11,434,820
Yield MT/ha	2.02	2.45	1.20	2.03	5.16
2030	**Rice**	**Maize**	**Groundnut**	**Tomato**	**Cassava**
Nigeria Population	265,000,000	265,000,000	265,000,000	265,000,000	265,000,000
Projected production (tons)	12,691,540	16,840,820	5,933,470	5,155,910	64,992,970
Projected consumption per capita kg	47.89	63.55	22.39	19.46	245.26
Land required	6,185,540	6,882,430	5,027,320	2,904,830	16,111,880
Yield MT/ha	2.05	2.45	1.18	1.77	4.03
Difference	**Rice**	**Maize**	**Groundnut**	**Tomato**	**Cassava**
Nigeria Population	46,000,000	46,000,000	46,000,000	46,000,000	46,000,000
Additional projected Production	3,246,620	3,215,830	1,173,470	1,457,740	6,037,890
Additional consumption per capita kg	4.77	-13.35	0.66	2.57	-23.94
Additional Land required	1,519,160	610,460	1,057,140	1,086,950	4,677,060

13. Agriculture central for poverty alleviation, especially for smallholder farmers who form the bulk of Nigeria's producers. With improved access to technology, markets, and services, these farmers can boost productivity, income, and living standards
14. Agriculture also ensures food security for Nigeria's rapidly growing population, which is expected to reach over 400 million by 2050 at the current rate of growth. Local farmers produce the bulk of food consumed, though food security remains a challenge due to climate change, insecurity, poor infrastructure, and limited access to financing for smallholder farmers.

3.2 Challenges of the Agricultural sector in Nigeria

15. The agricultural sector faces many challenges that threaten its productivity and growth. First, climate change, disrupts traditional farming practices, worldwide. Inconsistent weather patterns, harsh temperatures conditions, droughts, floods, and storms are making it harder for farmers to maintain consistent yields. Droughts leads to water shortages, while excessive rainfall causes soil erosion and crop damage, significantly affecting food security. This food deficit chart shows Food Demand and Supply Deficits in 2016, indicating the historical gap in Agricultural Productivity to meet domestic demand. See Figure II

See Figure II : Demand and Supply of key food commodities in Nigeria in 2016.



16. Resource degradation is another critical issue. Agriculture relies heavily on natural resources such as soil and water, but unsustainable farming practices, including overuse of chemical fertilizers and deforestation, have led to soil fertility loss and water contamination. Improper irrigation further exacerbates the degradation of these vital resources, making lands less productive over time; this is the case with the Kano River Project, situated at Kadawa and Kura LGA, Kano State. Similar problems exist in many large-scale surface irrigation schemes
17. In many regions, insecurity poses a serious threat to agricultural activities. Farmer- pastoralist conflicts, terrorism, and banditry disrupt farming operations, force farmers to abandon their land, and damage supply chains. This not only reduces agricultural production but makes it difficult for farmers to access markets for critical inputs like seeds and fertilizers and disposal of the farm produce.
18. The adoption of modern technology in agriculture is also limited. While advances in mechanization, precision farming, and digital tools have the potential to transform agricultural practices, many farmers are unable to access

or afford these innovations. The lack of infrastructure, training, and financial support further hampers technological progress in the sector.

19. Poor Land Tenure System: Nigeria's agricultural sector faces challenges such as poor land tenure system, low level of irrigation farming.
20. Post-Harvest Losses: Nigeria experiences significant post-harvest losses, estimated to range between 5% and 20% for grains, 20% for fish and aquaculture, and 50% to 60% for tubers, fruits, and vegetables. (FAO, 2024)
21. Limited access to finance by Smallholder farmers who struggle to access credit facilities, with only 10% having access to single-digit interest loans for production; processing firms and distributors also pose a serious constraint at critical periods. Similarly finance for acquiring new technologies are in short supply.

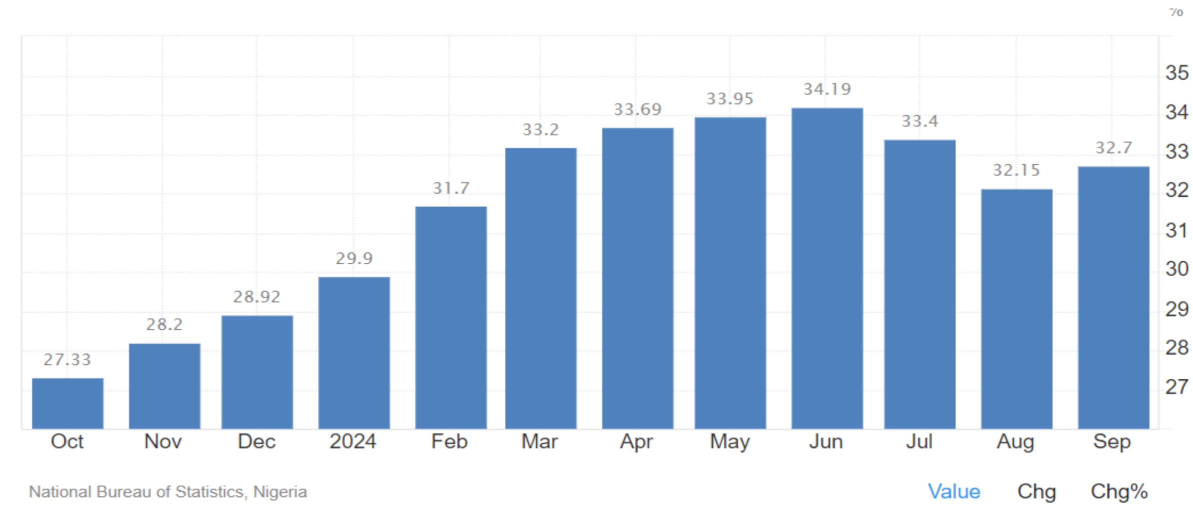
Agriculture, therefore, remains central to Nigeria's socio-economic progress, offering pathways to employment, economic growth, food security, and environmental sustainability. By adoption of modern farming techniques, expanding value chains, improving access to finance and training, Nigeria can fully harness its agricultural potential for a prosperous future (Yusuf, 2024).

4.0 **Indicators of the effects of Naira's free-fall and subsidy removal.**

From the very day of the announcements domestic supply chains were stifled. Prices of petroleum products, transportation by road, air and rail were jerked up. Price increased from

22. In 2024, Nigeria's **food inflation** surged to 35.41%, reaching a peak in April 2024 highs of 40.5% while the number of food-insecure Nigerians increased significantly to over 100 million. The sector enjoys substantial subsidies, along with all others, on energy costs and other forms of support which sudden withdrawal led to inaccessibility to key inputs and services for production and processing. See Figure I
23. The Manufacturers Association of Nigeria (MAN) and the report of the World Bank on Nigeria's industrial sector point to closure of many factories while other operation below capacity due to the surge in cost of energy which increased cost of production and distribution of their products. Up 30% decline were reported while many skilled workers lost their jobs.

Figure III showing Inflation rates in Nigeria OCT 2023- SEPT 2024.



Nigeria's **food imports** have surged to a 5-year high in the first quarter of 2024, despite the government's efforts to boost local food production. The country spent a whopping N920.54 billion on food imports from January to March 2024, which is a 95.28% increase from N471.39 billion in the same period last year (National Bureau of Statistics,2024). In fact, the NBS Foreign Trade Statistics report shows that the value of food received into the country through maritime, planes, vehicles and other mediums surged 29.4 percent from N711.4 billion expended in Q4 2023. "The major agriculture goods imported in Q1 2024 included durum wheat (not in seeds) from Canada with N130.26 billion and Lithuania with N98.63 billion." (NBS, 2024).

24. Food Insecure Nigerians have risen from 28million pre-COVID to over 100 million in 2024.In January 2024, Nigeria's food inflation surged to 35.41% from 33.9% in December 2023. The number of food-insecure Nigerians increased significantly, from 66.2 million in Q1, 2023, to100 million in Q1, 2024 (WFP, 2024), with 18.6 million facing acute hunger and 43.7 million Nigerians are showing crisis-level or above crisis level hunger coping strategies as of March,2024(NESG,2024)

25. Clearly, the sudden removal of subsidy has triggered a lot of structural and operational dislocations for the major actors along agricultural value chains that have profound effects on the economy and its ability to perform its key role stated earlier. Measures to address these could include:
26. Innovative agricultural practices: Addressing the growing challenges posed by climate change, increasing population, dwindling resources, and the need for environmental sustainability, demand change in traditional farming methods. Thus, issues like soil degradation, water scarcity, and pest resistance are making it difficult for conventional practices to meet the demands of modern agriculture. This has leads to an urgent need for new approaches that can improve productivity while minimizing environmental impact.
    a. Precision agriculture, involves the use of technologies such as GPS, sensors, drones, and satellite imagery, tools that enable farmers to closely monitor crop health and optimize the use of resources like water and fertilizers. Wide adoption and applying these inputs only where they are needed, reduces waste and improves efficiency.

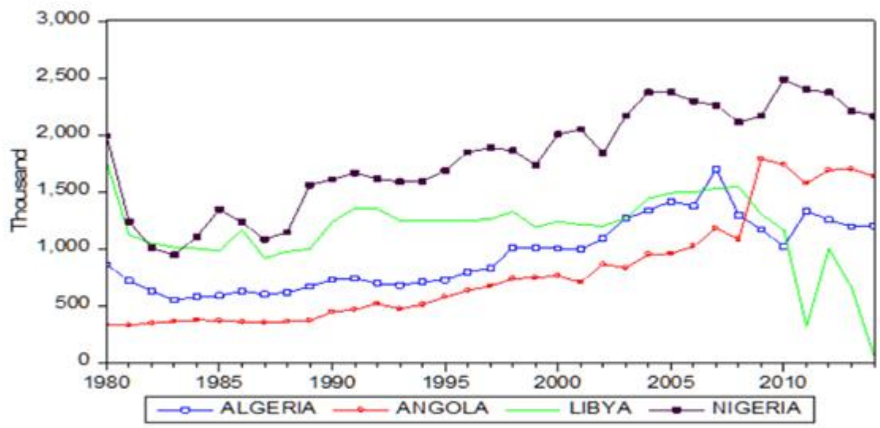
b. Techniques like conservation tillage, crop rotation, agroforestry, and organic farming help maintain soil health, prevent erosion, and promote biodiversity. These methods are designed to minimize the use of chemical inputs and reduce the environmental footprint of farming.
c. Similarly, climate-smart agriculture has emerged as a crucial strategy. The approach seeks to increase agricultural productivity and resilience while reducing greenhouse gas emissions. Farmers adopting climate-smart practices may use drought-resistant crop varieties, integrated pest management, and water-efficient irrigation systems to cope with changing weather patterns and resource constraints.
d. Urbanization and limited access to arable land have led to innovations like vertical farming and controlled environment agriculture (CEA). These methods allow crops to be grown in stacked layers or controlled indoor environments, maximizing space and resources. Vertical farming is especially useful in urban areas, where land is scarce, and it allows for year-round production of fresh produce.
e. Advances in biotechnology and the development of genetically modified organisms (GMOs) have also played a significant role in agricultural innovation. Crops engineered to resist pests, diseases, and environmental stresses can improve yields and reduce the need for chemical inputs, making farming more sustainable and productive.

5.0 Results and Discussion

5.1 Historical context of energy subsidies in Nigeria

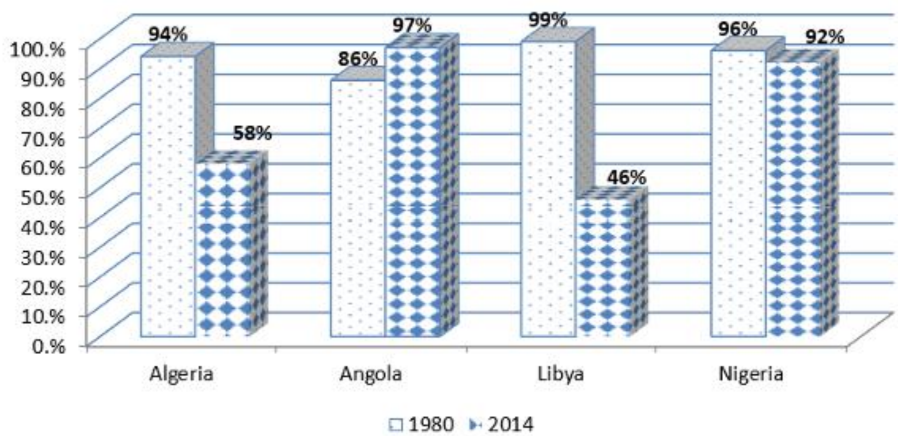
27. Nigeria's energy subsidy program has a long history, dating back to the 1970s when the government sought to shield citizens from the volatility of global oil prices. At the time, Nigeria was a major oil exporter, and the government's revenue was heavily dependent on oil exports. The subsidies were justified as a means of redistributing the country's oil wealth to its citizens, ensuring that even the poorest Nigerians could afford fuel and electricity.
28. Over time, however, the subsidy program became a significant drain on government resources. According to a 2020 report by the World Bank, Nigeria spent over $5 billion annually on fuel subsidies, representing a significant portion of the national budget. This spending crowded out investment in critical infrastructure, education, and healthcare, contributing to the country's slow economic development.
29. Meanwhile Nigeria being a key member of OPEC is expected to respect the Organizations regulations to sell petroleum products uniformly on the prevailing international prices. As a result, see the trend in four African members of OPEC namely Algeria, Angola,Libya and Nigeria. See Figure IV & V.

Figure IV : Export of Crude from African OPEC member countries 1980-2010 due to the political conflict and insecurity in the country that caused Libya unable to produce and meet the quota allocated by OPEC.



Source: OPEC Annual Statistical Bulletin (2015)

Figure 1 Exports of Petroleum Products of African OPEC Members (1,000 b/d)



Source: OPEC Annual Statistical Bulletin (2015)

Figure 2 Percentage of Petroleum Exports Per Total Exports

1 Figure 1 for Exports of petroleum products from African OPEC member countries

30. Despite several attempts to remove or reduce subsidies, successive governments have faced stiff opposition from the public and labour unions, leading to widespread protests and strikes. The most notable of these was in 2012 when the government of President Goodluck Jonathan attempted to remove fuel subsidies, leading to the `Occupy Nigeria` movement. This was repeated even recently by NLC to protests on non-implementation of agreements on subsidy, minimum wage. This forced the governments to partially reinstate the subsidies, highlighting the political sensitivity of the issue. The current administration has not bulged or succumb to pressure to review. Palliatives were however, rolled out to cushion their effects.

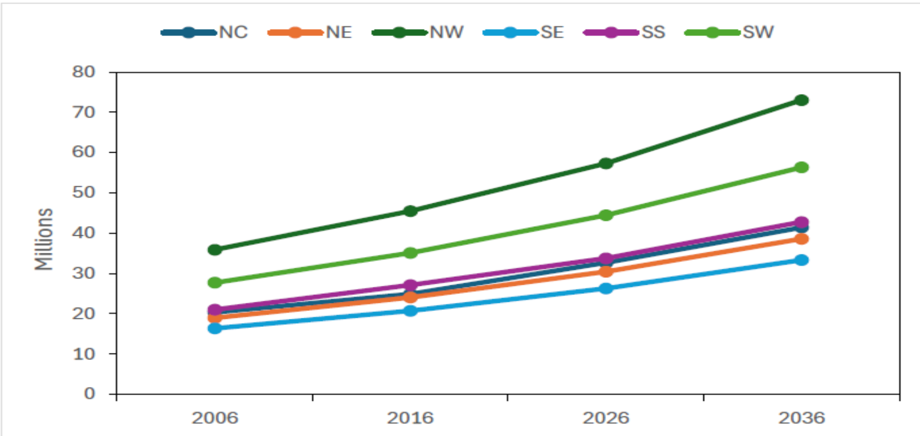
5.2 The impact of subsidy removal on the economy

31. The removal of energy subsidies is often seen as a necessary step to restore fiscal discipline and promote economic growth. In theory, subsidy removal should lead to more efficient resource allocation, as prices reflect the true cost of production. This should encourage investment in the energy sector, leading to increased supply and lower prices in the long run. So far, the FDI attracted to Nigeria as a result of these measures are yet to register their impacts on the economy. However, more debts from IMF and World Bank were secured or on the pipeline. See Figure III.
32. However, in the short term, the removal of subsidies can have significant negative effects on the economy. In Nigeria, the removal of fuel subsidies has led to a sharp increase in the price of fuel, which in turn has driven up the cost of transportation, food, and other goods. This has contributed to inflation, reducing the purchasing power of Nigerians and increasing the cost of living.
33. The inflationary effects of subsidy removal are compounded by the depreciation of the naira. As fuel prices rise, the demand for foreign exchange to import fuel increases, putting further pressure on the naira. The Central Bank of Nigeria (CBN) has struggled to stabilize the currency, with the naira losing over 30% of its value in 2023 alone. This depreciation has made it more expensive for Nigeria to import goods, leading to higher inflation and a further decline in living standards. As at October,2024 the Naira depreciation has worsened. From exchange rate of US$1= N460, it has now reached US$1= N1650.

5.3 The role of the democratic government

34. The current democratic government, led by President Bola Tinubu, has taken steps to remove energy subsidies as part of a broader economic reform agenda. In 2023, the government announced the full removal of fuel subsidies, citing the need to reduce the fiscal deficit and free up resources for development projects. This move was welcomed by International financial institutions like the International Monetary Fund (IMF) and the World Bank (WB), which have long advocated for the removal of subsidies.
35. The removal of subsidies has led to widespread public discontent, with many Nigerians protesting the higher cost of living and access to basic needs. The government has attempted to mitigate the social impact of subsidy removal by introducing social welfare programs, including cash transfers to vulnerable households. However, these programs have been criticized as insufficient, with many Nigerians struggling to cope with the rising cost of fuel and food, especially for a country battling to feed over 230 million people projected to reach over 400 million by 2036. See Figure II. The figure gives the population of each of Nigerias six geopolitical zones and the projected populations by 2036 at current population growth rates.

Figure IV. The population of Nigeria's six geopolitical zones and the projected populations 2006- 2036, at current population growth rates.



36. The democratic nature of Nigeria's government adds a layer of complexity to the subsidy removal debate. Unlike authoritarian regimes, which can implement unpopular policies with little regard for public opinion, democratic governments must balance economic reform with social stability. The government's ability to manage the fallout from subsidy removal will depend on its ability to communicate the long-term benefits of the policy while providing short-term relief to those most affected.

6.0 Conclusion and Recommendation

1. The removal of energy subsidies and the free fall of the naira represent two of the most significant economic challenges facing Nigeria, today. While the removal of subsidies is necessary to restore fiscal discipline and promote long-term economic growth, it has also led to short-term inflationary pressures and a decline in living standards. The depreciation of the naira has compounded these challenges, making it more difficult for Nigerians to afford basic goods and services.
2. The current democratic government must navigate through these challenges carefully, balancing the need for economic reform with the need to maintain social stability and cohesion. This will require a coordinated response that includes fiscal discipline, exchange rate management, and targeted social welfare programs. Thus, government must engage in a broader dialogue with stakeholders to build consensus around its reform agenda and ensure that the benefits of subsidy removal are shared equitably across society.
3. Nigeria's future lies in economic diversification, better governance, and engagement of both kinetic and non-kinetic approaches to tackling insecurity as well as embracing innovative best practices in agriculture. This could be the best way to overcome currency fluctuations and building a more resilient and prosperous economy.
4. Similarly, National and International platforms for trade need to be activated. AfCTA, ECOWAS, South-South Cooperation for peace should be engaged to reap the benefits of economic cooperation and networking.
5. **Removal of trade barrier and strengthening AfCFT** is key. Africa imports over US$100 billion worth of food annually and Nigeria is the largest importer. The grains come mainly from Ukraine and other countries. At the same time, African countries like Ethiopia, Zimbabawe and others produce surplus grains including wheat. However, the highest tariff is imposed on imported grains among African countries by sister African countries at 65% for food items among ourselves. This denies intra-African trade with consequent prohibition or creating artificial barrier on trading even when sister African countries are starving next-door and have to

trade in US Dollar. On the other hand, the aim of AfCFTA is to ease business among African countries by removing barriers to smooth flow of goods and services, 23ubterra cost of doing business and economically integrate the various communities for mutual benefits of the Region and African States.

6. In conclusion, while the removal of energy subsidies and the depreciation of the naira present significant challenges, they also offer an opportunity for Nigeria to reset its economic trajectory and build a more sustainable and equitable future. The way forward will require bold leadership, careful planning, and a commitment to both economic reform and social justice.

6.2 The way forward

7. The way forward for Nigeria in addressing the challenges posed by subsidy removal and the free fall of the naira requires a multifaceted approach.
8. First, the government must prioritize fiscal discipline by ensuring that the savings from subsidy removal are reinvested in critical sectors like infrastructure, education, and healthcare. This will help to build public trust in the government's reform agenda and demonstrate that the removal of subsidies is in the long-term interest of the country.
9. Second, the government must work to stabilize the naira by addressing the structural weaknesses in the economy that have contributed to its depreciation. This includes diversifying the economy away from oil exports, improving foreign exchange management, and encouraging investment in the non-oil sector. The CBN should also adopt a more flexible exchange rate policy, allowing the naira to adjust to market conditions while intervening when necessary to prevent excessive volatility.
10. Third, the government must strengthen social safety nets to protect the most vulnerable Nigerians from the negative effects of subsidy removal. This could include expanding cash transfer programs, improving access to affordable healthcare, and providing targeted subsidies for essential goods like food and transportation.
11. Finally, the government must engage in a broader dialogue with stakeholders, including labour unions, civil society, and the private sector, to build consensus around the need for subsidy removal and economic reform. This will help to reduce the risk of social unrest and ensure that the government's policies are seen as legitimate and fair.

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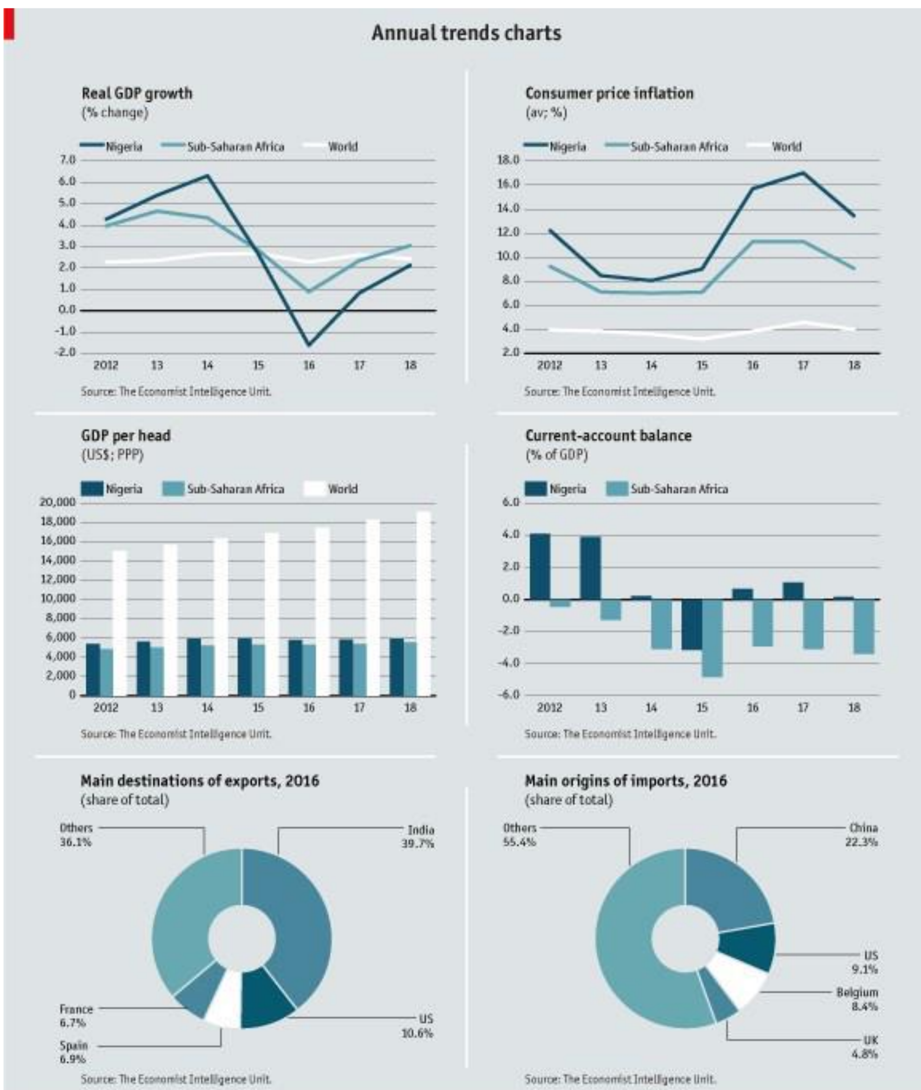

LEAD SPEAKER

CONSERVATION OF FORESTS AND WILDLIFE IN NIGERIA: THE PIVOTAL ROLE OF COMMUNITY ENGAGEMENT

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Abstract

Nigeria is a nation blessed with abundant natural resources in diverse forms and strategic locations, including expansive forests and a rich array of wildlife species. However, these invaluable ecosystems are constantly faced with threats such as deforestation, poaching and habitat loss. Preserving Nigeria's natural heritage is crucial for maintaining biodiversity and supporting the livelihoods of local communities. The article highlights the importance of forests and wildlife conservation in Nigeria, emphasizing the country's remarkable biodiversity and the essential services these ecosystems provide. It delves into various threats jeopardizing these resources, including deforestation, illegal wildlife trade, climate change and unsustainable land use practices.Recognizing the pivotal role of community engagement, the article explores how local communities can be empowered to participate in conservation efforts. By leveraging their intimate knowledge of the land and traditional practices, communities can contribute to monitoring, reforestation, and the development of tailored conservation strategies. The article presents case studies of successful community-led conservation initiatives in Nigeria, such as the Okwangwo Division of Cross River National Park, the Niger Delta Mangrove Restoration Project, and the Yankari Game Reserve initiative. These examples demonstrate the positive outcomes that can be achieved when local stakeholders are actively involved in preserving their natural resources. However, the article also acknowledges the challenges faced in fostering community engagement and ways to mitigate these barriers. Strategies to overcome these barriers, such as awareness programs, collaborative partnerships and incentive schemes, are discussed as crucial for the long-term success of conservation efforts in Nigeria.

Keywords: biodiversity, wildlife, conservation, community engagement

Introduction

Nigeria, a nation blessed with an abundance of natural resources as well as diverse forests and wildlife that are crucial to the delicate balance of its ecosystems. However, these valuable resources are constantly faced with threats such as deforestation, poaching, and habitat loss, which jeopardize their long-term survival. Recognizing the importance of preserving Nigeria's natural heritage, the role of community engagement has emerged as a pivotal component in the country's conservation strategies. Forests and wildlife conservation is the preservation, maintenance, sustainable utilization, restoration and enhancement of all species, breeds and strains of a variety of forest resources (plant and animal) especially those of economic, scientific and cultural interest to mankind for agriculture either at present or in the future (FAO, 2009). Community participation is the employment of local people to mobilize their people to make decisions, manage their resources and control the activities that affect their lives. Natural resources are of immense benefit to humanity as man depends on various forest and wildlife species for food, fuel, fibre, medicine and raw materials for a host of manufacturing purposes. The contribution of local communities in the conservation of forest has been recognized by the international community. Agarwal (2001) argued that any effort to rehabilitate the environment must rely on village members and not the government officials to do the job, because rural people already have the knowledge. Not only does this knowledge include information about different species of animals and plants, their behaviour and uses, as well as information about the way in which different aspects of the forest ecosystem inter-relate. Local people play an important role in the maintenance of forest resources. Depending on a number of historical, social and ecological factors, indigenous communities amass an extraordinary core of knowledge about how to manage the forest and utilize it sustainably. Agarwal (2001) therefore, maintained that community participation will enable the government and nongovernmental organizations to explore and exploit these local wisdom and initiatives to better conserve and manage the forest According to him, when local people participate, they will contribute their wealth of knowledge about nature to the conservation process, but where they are excluded from the forestry development process, then their contributions and experiences are either lost or left unharnessed. Plucknett (2006) observed that community participation in forest conservation has several positive effects. Some local people maintain mixed species pastures and thereby ensure food for their flock even during period of climate stress.

The significance of forests and wildlife conservation in Nigeria

Forests and wildlife conservation are crucial for Nigeria's ecological, economic, and social well-being. Forests play a vital role in regulating the climate, supporting biodiversity, and providing essential resources for the local population.

Forests act as natural carbon sinks, absorbing and storing vast amounts of carbon dioxide, which helps mitigate the effects of climate change. They also regulate rainfall patterns, preventing soil erosion, and maintain the water cycle, ensuring a reliable supply of freshwater. Additionally, forests are home to a diverse array of plant and animal species, many of which are endemic to Nigeria. Protecting these habitats is crucial for preserving the country's rich biodiversity and ensuring the survival of endangered species.

Forests also provide essential goods and services for the local communities. They offer a source of food, timber, and medicinal plants, supporting the livelihoods of rural populations. Sustainable forest management practices can also generate economic opportunities, such as ecotourism and the production of non-timber forest products. Conserving these natural resources ensures that they can be enjoyed and utilized by present and future generations. Beyond their ecological and economic significance, forests hold immense cultural and spiritual value for many Nigerian communities. They are often seen as sacred spaces, with certain trees and animals holding deep cultural and religious significance. Preserving these natural landscapes is crucial for maintaining the cultural heritage and identity of local populations.

Community Engagement: The Key to Conservation Success

Community participation in the conservation of forests and wildlife play a vital role in environmental management and sustainability. Involving local communities in the management and conservation of forests resources and wildlife creates incentives for them to become good custodians of these resources. This inclusiveness is more likely to build a conservation ethic where people understand that involvement in the conservation of resources is crucial (Sam et al., 2014). The involvement of community members in the conservation of resources is considered the best alternative, especially in the face of the gradual extinction of forest and wildlife resources (Sam et al., 2014). Community participation helps in the conservation of forests and wildlife and reduces threats that could undermine proper management. Some roles of community participation in the wild include: monitoring resources, protecting forests from illegal hunting (poaching) and bush burning, reducing the level of poverty, increasing wildlife habitat, improving water and air quality, increases productivity as well as income to all involved, increased community vitality, pride, identity and cohesiveness, decrease human disturbance, provision of health benefits such as reduced levels of anxiety, aggression and conflict resolution. Other benefits include tourism, recreational use, spiritual and cultural significance, genetic resources preservation, wildlife habitat protection and watershed protection.

The Importance of Community Involvement

Community engagement is a fundamental approach to achieving successful conservation outcomes in Nigeria. Local communities possess intimate knowledge of the land and its species, making them invaluable partners in conservation initiatives. Empowering local communities to manage and protect their natural resources fosters a sense of ownership and accountability, which enhances the effectiveness of conservation strategies. Engaging local communities is paramount to the success of forest and wildlife conservation efforts in Nigeria and by increasing local awareness and participation, conservation initiatives can harness the collective efforts of the people to protect these essential ecosystems for future generations. Additionally, the incorporation of traditional ecological knowledge held by these communities can offer sustainable solutions tailored to local contexts.

Empowering Communities: Strategies and Approaches

Empowering communities in the conservation of forests and wildlife is a crucial aspect of sustainable environmental management in Nigeria. Some of several strategies and approaches to achieve this goal include:

- **Environmental Education Programs**: Implement educational initiatives in schools and community centers focusing on the importance of biodiversity, ecosystem services, and sustainable practices is a key approach to empowering communities for conservation and sustainable development.
- **Participatory Planning**: Involve community members in decision-making processes related to conservation projects to ensure their voices are heard and local knowledge is utilized.
- **Promotion of Alternative Livelihoods**: Encourage practices such as agroforestry, ecotourism, and sustainable fisheries that lessen reliance on forest exploitation.
- **Access to Microfinance**: Provide small loans or grants to support community members in starting eco-friendly businesses, such as handicrafts that utilize non-timber forest products.
- **Strengthening Land Tenure Rights**: Advocate for policies that formalize land rights for indigenous and local communities, enabling them to manage and benefit from forest resources.
- **Supporting Local Governance**: Empower local institutions to enforce conservation laws and regulations, offering training in biodiversity management and conflict resolution.
- **Promote Community-Led Ecotourism**: Encourage communities to develop ecotourism initiatives that highlight their cultural heritage while generating income and awareness for conservation efforts.
- **Mobile Apps for Monitoring**: Introduce mobile technology for communities to report wildlife sightings, illegal activities, and forest changes, thus engaging them in wildlife monitoring.
- **Remote Sensing and GIS**: Train community members in using Geographic Information Systems (GIS) for mapping and planning conservation areas.
- **Conducting Periodic Assessments**: Collaborate with communities to assess biodiversity and ecosystem services, placing value on forests and wildlife beyond timber and game benefits.
- **Integrating Indigenous Knowledge**: Incorporate traditional ecological knowledge in biodiversity assessments and conservation planning to enrich strategies and improve outcomes.
- **Recognition Programs**: Develop recognition systems for communities that successfully implement conservation practices, such as awards or certifications.
- **Mediation Training**: Provide training in conflict resolution techniques to address disputes over resource use, ensuring collaborative and peaceful practices among community members.
- **Building Trusting Relationships**: Foster trust between communities, local governments, and conservation entities to reduce tensions and promote joint conservation efforts.

By employing these strategies, communities in Nigeria can take active roles in conserving their forests and wildlife, leading to sustainable development and improved livelihoods.

Roles of Local Communities

Local communities play a crucial role in conservation initiatives, leveraging their intimate knowledge of the land and its species. They are often the first to observe changes in wildlife populations and ecosystem health, providing critical data to guide conservation priorities. Indigenous and traditional knowledge held by these communities offer valuable insights into sustainable land management and wildlife protection.

Community members can participate in conservation efforts in various ways, such as:

- Forest monitoring and patrolling to protect wildlife and prevent illegal logging and poaching.
- Cultivating community nurseries to facilitate reforestation and restore degraded lands.
- Collaborating with organizations to develop and implement conservation plans tailored to local contexts.

Benefits of Community-Based Conservation

Engaging communities in conservation strategies offers numerous benefits that extend beyond biodiversity preservation, including:

- Empowerment and capacity building of local stakeholders
- Generation of economic opportunities through sustainable livelihoods
- Preservation of cultural heritage and traditional practices
- Mitigation of conflicts over resource use through increased dialogue and cooperation

Successful Case Studies

Community-led conservation initiatives have been crucial in protecting biodiversity and ecosystems in Nigeria, including areas like Okwangwo Cross River National Park, the Niger Delta, and the Yankari Game Reserve. Here are case studies from these three initiatives:

1. Okwangwo Cross River National Park

P. **Background**

Okwangwo is part of the Cross River National Park, which is one of the most biodiverse areas in Nigeria. It is home to endangered species such as the Cross River gorilla.

ii. Community engagement approach

- **Eco-Guards Program**: Local communities were trained to become eco-guards, enabling them to monitor and report illegal activities like poaching and illegal logging in the park. This initiative helped rebuild trust between park management and local communities.
- **Community Forestry Initiatives**: The park management involved local tribes in sustainable forest management practices. Communities participate in resource management decisions and share benefits from eco-tourism ventures, enhancing their economic incentives to protect the park.

iii. Outcomes

- Increased local participation in conservation efforts, leading to a reduction in poaching and illegal logging.
- Improved community livelihoods through eco-tourism initiatives, such as guided tours and cultural experiences linked to the park.

2. Niger Delta Restoration Project

P. **Background**

The Niger Delta is known for its rich biodiversity but has faced severe environmental degradation due to oil extraction and neglect of natural resources. The restoration project aims to reclaim and protect the ecosystem while engaging local communities

ii. Community engagement approach

- **Restoration of Mangroves**: The project involves local communities directly in reforestation efforts, particularly the planting of mangroves, which are crucial for biodiversity and preventing coastal erosion.
- **Livelihood Enhancement Programs**: Training programs were implemented to teach alternative livelihoods that are less damaging to the ecosystem, such as aquaculture and sustainable fishing practices. Communities receive support for eco-friendly agriculture.

iii. Outcomes

- Successful restoration of degraded areas with visible increases in mangrove coverage and a resurgence of wildlife.
- Enhanced community resilience through diversified livelihoods, leading to increased income and reduced dependence on environmental degradation.

3. Yankari Game Reserve Initiative

i. Background

Yankari Game Reserve is one of Nigeria's premier wildlife reserves, known for its diverse fauna and natural hot springs. In the past, the reserve faced challenges related to poaching and habitat destruction due to local communities' activities.

ii. Community engagement approach

Community-Based Tourism: The reserve engaged local communities by allowing them to provide services to tourists, including guiding, accommodation, and selling crafts. This helped communities see direct benefits from tourism.

Conservation Awareness Programs: The reserve implemented educational outreach to raise awareness about wildlife conservation and the importance of protecting biodiversity, fostering conservation-minded attitudes among locals.

iii. Outcomes

- Increased wildlife populations due to the reduction in poaching fueled by community involvement in tourism and conservation.
- Long-term economic benefits through community investments in education and health facilitated by income earned from tourism-related activities.

These case studies illustrate the effectiveness of community-led conservation in different ecological contexts across Nigeria. By empowering local populations and creating economic incentives for conservation, these initiatives have helped protect biodiversity while improving community livelihoods. Strengthening partnerships and enhancing community capacities are essential for sustaining these positive outcomes.

Overcoming Challenges: Addressing Barriers to Community Engagement

Community engagement in conservation efforts is not without its challenges. Economic and social barriers, such as poverty, population pressure, and cultural attachment to ancestral lands, often hinder the effective participation of local communities. Some of the ways in fostering a robust community-based conservation in Nigeria are as follows:

i. **Integration of diverse knowledge and values**: There is a need for a more pluralist approach that recognizes and integrates the different understandings, meanings, and values that various stakeholders (local communities, conservation authorities, etc.) have towards biodiversity, the environment, and nature. This "fusion knowledge" can help develop locally appropriate and adaptive resource management practices.

ii. **Inclusive and deliberative decision-making**: finding a fair and just means of including the plural values, knowledge, and interests of different stakeholders in the decision-making and management processes is key to an improved community based conservation. This requires moving beyond passive or coercive forms of participation and applying deliberative inclusionary processes that allow for learning, negotiation, and collective action.

iii. **Transforming conservation institutions**: creating new, flexible, and adaptable institutions for conservation and development that can manage complex ecological systems and accommodate diverse stakeholder interests and values is a key step in encouraging and sustaining community based conservation. These institutions must work across different scales, link global and local interests, and evolve based on principles of social learning to cope with ecological and social complexity.

Addressing these challenges requires a nuanced approach that takes into account the unique circumstances of each community.

Strategies for Successful Community Engagement

To overcome these barriers, strategies should focus on education, collaborative partnerships, and the implementation of incentive programs. By empowering communities through capacity-building initiatives, fostering multi-stakeholder dialogues, and providing tangible economic incentives for sustainable practices, conservation efforts can gain the necessary support and buy-in from local populations.

Conclusion

The conservation of Nigeria's forests and wildlife is a complex undertaking that requires a holistic approach. By placing community engagement at the heart of conservation strategies, Nigeria can harness the invaluable knowledge and commitment of its people to protect its natural heritage. To achieve this, community-based conservation policy should be implemented to the letter in a bid to curb environmental degradation and promote community involvement. The Community members should be involved in the planning, conservation of natural resources and be empowered by providing alternative means of livelihood for local people to reduce over-dependence on environmental resources. Through collaborative efforts, awareness-raising, and the creation of sustainable economic opportunities, communities can become active stewards of their environment, ensuring the long-term preservation of Nigeria's biodiversity for generations to come.

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LEAD PAPER

Fraction of Non-Renewable Biomass (Fnrb) Assessment for Nigeria

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ABSTRACT

When replacing biomass feedstock cannot keep pace with consumption, it becomes a non-renewable biomass source (NRB). If more wood is harvested than the landscape can replace, as is often the case in Nigeria and other developing countries where people rely heavily on fuelwood and charcoal, harvesting is not sustainable and tree cover will decline over time. The fraction of non-renewable biomass (Fnrb) measures the relative amount of wood harvested above the landscape's natural regeneration rate. The present Fnrb assessment for Nigeria is based on the Clean Development Mechanism Tool 30 using international and local data sources (Forest Reference Emission Level for Nigeria, data from the Federal Department of Forestry, FAO). An Fnrb value of 72.5% was computed for the country. This value is more than the current default value of 30% adopted by the CDM and suggests rapid depletion of accessible biomass. This indicates that l*arge percentages of wood harvest are non-renewable, and successful interventions can claim high emission reductions. It was assumed in this study that the only renewable biomass nationally was 'Demonstrably Renewable Biomass', using data for forests within protected areas. Recent reports indicate that this approach overestimates Fnrb because the available renewable biomass is underestimated as fuelwood sourced from lands other than protected areas is not included. This notwithstanding, projects aiming to reduce household biomass consumption through cookstove projects should be promoted to mitigate uncontrolled fuelwood collection practices among most rural communities, which can cause massive degradation of ecosystems and a decline in biodiversity.*

INTRODUCTION

Biomass energy is derived from organic material from living organisms, such as plants and animals**.** Common biomass materials used for energy include plants, wood, and waste. Biomass can be a source of renewable energy. Biomass feedstocks include wood and crops such as maize or sugarcane. If the biomass feedstock is not replenished as quickly as it is used, the biomass energy then becomes a non-renewable energy source. This contradicts the widely held notion that biomass energy is renewable. For example, biogas from landfill sites become depleted with the rotting of the organic matter. Also, since there is a growing promotion of recycling to reduce man-made waste (e.g. food waste, paper, plastics, etc.), these biomass types are becoming depleted and are therefore non-renewable.

Fraction of non-renewable biomass (Fnrb)

Carbon emission is the release of carbon compounds (-greenhouse gas emissions**,** the main contributors to climate change) into the atmosphere. In contrast, carbon footprint is the carbon dioxide emissions associated with a person or entity's activities and consumption.

To determine emission reductions, it is necessary to calculate the fraction of non-renewable biomass (Fnrb). Fnrb measures the relative amount of wood harvested above the landscape's natural regeneration rate. Interventions that support transitions to more efficient cooking practices can reduce forest degradation and climate-warming emissions because trees that would have been harvested if the intervention had not been introduced remain standing. The Fnrb is a critical input for calculating emissions reductions, especially from clean cooking interventions. C*lean cooking* is when a system meets the emission rate targets in the World Health Organization (WHO) guidelines (2014). It entails the use of cleaner fuels and energy-efficient modern stoves instead of traditional biomass or polluting fuels. Clean cooking reduces fuel needs and thus reduces the burden on families for fuel wood collection/sales and improves health.

Thus, Fnrb allows for comparison of intervention and non-intervention scenarios in the carbon market while considering variables like woodfuel demand sources and land cover change. Most of Nigeria's rural communities rely heavily on fuelwood collection for their livelihood, which has a vital role in sustaining the people's livelihoods and well-being. The fraction of non-renewable biomass (Fnrb) measures the relative amount of wood harvested beyond the landscape's natural regeneration rate. If more wood is harvested than the landscape can replace, as is the case in Nigeria and other developing countries where households and communities rely heavily on fuelwood and charcoal, harvesting is not sustainable, and tree cover will decline over time (Fig. 1). This leads to landscape degradation and may also contribute to long-term deforestation.

Promoting clean cooking systems can reduce climate-warming emissions and forest degradation from the increased standing stock of trees. The reduced emissions generate carbon credits for clean cooking projects. Locations with higher Fnrb values (meaning larger percentages of wood harvest are non-renewable) have the potential for greater emissions reduction (UNFCCC 2023).

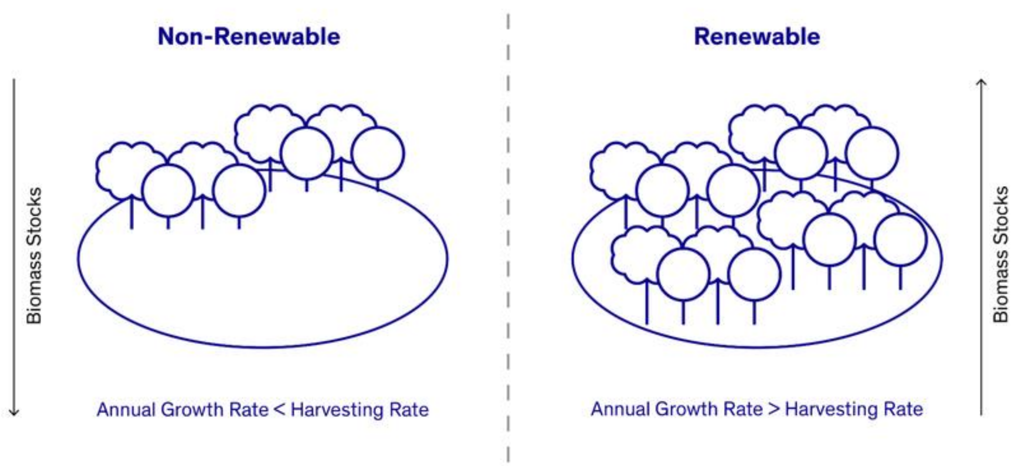

Figure 1. Harvesting in a sustainable manner that does not exceed an area's annual growth rate is viewed as renewable, as woody biomass stocks will remain constant or potentially increase; whereas harvesting at a rate that exceeds an area's annual growth rate is non-renewable, as it would lead to a decline in woody biomass stocks. Fnrb values close to 90% suggest rapid depletion of all accessible biomass in an area (Gwin et al., 2023)

METHODOLOGY FOR ASSESSMENT OF Fnrb

The present Fnrb assessment was based on Clean Development Mechanism (CDM) Tool 30 at the national level based on international and local data sources (Forest Reference Emission Level (FREL) for the Federal Republic of Nigeria, Federal Department of Forestry in FAO 2015, 2020). This approach for calculating emission reductions primarily relies on country-specific default values (or a similar tool for project-specific assessments) estimated by the Clean Development Mechanism and United Nations Framework Convention on Climate Change (UNFCCC), and approved by a locally designated national authority.

The Fnrb can be determined for the country, a project activity, or a program of activities (PoA). The NRB assessment approach provided in CDM (UNFCCC) methodology AMS-II.G was used. This option is based on the concept of Demonstrably Renewable Woody Biomass (DRB). The applicable equation is:

$$fNRB = \frac{NRB}{NRB + DRB} \quad (1)$$

Where:

Fnrb *Fraction of non-renewable biomass (fraction or*
%)NRB *Non-renewable biomass (t/yr)*

DRB *Demonstrably renewable biomass (t/yr)*

The Fnrb is estimated at the national level since the available data on forests are more accessible, complete, and accurate at the national level. The value of NRB can be derived from:

- The Total Annual Biomass Removals I, approximated by the quantity of woody biomass used annually in the country in the absence of the project activity;
- The proportion of R that is demonstrably renewable (DRB) and non-renewable (NRB).

Where:

$$NRB = R - DRB \quad (2)$$

R *Total annual biomass removals (t/yr)*

The Total Annual Biomass removal for the country was calculated as the sum of the Mean Annual Increment in biomass growth (MAI) and the Annual Change in Living Forest Biomass stocks (ΔF). The annual biomass removals (R) was calculated as the sum of the two:

$$R = MAI + \Delta F \tag{3}$$

Where:

MAI	*Mean Annual Increment of biomass growth (t/yr)*
ΔF	*Annual change in living forest biomass (t/yr)*

The Mean Annual Increment of biomass growth (MAI) was calculated as the product of the extent of Forest (F) in hectares in the country and the country-specific Growth Rate (GR) of the Mean Annual Increment:

$$MAI = F \times GR \tag{4}$$

Where:

F	*Extent of forest (ha)*
GR	*Annual Growth rate of biomass (t/ha-yr)*

The Demonstrably renewable biomass (DRB) was calculated as the product of the Protected Area extent of Forest (PA) in hectares and the country-specific Growth Rate (GR) of the Mean Annual Increment:

$$DRB = PA \times GR \tag{5}$$

Where:

PA	Protected Area Extent of Forest (ha)

The Fnrb result obtained at the national level is 72.5 % as described in Table 1 below.

Table 1: National Fnrb result for Nigeria

Data Symbol	Parameter	Value	Unit	Information Source
	Total Land Area of Country	91,077,000	Ha	Global Forest Resources Assessment 2020 Report Nigeria, Rome 2020
F	The extent of forest in the country (Ecological zones: Derived savanna, Guinea savanna, Sudan Sahel, Lowland rainforest, Mangrove swamp, and Montane Forest).	22,280,358	Ha	National Forest Reference Emission Level for the Federal Republic of Nigeria (Global Forest Resources Assessment 2020 Report Nigeria, Rome 2020)
GR	The growth rate of biomass	3.43	t/ha/yr	(Default GR value for Nigeria 3.43t $ha^{-1}yr^{-1}$) (CDM-WG 37th Meeting Report Annex 14).
MAI	Mean Annual Increment in Biomass Growth	76,421,627.9	t/yr	Calculation (MAI= F x GR)
ΔF	Annual change in living forest biomass	-9,961,910	t/yr	Calculated using an annual change of -163,310 ha using an average C density of 61 t C ha^{-1} (FRELs Nigeria FAO 2015, 2020).
R	Total annual biomass removals	66,459,717.9	t/yr	Calculation (R=MAI+ ΔF)
PA	Protected terrestrial areas (Forest area within Pas + forest areas with long-term management plan)	5,331, 840	Ha	Global Forest Resources Assessment 2020 Report Nigeria, Rome 2020; (FAO2015; knowledge.unccd.int/sites/default/files/Idn.., pdf file)
DRB	Demonstrably renewable biomass	18,288,211.2	t/yr	Calculation (DRB=PA x GR)
NRB	Non-renewable biomass	48,171,506.7	t/yr	Calculation (Total annual removals I-Protected area growth (DRB).
Fnrb		**72.5%**		**Using data for forests within Pas.**

Validated default Fnrb values are absent at the national level in Nigeria.

DISCUSSION

Since 2020, the country-specific defaults originally approved by the CDM and UNFCCC are no longer permitted for use in CDM projects. The default country-specific Fnrb values have expired (CDM/UNFCCC 2023). The United Nations Framework Convention on Climate Change is now promoting research to establish updated fraction of non-renewable biomass (Fnrb) values.

The present Fnrb assessment is based on CDM Tool 30 at the national level. An Fnrb value of 72.5% was computed for the country. This value is slightly less than the previous global country default value of 85% and more than the current default value of 30% adopted by the CDM (Gwin et al., 2023). Fnrb values close to 90% suggest rapid depletion of all accessible biomass in an area (Gwin et al., 2023). Such Fnrb values indicate that large percentages of wood harvest are non-renewable and successful interventions can lay claim to higher emission reductions (Ghilardi and Bailis 2024). Conversely, lower values of Fnrb indicate that smaller percentages of wood harvest are non-renewable, and interventions can claim fewer emission reductions. It was assumed in this study that the only renewable biomass nationally was 'Demonstrably Renewable Biomass' (DRB), using data for forests within protected areas. That is biomass originating from protected areas such as wildlife reserves, national parks, and community-protected forests. This implies that all biomass in other land areas that are not explicitly sustainably managed is considered non-renewable. Recent reports suggest that this approach overestimates Fnrb because the available renewable biomass is underestimated as fuelwood sourced from lands other than protected areas is not included; when in fact renewable and non-renewable conditions can exist in many contexts.

The updated Fnrb values for woodfuel interventions in Nigeria are estimated at 39% or 44% for urban Fnrb for the current decade (2020-2030) (Ghilardi and Bailis 2024). The higher value of 72.5% determined in this study suggests the need for further analysis of the sources of data used in TOOL 30 and the application of new calculation methodologies introduced by UNFCCC. The lower Fnrb values may compensate for a projected decrease in woodfuel demand. This notwithstanding, the uncontrolled fuelwood collection practice among most rural communities can cause massive degradation of ecosystems and a decline in biodiversity. Also, the burning of woodfuel can have damaging health effects. Projects aiming to reduce household biomass consumption include improved cookstoves. Cookstove projects distribute stoves that are cleaner or more efficient than traditional technologies so that people require fewer woodfuels for cooking and thus carbon emissions are reduced or avoided.

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TECHNICAL SESSION FOR THE 7TH INTERNATIONAL SAEREM/JOS2024 CONFERENCE

S/N	TOPIC/AUTHOR(S)	REMARKS
KNS	*Addressing the Naira's Free-fall in the Wake of Energy Subsidy Removal: A Policy Roadmap for Nigeria's Agricultural development under democracy.* **Muhammad Ahmad Makarfi, *PhD*; Professor Of Agricultural Economics; (*Former Nigerian Ambassador to the Federative Republic of Brazil*)**	**Keynote Speaker**
LS	**Conservation of Forests and Wildlife in Nigeria: The Pivotal Role of Community Engagement** **Zacharia Buba Yaduma *PhD*, Director General/CEO; Forestry Research Institute of Nigeria,Ibadan**	**Lead Speaker**
LP1	**Fraction of Non-Renewable Biomass (Fnrb) Assessment for Nigeria** **Prof. Ani Nkang FNES, FSAEREM, FIIA**	**Lead Paper**
SIC01A	**Evaluation of Insecticidal Potentials of Some Plant Materials Against Cowpea Weevil (*Callosobruchus maculatus)* on Stored Cowpea Seeds.** Okechukwu, O.M[1], Ugochukwu, G.U. [1], Azuike, P.A.[2], Okuwa, J.A.[1] and Okoro, L.C.[2]	**FCF/S24 TS01**
SIC01B	**Exploratory Landuse Activities and Particulate Matter Pollutants Concentration in A Selected Rivers East and Rivers South-East Community, Rivers State** **[1]Okwakpam, I. O., and [1]Onugha, A. C.**	**FCF/S24 TS02**
SIC01C	**Evaluation of Extension Services Delivery among Rural Populace on the Adoption Ofimproved Wheat Production Technologies in Bebeji Local Government Area of Kano State Nigeria.** [1]Mohammed, U., [1]Baba, K.C, [1]Ubandoma, G.A. [1]Adedeji S.O	**FCF/S24 TS03**
SIC02A	**Economic Analysis of Cowpea Production in Ankpa Local Government Area of Kogi State, Nigeria: Prospect For Food Security.** **M. K. Ibrahim[1], S. Danjuma[2*] and U. M. Shaibu[1].**	**FCF/S24 TS04**
SIC02B	**Assessment of The Eutrophication Level of Municipal Surface Water in Jos Metropolis, Plateau State** [1]Henry, M.U., [2]Henry, U.I.,[1]Lekduhur, J., [4]Eyoh, E.A. and Akintunde, S.	**FCF/S24 TS05**
SIC02C	**A Review of Using Rabbit Production To Improve Food Security And Animal Productivity In Nigeria. Muhammad, A.S[1], Shuaibu, H.I[2], Saidu, A.D[3]**	**FCF/S24 TS06**
SIC03A	Actions of *Vernonia amygdalina* (Bitter Leaf) Extracts on a Gastroenteritis Bacteria in a Coastal Agricultural Environment in Southwestern Nigeria Bello Hafiz[a] Adewale M. Taiwo[b] Bada Mutiu[c] Adeosun Mary Olasubomi[a] Adelanwa Olulaanu[d]	**FCF/S24 TS07**
SIC03B	**Organic fertilizer and growth inhibitors influencing the chlorophyll content of *Amaranthus cruentus* (L.) under drought conditions** **Aliyu, A.M[1&2]., Shittu, E.A[2]., and Muhammad, A[1].**	**FCF/S24 TS08**
SIC03C	**Effect of ill-health on Agricultural Productivity and Food Security in Kebbi State, Nigeria . Muhammad, A.M[1], Alhassan, Y. J[2], Manga, T.A[1] and Isah A[2]**	**FCF/S24 TS09**
SIC04A	**Impacts of egg position and duration of storage on external qualities of Isa brown eggs.** Olubisi O. Oyeleye*, Adelani A. Adeoye, Abiodun A. Rufai and Pelumi S. Olotu	**FCF/S24 TS010**

SIC04B	**Effect of Different Levels of Maca (*Lepidium meyenii* L.) Root Powder as Feed Additive on the Performance of *Clarias gariepinus* (Burchell, 1822) Hatchlings** ***Jibrin, B.[1] and Ali, M. E.[2]**	**FCF/S24 TS011**
SIC04C	**A Review on Applications of Artificial Intelligence Devices in Aquaculture. *Jibrin, B.[1] and Onyia, L.U.[2]**	**FCF/S24 TS012**
SIC05A	**Climate Change Mitigation Strategies: Socio-economic and Constraints of Poultry Farmers in Southern,** Nigeria **. *Nyong, Eteyen , * Elizabeth Atairet *Melford, Smart, Udumo Bassey Obeten, and **Kenneth Iwatt**	**FCF/S24 TS013**
SIC05B	**Greenhouse gas emissions from livestock production in Nigeria: exploring options for its mitigation** *Adeyemi, M. A. and Akinfala, E. O	**FCF/S24 TS014**
SIC05C	**Assessment of Black Seed *(Nigella sativa)* Oil on Growth Performances and Morphometric Indices of *Clarias gariepinus* Juveniles** ***[1]Ayebidun, O.V; [1]Olusola, S.E; [2]Ogunbameru, P.L**	**FCF/S24 TS015**
SIC05D	**Exploring Fungal Diversity: A Comprehensive Study of Fungi Species in Ondo Agro-Ecological Zone** **[1]Ariyo, A.C., [2]Ajayi, A.M., and [1]Adeyemi D. P**	**FCF/S24 TS016**
SIC05E	**Serum Indices of Broiler Chickens Offered Bitter Leaf (*Vernonia amygdalina*) EXTRACTS IN Drinking Water;** Asaniyan*, E. K.	**FCF/S24 TS017**
SIC05F	**Evidence of the Impact of Land Use on Some Soil Physiochemical Properties in A Tropical Alfisol, Southwest Nigeria.[1]Michael Rotimi Olojugba* [2]Amos Afolarin Olajide and Yemi Olanipekun**	**FCF/S24 TS018**
SIC05G	**Physical Properties of Bitumen Laden Soils: Implication for Soil Nutrient Conservation** **Ogunsusi, Kayode**	**FCF/S24 TS019**
SIC05H	**Profitability analysis of four-week-old broiler production enterprise in Okitipupa Township, Ondo State** P. T. Owombo[1]* A. A. Adeoye[2] F. E. Oke[1]	**FCF/S24 TS020**
SIC05K	**Sexual Dimorphism and Phenotypic Correlations among Hematological Parameters of Adult Scavenging Muscovy Duck in Okitipupa.** Olorunsola, R. A[1*], Adeoye, A. A[1]. And Akintola, M. M[1]	**FCF/S24 TS021**
SIC05L	**Sexual Dimorphism and Phenotypic Correlations among Physiological Parameters of Adult Scavenging Muscovy Duck..** Adeoye, A. A[1*,], Oyeleye, O.O[1]. and Akintola, M. M[1]	**FCF/S24 TS022**
SIC0M	**Evaluation of Pineapple (*Ananas comosus*) Peels as Phytogenic Feed Additives in the Diet of Juveniles *Clarias gariepinus*** [1]Olusola, Sunday Emmanuel, [2]Osijo, Anita Oluwafunke and [1]Ikuesan, Benson Banjoko	**FCF/S24 TS023**
SIC05N	**Quality Assessments of Potato-Based Drinks from Different Varieties of Potatoes** Faturoti Adeyanmola Oluwaseyi[a], Owheruo Joseph Oghenewogaga[b], Sawyerr Grace Olufunmilayo[a]	**FCF/S24 TS024**
SIC06A	**Administration of *Bridelia ferugenea* (Benth) leaves extract regulates pro-inflammatory cytokines and DPP4 Mrna in hepatic tissue of diabetic model rats.** ***Cecilia Oluwamodupe**	**FCF/S24 TS025**
SIC06B	**Nutritional Potentials of Nigerian Plants: A Comprehensive Exploration of Key Nutritional Components***Orumwense, L.A., Balogun, O.A., Oke, O.S., Ahmed, A.O. and Adisa, A.S.	**FCF/S24 TS026**
SIC06C	**Building Climate Resilience in Nigerian Agriculture: Challenges, Policies, and Sustainable Solutions *Adisa A. S., Orumwense L. A., Olawoore T. O., Adisa E. A., Ajayi T. O**	**FCF/S24 TS027**

SIC06D	**Use of Laser-Guided Variable-rate Sprayers for Pest and Disease Management in Fruit and Nursery Crops. Ugwu Kevin Ikechukwu**	**FCF/S24 TS028**
SIC06E	**Fabrication of Yam Minisett Cutting Machine** Ugwu Kevin Ikechukwu	**FCF/S24 TS029**
SIC06F	**Contributions of Third National FADAMA Development Additional Funding (AF) Project on Food Security Among Small Holder Fermers in Kebbi State, Nigeria. Aminu Yahaya Sanda[1]; Shehu Usman Hassan[2] ;Abdussalam Adamu Jega[3] ;Jibril Muhammad Yelwa[4] and Garba Lawal[5]**	**FCF/S24 TS030**
SIC06G	**Physicochemical Characteristics of Surface Water and Sediment in Tidal Flood Plain during Wet Season in Selected Oil Producing Areas of Akwa Ibom State. Obisike, Godson Uchechi.,[1] Ogbonna, Princewill C.,[2] Ubuoh, Emmanuel A.,[3] and Uchechi-Obisike, Queen Chinwenwa. [4]**	**FCF/S24 TS031**
SIC06H	**Effect of Soil Media and Organic Hormone on Germination and Early Growth of *Azanza garckeana* Ukanyirioha C. J., Erhabor T.A., Francis M.J. and Dahunsi O. M.**	**FCF/S24 TS032**
SIC06I	**Adaptation to Climate Change: An Assessment of Soybean Production and Sustainability in Bassa Local Government Area, Plateau State. Mbube, B. H, and Momoh, O. Y, Adesope, O. M**	**FCF/S24 TS033**
SIC06J	**Phytosociological Characteristics of Weed Biotypes of Cucumber (*Cucumis sativus* L.) as Influenced by 'eed Control Strategies and Staking.** *Shittu, E.A[1]., Adnan, A.A[1]., and Aliyu, A.M[2].	**FCF/S24 TS034**
SIC06K	**Studies on the Soil Toxicity Levels of Aquagrain on Vegetable Amaranth (*Amaranth tricolor)* Production ADNAN, A.A., SHITTU, E.A., and DAUDA, G**	**FCF/S24 TS035**
SIC06L	**Exploring the Role of Emotions in Climate Change Communication for Climate Action Dr. Sunday S. Gyang[1]; Prof. S. U. Dakyes[2]; Prof. Joseph I. Azi[3]**	**FCF/S24 TS036**
SIC06M	**Spatiotemporal Dynamics Influencing Farmers' Adaption and Social Capital in Farming Systems Resilience to Climate Change. Sesugh Uker[1], Muhammad B. Bello[2], Aminu Suleiman[3], Nasiru S. Bako[4]**	**FCF/S24 TS037**
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SIC06O	**Harnessing Potentials of Forest Food Resources in Our Environment** Nsien, I. B., Akpan, U.F., Ogar, B. I., Eric. E. E. and Ema, I. E.	**FCF/S24 TS039**
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SIC06Q	**Relationship between Organic Matter and Selected Soil Properties in the Nigerian Environment;** Ayodele Owonubi	**FCF/S24 TS041**
SIC06R	**Addressing the Naira's Free-fall in the Wake of Energy Subsidy Removal: A Policy Roadmap for Nigeria's Democracy:** Ahmad, Muhammad Makarfi[1]. And Sadiq, Mohammed Sanusi[2].	**FCF/S24 TS042**
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Climate Change Mitigation Strategies: Socio-economic and Constraints of Poultry Farmers in Southern, Nigeria

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Abstract

The study focused on Climate Change Mitigation Strategies: Socio-economic and Constraints of Poultry Farmers in Southern, Nigeria. *A three stages sampling procedure was used to randomly select one Hundred and Twenty-four respondents that was used for the study. Primary data was collected using questionnaire. Data collected were analyzed using descriptive statistics and multiple regression analysis. Result revealed that majority (56.5%) of respondents was male while 43.5% were female. Majority (72.6%) were married, 16.5% single 4.8% divorced while 6.5% were widow(er). About 83.9% were educated. The average age, farming experience, household size and farm size were 42 years, 9 years,5 persons and 380 birds, respectively. Majority (53.2%) had no access to extension services, while 46.8% had. Most (77.4%) respondents were engaged in off farm income while 22.6% were not. All respondents (100%) were members of cooperative and other farmers union. Majority (96.8%) had no access to credit while 3.2% had. Result of the multiple regression analysis showed that adoption of climate change mitigation strategies were influenced by house hold size, off farm income, group membership, education attainment, extension contact and farm size. The major constraints were high transportation cost, inadequate capital,high cost of feed, high market charges and lack of facilities. The study recommended that policies that will enhance educational attainment and asses to extension should be pursuit.*

Keywords: Climate Change, Mitigation, Strategies, Adopted, Deter

Introduction: Poultry are birds of several different species that have become domesticated for the production of meat, egg, and other related products like manure (Mozdziak, 2019). When compared to other domesticated animals, poultry animals such as chickens, turkeys, quails, swans, pigeons, guinea fowl, peafowl, and pheasants provide not only economic services but also significantly contribute to human food as a major supplier of meat, eggs, and raw materials to industries (feathers, waste products), source of income for people and source of employment Nyong, *et al*.,2023; Agyare, Boamah, Zumbi, and Osei, 2018). Products from poultry such as meat and eggs provide a potential source for meeting the basic and dietary needs of humans (Food and Agricultural Organization, 2023). Padhi (2016) observed that indigenous household chickens are very important in a subsistence economy where they provide major income to even the poorest household in the world. Alade and Ademola (2013) noted that Poultry production is a major source of protein which has empowered poultry farmers in developing economies to secure means of survival and livelihood. It is obvious that poultry production is practised traditionally and is held by smallholder marketers and farmers breeding for their own consumption in most regions of Nigeria, Nyong, *et al*.,2023; Aboki, 2013).

The majority of scientists believe that over time, the global warming has increased considerably, changing the climate (Onoja, Debus and Enete, 2011). The Intergovernmental Panel on Climate Change (IPCC) was founded by the World Meteorological Organization (WMO), Nyong, *et al*.,2023) and the United Nations Environment Program (UNEP) to investigate this matter. The Intergovernmental Panel on Climate Change gathers researchers from different countries and areas of activity with the objective of generating and organising information to forecast future scenarios of temperature, drought, flood, wind, and rainfall variation. Based on these scenarios, the possible socioeconomic and environmental impacts generated by Climate change, as defined by IPCC, is the variation between a region's typical climate conditions (such as rainfall, temperature, and wind) and a different but recurring set of those conditions. It is caused by an increase in greenhouse gas emissions (GHGs) in the atmosphere, which weakens the ozone layer and causes global warming Nyong, *et al*.,2023); (IPCC, 2021).According to the International Food Policy Research Institute (2018), more frequent floods and droughts increase the risk of immediate failures and long-term decreases in processing for both crops and animals. Rain-fed agriculture's dominance, the lack of funding for adaption measures, the baseline warming of the climate, and increased susceptibility to extreme (Oijstaeijen, Passel, Cools, Jan, De Bisthoven, Huge, Berihun, Ejigu, and Nyassen, (2020) in Africa make agriculture more vulnerable to climate change.

Climatic change poses the challenges of both loss of productivity and increase in cost of production. The question at this juncture is what strategies are adopted by poultry farmers to minimize the effect of climatic change threat? Several studies have been done on adoption of climate change mitigation strategies in Akwa Ibom state and Nigeria generally Nyong, *et al*.,2023) ; (Essien, Akpan and Udo, (2021); Oleyede and Adejumo (2018); Idowu, Oyinlola, Adeyemo, Oluyemi and Adejobi (2019). The study in Akwa Ibom consider the state generally, without considering that there is tendency for adoption of climate change mitigation strategy to vary in the different agricultural zone that make up the state. Sadly, none has been done in the study area which incidentally is one of the core poultry production zone in the state. Against this backdrop, this study analyzed climate change mitigation strategies adopted by poultry farmer in Oron Agricultural zone. The main objective of the study is to analyze climatic change mitigation strategies adopted by poultry farmers in Oron Agricultural Zone. The specific objectives are to: examine the socio-economic characteristics of poultry farmers in Oron Agricultural zone;; and estimate the effect or influence of socio-economic characteristics of poultry farmer on the adoption of climate change mitigation strategies on the study area.

Study Area: The state is bordered on the earth by cross River State, on the west by River State and Abia state and on the South by the Atlantic Ocean and the Southernmost tip cross River. The landscape of Akwa Ibom state is mostly flat and the land is arable from the saline water swamp forest in the south to the rainforest in the north and support extensive agriculture all year round. The population of the state according to (NPC 2006) was 5,545,758m. The state was created in 1987 from former Cross River State and is currently the highest oil and gas producing State of the country. The climate of the state can be described as a tropical rain**48** | P a g e P a g e | **4 8** y type which experience abundant rainfall with very high temperature, very clement tropical climate marked by two distinct seasons; the wet or rainy season and dry or sunny season. The majority of the rural populace engaged in arable crop farming and fishing as their main occupation.

Sampling Technique and Sampling Size.: The study was carried out in Oron Agricultural Zone, Akwa Ibom State, Nigeria. Three stage sampling techniques was used to select respondents for the study. First, four extension block that make up the zone was purposively adopted for the study, these were Oron, Urue Offong/Uruko, Okobo and Mbo respectively.. In the second stage, two (2) cells each were randomly selected from each block making a total of eight (8) cells. In the third stage 15 respondents each were selected from Oron, Urue Offong/Uruko, and Okobo making a total of 90 respondents while seventeen (17) respondents were selected from Mbo because Mbo have higher number of registered farmers. This gave a total of one hundred and twenty four (124) respondents that was used for the study.

Determination of the sample size was accomplished by employing the Taro Yamane (1967) formula.

The formula is given as:

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

Where;

n = Sample size

N = Sample free

e = Probability level (0.05)

$$= \frac{180}{1 + 180(0.05)^2} = \frac{180}{1.45} = 124$$

Therefore, n = 124

Analytical Techniques.

Objectives i, was analyzed using descriptive statistic such as mean, frequency variance and standard derivation.

Objective iv was analyzed using multiple regression analysis. The mathematical form of the model adopted is stated as follow:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n + E$

Where:

Y = climate change mitigation index compared by adopting and modifying the method of Adebeyo et. al., (2012). Here Y was computed by dividing the number of Climate change mitigation strategies adopted by each poultry farmers by the total number of climate change mitigation strategies adopted in the study area. The value of Y was between 0 and 1.

β_0 = The constant term
β_1 - β_{10} = are the coefficient to be estimated.
X_1 = Household size (number of persons)
X_2 = Farming experience (year)
X_3 = Off Farm income (Naira)
X_4 = Group membership (number of social group that a farmer belong)
X_5 = Education Attainment (year)
X_6 = farmers age (year)
X_7 = access to extension (number of source that a farmer get his/her poultry production information).
X_8 = Farm size (number of bird kept)
X_9 = Gender (male = 1, female = 0)
X_{10} = Marital status (married 1, others 0)
E = Stokecatic error term

Results and Discussion: Socio Economic Characteristics of Respondents

The results of the survey in Table 1 revealed that majority (56.5%) of the respondent were male while female accounted for the remaining 43.5%. This implies that poultry farmers was dominated by male in the study area. This result confirms the finding of Nyong, and Nweze,, 2012); Edet (2019); Ebong and Awatt (2023), who reported that majority of poultry farmers in Akwa Ibom state were male The result of the survey based on age shown in Table 1 revealed that majority (40.3%) of the respondent were between the age of 41 - 50 years, 37.1% were between the age of 51-60 years, 11.3% were between the age of 30 - 40 years, 8.1% were above 60 years and 3.5% were less than 30 years. The average age of respondent in the study area was 42years. This implies that the respondent were in their middle age and still active. This results is similar with the finding of Nyong, and Nweze,, 2012), Ubom, Okorie and Okon (2023) who reported that poultry farmers in Akwa Ibom State were within the average age of 42.89 years.

The result of the survey in Table.1 revealed that majority (52.4%) of the respondent had less than 10 years of experience, 44.4% had between 10 - 20 years of experience while 3.2% had above 20 years of experience. The average years of experience in the study area was 9 years. This result disagree that of Ubom, Okorie, and Okon (2023) who reported that poultry farmers in Akwa Ibom State had average experience of 6.98 years. The result of the survey in Table 4.1 revealed that majority (57.3%) of the respondent had between 5 -10 persons in their household size, 40.3% had less than 5 persons in their household size while 2.4% had 11-15 persons in their household size. The average household size in the study area was 5 persons. The implication is that respondents with larger household size will be influenced to adopt climate change mitigation strategies. This result is in line with that of Nyong, and Nweze,, 2012); Ebong and Awatt (2023), reported that poultry farmers in Akwa Ibom state had an average household size of 4-6 persons. The result of the survey based on access to extension has shown in Table 4.1 revealed that majority 53.2% of the respondent had no access to extension service while 46.8% had access to extension services in the study area. The result implies that extension service are not effective which explains why majority of the poultry farmers could not have access to their services.

The result of the survey in Table 1 revealed that majority (58.9%) of the respondent had a farm size between 300 birds, 16.1% between 500 -1000 and 4.8% above 1000. The average farm size in the study area had 380 birds. This result is in line with that of Nyong, and Nweze,, 2012), Edet (2019) who reported that farmers in Akwa Ibom State reared between 101 - 500 birds. The result of the survey in Table 4.1 revealed that majority 96.8% of the respondent had no access to credit while 3.2% had access to credit in the study area. The result implies that a significant portion of the respondent may face financial constraint when trying to adopt climate change mitigation strategies in their farm. This finding is in support with Nyong, and Nweze,, 2012); Oniah, Meremeku, and Agiopu (2018) who avers that majority of poultry farmers had no access to credit in Akwa Ibom, Cross River and River state.

Table 4.1 Socio Economic Characteristics of Respondents

Socio Economic Characteristics	Frequency (n=124)	Percentage (%)
Gender		
Male	70	56.5
Female	54	43.5
Total	**124**	**100**
Age (Mean = 42 years)		
< 30	4	3.2
30 – 40	14	11,13
41-50	50	40.3
51-60	46	37.1
Above 60	10	8.1
Total	**124**	**100**
Marital Status		
Single	20	16.1
Married	90	72.6
Divorced	6	4.8
Widow/Widower	8	6.5
Total	**124**	**100**
Educational Level (mean: 10years)		
Primary	44	35.5
Secondary	59	47.6
Tertiary	1	0.8
No farmer education	20	16.1
Total	**124**	**100**
Farming Experience (Mean = 9 years)		
< 10	65	52.4
10 – 20	55	44.4
> 20	4	3.2
Household Size (Mean = 5 persons)		
< 5	50	40.3
5 – 10	71	57.3
11-15	3	2.4
Total	**124**	**100**
Access to Extension Services		

Yes	58	46.8
No	65	53.2
Total	**124**	**100**
Cooperative/other union membership		
Yes	100	100
No	Nil	0.00
Total	**124**	**100**
Off farm participation		
Yes	96	77.4
No	28	22.6
Total	**124**	**100**
Farm size (mean: 380 birds)		
<300	25	20.2
300-500	73	58.9
501-1000	20	16.1
Above 1000	6	4.6
Total	**124**	**100**
Access to credit		
Yes	4	3.2
No	120	96.2
Total	**124**	**100**

Source: Field Survey, 2024.

Table 2 Multiple Regression estimate for factors influencing adoption climate change mitigation by poultry farmers in the study Area

The linear model was chosen as the lead equation from the three functional forms (linear, quadratic and double log) that were estimated due to its high R^2 value and the number of significant estimates. The value of estimated R^2in the lead equation was 0.7142, implying that about 71.4% of the variability in the adoption of climate change mitigation strategies was explained by the explanatory variable included in the model. The estimated value of F statistics was 466.76 significant at 1% (P>0.001) denoting the goodness of fit of the estimated model. Nyong, and Nweze,, 2012). Of the eleven variables that were included in the model, six were significant with varying signs. In our interpretation, any coefficient with a positive sign indicates that increasing such variable will increase the adoption of climate change mitigation strategies and vice-versa. From our result, while the estimated coefficient for household size was negative and significantly reduce the adoption of mitigation strategies (P>0.05) that of off-farm income, groups membership, educational attainment, extension contact and farm size were positive and significantly increase the adoption of climate mitigation strategies at 5, 1, 5, 1 and 5% probability levels respectively. Nyong, and Nweze,, 2012)

The positive relationship of off-farm income is justified because acquisition of off-farm income will increase poultry farmers total household income and liquidity position. Such highly liquid farmers may be willing to adopt and even pay for modern climate change seminars and conferences through which new climate change mitigation information and strategies are gotten and knowledge acquired. This finding is in line with those of Nyong, and Nweze,, 2012); Ekpo, Eyo and Ekwere (2021) who in their study reported their higher income increases the adoption of climate change mitigation strategies in Akwa Ibom State.

The plausible explanation for the positive coefficient of group membership is that membership of a farmers group such as cooperative will enhanced farmer’s chances of accessing modern climate change mitigation information as well as contact with climate change mitigation experts which they can leverage on to adopt climate change mitigation strategies. A study by Nyong, and Nweze,, 2012); Ukpong, Ekpo and Udo (2023) had previously reported that social network increase farmer’s chances of adopting climate change mitigation strategies in Akwa Ibom State.

The positive coefficient of farm size is also justified. Since farm size was measured by the member of birds in stock, larger stock will imply huge invested capital. With such huge capital, there is higher tendency for such farmers to adopt more mitigation strategies presumably not to lose both their equity and borrowed capital. Studies by Nyong, and Nweze,, 2012); have previously reported that higher farm size increase the adoption of climate change mitigation strategies.

Table 2 Estimates of the determinants of adoption of climate change mitigation strategies

Variable	*Linear+*	*Exponential*	*Double-log*	*Semi-log*
Constant	2.920	1.256	1.444	2.312
	(10.989)***	(7.188)***	(5.595)***	(3.867)***
Age	-0.003	-0.002	-0.046	0.024
	(-0.802)	(-0.586)	(-0.387)	(0.258)
Marital status	0.340	0.026	0.211	0.133
	(2.837)***	(0.329)	(0.771)	(1.392)
Household size	0.013	0.002	0.026	0.954
	(2.914)***	(0.477)	(0.541)	(1.237)
Level of education	0.010	0.416	0.051	0.088
	(3.088)***	(2.878)***	(3.213)***	(4.042)***
Household size	-0.002	0.006	0.016	-0.542
	(-0.229)	(0.557)	(0.318)	(-1.123)
Estimated annual income	-1.485E-7	-2.380E-7	1.472	23380.180
	(-0.970)	(-2.365)**	(4.016)***	(2.449)**
Farming experience	0.039	0.028	0.771	0.327
	(0.457)	(2.812)***	(2.531)**	(0.767)
Access to inputs	0.230	1.213	0.042	-0.167
	(3.114)***	(3.004)***	(3.117)***	(-3.082)***
Access to credit	0.149	0.007	0.019	-0.071
	(4.083)***	(0.152)	(0.365)	(-2.944)***
Extension contact	0.161	0.005	0.052	1.215
	(2.485)**	(0.803)	(0.970)	(2.587)**
Membership of cooperative	0.038	0.014	-0.035	0.134
	(2.399)**	(1.978)**	(-0.728)	(1.233)
R^2	0.694	0.877	0.589	0.494
Adjusted R^2	0.623	0.708	0.516	0.427
F-statistic	7.078***	5.976***	4.137***	4.399***

Source: Computed from field survey data, 2023

Note: ***, **, and * indicates statistically significant at 1%, 5% and 10% levels of significance respectively. + = Lead equation.

Constraints: Result in table 3 revealed that all (100%) of the respondents had one constraints to the other. This may imply that more are still needed to be done in order to help the poultry farmers to overcome such problems that are associated with climate change F. The table 3 revealed that 90% of the respondent has financial challenges, 70.9% has Road network constraint, 72.7%, Nyong, and Nweze,, 2012)

Table 3. Constraints of Arable Crop Farmers

Constraints	**Frequency/100**	**Percentage (%)**
Fin. Challenges		
Yes	99	90.0

No	11	10.0
Access to Credit		
Yes	73	66.4
No	37	33.6
Transport constraint		
Yes	61	55.5
No	49	44.5
Pest and Diseases		
Yes	43	39.1
No	67	60.9
Improved breed		
Yes	80	72.7
No	30	27.3
Access To Land		
Yes	89	80.9
No	21	19.1
Storage Facility		
Yes	83	75.5
No	27	24.5
Traditional Belief		
Yes	8	7.3
No	102	92.7
Access to ICT		
Yes	79	71.8
No	31	28.2
Extension Service		

Yes	75	68.2
No	35	31.8
Flooding Experience		
Yes	64	58.2
No	46	41.8
Access to Inputs		
Yes	88	80.0
No	22	20.0
Road Network Const.		
Yes	78	70.9
No	32	29.1

Source: Field Survey Data, 2024

Conclusion: The most adopted mitigation strategies included provision of adequate ventilation, proper waste management practices, and the use of energy-efficient lighting. Factors such as off-farm income, group membership, educational attainment, extension contact, and farm size were found to positively influence the adoption of mitigation strategies, while household size had a negative impact. These findings emphasize the importance of targeted interventions and support for poultry farmers in implementing effective climate change mitigation measures. Based on the finding of the study, we recommends that; Government and NGOs should encourage farmers provision of subsidy in the form of basic production input.; Policies that will increase educational attainment and access to extension service should be encourage.

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Effect of ill-health on Agricultural Productivity and Food Security in Kebbi State, Nigeria

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Abstract

This study was carried out to analyze the effect of ill-health on agricultural productivity and Food security in rural areas of Kebbi state, Nigeria. The motivation derives from the fact that rural areas which are strategically important for national food security are more prone to health hazards as a result of the poor nature of health services arising partly from neglect by government. The study revealed that the most prominent disease conditions affecting farm families were malaria fever, typhoid fever and diarrhea and these led to an average of 8.2 days reduction in time available for farm work in a farming season. Furthermore, result from the production function analysis revealed that the elasticity's of farms size (0.419), number of contacts with extension agents (0.018), and naira amount of credit accessed (0.25) were positively signed and significant at 1%, 10%, 1%, 5% and 1% respectively; while number of days of farm work lost to ill-health was negatively signed (0.09) and significant at 5%. Findings suggest that focusing on number of days of farming activities lost to ill health in a household might help elicit a clearer picture of the effect of ill -health on agricultural productivity and food security. More provision of and accessibility to health care services in the rural areas in order to reduce the incidence of diseases is recommended. Such efforts should also include the provision of adequate health and environmental education for the rural population.

Key words: Effect, of ill-health, Agricultural Productivity, Food Security, Kebbi State

Overview: Nigerian government has been given attention to rural areas due their significant to the country's agricultural foundation. Smallholder farmers provide almost 90% of Nigeria's food supply, and the majority of the country's industries are dependent on agriculture. It has also been reported that agricultural sector, which generates 70% of non-oil exports, contributes roughly 40% of the nation's GDP [Agwu and Anyanwu, 2019]. The majority of agricultural items come from rural areas. But they a lot of welfare and infrastructural issues. They are also vulnerable to health risks, such as HIV/AIDS, guinea worms and malaria are frequently more common in rural areas [Ahmed *et al*., 2015]. Because health is a significant kind of human capital, it matters both as a direct indication of welfare and a factor of productivity. Since health is correlated with capability, there is a great deal of consensus in the research regarding the relationship between economic development and health [Ajani and Ashigidigbi, 2018]. In addition to having a negative impact on the welfare of the affected households, health issues have a negative impact on agriculture and economic development because they reduce the number of hours that can be worked for economic purposes, cause early loss of human resources, and increase the financial burden of poor rural households. Economists generally agree that a country's health is a key factor in its development. According to Gallup and Sachs [Alaba and Alaba, 2009], nations with high malaria incidence only possessed 33% of the income levels of those without malaria in 1995, and their annual growth rate was 1.3% lower between 1965 and 1995. It has also been shown that also show that malaria lowers economic growth by 0.55% [Audibert, 2000].

Agriculture-related research has demonstrated the detrimental effects of illness, particularly on the well-being of farming households, which in turn have an impact on the growth of the economy as a whole. For example, [Bamire *et al*., 2012] reported that the effects of poor health on farm households are threefold: the loss of savings and assets in the process of dealing with diseases and their consequences; the absence from work due to morbidity (and eventual death); and the diversion of family time to care for the sick. They also stated that fewer cattle are raised, less acreage is farmed, less labor-intensive crops are planted, fewer varieties of crops are cultivated, and farming expertise is lost as a result of poor health. According to their findings, food insecurity and a reduction in home income—that is, a sharp fall in household livelihood—are the final effects of illness. The purpose of the study was to evaluate the overall effects of ill health on agricultural Productivity. The number of days lost to illness as a result of the common temporary (non-terminal, temporal) sickness conditions during the most recent farming season—which begins with the onset of the rainy season in April and lasts until October—was taken into account in this process. This is on top of the dearth of empirical data regarding the production-health relationship in the research region. Because local governments have not made a strong commitment to providing primary health care, the study area is predominantly agricultural and extremely sensitive to health risks [Idrisa *et al*., 2008]. The state under study happens to be the second poorest in the federation [ESRF, 2010]. Kebbi state's dominant industry is agriculture, it is also subsistence-based and primitive.
In order to fulfill the goal of this investigation, the subsequent research inquiries were posed: What socioeconomic traits do farmers possess? ; Which are the main medical issues that are common in the area? ; How many days of farming did you miss during the recent farming session because of illness? ;and. What effect do these health issues have on the agricultural productivity?
Objectives of the study The broad objective of the study is to analyze the effect of ill-health on agricultural productivity in Kebbi State, Nigeria. The specific goals were to: describe the socioeconomic characteristics of farmers; identify the most common health conditions influencing

agricultural productivity; find out the number of days a household missed from farming due to illness; and determine the effect of ill-health on agricultural productivity and food security.

Research Study Design :The Area of Study: The state Kebbi hosted the study. The state of Kebbi is located in northwest Nigeria, and Birnin Kebbi serves as its capital. In 1991, the state was formed by separating a portion of Sokoto State. Sokoto State, Niger State, Zamfara State, the Dosso Region in the Republic of Niger, and the country of Benin border Kebbi State. It is 36,800 km³ in total size (14,200 sq mi). Kebbi State is made up of 35 districts, four emirate councils (Yauri, Zuru, Gwandu, and Argungu), and twenty-one Local Government Areas (LGAs). And as of the 2016 population census, there are 4,440,050 people living there (NPC, 2006). Kebbi State was selected for this study because it is home to a sizable number of operational academic libraries.

Data Sources: The sources of data used for this study were primary (through structured questionnaire) and secondary (through available literature).

Procedure for Sampling and Data Gathering : For this study, a three-staged random sampling procedure was employed. Three LGAs were chosen at random from each of the four ADP Agricultural zones for the first stage. This provides the study with a total of twelve LGAs. In order to have a total of 36 communities for the sample in stage two, three communities were randomly chosen from each LGA. In order to provide 360 respondents for the study, 10 farmers were randomly chosen from each of the 36 communities in the third stage.

Results and Discussion

Table 3: Prevailing Ailments Types and Days lost to ill health

Type of ailment	Frequency	%	Cumulative%
Malaria	100	38.0	38
Typhoid	86	32.7	70.7
Diarrhea	40	15.2 14.0	85.9
Others	37	100.0	99.9 100.0
Total	263		
Days lost to illness		26.6	
1 – 5	70	15.96	26.6
6 – 10	42	10.64	74.7
11 – 15	28	3.8	93.3
>15	10	100.0	100
Total	150		

Table 4: Multiple Regression Results of the Effect of ill-Health on Agricultural Productivity and Food Security

Variables	Beta	t- value
Years of schooling	0.056	1.22
Days lost to sickness	-0.09	-2.25**
Farm size (Ha)	0.419	5.68***
Family size	0.099	1.67*
Chemical used (~~N~~)	0.018	2.75***
Labour	0.012	2.01**
Age of household head	- .248	-1.63
Credit accessed	0.25	3.70***
Extensio	0.06	1.3
Constant	6.6	18.38***

R^2 = 0.773, Adjusted R^2 = 0.760. * sig @10%, ** sig. @ 5%, *** sig. @ 1%.

Health Issues' Effect on Agricultural Productivity and Food Security: The effects of different variables on the farmers' agricultural productivity and food security in the study area are displayed in Table 4. According to the coefficient of determination, the independent variables accounted for 77.3% of the variation in output. Agricultural output increases with years of schooling (0.056), farm size (0.419), family size (0.099), number of contacts with extension agents (0.018), man-days of labor (0.012), amount of credit accessed (0.25) and amount spent on agricultural chemicals (0.06), according to the estimated elasticities of the variables. However, there was no significant correlation found between the years of education and the amount spent on agricultural chemicals. At 5%, the predicted elasticities for the number of days missed due to illness (-0.09) were substantial and negatively signed. Although negligible, the age of the head of the family (-0.248) also had a negative sign.

Discussion of Findings: There is a direct correlation between family size and labor availability; the larger the family, the more labor is available for farm work. Additionally, a strong correlation between labor as expressed in man-days and output was discovered by the study. In Nigerian agriculture, labor availability has a significant role in determining productivity levels, particularly in rural areas where mechanization is nonexistent. Farm output and loan availability had a favorable relationship as well. Additionally, there was a strong positive correlation between the number of extension interactions and agricultural output. In line with the conclusions of Bamire *et al*., [2012], this contact attempt to introduce innovation to the farmers and assist them in the adoption process. It has been discovered that having access to financing can boost agricultural output in a number of ways, including input acquisition, adoption of new ideas, and scaled-up production.
The output of the regression analysis also demonstrated a decline with the number of days that farmers were unable to farm due to illness. The results of Idrisa *et al*., [2008] that poor health limits the amount of time available for farm work are somewhat supported by this. In addition to decreasing output and the number of resources available for farming activity, illness reduce the volume of work on the farm which in turn lowers output. Farmers who suffer from illness may miss workdays. The timing and season of the sickness determine how severe this detrimental effect of health shocks is. The area's agriculture is weather-dependent, and crop output is time-sensitive. Thus specific crops must be grown at specific times, and agricultural practices like planting, weeding, and fertilizing have a big impact on yield. Delays in any of these cultural behaviors has a detrimental impact on output.

Conclusion: The purpose of this study was to determine the link between agricultural productivity and ill health. It shows a substantial association between agricultural productivity in Kebbi State and the number of days that farmers missed on farm due to illness. This has a detrimental effect on agricultural productivity and vice versa.

Recommendation: Access to healthcare should be improved for Nigerians living in rural areas, as health condition is a vital factor in agricultural productivity. Lack of treatment for illnesses (Table 3) affects Kebbi state's agricultural productivity, which has an impact on rural development and food security. To further understand the nature of the linkages between environmental and hygiene-linked illnesses it is strongly advised that extensive research be directed toward these circumstances.

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Effect of Soil Media and Organic Hormone on Germination and Early Growth of *Azanza garckeana*

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Abstract

Azanza garckeana is a valuable indigenous fruit tree species known for its nutritional and medicinal properties. This study aims to determine the impact of various soil media and organic hormones on germination rates and seedling growth of Azanza garckeana. The experiment was conducted using sawdust, loamy soil, compost soil, and sharp sand, with treatments of honey and aloe vera as organic hormones. Results indicated that sawdust and loamy soil were the most effective for germination, with sawdust achieving a 70% germination rate. Organic hormones significantly enhanced seedling growth, with loamy soil treated with honey showing the best performance. Specifically, germination rates were sawdust (70%), loamy soil (60%), compost soil (40%), and sharp sand (30%). Seedling height after 8 weeks was highest in loamy soil with honey (13.62 cm), while leaf length and collar girth were also significantly improved. The study concludes that selecting appropriate soil media and organic hormones is crucial for the successful cultivation of Azanza garckeana. Recommendations include the use of sawdust and loamy soil for germination, application of honey and aloe vera for growth enhancement, further research on long-term effects, and conservation efforts to protect the species.
Keywords: *Azanza garckeana, soil media, organic hormones, germination.*

Introduction: *Azanza garckeana* is a tree in the family Malvaceae, found throughout the warmer parts of Southern Africa in wooded grasslands, open woodland and thickets (David *et al*., 2022). it grows in a variety of soils and is found near termite mounds and deserted areas, while in Nigeria it grows in open woodlands in the North part of the country. The distribution of *Azanza garckeana* in Nigeria have been restricted and concentrated to some certain places like in Tula, Gombe State, resulting in its popular name "Goron Tula" in Nigeria. Environmental factors such as soil media and temperature have played a vital role in slow distribution and abundance of the plant (Oliver. *et al* 2000). Organic hormones, also known as plant growth regulators, can be beneficial for promoting early growth in forest nurseries (Small and Degenhardt , 2018). These hormones are naturally occurring substances that regulate various aspects of plant growth and development and encourage the development of strong and healthy root systems in seedlings (Amanah *et al*., 2022). Apart from providing support to the plant, a well-developed root system increases the surface area for water and nutrient uptake by plants and thus is significant for fast growth of seedlings in the nursery.

Soil media can have an impact on the germination and early growth of plants, including such as *Azanza garckeana* (David *et al*., 2022). Different types of soil media may have varying levels of nutrients conpositions, moisture retention, and aeration, all of which can affect the plant's ability to germinate and grow. Some soil media may be too compacted or nutrient-poor, leading to poor germination and stunted growth, while others may provide the ideal conditions for healthy growth. Overall, the combined effect of soil media and organic hormones on the germination and early growth of *Azanza garckeana* may have a positive impact on the plant's development. It is important to carefully select appropriate soil media and hormone treatments to optimize the growth and health of *Azanza garckeana*. This study therefore was aimed at evaluating the effects of soil media and hormones on the germination and early seedling growth of *Azanza garckeana.*

Materials and Methods: Study Site : The study was carried out at the Nursery of Federal College of Forestry, Jos (latitude 9^o 57 N and longitude 8^o 54' E). The study area lies in the Northern guinea savannah with mean annual rainfall between 1200mm and 1250mm and means temperature ranging between 23^{o}C and 25^{o}C. The climate of the state is cool due to its high altitude (about 118cm above sea level) and its soil is sandy-loam, light to dark in colour.

Seed Procurement: Seeds were procure at Yan goro Market, Jos. Seed Viability test was carried out by floatation method. (Isikuemen and Uwadia, 2014).

Methods: Four treatment was used in the research to test the effects of different soil media and organic hormone treatment on germination and early growth of *Azanza garckeana*.

Seed Sowing: After preparation of soil, viable seeds were sown into each polythene bag. Watering was done early morning and evening daily and weeding was carried out regularly.

Germination: Cumulative germination count was taken daily from the first day of germination and monitored until no further germination. Once counted, seedlings were tagged to avoid double counting.

Germination percentage (GP) was calculated as;

Germination Percentage (GP) =

$$\frac{\text{(Number of seeds that germinated)}}{\text{(Total number of seeds sown)}} \times 100$$

Seedling growth: Seedling height was measured 2 weeks after germination from the collar to the tip of the youngest leaf using a metre rule; stem collar diameter was measured at the root collar using thread and metre rule, leaflet length was measured using metre rule while leaf production were determined by counting directly as they emerged.

Soil media tests : Soil media test was achieved by sowing seeds of *Azanza garckeana* in soil treatment A, B, C and D representing loamy soil, compost soil, sharp sand and sawdust respectively.

Experimental Design and Layout: A total number of 40 perforated polythene bags containing soil were used in carrying out the experiment. It was laid in a completely randomized design (CRD) with five (4) treatments and ten (10) replicates. The experimental layout is shown below.

Results and Discussion: Results: Effect of different soil media on the germination of *Azanza garckeana*

Table 1 below shows the effect of different soil media as treatment on the germination of *Azanza garkeana* seed. The table as analyze reveals that seed from treatment A (SD) which were planted in a saw dust gives the good result as 7 seed out of the total seeds sown with the germination percentage of(70%), this was followed by the seed sown in loamy soil as 6 seeds germinated which gives the germination percentage of (60%), this was followed by the seed sown in compost soil with seed germination and germination percentage of(40%) this was followed by seeds sown in shape sand with 3 seeds and germination percentage of (30%) The table also reveals the days of seed emergence and late days of seed emergence (first and last days of seeds emergence). As revealed, SD emerged at 14 days after seeds were sown and lasted foe 11 days, followed by SS that shows emergence 14 days after seeds were sown and finished after 9 day, CS first emerged 41 days after seeds were sown and finished after 7 days, were LS shows emergence at first 16 days and finished after 10 days.

Table 1 : Effect of different soil media on the germination of *Azanza garckeana*

Treatment	No. of emerge seed	% of seed germination	Days of seed emergence	Days of late seed emergence
SD	7	70%	14	11
SS	3	30%	14	9
CS	4	40%	14	7
LS	6	60%	16	10

Effect of Soil Media on Seedling Height (cm) of *Azanza garckeana*: The effect of soil media on mean seedling height (cm) of *A. garckeana* were not significantly ($p \geq 0.05$) different at 2[nd] to 8[th] weeks after germination (Table 1). Results of the study equally shows an increased direction in seedling height as the weeks increases and the highest value for each stage was obtained from soil media of CS, this was followed in order of performance as CS > SS > LS > SD.

Table 2: Effect of Soil Media on Mean Seedling Height (cm) of *Azanza garckeana*

Treatments	SEEDLING HEIGHT (cm)			
	2WAG	**4WAG**	**6WAG**	**8WAG**
SD	3.67[a]	4.73[a]	5.21[a]	5.90[a]
SS	4.34[a]	5.52[a]	6.14[a]	6.83[a]
CS	3.72[a]	5.48[a]	6.55[a]	7.57[a]
LS	3.28[a]	4.31[a]	5.71[a]	8.01[a]
SE	**1.339**	**1.826**	**2.097**	**2.469**
p-value	***0.955***	***0.957***	***0.973***	***0.935***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination*

Effect of Soil Media on Leave Length (cm) of *Azanza garckeana*: There was no significantly different at 2[nd] to 8[th] week after germination in length of leaves as the seedling age increased base on the effects of different soil media from week 2 through to week 8 after germination (Table 2). However, the highest value for each stage was obtained from soil media of CS, this was followed in order of performance as SS > LS > SD.

Table 3: Effect of Soil Media on Mean Leave Length (cm) of *Azanza garckeana*

Treatments	LEAVE LENGTH (cm)			
	2WAG	**4WAG**	**6WAG**	**8WAG**
SD	1.31[a]	1.60[a]	2.07[a]	2.64[a]
SS	1.80[a]	2.51[a]	2.95[a]	2.83[a]
CS	2.00[a]	2.59[a]	2.88[a]	3.00[a]
LS	1.42[a]	2.05[a]	2.52[a]	3.10[a]
SE	**0.600**	**0.791**	**0.901**	**0.994**
p-value	***0.833***	***0.799***	***0.895***	***0.989***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination*

Effect of Soil Media on Colar Girth (cm) of *Azanza garckeana*: Result on table 3 reveals a non-significant difference ($p > 0.05$) in collar girth of seedling from 2[nd] to 8[th] week after germination. There was an increase in mean collar girth as the seedling age increased base on the effects of different soil media throughout the trail periods (2[nd] to 8[th] week after germination) and the highest value for each stage was obtained from soil media of SS, this was followed by LS > CS and SD.

Table 4: Effect of Soil Media on Mean Colar Girth (cm) of *Azanza garckeana*

Treatments	COLAR GIRTH (cm)

	2WAG	4WAG	6WAG	8WAG
SD	0.20ᵃ	0.25ᵃ	0.42ᵃ	0.51ᵃ
SS	0.43ᵃ	1.22ᵃ	0.82ᵃ	0.69ᵃ
CS	0.29ᵃ	0.46ᵃ	0.58ᵃ	0.53ᵃ
LS	0.40ᵃ	0.53ᵃ	0.81ᵃ	0.43ᵃ
SE	**0.113**	**0.362**	**0.208**	**0.187**
p-value	***0.462***	***0.274***	***0.470***	***0.797***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination*

Effect of Soil Media on Number of Leaves of *Azanza garckeana*: Result on table 4 reveals a non-significant difference ($p \geq 0.05$) in seedling number of leaves from 2nd to 8th week after germination. There was an increase in mean number of leaves as the seedling age increased base on the effects of different soil media throughout the trail periods (2nd to 8th week after germination) and the highest value for each stage was obtained from soil media of SS and CS, this was followed by LS > SD.

Table 5: Effect of Soil Media on Mean Number of Leaves of *Azanza garckeana*

Treatments	NUMBER OF LEAVES			
	2WAG	**4WAG**	**6WAG**	**8WAG**
SD	1.60ᵃ	2.70ᵃ	3.50ᵃ	3.51ᵃ
SS	2.30ᵃ	3.30ᵃ	4.30ᵃ	4.30ᵃ
CS	2.50ᵃ	3.20ᵃ	3.90ᵃ	4.60ᵃ
LS	1.70ᵃ	2.40ᵃ	3.30ᵃ	4.30ᵃ
SE	**0.725**	**1.030**	**1.288**	**1.473**
p-value	***0.773***	***0.916***	***0.949***	***0.871***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination*

Effect of Hormones on Seedling Height (cm) of *Azanza garckeana*: Result on table 5 shows the effect of organic hormones on mean seedling height (cm) of *Azanza garckeana*. The mean values recorded for each soil media displayed a non-significant difference ($p \geq 0.05$) on seedling height (cm) of *Azanza garckeana* treated with honey and aloe vera for 2nd to 8th weeks after germination. There was an increase in mean seedling height (cm) as the weeks increased base on the effect of organic hormone on seedling height (cm) of *Azanza garckeana* (2nd to 8th weeks after germination). The highest value for each soil media treated with honey was obtained from soil media of LS, this was followed in order of performance as SS > CS > SD.The result on seedling height (cm) of *Azanza garckeana* treated with aloe vera reveals that soil media of LS exhibited highest mean value, this was followed by SS > CS > SD respectively. The independent T-test result on effect of hormones on mean seedling height (cm) of *Azanza garckeana* was not significantly ($p \geq 0.05$) different (0.530, 0.776, 0.825 and 0.893) at 2nd to 8th weeks after germination respectively.

Table 6: Effect of Hormones on Mean Seedling Height (cm) of *Azanza garckeana*

Hormones	SEEDLING HEIGHT (cm)			
	2WAG	**4WAG**	**6WAG**	**8WAG**
Honey				
SD	7.66ᵃ	8.24ᵃ	9.00ᵃ	9.42ᵃ
SS	7.18ᵃ	8.50ᵃ	9.78ᵃ	10.92ᵃ
CS	7.56ᵃ	8.30ᵃ	8.98ᵃ	9.50ᵃ
LS	10.80ᵃ	12.04ᵃ	13.14ᵃ	13.62ᵃ
SE	**4.283**	**4.746**	**5.190**	**5.475**
p-value	***0.926***	***0.927***	***0.931***	***0.942***
Aloe vera				
SD	2.94ᵃ	6.74ᵃ	7.72ᵃ	8.20ᵃ
SS	7.12ᵃ	8.76ᵃ	10.60ᵃ	12.12ᵃ
CS	8.02ᵃ	8.66ᵃ	9.22ᵃ	9.72ᵃ
LS	8.48ᵃ	9.58ᵃ	10.52ᵃ	11.58ᵃ
SE	***3.538***	***4.098***	***4.509***	***4.829***
p-value	***0.680***	***0.967***	***0.964***	***0.936***
*Independent T-test (Honey * Aloe vera)*	***0.530ⁿˢ***	***0.776ⁿˢ***	***0.825ⁿˢ***	***0.893ⁿˢ***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.

KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination;* ***SE = Standard Error; ns = not significant***

Effect of Hormones on Leave Length (cm) of *Azanza garckeana*: Result on table 6 shows the effect of organic hormones on mean leave length (cm) of *Azanza garckeana*. The mean values recorded for each soil media displayed a non-significant difference ($p \geq 0.05$) on seedling leave length (cm) of *Azanza garckeana* treated with honey and aloe vera for 2nd to 8th weeks after germination. There was an increase in mean leave length (cm) as the weeks increased base on the effect of organic hormones on leave length (cm) of *Azanza garckeana* (2nd to 8th weeks after germination). The highest value for each soil media treated with honey was obtained from soil media of LS, this was followed in order of performance as CS > SD > SS.The result on leave length (cm) of *Azanza garckeana* treated with aloe vera reveals that soil media of LS exhibited highest mean value, this was followed by SS > CS > SD respectively.The independent T-test result on effect of hormones on mean leave length (cm) of *Azanza garckeana* was not significantly ($p \geq 0.05$) different (0.870, 0.742, 0.711 and 0.720) at 2nd to 8th weeks after germination respectively.

Table 7: Effect of Hormones on Mean Leave Length (cm) of *Azanza garckeana*

Hormones	LEAVE LENGTH (cm)			
	2WAG	**4WAG**	**6WAG**	**8WAG**
Honey				
SD	2.76^a	3.00^a	3.18^a	3.46^a
SS	2.32^a	2.80^a	3.20^a	3.74^a
CS	2.68^a	3.10^a	3.34^a	3.62^a
LS	3.64^a	4.22^a	4.66^a	5.08^a
SE	**1.481**	**1.684**	**1.829**	**2.006**
p-value	***0.933***	***0.932***	***0.927***	***0.936***
Aloe vera				
SD	2.88^a	3.20^a	3.44^a	3.80^a
SS	2.80^a	4.00^a	4.58^a	5.24^a
CS	3.06^a	3.38^a	3.70^a	3.86^a
LS	3.30^a	4.02^a	4.48^a	4.92^a
SE	**1.496**	**1.722**	**1.888**	**2.047**
p-value	***0.995***	***0.980***	***0.965***	***0.942***
*Independent T-test (Honey * Aloe vera)*	***0.870^{ns}***	***0.742^{ns}***	***0.711^{ns}***	***0.720^{ns}***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination;* ***SE = Standard Error; ns = not significant***

Effect of Hormones on Colar Girth (cm) of *Azanza garckeana*: Result on table 8 shows the effect of organic hormones on mean collar girth (cm) of *Azanza garckeana*. The mean values recorded for each soil media displayed a non-significant difference ($p \geq 0.05$) on seedling collar girth (cm) of *Azanza garckeana* treated with honey and aloe vera for 2nd to 8th weeks after germination. There was an increase in mean collar girth (cm) as the weeks increased base on the effect of organic hormones on collar girth (cm) of *Azanza garckeana* (2nd to 8th weeks after germination). The highest value for each soil media treated with honey was obtained from soil media of LS, this was followed in order of performance as CS > SS > SD. The result on collar girth (cm) of *Azanza garckeana* treated with aloe vera reveals that soil media of SS exhibited highest mean value, this was followed by LS > CS > SD respectively. The independent T-test result on effect of hormones on mean collar girth (cm) of *Azanza garckeana* was not significantly ($p \geq 0.05$) different (0.813, 0.893, 1.000 and 0.864) at 2nd to 8th weeks after germination respectively.

Table 8: Effect of Hormones on Mean Colar Girth (cm) of *Azanza garckeana*

Hormones	COLAR GIRTH (cm)			
	2WAG	**4WAG**	**6WAG**	**8WAG**
Honey				
SD	0.66^a	0.90^a	1.04^a	1.14^a
SS	0.66^a	1.04^a	1.28^a	1.54^a
CS	0.74^a	0.96^a	1.72^a	1.26^a
LS	0.94^a	1.24^a	1.00^a	1.76^a
SE	**0.389**	**0.526**	**0.623**	**0.707**
p-value	***0.950***	***0.970***	***0.838***	***0.924***
Aloe vera				
SD	0.56^a	0.74^a	0.86^a	0.96^a
SS	1.04^a	1.58^a	1.78^a	1.90^a
CS	0.74^a	0.82^a	0.96^a	1.00^a
LS	0.90^a	1.18^a	1.44^a	1.54^a

SE	**0.370**	**0.467**	**0.545**	**0.586**
p-value	***0.816***	***0.578***	***0.612***	***0.627***
*Independent T-test (Honey * Aloe vera)*	***0.813^{ns}***	***0.893^{ns}***	***1.000^{ns}***	***0.864^{ns}***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination;* ***SE = Standard Error; ns = not significant***

Effect of Hormones on Number of Leaves of *Azanza garckeana*: Result on table 9 shows the effect of organic hormones on mean number of leaves of *Azanza garckeana*. The mean values recorded for each soil media displayed a non-significant difference (p $\geq$0.05) on seedling number of leaves of *Azanza garckeana* treated with honey and aloe vera for 2nd to 8th weeks after germination. There was an increase in mean number of leaves as the weeks increased base on the effect of organic hormones on number of leaves of *Azanza garckeana* (2nd to 8th weeks after germination). The highest value for each soil media treated with honey was obtained from soil media of LS, this was followed in order of performance as SS > CS > SD. The result on number of leaves of *Azanza garckeana* treated with aloe vera reveals that soil media of LS exhibited highest mean value, this was followed by SS > CS > SD respectively. The independent T-test result on effect of hormones on mean number of leaves of *Azanza garckeana* was not significantly (p$\geq$0.05) different (0.860, 0.789, 0.601 and 0.630) at 2nd to 8th weeks after germination respectively.

Table 9: Effect of Hormones on Mean Number of Leaves of *Azanza garckeana*

Hormones	NUMBER OF LEAVES			
	2WAG	**4WAG**	**6WAG**	**8WAG**
Honey				
SD	4.20^{a}	4.80^{a}	5.40^{a}	6.00^{a}
SS	4.40^{a}	5.80^{a}	7.40^{a}	8.80^{a}
CS	5.20^{a}	6.20^{a}	6.60^{a}	7.40^{a}
LS	6.00^{a}	7.40^{a}	8.20^{a}	9.20^{a}
SE	**2.619**	**3.142**	**3.490**	**3.922**
p-value	***0.960***	***0.949***	***0.949***	***0.936***
Aloe vera				
SD	4.60^{a}	5.20^{a}	6.20^{a}	7.20^{a}
SS	5.20^{a}	7.20^{a}	9.80^{a}	10.60^{a}
CS	4.80^{a}	5.60^{a}	6.60^{a}	7.40^{a}
LS	6.40^{a}	8.40^{a}	10.00^{a}	11.40^{a}
SE	***2.530***	***3.062***	***3.665***	***4.160***
p-value	***0.958***	***0.872***	***0.820***	***0.846***
*Independent T-test (Honey * Aloe vera)*	***0.860^{ns}***	***0.789^{ns}***	***0.601^{ns}***	***0.630^{ns}***

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Duncan multiple range test.
KEY: *SD = Saw dust; SS = Sharp Sand; CS = Compost Soil; LS = Loamy Soil; WAG = Weeks after germination;* ***SE = Standard Error; ns = not significant; ** = Significant***

Discussion :Effect of different Soil Media on the germination of *Azanza garckeana seedling*: The result for germination percentage, days of emergence, days of late seed emergence and number of emerged seed shows that the seeds sown in saw dust (SD) was was better in all of the parameters examined as it gave the highest germination percentage of 70%, this finding is in agreement with Olasan *et al* (2021) who reported that saw dust enable germination and growth performance of bambara groundnut. This was followed by seeds sown in loamy soil 60%, then the seeds sown in compost 40%, seeds sown in shape sand which gives the least results with 30%. This finding disagree with Rashid *et al*. (2021), who reported After feeding each plant in each soil in an equal amount, it was found that the productivity of plants in loamy soil was higher than that of plants in the other soil samples (Plants grown on clay soil improved over those grown on sand and silt soil, but not as much as those grown on loam. In sandy soil, the plants grew the least well. This demonstrates that loamy soil is best for Triticum aestivum plant growth and that loamy soil increases wheat crop productivity the highest In regard to seeds sown in saw dust, sharp sand and compost soil were not significantly different with few days of emergence and lastly seeds sown in loamy soil as it shows longer period of seed emergence of 16 days.

Effect of different Soil Media on the growth of *Azanza garckeana seedling:* The different soil media affected the germination of A. garkeana seeds and significantly (p<0.05) affected seedling performance of this species. This agreed with the findings of Kundu *et al*., (2011) asserted that the exposure of different types of abiotic and biotic stresses, such as drought, high temperature, salinity and pathogens adversely affected the growth and productivity of Vigna mungo. Also, Jawayria *et al*., (2018) reported that Variation in seedling growth performance of pea (Pisum sativum L.) seedlings can be attributed to the treatment of different types of soil in investigating the effect of different soil medias on the growth of Azanza garckeana In terms of seedling height, the result of the finding reveals that there was no significant difference from week 2nd to 8th as compose manure gave gave the best best seedling height this was followed by shape sand, loamy soil and saw dust.In terms of leave length the result shape sand compose manure had the best performance this was followed by shape sand, loamy soil, the least was saw dust this finding also disagree with the finding of Dada *et al* (2019) who reported seedlings of A. muricata in the control experiment had the highest mean leaf area of The result for colar girth shape sand this was followed by loamy soil compose manure and saw dust gave the least performance. The result also shows that shape sand gave the best leave number this was followed by compose manure, then loamy soil and was obtained from saw dust this finding disagrees with Abdulazeez (2017) who reported that loamy soil is an ideal soil for sufficient vegetative growth, root development, uniform seed germination, uniform seedlings and post seedlings management of the plant.

The overall best soil media indicated that compost soil indicates the best result for growth of Azanza garkeana seedlings this research is in line with (Sayara *et al*. 2020) who started that to improve soil aggregation, restore soil organic carbon and nitrogen, and increase agricultural sustainability, compost application is being advocated as a substitute for synthetic fertilizers (Choudhary *et al*. 2018). Almost all the previous literature provides information regarding. This finding contradicts that of (Rashid *et al.* 2021) who reported that loamy soil is best for Triticum aestivum plant growth and that loamy soil increases productivity the highest. This finding also disagrees with the research of Dada *et al* (2019) who reported that. At the least of all soil media used for seedlings growth is saw dust which could be as a result of excessive organic carbon.

Effect of different growth hormones on the growth Azanza garckeana seedling.: The effect of two different organic growth hormone (honey and aloe vera) on the growth of Azanza garckeana as determine by the plant's height, leave length, leave number and colar girth as planted in different growth media, The finding reveals that there was a non-significant difference ($p > 0.05$) on seedling height (cm) of *Azanza garckeana* treated with honey and aloe vera for 2nd to 8th weeks after germination. the effect of growth hormones reveals that both horney and aloe vera performs best on the seedling in loam soil. The result of this finding is in contradiction with the finding of (Mirihagalla, and Fernando, 2020) who reported that honey and aloe vera perform best on saw dust growth medium ho reported that , Aloe leaf extract has beenused to improve vegetative growth ofsome crop species. leaf powder, Aloe vera as a bio stimulant, was used to enhance growth and yield of *Abelmoschus esculentus.* So also many basil varieties were treated with Aloe vera as bio-fertilizer and some plant extracts on growth and yield (Ahmed *et al.,* 2014

Conclusion: The study on the effect of different soil media and organic hormones on the germination and early growth of *Azanza garckeana* revealed significant findings. Sawdust and loamy soil were the most effective soil media for germination, with sawdust showing the highest germination percentage. Compost soil and sharp sand also supported germination but to a lesser extent. Organic hormones, specifically honey and aloe vera, positively influenced seedling height, leaf length, and collar girth, with loamy soil treated with honey showing the best overall growth performance. These findings highlight the importance of selecting appropriate soil media and organic hormones to enhance the germination and early growth of *Azanza garckeana.*

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Effect of Cassava Starch Coatings on the Sensory Characteristics of Orange Fruits (*Citrus sinensis* L. *osbeck*) Sold in Yola, Adamawa State, Nigeria

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Abstract

Effect of cassava starch coatings on the sensory characteristics of orange fruits sold in Yola, Adamawa State, Nigeria was investigated. The experiment was laid out in completely randomized design (CRD) with four treatments, the obtained data were analysed using SAS statistical software package. Fresh oranges of uniform sizes were purchased from Jimeta fruits and vegetables market, the name of the cultivar was Ibadan Sweet. The oranges were treated and coated with different concentration of cassava starch solution (0, 30g, 40g and 50g). Dipping method was used as the process of applying the coating on the oranges for a period of one minute and removed to air dried. The coated and uncoated oranges were stored for a period of 27 days under ambient room temperature. Data were taken at an interval of 3 days. The results indicated that, in terms of marketability of the fruits after 6 days in storage, oranges coated with 30g was the highest having (100%) while, the lowest was found to be in the control and 50g having both (86.66%) respectively. Signs of disease incidence occurred on the oranges after 9 days of storing, which was highest in the control and 50g cassava starch coating with both having (13.33%). From this study, oranges coated with 30g cassava starch was recommended because it maintained the best fruit quality in terms of low percentage decay and disease incidence, higher marketability and overall good sensorial attributes. Also, further study should be carried out in order to compare it with other starch-based substances such as corn starch.

Keywords: Cassava Starch, Coatings, Sensory Characteristics. Orange Fruits.

Introduction: Orange (*Citrus sinensis* L. *osbeck*) is an important fruit in Nigeria. It is very rich in vitamin C; folic acid and it is also as a good source of fibre (Tafinta *et al*., 2013). It also contains a host of other important nutrient element like foliate, thiamin, niacin, vitamin B6, phosphorus, magnesium and copper (Mba, 2018). Orange is one of affordable fruit in Nigeria, a major source of vitamin C and a choice fruit for roadside merchants and hawkers. Its major products include orange juice, concentrates, fresh squeezed juice, smoothies and marmalades. Orange, like any other perishable fruits and vegetables is susceptible to wastage and losses in Nigeria. According to Yusha'u (2017) a large percentage of oranges produced in the country annually are wasted along the supply chain. Post-harvest loss in orange fruit production are due to improper care of the fruit and use of inappropriate harvesting equipment with high postharvest losses occurring during harvesting, transportation, marketing, storage, display for sale and sometimes glut in the market with poor demand (James *et al.,* 2017). Coating is a modified atmosphere technology applied directly to the product surface in addition to or as a replacement for natural protective waxy, and provides a thin layer barrier to moisture, O_2 and CO_2 exchange (Porat *et al.,* 2018). Its main goals are to inhibit ethylene production and/or action, which, in turn, delay respiration rate, delay ripening, prolonging shelf life, and reducing postharvest losses. Cassava is an important source of starch worldwide. This is because cassava starch is one of the most naturally abundant biopolymers, and the most used component for polysaccharides films. It is widely available, inexpensive and has good film-forming properties (Souza *et al.,* 2013). In recent years, the potential use of cassava starch as an edible film or coating have been studied widely with promising results (De Moraes *et al.,* 2013). This study was conducted to investigate the effect of cassava starch coatings on the sensory characteristics of orange fruits sold in Yola, Adamawa State, Nigeria

Materials and Methods: Study Area: The study was conducted at the laboratory of the Department of crop production and horticulture, Modibbo Adama University, Yola. Yola is located in northern guinea savanna region of Nigeria ($9^0 21^{''} 9^{''}$ N and longitude $12^o 30^{''} 15^{''}$ E) at an altitude of 224.4m above sea level. The climate in the region consists of two distinct seasons, rainy season (May to October) and dry season (November to April). The experiment was laid out in completely randomized design (CRD) with four treatments. Freshly matured, unbruised and undamaged sweet orange fruits were purchased from Jimeta fruits and vegetables market, while the commercially available cassava starch was purchased from Jimeta ultra-modern market, Yola, Adamawa State, Nigeria. Orange fruits of uniform maturity stage with peel colour as a criterion to judge maturity was purchased from Jimeta fruits and vegetables market. The orange fruits were graded, sorted and transported using manual labour to the experimental site using fibre boards (cartons) and taken to the laboratory. The orange fruits were again sorted and mechanically injured orange fruits were discarded. The orange fruits were stored under ambient condition. The cassava starch coating solution was prepared by dissolving 30, 40 and 50g in hot water. Cassava starch emulsion was prepared by suspending 30, 40 and 50 grams of cassava starch made up to a volume of 600ml of hot water respectively, with continuous stirring until gelling was formed. The emulsion was allowed to cooled off and settle down. The orange fruits were then dipped into the different concentration of the starch emulsion for one minute and then allowed to air dried. For each treatment, ten orange fruits were placed into a perforated bowl and replicated three times. The coated as well as the uncoated i.e. the control orange fruits were left uncovered in the laboratory at room temperature and observed for the period of 27 days, data were taken at an interval of 3 days. The sensory characteristics evaluation was the attributes of general appearance, colour, texture, taste and acidity of the different treatments was evaluated by taste panellist. They were guided with a 9-point hedonic scale which is (1-Like extremely; 2- Like very much; 3- Like moderately; 4- Like slightly; 5-Neither like nor dislike; 6-Dislike slightly; 7- Dislike moderately; 8- Dislike very much; 9- Dislike extremely). The sensory test was carried out on initial day i.e. 0, 5th, and 10th days after coating the orange fruit. A total of number of twelve (12) panellist were randomly selected to conduct the sensory test. Data collected was analysed using SAS 9 statistical package. Mean separation was done using LSD at 5% confidence intervals.

Results: Table 1 shows the intervals of the 9 scale classes for the score means for the sensory characteristics parameters of untreated or treated with 30g, 40g, or 50g cassava coatings under storage 0, 5 and 10 days. The observed parameters were general appearance, texture, taste, colour, and the acidity levels as assessed by 12 panellists. There was significant effect for general appearance in day 5 and 10 (P=0.019 and 0.037) but, there was no significant difference in 0 day (P=0.863). There was significant effect for texture in day 5 and 10 (P=0.026 and 0.250) but, there was no significant difference in 0 day (P=0.400). There was significant effect for taste in day 5 and 10 (P=0.019 and 0.029) but, there was no significant difference in 0 day (P=1.000). There was a highly significant effect for colour in day 5 and 10 (P= 0.001 and 0.004) respectively but, there was no significant difference in 0 day (P=0.863). There was a highly significant effect for acidity level of the orange in day 5 (P=0.005) and a significant difference in 10th day (P=0.004) but, there was no significant difference in 0 day (P=0.539).

Table 7: Effect of cassava starch coatings on sensory evaluation of orange fruit.

	Days in storage (Appearance)		
TREATMENTS	0	5	10
T1	4.00	2.33	2.00
T2	3.67	3.33	2.00
T3	3.33	3.33	3.67
T4	3.33	4.33	4.33
MEAN	3.58	3.33	3.00
P value	0.863	0.019	0.037
LSD (0.05%)	2.105	1.087	1.803
	Texture		
T1	2.33	3.33	5.00
T2	1.67	1.33	3.00
T3	1.33	2.00	4.00
T4	2.00	1.33	6.00
MEAN	1.83	2.00	4.50
P value	0.400	0.026	0.250
LSD (0.05%)	1.331	1.331	3.261
	Taste		
T1	3.33	2.33	2.00
T2	3.33	3.33	2.33
T3	3.33	3.33	4.33
T4	3.33	4.33	5.67
MEAN	3.33	3.33	3.58
P value	1.000	0.019	0.029
LSD (0.05%)	2.549	1.087	2.491
	Colour		
T1	4.00	1.33	1.00
T2	3.67	3.33	2.00
T3	3.33	3.33	3.67
T4	3.33	4.33	4.33
MEAN	3.58	3.08	2.75
P value	0.863	0.001	0.004
LSD (0.05%)	2.105	1.087	1.537
	Acidity level		
T1	4.67	1.33	1.33
T2	4.33	3.00	2.00
T3	3.33	3.33	4.00
T4	4.00	4.33	5.00
MEAN	4.08	3.00	3.08
P value	0.539	0.005	0.024
LSD (0.05%)	2.105	1.331	2.369

Discussion: The change in appearance was recorded for uncoated (control) and coated oranges. The coated oranges were found to have a longer shelf life compared to uncoated ones. Coated oranges were glossy in appearance and had a much smoother surface compared to uncoated ones. Among the coated ones, 30g coated oranges appeared better compared to 40g and 50g coated ones in terms of good appearance and shelf life. It was found that the most liked attributes of coated tomatoes were brightness, appearance and colour. The treated oranges had a good appearance and recommended better quality. Shiny and smooth surface of the coated orange may be endorsed to the smooth and see-through features of the cassava starch. This is in agreement with the findings of Etebu and Nwauzoma (2014). The texture of all the treatments from day 0 up to day 5 is liked very much by the panellist, after day 5, there was a shift to the treated oranges which were liked very much compared to the control group, which were slightly liked. The results obtained was in corroboration with the study of Fakayode *et al*. (2010) which reported similar findings on orange fruits. Overall fruits coated with cassava starch had the highest rating for both conditions of storage. Based on sweetness alone untreated fruits was most preferred up to day 5 of storage owing to the taste quality. The 50g and 40g cassava starch coating had the rejected taste because of the inability of gas exchange between the fruit and the atmosphere. Musasa *et al.* (2013) reported that beeswax and starch combination allow for gas exchange (O_2 and CO_2) and reduced accumulation of volatile compounds associated with fermentative metabolism. At the initial stage of the experiment all the fruits were green in colour. Fruit colour of orange fruits of the control group changed from different shades of green to green with traces of yellow during storage. Fruits treated with cassava starch remain green up to 10th day after treatment, compare to other treatments i.e. untreated. This could be due to cassava starch coating being more effective in delaying the ripening of mature orange fruits compared to control. This was in agreement with the findings of Adewale *et al.* (1996) which reported that the rate of colour development in the skin of uncoated fruits might be attributed to the degradation of chlorophyll during a fast ripening and senescence processes of the fruits. On the other hand, the delayed changes in colour of 1.5, 2.0 and 2.5% coated fruit might be attributed to the decreased O_2 and increased CO_2 internal concentrations, which have slowed down the ripening. From the test result it is discovered that coated fruits retained more amount of acid content during storage of orange fruits. This was probably because cassava starch coating acted as a gas barrier, inhibiting oxygen from entering the fruit, acidity is lost at later stage of storage.

Conclusin: The coating of orange fruits with cassava starch under ambient room temperature has slowed down weight loss during storage. Although, the fruits coated with 30g cassava starch gave a good result in terms of less weight loss, low shrinkage, less decay and disease incidence, good marketability percentage and had an acceptable during the 27 days storage period. It is therefore concluded that, the use of cassava starch coatings could delay the postharvest senescence process and can maintain the quality of orange fruits, thus extending shelf life for 15 days.

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Assessment of the Eutrophication Level of Municipal Surface Water in Jos Metropolis, Plateau State

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Abstract

Water bodies provide aquatic animals for human consumption and also serve as sources of water for domestic, agricultural and industrial usage. However, the water bodies are faced with the challenges of continuous anthropogenic effects caused by human activities. This study is aimed at assessing the eutrophication level of municipal surface water in Jos metropolis by analysing the physico-chemical parameters of the water and algal bloom. The physico-chemical parameters analyzed are pH, temperature, electrical conductivity, dissolved oxygen, chemical oxygen demand, total dissolved solids, phosphate, sulphate and nitrate. The algal bloom was also assessed by spectrophotometric method. The result showed that pH and electrical conductivity values for both water was within the WHO permissible limit while temperature for the water bodies exceeded the limit. The chemical parameters of Rayfield and Lamingo water dam samples showed that sulphate content, dissolved oxygen, total dissolved solids, phosphate and nitrate all showed significant difference ($p \leq 0.05$). Rayfield sample gave higher values in the dissolved oxygen (40.00±1.30) and phosphate (35.10±0.22), Lamingo sample gave higher values in the sulphate (40.00±1.30), total dissolved solids (23.5±0.30) and nitrate (19.90±0.19) when compared with each other. The result of the sulphate content, total dissolved solids, phosphate content and nitrate content were above the WHO permissible, while that of the chemical oxygen demand was observed to be lower than the WHO limit while the algal bloom The value of the algae bloom recorded in Lamingo dam showed a significant higher value (28.90±1.96) than that of the Rayfield water dam sample, with a mean value of 25.00±1.32. The algae bloom of the water sample in the two locations were however, higher than that of the WHO standard.

Keywords: Eutrophication, water quality

Introduction: Eutrophication is a process of both natural and anthropogenic origin, which has been defined in numerous ways, that ranges from the natural ageing of a water body to a eutrophic status. This takes place over a long geological time, to a quick rise in trophic position of a water body as an outcome of anthropogenic activities, and this is called cultural eutrophication (Sonarghare *et al*., 2020 and Akinnawo, 2023). Eutrophication is categorized by excessive growth of plants and algae ensuing from increased availability of limiting growth factors (for example sunlight, carbon dioxide, and nutrient fertilizers) required for photosynthesis (Sonarghare *et al*., 2020; Zhang *et al*., 2023). Thus rendering eutrophication a detrimental factor that results in the pollution of water bodies which threatens the continued existence of aquatic organisms as a result of algae blooms ensuing from the nutrient enrichment of water bodies attributed to the dependence of the human populace on nutrient and fertilizers for food production (Carpenter, 2008; Akinnawo, 2021; Zhang, 2022 and Akinnawo, 2023). Eutrophication therefore causes progressive deterioration of water quality especially lakes due to luxuriant growth of plants with the effect that the overall metabolism of the water is affected (Richard, 2010). Surface water refers to all those water bodies that accumulate on earth's surface. It includes oceans, rivers, streams, lakes, ponds, creeks, wetlands and reservoirs. Surface water includes water found in stream, river, lakes, marshland, snow, ocean water or any other water found on earth's surface. It is collected at ground level and can be collected by precipitation. This water is naturally open to the atmosphere (Shoshana, 2012). The aim of this work is to assess the eutrophication level of water surface water in Jos metropolis.

Materials and Methods: Sample Collection: The water sample was collected from Lamingo Dam Jos North Local Government and Rayfield Resort Jos South Local Government in Plateau State. The water was collected in a prewashed polyethene bottle that was previously rinsed with nitrate acid to avoid contamination, labelled properly and taken to University of Jos Biochemical Lab for further chemical analysis

Physico-Chemical Parameters of the Surface Water : The analysis of pH, electrical conductivity and total dissolved solids were carried out using standard protocols and methods of American Public Health Association (APHA, 2012).

Nitrate Content: Exactly 25 ml of water sample was pipette into a clean conical flask and 2-3 drops of diphenylamine was added as an indicator. The water was titrated with 0.02 ml of H_2SO_4 solution (which turn blue). The blue color indicates the presence of Nitrate which mark the end point.

Sulphate Content : Exactly 25ml of the water sample was place in 250ml conical flask. Barium chloride solution was titrated through the burette into the water. The appearance of white precipitate indicated the present of sulphate in the water.

Determination of Phosphate Content : Exactly 50ml of the water sample was measured and place in 250ml beaker. The sample was acidified with concentrated nitric acid and white ammonium molybdate. The present of phosphate ion was indicated by formation of bright yellow precipitate layer of ammonium phosphate molybdate. This solution was filtered and dried in a desiccator and weighed.

Calculation = Initial weight - Final weight

Initial Weight = Weight of filter paper

Final Weight = Weight of the filtrate

$= W_2 - W_1$

Dissolved Oxygen (The Winkle Method): The winkle method is done by noting a color change when titrating a fresh water sample. Exactly 25 ml of the water sample was pipette into a clean conical flask. 2ml of alkali iodide reagent and starch solution was added as an indicator. The water sample was titrated with 0.02 ml H_2SO_4 solution until the blue colour disappear. The burette reading was noted as the end point.

Chemical Oxygen Demand (COD): Exactly 50ml of the water sample was measured and place in 250ml beaker. Another 50ml of deionize water was measured and place in 250ml beaker. 2 ml of HCl and 3 ml of HNO_3 acid was added to the water samples. The sample was transferred to hot plate and allowed to digests under the fume cupboard at temperature of 200 ^{0}C for 30 minutes. After 30minutes, both water samples were removed and place in desiccator to cool to room temperature. Spectrophotometer was use to read the absorbance at 450nm. Deionize water was used as blank sample.

Biochemical Oxygen Demand (BOD): This was done by taking the initial reading at the point of collection of the water samples while the final reading was taken after the water was incubated in the laboratory for 5 days. The Biochemical oxygen demand (BOD) was determined by subtracting the initial dissolved oxygen (DO) from the final (DO).

Quantitative Determination of Algal Bloom : Spectrophotometer was used to read the absorbance of light that passes through the water samples at 4.36 nm using deionize water as blank. Algae bloom absorb light so by streaming a beam of light through the water sample of algae at certain frequency using this device you will be able to measure the amount of light that has pass through or that has been blocked.

Result and Discussion

Table 1: Physico-chemical parameters of Rayfield and Lamingo Dam Water Quality with WHO Standard

Physical Parameters	***Rayfield***	***Lamingo***	***WHO***
pH determination	7.93±0.07^a	6.70±0.11^b	6.5-85
Temperature	25.00±2.00	22.00±1.00	18.5^{o}C
Electrical Conductivity	199±7.00	203±0.30	300 µS/cm
Chemical Parameters (mg/mL)			
Sulphate Content	28.1±1.20^b	40.00±1.30^a	25
Dissolved Oxygen (DO)	40.00±1.30^a	2.77±0.36^b	6.5-8
***Chemical** Oxygen Demand*	1.1±0.03	1.26±0.11	2.25-500
Total Dissolved Solid	19.9±0.40^b	23.5±0.30^a	15.0
Phosphate content	35.10±0.22^a	30.00±1.20^b	15.0
Nitrate content	17.8±0.12^b	19.90±0.19^a	10

All values are expressed as mean± (standard deviation, n=3); means within the same row (Rayfield and Lamingo) having similar superscript alphabets are not significantly different at $p \leq 0.05$. Values (Rayfield and Lamingo) without superscript alphabets are not significantly different at $p \leq 0.05$. s/m = Siemens/meter.

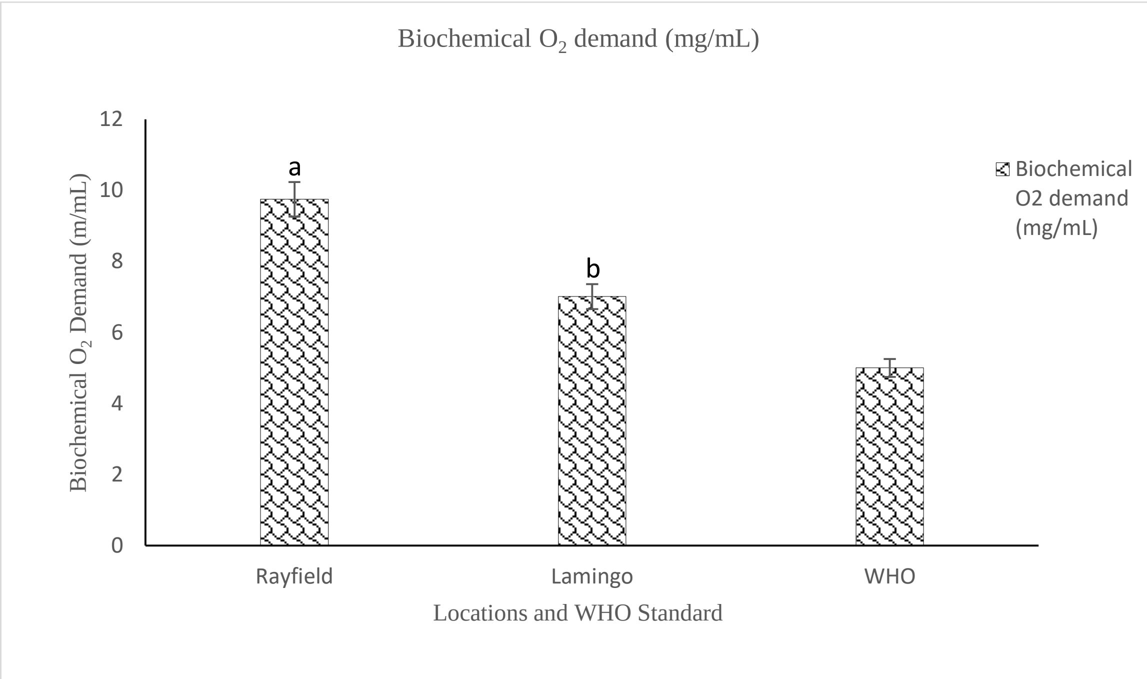

Figure 1: Biochemical Parameter of Rayfield and Lamingo Dam Water

a

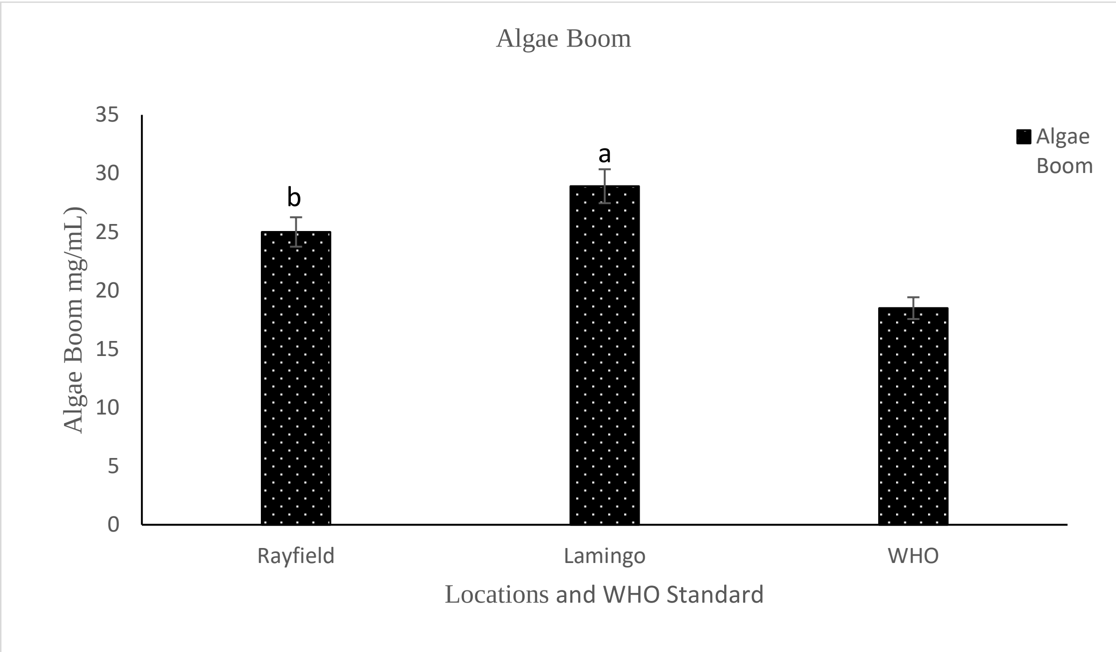

Figure 2: Algae Bloom of Rayfield and Lamingo Dam Water Samples

Discussion: Lakes and dams are water bodies that form essential parts of the ecosystem. They provide aquatic animals for human consumption and also serve as sources of water for domestic usage. Water bodies existing around cities also add beauty to the environment. They are however, faced with the challenges of continuous anthropogenic effects caused by human activities. They contain different forms of impurities brought by weathering, leaching, aerosol dissolution, mining activities and use of metallic materials etc (**Chen *et al*., 2020**). The high temperature of the water bodies could be as a result of impurities present in the water. Impurities normally account for changes in the temperature of water bodies by slightly raising the temperature beyond the normal range (Hodneland *et al*., 2019). Higher temperature observed in Rayfield dam must have been as a result of higher human activities and social activities which occur around the dam, thereby raising the water temperature as compared to that of Lamingo dam with only farming activities. **In an established system, the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Patil *et al*. (2012) reported that drastic temperature changes of water bodies can be fatal to aquatic organisms.** The temperature of the two water bodies, however showed significant difference from each other at $p \leq 0.05$, although, Lamingo dam gave higher mean value of 25.00±2.00 ^{0}C. They were, however within the WHO permissible limit. The electrical conductivity of the two water bodies, however, showed significant difference from each other at $p \leq 0.05$. Lamingo gave higher mean value of 203±0.30 s/m while Rayfield gave a lower mean value of 199 ±7.00 ^{0}C. The electrical conductivity of the two samples were below the WHO permissible limit.

The pH of the two dams can be an indication of how polluted the water has become or how less polluted it is as a result of the anthropogenic activities in the area. The result in Table 1 showed that significant difference occurred ($p \leq 0.05$) among the Rayfield and Lamingo dam samples in term of their pH values. **The acidic level in the Lamingo dam could be as a result of the effects of chemicals and fertilizers being washed to the dam due to farming activities which occur all-year-round around the dam. The slight alkalinity in the Rayfield dam might be due to fermentation of organic matter released during social activities around the vicinity of the water. This is similar to the published work of Aprol *et al*. (2021) stating that alkalinity pH in Lake Burullus, Egypt could be due to fermentation of organic matter.** The chemical parameters of Rayfield and Lamingo water dam samples is presented in Table 1. The result showed that sulphate content, dissolved oxygen, total dissolved solids, phosphate and nitrate all showed significant differences ($p \leq 0.05$). Rayfield sample gave higher values in the dissolved oxygen (40.00±1.30) and phosphate (35.10±0.22), Lamingo sample gave higher values in the sulphate (40.00±1.30), total dissolved solids (23.5±0.30) and nitrate (19.90±0.19) when compared with each other (Table 2). The result of the sulphate content, total dissolved solids, phosphate content and nitrate content were above the WHO permissible, while that of the chemical oxygen demand was observed to be lower than the WHO limit.

Dissolved oxygen relates to the available oxygen to aquatic animals and it is of importance to their survival. Under low dissolved oxygen, many marine plants and animals may not survive (Sharawy *et al*., 2020). The result of the Lamingo dam water sample gave a low dissolved oxygen value. The low level of dissolved oxygen in the Lamingo dam could be as a result of the less plant growth in the water due to the released acidic materials which do not support plant growth. This could have led to less photosynthetic activities and hence, less oxygen released, since photosynthesis releases oxygen as by-product. The high value of dissolved oxygen in Rayfield dam water could be a s a result of high plankton which causes higher photosynthetic activities. This is similar to the work of Magouz *et al*. (2021); ELshobary *et al*. (2020) and El-Shenody *et al*. (2019) which stated that high value of dissolved oxygen could be due to abundance of plankton which enhance water quality.

Nutrients from anthropogenic pollution can degrade water quality and alter the balance of marine food webs (Abo-Taleb *et al*., 2020; Ashour and Kamel, 2017). Nitrate (NO_3) is considered as the most stable and predominant inorganic nitrogen form in seawater, in addition to major nutrients for the phytoplankton growth. Nitrate serves as another electron acceptor under anoxic conditions. The nitrate content of the two dam water samples is 17.80±0.12 and 19.90±0.19 for Rayfield and Lamingo respectively which were observed to be higher than the WHO limit of 10 mg/ml. The high nitrate content might have been due to the mineralization of organic matter around the water bodies, and the release of nitrogenous fertilizer used for farming activities. The result obtained (1780 mg/l and 1990 mg/l) higher in comparison with that of Aprol *et al*. (2020) in which 0.13 to 1.64 mg/l were obtained from Burullus Lake in Egypt. The result of biochemical oxygen demand shows that significant difference occurred among the two sample at $p \leq 0.05$. The mean value of the Rayfield water dam sample (9.75±0.05 mg/ml) was higher and significantly different from that of the Lamingo water dam sample (7.01±0.80 mg/mL) in terms of their biochemical oxygen demand at $p \leq 0.05$. In comparison with the WHO standard, the two values are higher than the WHO value of 5.00 mg/ml. Algae require oxygen for their growth and therefore, increased algae bloom corresponds to low oxygen availability. It was also reported that most river with biochemical oxygen demand of more than 8 mg/ml is considered severely polluted (Grover and Walts, 2013).

The result of the algae bloom in Rayfield and Lamingo water samples is as presented in Figure 2. The result showed that significant difference occurred between the two data obtained at $p \leq 0.05$. The value of the algae bloom recorded in Lamingo dam showed a significant higher value (28.90±1.96) than that of the Rayfield water dam sample, with a mean value of 25.00±1.32. The algae bloom of the water sample in the two locations were however, higher than that of the WHO standard. The higher algae bloom in the It has been reported that increase in water temperature gives rise to nitrate algae growth (Anderson *et al*., 2012), thereby confirming the increased algae bloom Lamingo sample than that of the Rayfield water sample in this research work.

Conclusion: In conclusion, lakes and dams are water bodies that form essential parts of the ecosystem. They provide aquatic animals for human consumption and also serve as sources of water for domestic usage, however, they are faced with challenges of continuous anthropogenic effects caused by human activities. This study revealed that the physical and chemical parameters of Lamingo and Rayfield lake water bodies differ from each other as a result of the anthropogenic activities occurring in the area which had influence on the physical and chemical properties of the water. The human activities around Lamingo dam and Rayfield lake water influenced the biochemical oxygen demand and the algae bloom of the water. The control of these human activities will make the water suitable for domestic use and also make it habitable for aquatic animals.

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Assessing Adoption of Soybeans Technologies by Smallholder Farmers in Danko-Wasagu Local Government Area of Kebbi State, Nigeria

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Abstract

The study assessed adoption of soybeans technologies by smallholder farmers in Danko-Wasagu Local Government area ofKebbi State, Nigeria. A multistage sampling was used to select Ninety (90) respondents as sample size from the study area. Data collected using structured questionnaire were analyzed using descriptive statistics. The results of socioeconomic characteristics revealed that majority (70%) of soybeans farmers were males, majority (54%) of soybean farmers had primary education, majority (57%) of soybeans farmers had farming as their main occupation, and majority (70%) of soybeans farmers had household size between of 1 – 5 persons. Results on the extent of technologies adoption of pre-planting operations revealed that, majority (50%) of the respondents adopted ploughing technology, (51%) adopted seed rate technology, (50%) adopted the technology of weeding while, (51%) accepted the technology in term of thinning/supply. Results on perception of innovation indicated that soy beans farmers have agreed (4.40) that innovations or technologies have advantages but were expensive (4.50) compared with the traditional methods. It was further established that technologies were simple and affordable (4.63)and were also flexible and reliable(4.55). The study conclude that majority of soybeans farmers are male with low informal education background with low awareness of soybeans technologies in the study area. Based on the result findings, it was recommended that government, non-governmental and financial institutions should make available credit facilities in order to boost soybeans production and for continuous adoption of new technologies by soybeans farmers.

Key words: *Adoption, Technologies, Smallholder Farmers, Soybeans*

Introduction: Soybeans (*Glycine max*) are an upright branching herbaceous warm season beans on annually plants belonging to the family paliniodeace (*leguminoceace*). Soybeans are a staple food of the ancient people for thousands of years. Soybeans were known as one of the five sacred grains the others were wheat, rice, barley and millet. Some historians attributed the survival of China as a nation to their consumption of soybeans as a major source of protein and calories in their diet. Today soybeans products are consumed in vast amount in the world. It is believed that soybeans were first cultivated in China as back as 2838BC. The Northern China was claimed to be the area of its spread to different parts of the world (Egrinya *et al.,* 2011).

Soybeans were first introduced to Nigeria in 1908 (Adekoya, 2010). Most of the early research on the crop was carried out at the moor plantation in Ibadan; Oyo State Germination of soybeans was of great obstacle. Adekoya, (2010) reported that the sudden change in the storage temperature may have been responsible for the rapid deterioration of the embryo and the subsequent failure of the seed to germinate. The main growing areas in Nigeria include the southern Guinea Zone, Benue State, Abuja in Federal Capital Territory and Southern Division of Kaduna State (Egrinya *et al.,* 2011). The economic importance and users of soybeans has becomes a mystery because of the vast uses and applications it is put into, hence it is called a miracle seed (Austine, 2008). Consumer acceptance surveys showed that it has an excellent taste that is highly acceptable to both children and adults and improves the nutritional quality of Nigeria diet and should be given more emphasis in the food marketing system both as cash and a food crop.

A product called Soy Musa produced by the National Horticultural Research Institution Ibadan (NIHORI) is acknowledge being highly nutritive and well accepted by children of all ages soybeans is the most nutritious because it is a very good source of protein and energy. Smith and Cricle, (2010) has estimated that one acre of soybeans will provide enough protein to sustain a moderately active man for 2,224 days. Soybeans also contain small proportion of Sulphur containing amino acids such as methionine and cyanine, thiamin (vitamin B carbonyls niacin) (Vitamin B6) Phosphorus and calcium (FAOSTAT, 2013). Soybean and soy products, particularly soybean meal, have become increasingly important commodities. China and EU have the dominant place in the total soybean world import (47% and 22%, respectively) (Anonymous, 2011), while EU accounts for 44% of the total soybean meal import. To reach the level of consumption of EU-27 resident, more than 270 000 ha of soybean would be required, which is twice more than achieved in the period 2000-2009. Consequently, the participation of soybean in the sowing structure would be increased to 8%, which is acceptable in terms of proper crop rotation (Bosnjak *et al.,* 2012).

As legume species an annually formation of root and nodule biomass and their decomposition contributed to soil fertility improvement (Vasileva *et al.*, 2016). According to Basic *et al.* (2007) there are insufficiently used capacities for soybean production and processing in Serbia of about 745 000 tons annually. This is an additional reason for the above-mentioned statement that there is stillroom for increasing of soybean production, regardless of the fact that the soybean acreages has already increased by 88 times in the last 50 years. Many factors may have major influences on the extent of adoption of technologies such as characteristics of farm practice; the adopters; the change agents (extension worker, professional, etc.); and the socioeconomic, biological, and physical environment in which the technology is adopted (Fadeyi, Ariyawardana, & Aziz (2022). Nonetheless, Elia, (2018 as cited in African development bank group, 2012) argued that the "adoption gap" could be explained by the "knowledge gap," or the extent to which farmers are still unaware of the new technologies. Hence, the African development bank group, (2012) therefore emphasized the need for further extension services to disseminate knowledge about the significance of new technologies on soya bean production to potential farmers.Despite many studies on soybeans technologies, there are dearth of information on perceptions; awareness and adoptions of soybeans technologies in the study area. It is against this backdrop that this study intends to assess the extent of adoption of soybeans technologies in some selected communities in Danko/Wasagu Local Government Area of Kebbi state, Nigeria.

Methodology: Danko/Wasagu Local Government is one of the twenty-one (21) Local Governments Areas of Kebbi State. It covers an area of four thousand two hundred and eight (4,208km2) square kilometers, with an estimated population of about two hundred and sixty-five thousand, two hundred and seventy-one (265,271) people (National Population Commission, 2006). It is bordered in the south by Sakaba Local Government Area, in the west by Zuru Local Government Area, while North-East by Bukkuyum Local Government Area of Zamfara State (KBSG, 2003). The area lies between latitude 11025” N and longitude 5040” E with weather condition characterized by a single raining season and a long dry season. The average rainfall is 720mm per annum, the rainy season period is between May to October, November to February is cold due to dry harmattan, and March to April is hot and the average temperature is 370C. The area is flat or low topography with fertile soil, covered by sandy soil, sometimes coarse in texture with several fadama and alluvial plain soils suitable for agricultural activities. The area is made up of eight (8) administrative districts namely; Danko, Wasagu, Ribah, Waje, Kanya, Bena, Kyabu, and Wari Districts (Girma, 2008). The purposive sampling technique was used to select five (5) villages namely; Awala, Machika, Waje, Kanya, and Yar’ali for the study. A structured questionnaire was used to collect data from the respondents (100) with the help of an interpreter for those that can read and write. The data collected from the administered questionnaires were analyzed using descriptive statistics such as frequency counts, means, and percentages.

Results and Discussion A). Socio-economic characteristics of sampled Farmers

Table 1: Socio-economic characteristics of sampled Farmers

Variable	*Frequency*	*Percentage (%)*
Sex		
Male	63	70
Female	27	30
Education Background		
Primary Education	49	54.4
Secondary School	26	28.9
Tertiary Education	8	8.9
Non formal education	7	7.8
Occupation		
Farming	51	56.7
Civil Servant	25	27.8
Studentship	9	10
Trading	5	5.6
Family Size		
1-5	63	70
6 and above	27	30

Source: Field survey 2022.

The result on sex indicated that majority (70%) of soybeans farmers were males, while the remaining 30% are females. This indicated men domination in soybeans production in the study area even though women contribute greatly to the agricultural sector of the economy. This assertion is however, disagreed with the findings of Arene (2016) that 50% of the food in Nigeria is produced by women. Result on education revealed that (54%) of soybean farmers had primary education, (29%) had secondary education, (9%) had tertiary education, while (8%) had no formal education. This indicated that majority of soybean farmers in the study area had one form of formal education or the other. This finding has therefore reflected the importance of education in agricultural production activities. The more an individual is exposed to any form of education, the more likely he adopts new technologies.

Results on occupation revealed that majority (57%) of soybeans farmers practiced farming as their main occupation. The implication is that, soybeans production in the study area is not a part time job and that most farmers depend on it as a sole means of livelihood. The results on family size revealed that a majority (70%) of soybeans farmers had household size of 1 – 5 persons. This indicated that soybeans farmers in the study area have responsibilities of family on them. This implied that those with small household size have limited supply of family labour compared to those with large household size.

B). Result on the Extent of Adoption

Table 2: Extent of Adoption of Technologies by sampled Farmers

		Extent of Adoption						
Operations	**Technologies**	Unaware (%)	Aware (%)	Interested (%)	Trial (%)	Accept (%)	Adoption (%)	Rejected (%)
Pre –planting	Land Cleaning	9.0	34.0	12.7	1.0	5.0	38.0	0.0
	Ploughing	2	6	7	3	26.2	50	5.8
	Harrowing	9.5	8.0	12	6	4	40.5	20
	Ridging	4	34.5	20	9.5	32	0	0
	Seed Selection	5.8	12.7	38	12.7	34	5	1
	Seed Dressing	0	34	5	12.7	38	9	1
Planting	Planting	8	35	5	13	38	1	0
	Seed rate	4	4	6	4	51	25	6
	Mode of Planting	6	13	39	12	35	4	1
	Weed Control	2	7	6	3	26	50	6
	Thinning/Supply	6	4	4	25	51	6	4
	Fertilizer Application	7	12	32	19	36	3	1
Post – Planting	Harvesting	34	9	12.7	5	20	18	1
	Threshing	4	3	9	13	20	19	5
	Winnowing	4	34.5	20	9.5	32	0	0
	Bagging	5.8	12.7	38	12.7	34	5	1
	Storage	4	30	9	13	20	19	5

Source: Field survey 2022.

The results on the extent of adoption of technologies in soybean production in terms of pre-planting operation indicated that majority (50%) adopted ploughing technology, while the rest were either unaware, aware, interested, were at trials, accepted or rejected different technologies. Results on seed rates, results revealed that majority (51%) adopted seed rate technology, while the rests either were unaware, were aware, were interested, tried, accepted, or rejected. Results on weeding result reveals that majority (50%) adopted weeding technology whereas the remaining either were aware, unaware, interested, tried accepted or rejected. Results on thinning/supply, result reveals that (51%) accepted the technology and the remaining either were unaware, interested, tried, adopted, aware or rejected.

C). Perceptions on new Technologies

Table 3 Farmers perceptions on new Technologies (n=90)

PERCEPTIONAL STATEMENTS	SA	A	UD	D	SD	WS	WM	Remarks
High Advantage	29	60	1	-	-	484	4.40	Agreed
It is expensive	51	36	2	1	-	495	4.50	Agreed
Simple and affordable	73	13	-	4	-	509	4.63	Agreed
Flexible and reliable	62	20	4	3	1	501	4.55	Agreed
It is complex	14	76	-	-	-	464	4.22	Agreed

Source: Field survey 2022.

Keys: SA=strongly agreed (5) A= Agreed (4) UD=Undecided (3) D=Decided (2) SD=Strongly Disagree (1) WS= Weighted Sum, WM = Weighted Means.

The results on perception indicated that soybean farmers agreed on the statement of, it has advantage (4.40) in assisting their level of priority, but it is expensive compared to traditional method (4.50). This result implies that through the application of innovation in soybeans production, it has a very high advantage to be derived compared with the traditional method. It was further established that other farmers agreed that innovation was simple and affordable to adopt in soy beans production (4.63) as it helps in reducing farmer`s labour on farming. Also it was found that innovations/ technologies were flexible and reliable to apply (4.55) and complex to adopt (4.22) it means it requires technical knowhow to be operated. This result is in line with the findings of Bosnjak *et al*, (2012) who reported that adoption of innovation bring far more benefits to the people of low income in farming perspective.

D). Result on Problems of Adoption of Soybean Technologies: The problems faced by soybean farmers include inadequate improved soybean variety, lack of capital by farmers, lack of awareness, insect problem, inadequate processing equipment and land tenure. The result indicates that the major problem faced by soy beans farmers was inadequate capital in the study area.

Conclusion and Recommendations Based on the results of the study, it could be concluded that factors such as simplicity, affordability, flexibility, reliability and complexity affects adoption of soybeans technologies among soybeans studied in the study area. From the findings of this research, it was recommended that government, non-governmental and financial institutions should make available credit facilities in order to boost soybeans production and for continuous adoption of new technologies by soybeans farmers.

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Evaluation of Insecticidal Potentials of Some Plant Materials against Cowpea Weevil (*Callosobruchus maculatus)* on Stored Cowpea Seeds

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Abstract

A Laboratory study was conducted in the Laboratory of the Department of Agricultural Technology Federal Polytechnic Nekede, Imo State to investigate the effect of Dennettia tripetala , Moringa oleifera , Chromolaena odorata ,Vernonia amygdalina, and Citrus limon powder extracts in the control of Callosobruchus maculatus of stored Cowpea (Vigna unguiculata) . The experimental design was Completely Randomized Design (CRD) with six treatments replicated four times. Fifty (50) adult Callosobruchus maculatus were introduced to 100 gram of the powder plant extract. The effect of the treatments were assessed on the mean number of mortality, longevity of weevil , number of punctures (holes) on cowpea seeds and weight loss of Cowpea seeds.. The results showed that the plant powders were effective against Callosobruchus maculatus in all parameters tested. The highest mortality of weevil was observed in Moringa oleifera (43), followed by Citrus limon powder (11), while Control had zero mortality activity. The results obtained suggests that the plant materials posses insecticidal properties and can be utilized in protecting stored cowpea from C. maculates infestation since they are environmentally friendly, cheaper than synthetic insecticides and safer for humans

Keyword: Evaluation, Insecticidal properties, Plant materials and Cowpea weevils

Introduction: Cowpea (*Vigna unguiculata*), is an edible legume crop and an annual cultivated for its seeds or for fodder. Due to its high protein content, it is used as an important human food in several part of the world (Diaga, 2011) Cowpea grain production is hindered by insects in most cowpea producing area, which lead to economic losses (Spochacz *et al.,* 2018). As the demand for food increases with an ever growing population, it becomes necessary to protect crops and stored grains from pests. Cowpea weevil (*Callosobruchus maculatus*) causes significant damage to store pulses (Bibi *et al.,* 2022). It can cause as much as 90% damage during the three to six months of storage (Agour *et al.,* 2022). Synthetic pesticides can adversely affect non-target organisms, including humans, accumulate in the environment, pollute soil and ground water (Rani *et al.,* 2021), although they are effective in pest management. Of recent, phyto-chemicals have been successfully used to manage pests in crops (Basile *et al.,* 2022). Extracts of plants and other secondary metabolites of plants, micro organisms and enzymes are becoming increasingly popular as alternatives to synthetic pesticides (Batiha *et al.,* 2021). Bio-insecticides can be very effective, selective and environmentally friendly. (Tozlu *et al.,* 2011). Several plant extracts have been used to control various stored insect pests. Essential oils of some aromatic plants have been recognized and antibacterial properties (Zimmermann *et al.,* 2021). The aqueous extract of neem kernel has been used to protect crops from infestation with pests (Ghoneim *et al.,* 2021). The harmful effects of synthetic pesticides have led to the discovery of botanicals or phyto-chemicals. This work is aimed at evaluating the insecticidal potentials of some plant materials against cowpea weevil (*callosobruchus maculatus)* on stored cowpea seeds**.**

Materials and methods

2.1 Experimental Location:
The experiment was carried out at the Laboratory of the Department of Agricultural Technology Federal Polytechnic Nekede, Owerri Imo state

2.2 Insect Culture
Infested Cowpea seeds were purchased locally from cluster market Nekede, in Owerri, Imo State. The weevils (Cowpea bruchid) were cultured by weighing 1000g of the infested cowpea seeds in plastic containers that covered with muslin cloth and held tightly with rubber band to avoid escape of the insects. The muslin cloth was used to ensure adequate aeration and prevent entering of other insects. The insects were cultures for 105 days in Agricultural Technology Laboratory, Federal Polytechnic Nekede, Imo State. The insect culture was carried out under ambient environmental conditions

2.3 Collection of Uninfested Cowpea Seeds:
Uninfested and susceptible cowpea seeds were purchased from National Cereal Research Institute, Amakama Umuahia. The seeds were graded manually to obtain uniform sized seeds . Hundred grams (100g) of uninfected and undamaged bean seeds were placed into 200ml plastic containers and covered with a white muslin cloth.

2.4 Collection of plant materials
The plant materials used namely: Leaves of *Dennettia tripetala*, *Moringa oleifera, Chromolaena odorata*, *Vernonia amygdalina*, and peels of *Citrus limon* were sourced within Nekede Community.

2.5 Preparation of Plant Material
The leaves of *Dennettia tripetala, Moringa oleifera, Chromolaena odorata and Vernonia amygdalina* were washed and air dried at room temperature for 10 days. The dried leaves were later pulverized separately into fine powder with the aid of an electric blender. The peel of *Citrus limon* was obtained from fresh ripe lemon fruits (*Citrus limon*) which was purchased from fruit dealers at Owerri main market. It was peeled, washed with clean water and air dried for 15 days at room temperature. It was then ground into fine powder using

a warring laboratory dry mill. This was packed into air tight containers and put in a refrigerator at 4ºC to retain its good quality before application.

2.6 Application of plant materials

Each of the plastic containers containing 100g of uninfected and undamaged cowpea seeds was treated with the plant powders (**Table 1**) at the rate of 100g each by mixing thoroughly to ensure adequate contact with the cowpea seeds. Prior to the introduction of the insect into treated grains, the insects were picked individually using entomological forceps. Fifty (50) adult *Callosobruchus maculatus* were introduced into each treatment. The top of the plastic containers were covered with a muslin cloth and held with rubber bands. The treatments were arranged in Completely Randomized Design (CRD) with four replications.

2.7 Statistical Analysis

The data collected was subjected to analysis of variance (ANOVA) and treatment means was separated using Fisher's least Significant Difference (LSD).

3.0 Results

Table 1: Plants to be evaluated for insecticidal properties

Common name	Scientific name	Family	Part used
Pepper fruit	*Dennettia tripetala*	Annonaceae	Leaves
Odudu oyibo	*Moringa oleifera*	Moringaceae	Leaves
Siam weed	*Chromolaena odorata*	Asteraceae	Leaves
Bitter leaf	*Vernonia amygdalina*	Asteraceae	Leaves
Lemon	*Citrus limon*	Rutaceae	Peels

3.2 Effect of the different plant materials on mortality and longevity of *Callosobruchus maculatus*.

The plant materials used in this study reduced the mean population of the adult cowpea weevil introduced. The Control treatment shows no significant effect in mortality in all the weeks of observation (I week to 12 weeks). The *Moringa oleifera* leaf powder showed a high significant mortality effect in the reduction of *C.maculatus* population in all weeks (**Table 2**). *Moringa oleifera* leaf powder reduced the mean population introduced from fifty (50) to seven (7) when compared to *Chromolaena odorata* (21), *Vernonia amygdalina* (18), *Dennettiatripetala* (14), and *Citrus limon* (11) respectively.

The Longevity in days of *C. maculatus* for *Moringa oleifera* , *Citrus limon*, *Dennettia tripetala, Vernonia amygdalina* and *Chromolaena odorata* were 4 , 7 , 9 , 12 and 13 respectively after application (**Table 2**).

Table 2: Effect of different plant materials on the mortality and longevity of *Callosobruchus maculatus.*

3.3 Effect of different plant materials on the mean Number of holes on Cowpea seeds.

The mean number of holes on cowpea seeds caused by *C.maculatus* shows that control treatment gave the highest mean number of holes on cowpea seeds at 2 WAI (19.3), 4 WAI (26.8), 6 WAI (36.4), 8 WAI (40.2), 10 WAI (47.1), and 12 WAI (49.8) respectively. The least mean number of holes on cowpea seeds was recorded on *Moringa oleifera* at 100g in 2 WAI (3.0), 4 WAI (6.2), 6 WAI (7.4), 8 WAI (8.6), 10 WAI (9.0), and 12 WAI (9.8) (Table 3).

Table 3: Effect of different plant materials on the mean Number of holes on Cowpea seeds.

Plant powder Extracts	Weight (grams)	Mean number of weevil introduced	Mean number of dead weevil in (weeks)	Mean number of alive	Longevity in (days)
Control	0	50		80	84
D.tripetala	100	50		14	9
M.oleifera	100	50		7	4
C.odorata	100	50		21	13
V.amygdalina	100	50		18	12
C.limon	100	50		11	7
LSD 0.05		**0.0**		**6.5**	**5.9**

Treatments	**2 WAI**	**4 WAI**	**6 WAI**	**8 WAI**	**10 WAI**	**12 WAI**
Control	19.3	26.8	36.4	40.2	47.1	49.8
D.tripetala	12.0	16.3	17.5	19.2	21. 8	23.1
M.oleifera	3.0	6.2	7.4	8.6	9.0	9.8
C.odorata	13.8	17.9	18.5	21.4	23.1	24.8
V.amygdalina	13.1	17.0	17.9	20.3	22.7	24.2
C.limon	8.2	12.4	13.1	14.5	15.0	15.7
LSD (0.05)	**1.8**	**3.2**	**3.5**	**4.4**	**4.7**	**5.6**

Effect of different plant materials on Weight Loss of Cowpea seeds.: The mean weight loss of cowpea seeds was recorded highest in control treatment with 57g which was significantly higher than the cowpea seed treated with the different plant materials.. However, cowpea seeds treated with *Moringa oleifera* powder significantly reduced the number of *Callosobruchus maculatus* resulting to the lowest mean weight loss (8g) when compared with the other treatments at 5% probability level (Table 3).

Table 5: Effect of different plant materials on weight loss of Cowpea seeds.

Treatments	Initial Weight of Cowpea seeds (g)	Final Mean Weight of Cowpea seeds (g)	Mean Weight Loss (g)
Control	100	43	57
D.tripetala	100	79	21
M.oleifera	100	92	8
C.odorata	100	68	32

V.amygdalina	100	73	27
C.limon	100	85	15
LSD (0.05)	**0.0**	**6.5**	**5.8**

Discussion: Results obtained from the study have shown clearly that thedifferet plamt materials affected the survival of stored cowpea seeds weevil (*Callosobruchus maculatus*). Although few had considerable lesser effect during the same duration of storage, all the different plant materials significantly reduced adult survival of *Callorobrachus maculatus* at 84 days after infestation relative to the Control at P<0.05 level of probability. The differet plamt materials are rich in phytochemicals such as Alkaloids, Flavonoids, Saponins, Tannins, and Phenols (Ogunwolu and Idowu, 2021).Alkaloid ranked the most efficient and therapeutically significant plant substance. The high alkaloid content in *Moringa oleifera* could be partly responsible for the bitter principle associated in *Moringa oleifera* leaves.

Moreso, alkaloids on acid base titration is poisonous and this could have been responsible for its insecticidal properties (Ivbijaro and Agsaje, 2021).The repellent and insecticidal properties exhibited by the test plants could be linked to the presence of phytochemicals. The astringent, bitter and poisonous properties could be responsible for its insecticidal actions. This study agrees with Bibi *et al.,* (2022) which states that plants pose phytochemicals in different concentrations that protect the stored grains for external pests influence. The study is in conformity with Batiha *et at.,* (2021) who observed that crude extracts of *Moringa oleifera* leaf showed repellent action on cashew and mango fruits. The bitter taste permeates membranes contained in *Moringa oleifera* leaf tallied with the work reported by Okpara (2015) that organic compounds extracted from plant materials like Citrus peels, *Moringa oleifera and Vernonia amygdalina* leaves were antimicrobial, antifungal and repellent insecticides.

Other authors that have reported the insecticidal effect of some plant extracts on insect pests; Agour *et al.,* (2022) reported on essential oil antimicrobial activities on the protection of Cowpea weevil. Androutsopoulou *et al.,* (2021) evaluated extracts of rose *geranium* as a natural preservatives of Cowpea in terms of toxicity, antimicrobial, and antiviral activities, Nwachukwu *et al.,* (2013) observed that powdered peel extract of *Citrus sinensis* had significant effect on the control of *Cryptolestes furrugineus* pest of stored millet. The present study revealed that *Moringa oleifera* leaf extracts offer great potentials to synthetic insecticides for the control of weevil pests of stored Cowpea seeds and consequently led to better Cowpea seeds protection in the storage.

Conclusion and Recommendations: Significant improvement was recorded in the use of the plant materials in the control of stored weevil pest of cowpea. The Study revealed that the plant materials was effective and had insecticidal activity similar to synthetic chemicals for the control of *C. maculatus*. However *Moringa oleifera* had a more profound effect on the overall performance and control of stored weevil pest of cowpea. Therefore, these botanicals which are environmentally friendly and provide food safety can be used as an alternative to synthetic chemicals for the control of *C. maculatus* in stored cowpea. Moreover, the local availability of these botanicals makes it easy for small holder farmers and reduces the cost of cowpea production.

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Exploratory Landuse Activities and Particulate Matter Pollutants Concentration in A Selected Rivers East and Rivers South-East Community, Rivers State

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Abstract

The study examined exploratory land-use activities and particulate matter pollutants concentration in a selected Rivers East and Rivers South-East community, Rivers State. The study adopted the completely randomized block design (CRBD). Ambient air quality readings were taken in-situ in four (4) stations (two each from each of the communities) using the Aero Qual 500 Series (Gas Monitor), GT 321 Particulate Metre, Automated Global Position System (GPS), and Extech Meteorology Metre, While mean and clustered column chart was used to analyze the data. The study revealed the concentrations of 694 ppm and 613 ppm for CO_2 in Bodo and Igwuruta communities respectively were higher than the WHO daily approved limit of 462 ppm. The study further revealed that the higher concentration of particulate matter pollutants (PMPs) like (NO_2 = 0.098 $\mu g/m^3$, O3 = 0.04 $\mu g/m^3$, So_2 = 0.00 $\mu g/m^3$, H_2S = 0.01 $\mu g/m^3$, CH_4 =0 $\mu g/m^3$, CO = 0.5 $\mu g/m^3$, NH_3 =0.3 $\mu g/m^3$, Pm 2.5 = 0.022 $\mu g/m^3$, Pm 10 = 0.018 $\mu g/m^3$, temperature = 34.6°C) obtained at the Bodo artisanal refining sites than that obtained at the Igwuruts flow station were all still within the WHO daily approved limits for the specific PMPs. Also, the excessive concentration of CO_2 accentuates the presence of "block soot" that exacerbates the discolouration of vegetation as well as residents high susceptibility to skin diseases, intense heat, respiratory complications like cough, carthar, etc. The study recommended amongst others that more trees specifically the "Dogoyaro" should be planted to absorb the excess CO_2 that accentuates the buildup of black soot that dirts car windshield, roof surfaces, house floors and windows including causing skin: rashes, aging and infections, asthma, bronchitis among other health effects on the residents around the environs of the Agbada/Igwuruta flow station and Bodo artisanal refining site.

Keywords: *Exploratory land-use activities, particulate matter pollutants, Rivers East, Rivers South-East*

Introduction: Anthropogenic induced spatial land uses whether ethically or unethically conducted are very highly susceptible to accentuating the release of solid, liquid and gaseous effluences likely to deteriorate the quality of the recipient environmental component notably; the atmosphere, waterbody, wetland etc. Alluding to this, Barango (2023) reiterated that both the legitimate and illegitimate exploration of crude oil together with urbanization and industrialization activities give rise to the human or anthropogenic-driven spatial land-uses that would over the short or long-run exert either positive or negative impacts on the natural resources and systems in any environment. For instance, crude oil exploration and refining as a spatial land-use activity when conducted in defiance of the extant standardized regulations could likely accentuate unavoidable oil spillage, pipeline leakages, gas flares, and release of untreated forms of effluents. Thus, the release of liquid, gaseous and solid forms of effluents could result to air pollution and environmental degradation that may likely diminish and extinct the vast mangrove habitats and even other environmental resources and functions in any area (Sibe et al., 2019).

Gas flaring is the rapid oxidation of natural gas with the discharge of gaseous, particulate matter, pollutants and heat into the atmosphere (Fawole et al., 2016). The release and subsequent concentration of particulate matter in the atmosphere would over the near or long-run be responsible for triggering pollutants. Accordingly, the existence of toxic pollutants are known to exert poor air quality, infections among other negative impacts on living things like humans, microorganisms, plants and animals (Onugha, 2022). Also, the presence of toxic pollutants could specifically lead to the decolouration and corrugation of the non-living components like plastics, pipes, rods, etc. in that environment (Ubong et al., 2015; Amaecho-Onyerimma & Onugha, 2021). In this regard, the American Association for the Advancement of Science (AAAS) earlier reported that gas flaring is responsible for the generation of greenhouse gases, chronic respiratory diseases, and vegetative discoloration among others in an environment (AAAS, 2015). Against this backdrop, the flaring of gas could be ascribed as the primary source of human or anthropogenic activities inducing toxic pollutants that are responsible for poor air, water and soil quality that would seriously trigger public health issues and ecological degradation likely to distort ecosystem services (Osuoha, 2017).

Amaechi-Onyerimma et al. (2023) scrutiny of the effect of gas flaring around the environs of the Igwuruta or Agbada flow station revealed that the emission of pollutants like CO_2, NO_2, So_2, H_2S, CH_4, CO, NH_3, Pm 2.5, Pm 10 among others significantly contributed to poor air quality that heightens the occurrence of skin diseases, cancer and respiratory ailments (especially cough, cold and Cathar, etc.). This standpoint was earlier corroborated in the study by Monday (2018) that the release and presence of Pm 2.5, Pm 10, CO_2, H_2S, NH_3, and NO_2 among other particulate matter pollutants in a specific gas-flared environment severely impacts a very long distance and area beyond the pollutant generated community due to the trans-boundary nature of air pollution.

Industrial, artisanal refining, and construction among other human-driven land-use activities appear to be the common sources for the emission of substances with certain levels of toxicity into the atmosphere. This act could result in air pollution that would likely occur from human activities and practices that accentuate the emission of varying quantities of harmful substances into the atmosphere. Thus, a toxin or pollutant saturated environment triggers the alteration of the natural air condition of that place thereby, causing breathing complications that discomforts or harms the health of human and animals as well as destroy plants and vegetation that all play vital functions and services in any ecosystem (Simbi-Wellington, 2020).

The increasing spate of illegal refining heightens the presence of pollutants (conceptualized as blighted, wrecked or ruined carbon and impurities in the air, land and waterbody. In specificity, a pollutant is a carbonaceous substance produced from incomplete combustion of coal, wood and oil that is synonymous with artisanal refining processes (UNEP, 2011; Cho, 2016; Giwa et al. 2017). This standpoint could imply that illegal or artisanal refining could account for the release of majority of the pollutants from spatial land-use activities. Thus, the eventual release of pollutants into the atmosphere alters the erstwhile clean and decent air quality to polluted air that is saturated with pollutants. Pollutants are so tiny that they can penetrate the spores on the human body and the nostrils thereby, affecting human visibility and health as well as harm ecosystems, reduces agricultural productivity and exacerbates global warming (WHO, 2017; UNESCO, 2020).

The sufficient concentration of solid, liquid and gaseous substances or elements over a period of time and under certain concentration would give rise to air pollution that would tend to interfere with human, biodiversity and environmental health, welfare and safety (WHO, 2014; 2022). Monday (2018) reiterated that air pollution occurs when harmful substances including particulates and biological molecules are introduced into the atmosphere causing alteration of the atmospheric conditions. Implicitly, the alteration of the atmospheric conditions can cause discomfort and unsafe conditions to humans resulting to diseases, allergies or death to humans as well as causing harm to other living organisms such as animals, and food crops that may damage the natural or built environment.

In specificity, the presence or existence of toxic or harmful pollutant substances in the air, cloud or atmosphere accentuates air pollution that would in-turn affect human and environmental health and wellbeing in and beyond the source region or area (Ede & Edokpa, 2015). In a nutshell, human-driven spatial land-use activities appear to be one of the major source of air pollution with contaminants likely to negatively impact firstly on the immediate and adjoining environment (Osuoha, 2017). Corroborating these views, Onugha (2022) observed that the consequence of these pollutants could have debilitating or devastating effects on the edaphic, aquatic and atmospheric systems and resources as well as biodiversity and humans in and around the particulate matter sourced or generated and saturated environment.

The saturation of pollutants on the air would severely impact on human health and skin include; skin aging, atopic dermatitis and psoriasis (Drakaki et al., 2014), eye and skin irritation (Ideal-response, 2021), skin cancer (Kohanka & Kudasz, 2022) including eczema, urticaria, rashes and skin infection (Puri et al., 2017). Also, impurities or pollutants in the atmosphere can trigger respiratory diseases such as asthma, skin disorders and reproductive problems from exposure to polluted air that can lead to the presence of black carbon (i.e. black patches and droppings) on roof surfaces, cars, floors, windows, etc. (Owhor et al., 2023). Thus, the varying effects of gas flaring on the quality and health of humans and the environment put to naught the oil companies' idea of saving operational costs for venturing into gas flaring as well as consideration of the revenue of about 85% and 90% of the country's earning and export respectively generated from petroleum (Izah & Ohimain, 2015). In light of the foregoing, Monday (2018) stressed the relevance of integrating mitigating strategies to address the transboundary effect of air pollution, which could severely impact a very long distance beyond the pollutant sourced area, community or environment hosting that spatial land-use activities like crude oil exploration, artisanal refining, etc.

Aim and Objectives of the Study: The study investigated exploratory land-use activities and particulate matter pollutants concentration in selected Rivers East and Rivers South-East Community, Rivers State. The specific objectives include to: Determine the concentration of the particulate matter pollutants in the exploratory land-use activity existing in each of the selected communities in the study area.
Ascertain the impact of the mean concentration of the particulate matter pollutants on the biodiversity and humans in the exploratory land-use activity existing in each of the selected communities in the study area.

Study Area: The study was conducted in Igwuruta and Bodo communities. Igwuruta and Bodo are two communities selected from Ikwerre Local Government Area in Rivers East Senatorial District and Gokana Local Government Area in Rivers South-East Senatorial District respectively. Geographically the facility is located on longitude 7° 0 ' – 7^0 10'E and latitude 4^0 31' – 4^0 40'N in Rivers State of Nigeria (Gobo et al., 2009). Also, Igwuruta community is bounded on the north by Okomoko community (Etche LGA), on the south by Eneka community, on the east by Rukpokwu community (both in Obio-Akpor LGA), and on the west by Omagwa community (Ikwerre LGA).

Geographically, Bodo community is located approximately on latitude 4° 66' 049" N longitude 7° 28' 347" E (Geody, 2017). Equally, the meteorological conditions of these two communities in the study area display climatic characteristics that could be classified as semi-hot equatorial zone. The equatorial maritime air mass characterizes the climate with high humidity and heavy rainfalls (annual mean ranges between 72% -81% and 3,000mm-4,000mm while average monthly temperatures vary from 28ºC to 33ºC and 21ºC to 23ºC, respectively (Oweisana et al., 2021). Economically, the study area play host to many public and private primary and secondary schools, markets, banks, private business entities, public health facilities, private hospitals, etc. While infrastructurally, these communities are adorned with roads, buildings as well as oil installations like flow stations that are operated by the SHELL joint venture in both communities.

In addition, Igwuruta community play host to at the Agbada flow station (as a legitimate and approved exploratory land-use activity), which is owned and operated by the Nigeria National Petroleum Corporation (NNPC)/Shell Petroleum Development Company (SPDC) Joint venture gas gathering station. While artisanal or illegal refining activities was investigated Bodo, which is also an oil bearing community (Shell Nigeria, 2017). However, both the legitimate and approved exploratory land-use activity in Igwuruta community as well as the illegitimate artisanal refining activities in Bodo community practice "open gas flaring", which Gobo et al. (2009) described as an illegal practice with far-reaching social, economic, health, aesthetic and developmental effects on humans, biodiversity and environment. See Figures 1 and 2 for the two exploratory land-use activities in Igwuruta community and Bodo community respectively.

Materials and Methods: Sample Site Location: Four (4) sampling points or stations across the two (2) sampled communities were used in this study. The sampling points or stations were purposively selected for the air quality parameters in Station A (Upstream of the Agbada Flow Station II), and Station B (Downstream of the Agbada Flow Station II) both in Igwuruta community. While Station C (St. Pius College), and Station D (Artisanal refining site) were all located in Bodo community. The coordinates of the sampling stations include: Point A (100m from the flow station) with **Northings-**04^0 55' 57.0"N, and **Eastings-** 007^0 0' 55"E, Point B (200m from the flow station) with **Northings-** 04^0 55' 57.0"N, and

Eastings- 007^0 0' 56"E. Also, Point C (500m from artisanal refining site) with **Northings-** 04^0 37' 33.1"N, and **Eastings-** 007^0 16' 16.50"E, and Point D (100m from the artisanal refining site) with **Northings-** 04^0 61' 91.106"N, and **Eastings-** 007^0 28' 97.348"E.

Research Design: This study adopted the experimental design. The experimental design is applied to a study where the manipulation and control of one or more intervening variables may depend on the subjects, experimenter, tools of experiment and other paramount environmental factors (Nwankwo, 2016). Furthermore, the study also adopted the completely randomized block design (CRBD) due the similarity of the experimental points.

Instrumentation and Method of Data Collection: Five instruments via: Aero Qual 500 series gas detector for obtaining indoor air quality (IAQ), the handheld GT 321 (is a portable particle counter that counts particles down to 0.3 microns), the Automated GPS (used for taking the coordinates of the sampling points above), Extech Meteorology Metre (used for collecting the Temperature, Relative Humidity, and Windspeed readings), and Measuring Tape (used for the determination of the distance of the sampling points) were used by the researcher and research assistant for conducting the air quality assessment around the Agbada flow station in Igwuruta community and artisanal refining site in Bodo community. Instructively, four (i.e. Aero Qual 500 series, GT 321, the Automated GPS, and Extech Meteorology Metre, except for the Measuring Tape) out of the five instruments or equipment were pre-calibrated before usage for quality assurance purposes.

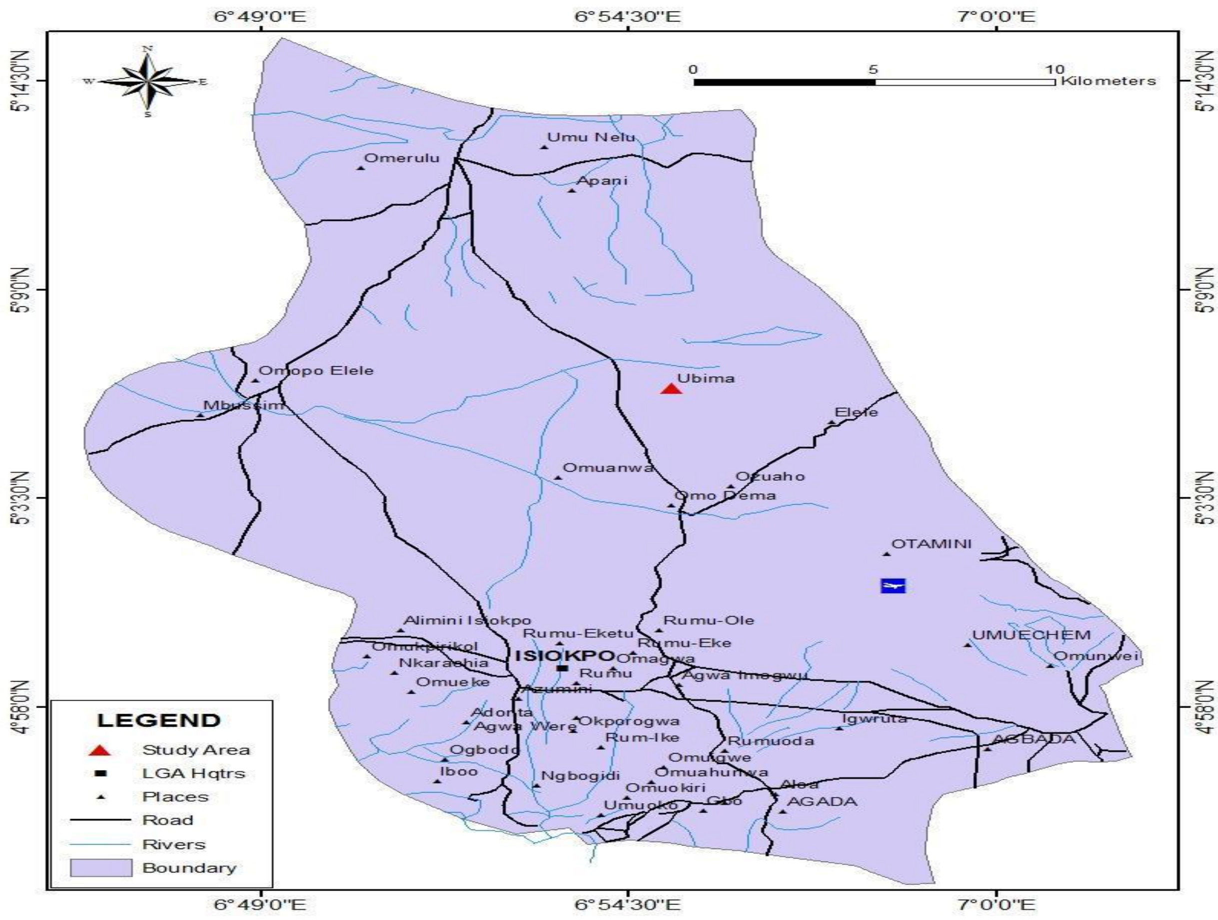

Figure 1: Ikwerre Local Government Area showing Igwuruta Community

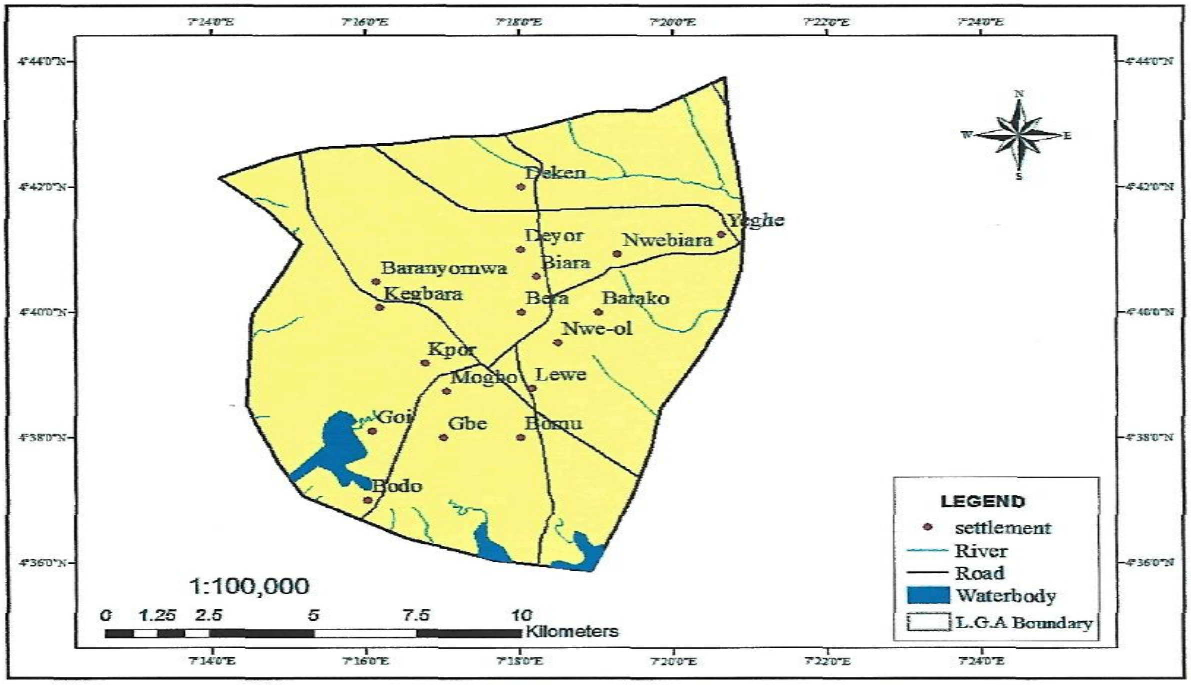

Figure 2: Gokana Local Government Area showing Bodo Community

Data Analysis: Relevant Statistical Analytical tools like mean, and clustered column chart were utilized to determine the objectives stated in this study.

RESULTS

Table 1: Concentration of the particulate matter pollutants (PMPs) in the exploratory land-use activity existing in each of the selected communities in the study area

PMPs	Unit	Igwuruta Community		Bodo Community		WHO Daily Standard Compared
		ST A	**ST B**	**ST C**	**STD**	
Pm 2.5	µg/m^3	0.009	0.009	0.011	0.018	35 µg/m^3
Pm 10	µg/m^3	0.013	0.013	0.016	0.022	150 µg/m^3
NO_2	µg/m^3	0.056	0.064	0.069	0.098	100 ppb
CO	µg/m^3	0.2	0.2	0.4	0.5	0.200 µg/m^3/9 ppm
SO_2	µg/m^3	0.00	0.00	0.00	0.00	75 ppb/ 0.5 ppm
CH_4	µg/m^3	0	0	0	0	0.83 µg/m^3
H_2S	µg/m^3	0.00	0.00	0.01	0.01	125 µg/m^3
O_3	µg/m^3	0.02	0.01	0.03	0.04	0.10 µg/m^3
NH_3	µg/m^3	0.2	0.2	0.3	0.3	0.53 µg/m^3
CO_2	µg/m^3	613	565	594	572	462 µg/m^3
Temp.	ºC	34.0	30.4	32.3	34.6	-

Source: *Researcher's Fieldwork*, *2024; WHO, 2005; Akpoghelie et al., 2016; USEPA, 2016.*

The various particulate matter pollutants in the exploratory land-use activities are shown in Table 1. The result of the parameter measured revealed that Station A (i.e. Igwuruta community) had the highest concentration of CO_2, (613 ppm) than Stations C and D (Bodo community) with 694 ppm and 572 ppm respectively. However, the concentrations of CO_2 in all the sample stations were higher than the WHO approved limit of 462 ppm for CO_2 in the air. Also, Stations C and D (i.e. Bodo community) had the highest concentrations of Pm 2.5 (0.011 µg/m^{3}and 0.018 µg/m^3 respectively), Pm 10 had the highest concentration of 0.022 µg/m^{3}and 0.016 µg/m^{3}for Stations D and C respectively. Similarly, Stations C and D had the highest concentration of O_3 (0.03 µg/m^3 and 0.04 µg/m^3 respectively). For CO, Bodo community had the highest concentrations of 0.4 µg/m^3 and 0.5 µg/m^3 than the Stations in Igwuruta community with 0.2 µg/m^3. While the highest concentrations of 0.098 µg/m^{3}and 0.069 µg/m^{3}for NO_2 that were recorded at Stations C and D in Bodo community were higher than the concentrations of 0.064 µg/m^{3}and 0.056 µg/m^{3}for NO_2 obtained at the sampled stations in Igwuruta community. However, the concentrations of Pm 2.5, Pm 10, O_3, CO, and NO_2 in the selected communities were all below the WHO approved limits of 35 µg/m^3, 150 µg/m^3, 100 µg/m^3, 200 µg/m^3, and 100 ppb respectively.

Station D (i.e. Bodo community) had the highest Temp. (34.6 ºC) than Station A (Igwuruta community) with 34.0 ºC. Also, the concentrations of 0.00 µg/m^3 and 0 µg/m^3 for So_2 (Sulphur Dioxide) and CH_4 (Methane) respectively around the sampled communities were the same but still fell below the WHO approved limit of 75 ppb/0.5 ppm and 0.83 µg/m^3 for So_2 and CH_4 respectively. While H_2S (Hydrogen Sulphide), and NH_3 (Ammonia) had the same concentrations in the sampled stations in the Igwuruta community and Bodo community. Furthermore, the result in Table 1 implies that Station D (artisanal refining site at Bodo community) was the hottest, and Stations C and D (i.e. Bodo community) were filled with the highest level of impurities or pollutants in the air. Hence, the high concentration of Co_2, Temperature, O_3, Pm 2.5, and Pm 10 indicates that the residents around the Bodo community could be susceptible to internal heat, hearing defects, shock, and possible hypertension from exposure to the pollutants.

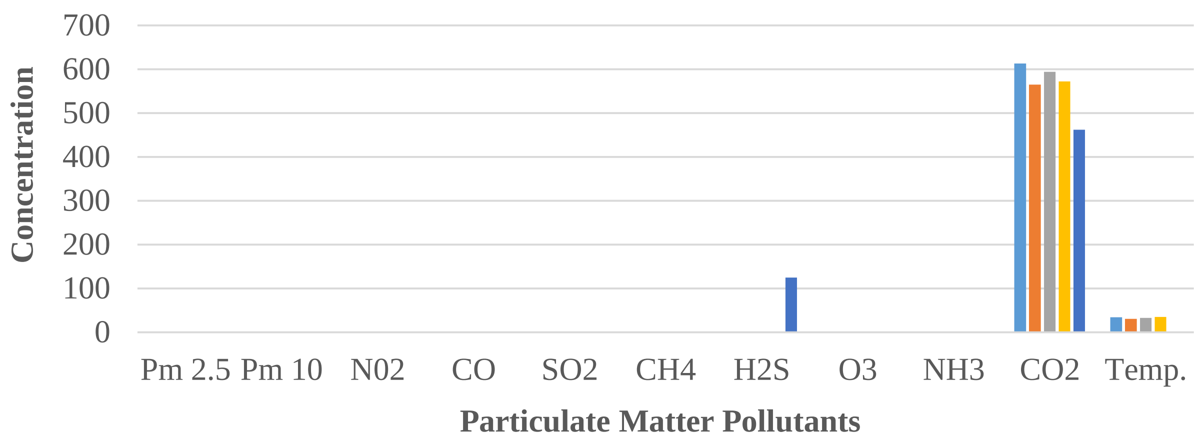

Fig. 1: Mean concentration of the particulate matter pollutants in the exploratory land-use activity existing in each of the selected communities in the study area

Table 2: The impact of the mean concentration of the particulate matter pollutants on the biodiversity and humans in the exploratory land-use activity existing in each of the selected communities in the study area

PMPs	Igwuruta Community	Bodo Community	WHO Daily Standard	Decision	Impact on Biodiversity	Impact on Humans
CO_2	589 µg/m^3	583 µg/m^3	462 µg/m^3	Very High	Short and long term effect leading to the: Discolouration of vegetation and intense heat of animals	Short and long term vulnerability to**:** **S**kin diseases or disorders, cancer, ear problems, respiratory problems
CO	0.2 µg/m^3	0.45 µg/m^3	0.2 µg/m^3	Very High		
O_3	0.02 µg/m^3	0.035 µg/m^3	0.10µg/m^3	Very High		
NO_2	0.060 ppb	0.084 ppb	0.100 ppb	Fairly High		
SO_2	0.00 ppm	0.00 ppm	0.5 ppm	Fairly High		
NH_3	0.2 µg/m^3	0.3 µg/m^3	0.53µg/m^3	Fairly High		
Temp	32.2 ºC	32.3 ºC	-	Hot		
Pm 2.5	0.009 µg/m^3	0.0145 µg/m^3	35 µg/m^3		Breathing Difficulty	Breathing Difficulty

Pm10	0.013 μg/m³	0.021 μg/m³	150 μg/m³	Poor air quality
CH_4	0 μg/m³	0 μg/m³	0.83 μg/m³	
H_2S	0.00 μg/m³	0.01 μg/m³	125 μg/m³	

Source: *Researcher's Computation*, *2024*

Table 2 shows the impact of the mean concentration of the particulate matter pollutants on the biodiversity and humans in the exploratory land-use activity existing in each of the selected communities in the study area. The presence or concentration of CO_2, NO_2, O_3, So_2, H_2S, CH_4, CO, NH_3, Pm 2.5, and Pm 10 in the air or environment around the Agbada flow station in Igwuruta community and the artisanal refining site in Bodo community indicates the higher likelihood for the discolouration of vegetation as well as intense heat by animals (see Plates 1 and 2). Also, the high concentration of CO_2, NO_2, O_3, So_2, H_2S, CH_4, CO, NH_3, Pm 2.5, and Pm 10 in and around Igwuruta and Bodo communities could make the residents in these areas to be highly susceptible to skin diseases, cancer, ear problem, respiratory problems or breathing difficulties that heighten the possibility of contacting of cough, cold and carthar, etc.

Plate 1: Discoloured vegetation at St Pius College 500m close to the Artisanal Refining Site in Bodo Community

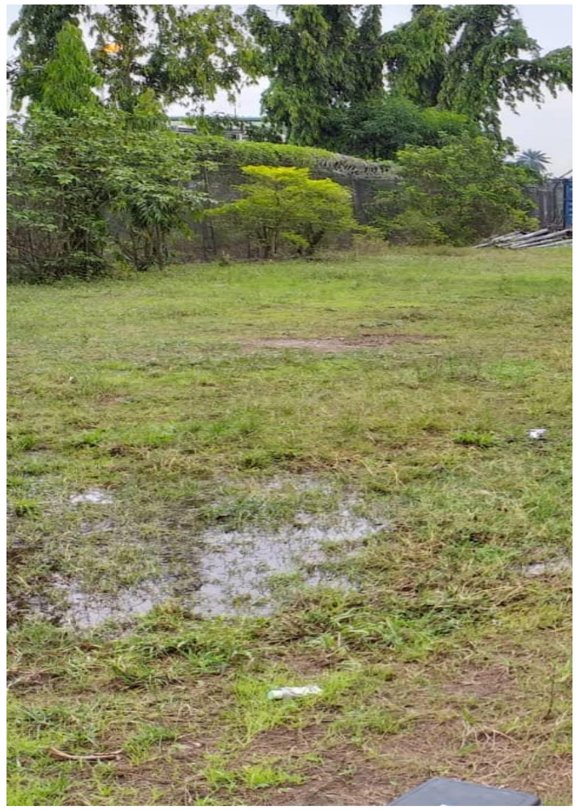

Plate 2: The colour of the vegetation 100m from the Agbada Flow Station in Igwuruta Community

Discussion of Findings: The result in Table 1 revealed that the concentration of particulate matter pollutants like CO_2, $N0_2$, O_3, SO_2, H_2S, CH_4, CO, NH_3, Pm 2.5, Pm 10, and Temperature in the artisanal refining sites in Bodo community was higher than that in the environs around the Agbada flow station in Igwuruta community. This finding aligns with the studies conducted by (UNEP, 2011; Cho, 2016; WHO, 2017; WHO, 2018; & UN, 2020) that artisanal refining account for the release of majority of the pollutants into the atmosphere that eventually alters the erstwhile clean and decent air quality to polluted air. Thus, the accumulation of these heat causing, climatic distortion, global warming exacerbating and health-impacting pollutants that affect human visibility, breathing and skin as well as harm ecosystems thereby, leading to reduced agricultural productivity in the society.

Also, the result in Table 1 revealed that the concentration of CO_2 in Bodo and Igwuruta communities were both higher than the daily WHO standard or limit for CO_2 in the atmospheres while the other particulate matter pollutants like $N0_2$, O_3, SO_2, H_2S, CH_4, CO, NH_3, Pm 2.5, and Pm 10 were within the daily WHO standards or limits for the specific particulate matter pollutant. This finding is in agreement with the previous findings by Dami et al. (2012); Seiyaboh and Izah (2017) and Owhor et al. (2023) that gas flaring leads to the release of three major components including noxious gases, heat, and noise, including gaseous pollutants or toxic chemicals that generally upset the water food web and affects health and environment of living organisms that depend on them.The result in Table 2 revealed a high concentration of Pm 2.5, Pm 10, CO, O_3, and Co_2, which affects the environs around Bodo and Igwuruta communities. The high concentration of Pm 2.5, Pm 10, CO, O_3, and Co_2 indicates poor air quality which implies that the residents around the Bodo and Igwuruta communities could experience or suffer from skin diseases, cancer, ear problem, respiratory problems (like possibility of possible contacting of cough, cold and carthar, etc. Instructively, CO_2 value reduces as you move away from the gas flare point. Equally, CO_2 values from the study areas tend to reduce across sampling periods thereby showing both temporal and spatial variation. This finding is consistent with earlier finding by Ozabor and Obisesan (2015) that high concentration of temperature from flared gases has the tendency to stir hot climate that affect several plant species especially productivity and growth. In addition, this finding is consistent with the studies by (Drakaki et al., 2014; Giwa et al., 2014; Giwa, 2017; Puri et al., 2017; Kohanka & Kudasz, 2022; & Owhor et al., 2023) that humans exposure to air that is inundated with pollutants accentuates the presence of carbonaceous black carbon or black soot substance on roof surfaces, cars, floors, windows, etc. alongside triggering skin problems (like eczema, urticaria, atopic dermatitis, rashes, skin aging and skin infection), respiratory disorders like asthma, bronchitis, etc. as well as health effects that can climax to reproductive complications.

Conclusion: The study established that both the legitimate and illegitimate crude oil exploration activities in Igwuruta and Bodo communities respectively were conducted in defiance to the operational, regulatory and environmental standards thereby, accentuating the issue of gas flaring. However, the flare of gas from the artisanal refining site in Bodo community led to the emission and high concentration of pollutants like CO_2, NO_2, O_3, So_2, H_2S, CH_4, CO, NH_3, Pm 2.5, Pm 10 and Temperature more than the concentration in the Agbada flow station in Igwuruta community. Implicitly, the high concentration of Pm 2.5, Pm 10, CO, O_3, Co_2, and NO_2 could significantly contribute to poor air quality. Thus, the presence of poor quality air saturated with smog and soothe could increase humans exposure and vulnerability to eczema, rashes, other skin diseases, eye irritation, cancer among other respiratory problems. In specificity, breathing complications could heighten the possibility of contacting mild infectious diseases like cough, cold and carthar as well as severe respiratory diseases among which include asthma, heart pain and chronic bronchitis in and around these two selected communities.

Recommendations: Based on the findings of the study the following recommendations were made: The government should as a matter of urgency ensure that the management of the Agbada flow station embarks on an unbiased, all-inclusive, comprehensive and implementable UNEP recommended pre and post procedural environmental and social impact assessment in order to adopt sustainable oil exploration methods that would help preserve and enhance the wellbeing, health, and safety of the humans, biodiversity and environment in the two communities. Given the high concentration of CO_2, more trees specifically the "*Dogoyaro*" should be planted to absorb the excess CO_2 that accentuates the buildup of black carbon or black soot that can dirt car windshield, roof surfaces, house floors and windows including causing skin: rashes, aging and infections, asthma, bronchitis among other health effects on the residents around the environs of the Agbada/Igwuruta flow station and Bodo artisanal refining site.High temperature-resistant plants especially Lantana should be planted in the communities bordering the Agada/Igwuruta flow station and Bodo artisanal refining sites with high intensity of temperature.

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Antimicrobials Resistance in Pseudomonas *Spp.* Isolated From Aquaculture Systems: Molecular Identification and Implications

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Abstract

The aim of this research was to identify Antimicrobial resistant Bacteria to mitigate biotransformation of antimicrobials in food chain and the host organism. In this study, water sample collected from the research area was used to culture bacteria in six different media with different concentrations of antibiotics (40mg, 80mg, 120mg, 160mg, 200mg, and 250mg of Tetracycline)in order to test the bacterial resistance through ager-nutrient dilution method. After obtaining the isolate, the morphological characteristics, gram staining and spore staining of sample A5 with bacterial growth at antibiotics concentration of 200mg was observed and furthered for molecular analysis. The 16SrRNA gene being the most conserved gene in bacteria was sequenced and phylogenetic analysis was conducted by comparing the gene with genes previously deposited in the gene bank using BLAST. Alignment and construction of phylogenetic tree using CUSTAL-W Software was then conducted. The result indicated a successful growth of Psuedomonas spp from sample A5 at 200mg of Tetracycline with the BLAST result of 91.99% highest score similarity index of our sequence with Pseudomonas spp. The bacteria strived to resist the Antibiotics and may possibly play role in Biomagnification. It is therefore concluded to be a resistant Bacteria. It is recommended that resistant bacteria should be tested on other antibiotics besides Tetracycline and resistant gene should be tested on other means of degradation and growth factors besides Antibiotics.

KEYWORDS: Antimicrobial, Biotransformation, Bioaccumulation, Tetracycline

Introduction: Aquaculture is critical for food security, poverty mitigation, and economic growth, with global production of farmed aquatic animals expected to meet growing fish demand (FAO and WHO, 2003). However, the industry's consolidation into fewer, larger farms has heightened the risk of infectious diseases, resulting in substantial antibiotic use despite known negative impacts (Arun and Rahul, 2019). Antibiotics, frequently used in human medicine and agriculture, accumulate in water systems, particularly in countries like China, where over 162,000 tons were used in aquaculture in 2013 (Zhang *et al.*, 2015). This accumulation introduces resistant bacteria into the food chain, making aquaculture a significant antibiotic reservoir (Zhoa *et al.*, 2021; Reuben *et al.*, 2018). Some antibiotics, like penicillin, degrade easily, others, like tetracycline, persist in the environment, adding to bioaccumulation risks (Sarmah et al., 2006). Global antibiotic use in food animals was estimated at 63,151 tons in 2010, projected to rise by 67% by 2030, especially in emerging economies (Boeckel *et al.*, 2015). Aquaculture thus poses a direct human exposure risk through consumption of treated fish, which can lead to bacterial resistance and health issues (Pruden *et al.*, 2013; European Commission, 2001).
The concept of "pseudo-persistence" indicates that continual antibiotic inputs from pollution sources exceed natural degradation capacities, increasing bioaccumulation and biomagnification risks (Mackey, 2014). Antimicrobial resistance, where bacteria survive antibiotic exposure, is accelerated by routine antibiotic use, threatening treatment efficacy and complicating health interventions (Chopin, 2006; Zhu *et al.*, 2013). This issue necessitates assessment of the environmental and health impacts of antibiotic contamination. As fish and other aquaculture products move up the food chain, they may transport antibiotic residues, with potential health consequences for humans as the final consumers (Yujie *et al.*, 2019). To address this, isolating and studying antibiotic-resistant bacteria and exploring alternative, cost-effective bacterial control methods in aquaculture are urgently needed to reduce environmental and public health risks.

Materials and method: Study area: Gombe Main Market is located in Gombe state, Gombe local government area, located between longitude 10°17' 20"N and latitude 01110.6803" SW. Gombe State is located in the North Eastern part of Nigeria with the population of over Two million people (2006 Census). It shares boundary with Bauchi, Borno, Yobe and Adamawa and Taraba. Gombe State has a land area of 20, 265 Sq/Km located on Latitude 9°30 and 12°30N and Longitude 8°45' and 11°45E with an annual rainfall of 850mm on average (National Population Census Commission, 2017).
Sample Collection: Water sample was collected from the research area (Gombe Main Market) aseptically using a sterile sample collection bottle of 30ml, it was transported to Gombe State University Laboratory of Biological Sciences immediately to avoid contamination, hence it was stored in incubator at an ambient temperature of 32°C as described by Odera *et al.*, 2020.

Minimal Media Preparation: In order to test the bacterial resistance, 2.8g nutrient agar was prepared for each media of different Antimicrobial concentration (40mg, 80mg, 120mg, 160mg, 200mg, and 250mg of Tetracycline) and autoclaved at 121°C for 15minutes as described by Lopez *et al*, (2012). The water sample collected from the study area was then used to culture bacteria in the prepared media with different concentrations of antibiotics through ager-nutrient dilution method as described by Shyamal (2013). The media was prepared in duplicate to avoid and minimize error, making the total of Fourteen (14) plates.

Table 1: Growth media preparation:

Media	Volume of distilled water (ml)	Growth media concentration (g)(NA)	Antibiotics (Tetracycline) concentration (mg)
1	100	2.5	40
2	100	2.5	80
3	100	2.5	120
4	100	2.5	160
5	100	2.5	200
6	100	2.5	250
7	100	2.5	Control

Screening of Bacterial Isolates: Bacterial isolates were tested for resistance to tetracycline at concentrations of 40 mg/L, 80 mg/L, 120 mg/L, 160 mg/L, 200 mg/L, and 250 mg/L. Growth patterns at different concentrations were recorded, and isolates showing resistance were selected for further analysis.

Table 2: Screening of Bacterial Isolates:

Media	Volume of distilled water (ml)	Growth media concentration (g)(NA)	Antibiotics (Tetracycline) concentration (mg)	Plate A	Plate B
1	100	2.5	40	A1	B1
2	100	2.5	80	A2	B2
3	100	2.5	120	A3	B3
4	100	2.5	160	A4	B4

5	100	2.5	200	A5	B5
6	100	2.5	250	A6	B6
7	100	2.5	Control	A7	B7
				Total: 14 plates	

A total of Fourteen (14) Plates were prepared for the experiment, Twelve (12) plates had different Antibiotics concentrations, Two (2) plates served as controls and Thirteen (13) plates were inoculated with the water sample leaving one control plate to verify the purity of the media. The media were kept at incubator for 30 hours at 24° C. **Morphological and Biochemical Analysis**: Pure colonies from resistant strains were sub-cultured and analyzed for morphological characteristics such as colony shape, color, and texture. Gram staining and endospore staining were performed to determine bacterial types and structures.

Molecular Identification: DNA was extracted from the resistant strains, and PCR amplification of the 16S rRNA gene was conducted. Gel electrophoresis was used to verify the presence of the gene, and sequencing was performed to identify the bacterial species. Insilico analysis using BLAST and phylogenetic tree construction helped confirm the identity of the isolates. Amplification of the 16S rRNA gene was done using ribose PCR primers (forward and reverse primers) and the reverse primers (RIBOS-2) was used as enzymes. The sequences of primers used are:

GGACTACAGGGTATCTAAT 16S for primer RIBOS-1 Forward

AGAGTTTGATCCTGG 16S REV primer RIBOS-2 Reverse

For reaction set-up, templates, specific primers and water are added to the premix. 20ul reaction is made using:

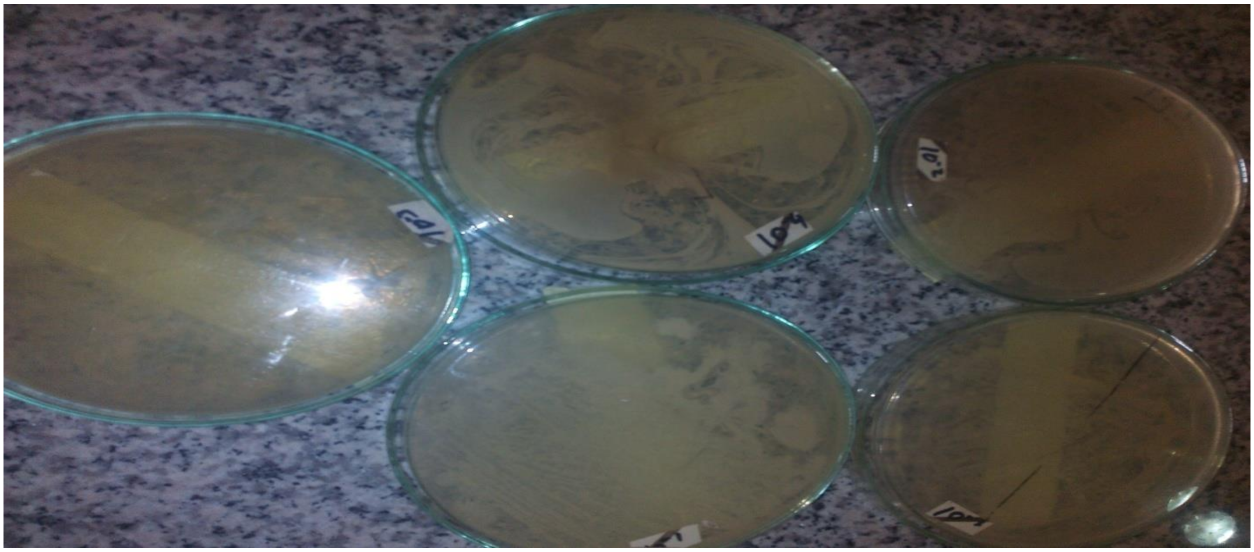
1st round set up

- dH_2O 16µL
- Primer 1 1µL
- Primer 2 1µL
- Template 2µL (Table 4)

Table 3: PCR Cycle for 16S rRNA Amplification

PCR steps	Temperature (^oc)	Time (Seconds)	Cycle
Pre-denaturation	94	300	1
Denaturation	94	30	1
Annealing	55	30	1
Extension	72	30	30
Final extension	72	300	1
Storage	4	43200	1

PHYLOGENETIC ANALYSIS OF 16S rRNA GENE: The 16S rRNA sequence that was obtained, aligned and compared with the sequences deposited in Gene Bank database from National Center for Biotechnology Information (NCBI), using BLAST analysis tool. After that, the command of BLAST was used in or



der to align our sequence. Next, the construction of phylogenetic trees was carried out by using the CULSTAL-W Software.

Results: **Bacterial Isolation and Screening**: Bacteria were successfully cultured from various antibiotic concentrations. Strains A5 and A6 showed notable resistance to tetracycline, with strain A5 demonstrating higher growth rates. Morphological analysis revealed distinct characteristics for these strains.

Plate 1: Successful plates with growth at the concentration of 200 mg and 250 mg of TTC

Pure colonies were obtained from a sub-culture done from the plates with successful growth at higher antibiotics concentrations (Plate A5 and A6) for morphological analysis.

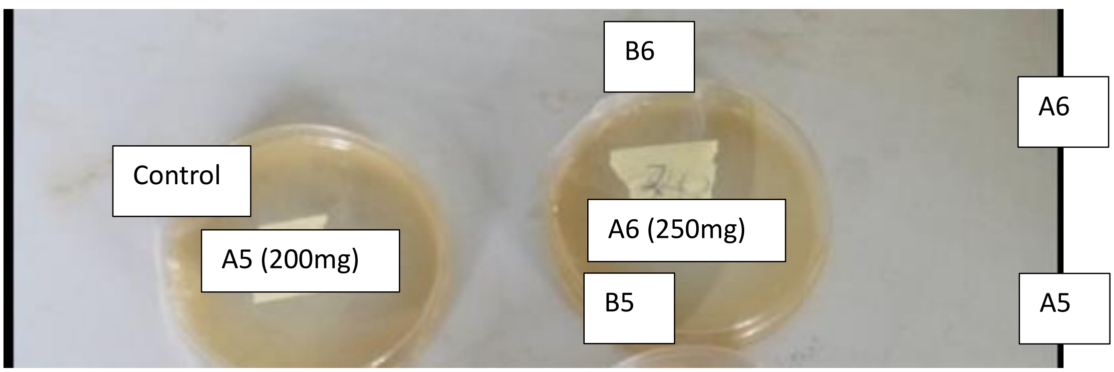


Plate 2: Plate A5 and A6 (200 mg and 250 mg TTC) pure strain Sub-cultured

Table 4: Morphological characteristics of the Isolate (Sample A5):

S/N	Characteristics	Observation
1	Colony	Not Clustered

2	Colour	Milky bright
3	Shape	Spherical
4	Elevation	Curve
5	Edge	Regular (Entire)
6	Pigment	Absent
7	Opacity	Opaque
8	Surface	Smooth
9	Degree of growth	Scanty

Gram Staining and Endospore Staining: Isolates were identified as Gram-negative bacteria with pink-red vegetative cells upon endospore staining, confirming their bacterial nature.

Table 5: Staining characteristics of the Isolate:

Characteristics	Observation	Interpretation
Gram staining	Red Coloured	Gram Negative
Spore staining	Pink-red vegetative cells	Endospore

DNA Extraction and PCR: DNA extraction yielded a concentration of 103.1 ng/µL with a purity of 2.1. PCR results showed a positive band for the 16S rRNA gene at approximately 789 base pairs. Sequencing and BLAST analysis identified the isolates as *Pseudomonas spp.* with a 91.99% similarity index.The result of the PCR was confirmed by the presence of positive band of the DNA which was detected by gel electrophoresis method. The gel electrophoresis was carried out in order to monitor the outcome of PCR reaction. However, plate 3 showed a band in lane A5 with approximate 789 base pairs compared with the ladder in lane 1 which is the DNA ladder.

The DNA ladder obtained shows the size of A5 ladder which represent the length of its base pairs shown in Plate 3:

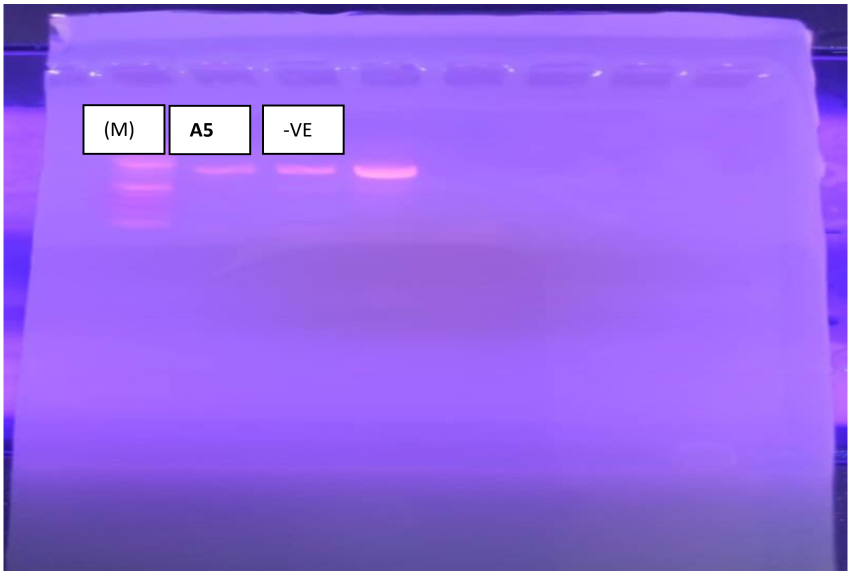


Plate 3: Gel of 16s rRNA gene of Strain A5

Where: Lane 1 (M) = DNA ladder, Lane 2 = A5, Lane 3 (-VE) = Control

Phylogenetic Analysis: Phylogenetic analysis using MEGA6 software clustered strain A5 with *Pseudomonas spp.*, confirming its identification and illustrating its evolutionary relationship with other strains.

Table 6: Blast Result showing score of similarity of strain A5 with *Pseudomonas*

	Description	Scientific Name	Max Score	Total Score	Query Cover	E value	Per. Ident	Acc. Len	Accession
✓	Pseudomonas sp. DY-1(2016) 16S ribosomal RNA gene, partial sequence	Pseudomonas sp. DY-1(2016)	1009	1009	97%	0.0	91.99%	1446	KU942677.1
✓	Stenotrophomonas pavanii strain DYJOTU14 16S ribosomal RNA gene, partial sequence	Stenotrophomonas pavanii	1007	1007	97%	0.0	91.89%	1451	MT875421.1
✓	Stenotrophomonas sp. strain SSPR1 16S ribosomal RNA gene, partial sequence	Stenotrophomonas sp.	1005	1005	97%	0.0	91.88%	1449	MF521553.1
✓	[Pseudomonas] geniculata strain BCR5 16S ribosomal RNA gene, partial sequence	[Pseudomonas] geniculata	1005	1005	97%	0.0	91.88%	1132	KY437100.1
✓	[Pseudomonas] geniculata strain SVR4 16S ribosomal RNA gene, partial sequence	[Pseudomonas] geniculata	1005	1005	97%	0.0	91.88%	989	KY437099.1
✓	Pseudomonas sp. FRT-Slr-20 16S ribosomal RNA gene, partial sequence	Pseudomonas sp. FRT-Slr-20	1005	1005	97%	0.0	91.88%	921	KM287523.1

After obtaining the above information through Basic Local Alignment Search Tool (BLAST), the organism is aligned using Three (3) different templates and an Outgroup (E. *coli*) in order to get the similarity index to which the organism is more similar to our isolate.

```
muawiyya        -----------------------------------TGCGGGCTACCATGCAGTCGAACGG   25
NR_024570.1     AGTTTGATCATGGCTCAGATTGAACGCTGGCGGCAGGCCTAACACATGCAAGTCGAACGG   60
KY437100.1      --------------------------GAGCAGGGGGGTGGCTACACATGCAGTCGAACGG   34
KU942677.1      ----------------------------GTGCTCAGCTCCGCTACCATGCAGTCGAACGG   32
KM287523.1      --------------------------------------GGCTACACATGCAGTCGAACGG   22
                                                                  **********

muawiyya        CAGCA-------CAGASCTTGCTCCCTGGTGGGGTGGSGGCGGGTGAGGAATACATCGGA   78
NR_024570.1     TAACAGGAAGCAGCTTGCTGCTTTGCTGACGAGTGGCGGACGGGTGAGTAATGTCTGGGA   120
KY437100.1      CAGCACAGAGGAGCTTGCTCCTTGGGTGGCGAGTGGCGGACGGGTGAGGAATACATCGGA   94
KU942677.1      CAGCACAGAGGAGCTTGCTCCTTGGGTGGCGAGTGGCGGACGGGTGAGGAATACATCGGA   92
KM287523.1      CAGCACAGAGGAGCTTGCTCCTTGGGTGGCGAGTGGCGGACGGGTGAGGAATACATCGGA   82
                 * **            **   *   **  * *  *  * ******** ***   * ***

muawiyya        ATCTACTCTGTCGTGGGGGATAACGTAGGGAAACTTACCTAATACCGCAACSACCTA---   135
NR_024570.1     AACTGCCTGATGGAGGGGGATAACTACTGGAAACGGTAGCTAATACCGCATAACGTCGCA   180
KY437100.1      ATCTACTCTGTCGTGGGGGATAACGTAGGGAAACTTACGCTAATACCGCATACGACCTAC   154
KU942677.1      ATCTACTCTGTCGTGGGGGATAACGTAGGGAAACTTACGCTAATACCGCATACGACCTAC   152
KM287523.1      ATCTACTCTGTCGTGGGGGATAACGTAGGGAAACTTACGCTAATACCGCATACGACCTAC   142
                * ** *    * * **********    ******       *   *   *

muawiyya        --CGGGTGAAAGCGGGACCTTCGGCCTTGCGCGATTGAATGAGCCGATGTCGGATTACTA   193
NR_024570.1     AGCACAAAGAGGGGGACCTTAGGGCCTCTTGCCATCGGATGTGCCCAGATGGGATTAGCT   240
KY437100.1      GGGTGAAAGCAGGGGACCTTCGGGCCTTGCGCGATTGAATGAGCCGATGTCGGATTAGCT   214
KU942677.1      GGGTGAAAGCAGGGGACCTTCGGGCCTTGCGCGATTGAATGAGCCGATGTCGGATTAGCT   212
KM287523.1      GGGTGAAAGCAGGGGACCTTCGGGCCTTGCGCGATTGAATGAGCCGATGTCGGATTAGCT   202
                           * **  * *  *****   ** ** * *** *** *  * ******

muawiyya        GTTGG-CGGGGTAAAGGCCCACC---AGGCACATCCGTASCTGGTCTGAGAGGATGATCA   249
NR_024570.1     AGTAGGTGGGGTAACGGCTCACCTAGGCGACGATCCCTAGCTGGTCTGAGAGGATGACCA   300
KY437100.1      AGTTGGCGGGGTAAAGGCCCACCAAGGCGACGATCCGTAGCTGGTCTGAGAGGATGATCA   274
KU942677.1      AGTTGGCGGGGTAAAGGCCCACCAAGGCGACGATCCGTAGCTGGTCTGAGAGGATGATCA   272
KM287523.1      AGTTGGCGGGGTAAAGGCCCACCAAGGCGACGATCCGTAGCTGGTCTGAGAGGATGATCA   262
                  * *  ******* *** ****     *   **** ** ***************** **
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Fig. 1: Multiple Sequence Alignment using Clustal W

PHYLOGENETIC TREE CONSTRUCTION : Five different strains' sequences were chosen from the result of BLAST with strain A5 sequence to perform the alignment by using MEGA6 software and the Neighbor-joining bootstrap method was used to construct the phylogeny tree in order to show the evolutionary relationship between the Bacterial species as shown in Figure 3.

Figure 1 showed that the bacterium A5 with accession number KU942677.1 (MUAWIYYA) was clustered with *Pseudomonas spp*.

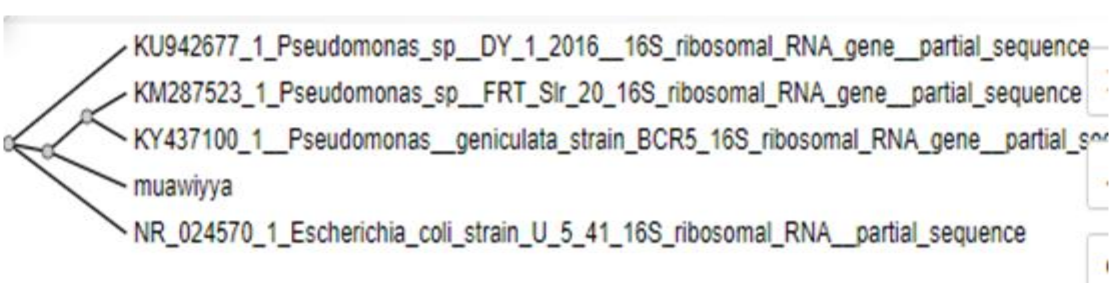

Fig. 3: Phylogeny construction using Clustal W

Discussion: Aquaculture is a major sector that supplies a significant amount of animal food globally. Reports have shown how diseases caused by microorganisms especially bacteria are putting setbacks in aquaculture by depleting the production of fish and fisheries products. As a result, the use of antibiotics as therapeutic agent is deployed. Regardless of the importance of antibiotics in reducing bacterial loads, the bacteria may resist the antibiotics (AMR) and the antibiotics might be accumulated in the food chain through bioaccumulation and result to Biomagnification.
Therefore it is necessary to know the Antimicrobial resistance bacteria to mitigate its adverse effect on aquaculture product, consumers and the immediate environment. The bacteria named *Pseudomonas spp* was isolated, identified using molecular tools and tested on Tetracycline (Predominant Antibiotics used in Aquaculture) at the concentration of 40 mg, 80 mg, 120 mg, 160 mg, 200 mg and 250 mg which was seen to be resistant to the Antibiotics and hence it is potential for biomagnification as it may persist to be transformed and circulate in the food chain through bioaccumulation. Merve and Nursen (2019) have not included Tetracycline among the Antibiotics banned for human use and food production after considering its effectiveness in degrading bacteria and Edward *et al.,* (2018) stated the effectiveness of Oxytetracycline in hemorrhagic septicemia caused by *Psedomonas spp* whereas this research showed the resistance of Tetracycline in treating Gram negative bacteria identified as *Psedomonas spp.*

Yojiro *et al.,* (2010) monitor the incidence of antimicrobial resistance gene in fish farms and the prevalence of antimicrobial genes in gram negative bacteria in Northern part of Egypt where they found 33.2% of gram negative bacteria showed multiple drug resistance and harbors at least on antimicrobial resistance gene and PCR and DNA sequencing showed 26.3% isolates contains Tetracycline resistance gene and 6.9% isolates were positive for class 1 integrons with 12 different genes cassette. Therefore *Pseudomonas spp.* possess the antimicrobial resistance genes as identified in this research. In this research, Bacterial strain A5 and A6 among the isolates proved to be the most successful bacteria which shows growth at concentration of 200 mg/L and 250 mg/L of Tetracycline (TTC) but Strain A6 has the fewest colony with low DNA concentration and purity, but also strive to survive the Antibiotics. Based on the result, it suggest that A5 strain is closely related to the respective *Pseudomonas spp*. Therefore, the current isolate is designated as *Pseudomonas spp (*A5). To the best of my knowledge, the bacteria was never isolated and identified (molecular identification) in the research area by any other person based on literature and NCBI report, but similar research was conducted by Haong *et al., (*2014) in Vietnam where molecular characterization of antibiotics resistance bacteria isolated from Cat Fish was conducted and *Pseudomonas spp* and *Aeromonas spp* were collected from intensive Cat Fish farms. *Pseudomonas spp* shows high level of resistance to multiple antibiotics where the percentage of multiple drug resistance of *Pseudomonas* was about 96% with an index value of 0.457. Approximately 33% of *Pseudomonas spp* found in this research contained 1 integrons that harbors common resistance genes like "aadA" "dfrA" and "catB". This indicated that *Pseudomonas spp* were exposed to high risk source of contamination in where antibiotics are commonly used. This research could give the avenue to know the economic importance of *Pseudomonas spp* to accomplish environmental needs especially the controversies bedeviling the use of Antibiotics in Aquaculture which usually leads to water pollution and Bioaccumulation of Antibiotics in food chain that resulted to resistance. The result of these studies suggest that, the bacteria might have the potentials of Bioaccumulation of Tetracycline which is predominantly used in Fish Farming. The Bacteria (*Pseudomonas spp*) can be further studied for commercializing its resistant gene in the production of improved variety products that may be resistant to Pathogenic Bacteria as in the case of food crops through Recombinant DNA Technology.
Conclusion: Pseudomonas spp. was successfully isolated from the Gombe Fish Market pond and demonstrated resistance to tetracycline across various concentrations. Strains A5 and A6 were particularly notable for their resistance capabilities. This research contributes to the understanding of antibiotic resistance in aquaculture and suggests potential avenues for further study and management.

Recommendations: Further Investigation: Examine the interaction of resistance genes with various growth factors and environmental parameters; Broader Testing: Assess resistance to multiple antibiotics beyond tetracycline to understand multi-drug resistance.**;** Inhibitory Testing: Conduct tests on other predominant antibiotics used in aquaculture to validate findings.**;** Molecular Studies: Explore the economic importance of resistant genes and their potential applications in developing improved aquaculture products through recombinant DNA technology.

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Economic viability of catfish farming in Ado-Ekiti Metropolis, Ekiti State, Nigeria.

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Abstract

Fish is an excellent source of animal protein that contains essential amino acids necessary for human health, and this has led to high demand for fish due to the growing population and increased awareness of nutrition in Nigeria. The study assesses the economic viability of catfish farming in Ado-Ekiti metropolis, using a multi-stage sampling technique to randomly select 90 registered fish farmers. Structured questionnaires were used to collect primary data. Descriptive statistics, farm budgetary analysis, and a 3-point Likert scale were used to achieve the objectives of the study. The findings revealed a mean age of 50 years, 58% female, 71% married, and 73% educated, with an average of 5 persons per household. The findings further revealed an average total revenue of ₦ 1,185,662.22, with investment of ₦ 1,037,295.10 as total cost per production cycle. These consist of total variable costs (₦ 717,872.88), which accounted for 62.2% of total cost, and the total fixed cost (₦ 319,422.22), which accounted for 30.8% of total cost. The net farm income was ₦ 148,367.12, with a gross margin of ₦ 467,789.34 and RoI of 14%. The profitability ratio of 0.13 means that for every N1 invested into catfish farming, 13% (N0.13k) was generated as profit, while 87% (N0.87) was attributed to the total cost. The study identifies catfish farming as economically viable and profitable in the study area. However, poor road network, inadequate capital, and high costs of feed and input were the major challenges of catfish farming in the study area. **Keywords:** Fish, catfish, profitability, farm budgeting techniques.

Introduction: Fish is an excellent source of animal protein that contains essential amino acids necessary for human health (Tilami & Sampels, 2017). It is a nutrient-rich food that provides omega-3 fatty acids, which is a good source of vitamins D, B12, and selenium (Wright et al., 2018). It is also an essential part of animal feed, which serves as a source of raw materials for industries and provides employment to over 1.48 million of the nation's active population, who earn a living through fisheries-related activities (Odioko & Becer, 2022). Fish remains an important dietary element in Nigeria, especially in the southern part of the country, where fish is highly valued and is one of the cheapest sources of animal protein available to many Nigerians (Food and Agriculture Organization [FAO], 2020). According to Abdulrahman (2022), fish farming is a form of aquaculture that involves the breading and rearing of fish for commercial purposes using artificial means. Nigeria is ranked as the leading aquaculture-producing nation in Sub-Saharan Africa. According to Ogunji and Wuertz (2023), Nigerian aquaculture production rose to more than 300,000 metric tons in 2015 from about 2000 metric tons in 1960 and dropped to 260,000 in 2020 due to the COVID-19 pandemic. However, this figure has since improved with Nigeria producing over 1 million metric tons annually, and this has contributed about 1.16% to the national GDP in 2021 and 0.47% in 2022 (Abba, 2023).

With a growing population of more than 220 million people and the growing awareness of nutrition in Nigeria, the high demand for fish products as a source of protein has led to a steady demand for fish in local markets, restaurants, and households. The estimated annual average per capita fish consumption in Nigeria is between 11.2 and 13.3 kg per person (Ogunji and Wuertz, 2023), and this is still lower compared to the world's average of 20.3 kg/capita/year (Bradley et al., 2020). The average Nigerian consumes about 40% of their animal protein from fish, which has been shown to help treat malnutrition-related disorders (Legbara, 2019). Nigerian domestic fish production is around 1.2 million metric tons, which fall short of the 3.6 million metric tons demanded annually (Kehinde, 2022), leading to significant imports to bridge the gap. In 2022, Nigeria spent approximately N122.5 billion (about $270 million US dollars) on fish imports, representing a 53.84% decline from N265.4 billion ($580 million US dollars) spent in 2021 (Odifa, 2023). According to the Ekiti State Digest of Agricultural Statistics (2021), Ekiti State total fish production in 2021 was 3,191,502 kg (3,191.50 metric tons). This is made up of 3,164,240 kg (3,164.24 metric tons) from aquaculture and 27,262 kg (27.26 metric tons) from artisanal, respectively. Out of these figures, about 300 metric tons, representing 9.1% of the state fish production, are produced within Ado Ekiti metropolis. The majority of fish farmers in Nigeria today operate on a small scale, with ponds ranging from small earthen ponds of 0.02–0.2 hectares to large concrete pools of 25–40 meters (Kehinde, 2022). Catfish, tilapia, and carp are the most frequently grown fish species. Catfish, typically grown in ponds and tanks, is the most farmed species in Ekiti State, constituting 99.9% of the total aquaculture production by volume (Ekiti State Digest of Agricultural Statistics [EKSDAS], 2021). A large number of small-scale fish farmers in Nigeria concentrate on catfish farming due to a variety of features attributed to catfish. For example, catfish can easily adapt to their environment with a fast growth rate and reduced production cost, stock in ponds, and be easily sold live at a good market price with a rich source of high-quality protein, which is highly demanded as food in Nigeria (Oladimeji, 2017). Despite all these enormous opportunities and positive features in the fisheries and aquaculture sectors, catfish production remains low in Nigeria. With a yearly fish requirement of about 3.6 million metric tons to meet the consumption need of over 220 million Nigerians, the aggregate supply (captured and farmed) is about 1.2 million metric tons. This shows a huge potential for investment and expansion in catfish farming, as catfish production accounts for 65.61% of national aquaculture production (Ogunji and Wuertz, 2023). Hence, this study is necessitated by the dearth of data reflecting the current market trends and production cost on the economic viability of catfish farming in the study area. The study investigated the economic viability of catfish farming in Ado-Ekiti metropolis, Ekiti State, Nigeria.

Specifically, the study assessed the socio-economic and institutional characteristics of catfish farmers, the profitability of catfish farming, and the challenges of catfish farming in the study area.

Materials and Methods: Study Area: The study was conducted in Ado-Ekiti Local Government Area, which is one of the sixteen (16) local government area in Ekiti State. Ado-Ekiti is a town and the capital of Ekiti State. It is located between the latitude 7^0 37^1 N and longitude 5^0 13^1 E. It is bothered to the south by Ikere and Isi Orun, to the east by Gbonyin, to the north by Ido Osi, then to the west by Ekiti west and Ijero local government areas. The Local government area is subdivided into 13 wards, with an estimated population of 536,000 at 3.88% growth rate. The main language spoken by the indigenes of Ado Ekiti is the Ekiti dialect and Yoruba language.

Sampling Procedure and Sample Size: A two-stage sampling procedure was adopted in selecting registered fish farmers for the study. The first stage involved a random selection of six (6) communities from Ado-Ekiti metropolis: Ado-Ekti main town, Ajilosun, Moferere, Oke Ila, Falegan (Ilawe road), and Ajebamidele. The second stage was the random selection of 15 small-scale catfish farmers from each community, making a total of 90 catfish farmers constituting the sample for the study. Primary data were collected with the use of structured questionnaires designed in line with the objectives of the study.

Method of Data Analysis: Descriptive statistics, farm budgetary analysis, and a 3-point Likert scale were used to achieve the objectives of the study. Descriptive statistics such as means, percentages, and frequency distributions were used to describe the socio-economic and institutional characteristics of the catfish farmer. Farm budgetary analysis was used to measure and evaluate the costs and return components and the profitability of the catfish enterprise. According to Omolayo (2018), a farm budget is a detailed physical and financial plan for the operation of a farm for a certain period. The farm budgetary analysis therefore, helps to determine the total cost and total revenue that accrued to the enterprise within a specific production cycle. The Gross Margin Analysis (GMA) is one of the simplest analytical tools used in farm management to evaluate the efficiency of an enterprise (or farm plan) in order to assess and compare the various enterprises existing within the farm business. Gross margin (GM) is the difference between the Total Revenue (TR) and the Total variable cost (TVC). The model for estimating farm budgeting techniques is outlined thus:

GM = TR – TVC
where: TR = Total Revenue
TVC = Total Variable Cost
TR was obtained by multiplying the total output with market prices of the output expressed in naira. TVC comprises expenses on stocking of birds, energy & water, labour, vaccination, etc., while the Total Fixed Cost (TFC) comprises expenses on land, equipment, generator, farm houses, etc.

The Net Farm Income (NFI) = TR – TC,
where: TR = Total Revenue
TVC = Total Variable Cost
TFC = Total Fixed Cost
TC = Total Cost (TVC + TFC)
Therefore, NFI = TR – TC
Return on Investment (RoI) = NFI / TC multiply by 100
Profitability Ratio (PR) – NFI / TR

A 3-point Likert scale was also used to evaluate the extent of the challenges facing small-scale catfish farmers in the study area. This was structured into Not a challenge, Minor challenge, and Major challenge, with corresponding values of 1, 2, and 3 respectively. The criteria reference or cut-off point for the mean value was 2.00 using Statistical Package for Social Sciences (SPSS). This implies that 2 and above is regarded as major challenge, while below 2 is minor challenge.

Results and Discussions: Socio-economic and institutional characteristics of the catfish farmers.
Table 1 depicts the socio-economic and institutional characteristics of catfish farmers in the study area. The table revealed that the average age of catfish farmers in the study area is 50 years. This result is in line with the findings of Enwelu et al. (2023), who reported that most of the catfish farmers in Nigeria were young people within the productive age range of 40-49 years. Also, 58% of the catfish farmers are female, and this finding is in contrast with Aloysius et al. (2020) and Kehinde (2022), who reported that catfish farming is dominated by males. The table further revealed that 71% of the fish farmers are married, with an average household size of 5 persons. Also, the majority (73%) of the fish farmers have formal education, with an average income of N1,185,662.22 per production circle. Furthermore, 53% of the catfish farmers have access to loans, while only 44% have access to extension services. However, 56% and 84% of the catfish farmers have no access to training on catfish farming and government support, respectively, in the study area.

Table 1: Socio-economic and institutional characteristics of the catfish farmers.

Variable	Frequency (N=90)	Percentage	Mean
Age			50
30 – 39	14	16	
40 – 49	35	39	
50 – 59	20	22	
60 - 70	19	21	
70 and above	2	2	
Sex			
Male	38	42	
Female	52	58	
Marital Status			
Single	0	0	
Married	64	71	
Others	26	29	
Household Size			5
1 – 3	28	31	
4 – 9	42	48	
7 – 9	20	22	
Level of Education			
No formal education	24	27	
Primary education	20	11	
Secondary education	32	35	
Tertiary education	24	27	
Total Income – *(Revenue in Naira)*			₦1,185,662.22
1,000 – 500,000	8	9	
501,000 – 1,000,000	38	42	
1,001,000 – 1,500,000	22	24	
1,501,000 – 2,000,000	14	16	
2,001,000 and above	8	9	
Access to Credit/Loan			
Yes	48	53	
No	42	47	
Training on Fish Farming			
Yes	40	44	
No	50	56	
Government Support			
Yes	14	16	
No	76	84	

Source: Field Survey, 2024

Profitability (Cost and Returns) of catfish farming: As indicated in Table 2, the cost and returns analysis revealed that ₦1,185,662.22 was realized as average Total Revenues (TR) from the sales of catfish for one production cycle. The result also shows that an average catfish farmer invested ₦1,037,295.10 as Total Costs (TC) of production for the enterprise per cycle. These consist of both Total Variable Cost (TVC) and Total Fixed Cost (TFC). The TVC (₦717872.88) accounted for 62.2% of the total cost, while the TFC (₦319,422.22) accounted for 30.8% of the total cost of production. ₦22,720.00, which stands for fingerlings, represent 2.2% of total cost, while feed cost (₦654,533.33) represents 63.1% of total cost, which is the largest part of the production cost. Electricity (₦36,737.78) represents 3.5% of the total cost, while petrol and lime (₦3,881.77) account for less than 1% of the total cost of production. The table also revealed that the total fixed cost for the enterprise for one production cycle was ₦1,037,295.10, while the Net Farm Income (NFI) realized was ₦148,367.12. The Gross Margin (GM) for the production cycle is ₦467,789.34, and the Gross Margin Ratio (GMR) is 0.37. The GMR is used to compare the GM of the enterprise to its TR. It shows how much profit the farm makes after paying its TVC. The GMR (0.47) indicates that for every ₦1 revenue generated by the fish farmer, ₦0.39k is retained, while ₦0.61k is attributed to TVC. The table further revealed that the Return on Investment (RoI) is 0.14 (14%). The RoI is a profitability matrix that measures the profitability of an investment relative to its cost. It calculates the percentage return on investment, and it is used to evaluate the performance of an enterprise over a given period of time. With RoI (14%), this implies that for every N1 invested in fish production, the catfish farmer generates a return of N0.14k. The Profitability Ratio (PR) evaluates the enterprise's ability to generate profit above its production cost. The PR is 0.13, which implies that for every N1 invested into catfish farming, 13% (N0.13k) was generated as profit, while 87% (N0.87) was attributed to the total cost of production. This shows that the catfish farming business is fairly profitable in the study area. The result of this study is in line with the submission of Idris-Adeniyi et al., (2018), and Enwelu et al., (2023) that catfish farming is profitable.

Table 2: Cost and returns for fish farming in the study area

Variable	Total Cost of Production (₦)	Mean Value (₦)	% of Mean Value
Total Revenue (TR)	106,709,600.00	1,185,662.22	
Variable Cost			
Fingerlings	2,044,800.00	22,720.00	2.2
Feeds	58,908,000.00	654,533.33	63.1
Electricity	3,306,400.00	36,737.78	3.5
Petrol	341,760.00	3,797.33	
Lime (*for water treatment*)	7,600.00	84.44	
Total Variable Cost (TVC)	**64,608,560.00**	**717,872.88**	69.2
Fixed Cost			
(Depreciation on fixed asset @ 10%)			
Ponds	1,563,800.00	17,375.56	
Generator	34,000.00	377.78	
Tank	169,000.00	1,877.78	
Pumping Machine	1,108,000.00	12,311.11	
Total Fixed Cost (TFC)	**2,874,800.00**	**319,422.22**	30.8
Total Cost (TC) = (TVC + TFC)	**67,483,360.00**	**1,037,295.10**	
Net Farm Income (NFI) = (TR – TC)		148,367.12	
Gross Margin (GM) = (TR - TVC)		467,789.34	
Gross Margin Ratio (GMR) = (GM/TR)		0.39	
Return on Investment (ROI) = (NFI/TC)		0.14	
Profitability Ratio (PR) = (NFI/TR)		0.13	

Source: Field survey 2024

Challenges of catfish farming in the study area.;The Table 3 shows the challenges facing catfish farmers in the study area. The table revealed that poor road network with a mean of 2.44 $\pm$0.69 was ranked 1st, while inadequate capital for investment was ranked 2nd with a mean of 2.40 $\pm$0.61. High cost of feed and input with a mean of 2.31 $\pm$0.70 was ranked 3rd, while price fluctuation and inadequate processing facilities were ranked 4th with mean of 2.24 $\pm$0.74 respectively. The table further revealed that poor customer attitudes was ranked 6th with a mean of 2.02 $\pm$0.0.62, while problem of market location was ranked 7th with a mean of 1.78 $\pm$0.82. This result shows that the major challenges facing fish farmers in the study area include poor road network, inadequate capital for investment and high cost of feed and other inputs needed for fish farming.

Table 4.4: Challenges of fish farming.

Challenges	Mean (N=90)	Std. Dev.	Ranking
Poor road network	2.44	0.69	1st
Inadequate capital for investment	2.40	0.61	2nd
High cost of feed and input	2.31	0.70	3rd
Price fluctuation	2.24	0.74	4th
Inadequate processing facilities	2.24	0.71	4th
Poor customer attitudes	2.02	0.62	6th
Problems of market location	1.78	0.82	7th

Source: Field survey, 2024.

Conclusion: This study concludes that catfish farming is a relatively viable (profitable) enterprise in the study area, even though the high variable cost incurred by catfish farmers, which is attributed to the high cost of feed, representing over 63% of the total cost of production, is due to the removal of fuel subsidies by the government.

Recommendations: The Ekiti State Government should ensure adequate provision and maintenance of basic infrastructures, such as a good road network, electricity, water, hospitals, etc., to reduce the cost of production in catfish farming. They should also encourage veterinary doctors with good incentives to provide sufficient training on hygienic management of catfish farms to farmers in rural areas. This has the power of increasing productivity and farm income, thereby reducing poverty among the catfish farmers in the State. The state government should collaborate with agriculturally friendly banks (commercial and microfinance) to develop a farmer-friendly credit policy that will provide easy access to credit for catfish farmers at a lower interest rate so that they can expand production to meet the consumption demand of the consumers in the State. Adequate extension services, such as training and support on best feed formulation, fish processing, and farm management techniques, should be extended to catfish farmers by the extension agents to enhance the efficiency and productivity of the catfish farm business. This will also expose them to much needed information that will enhance their knowledge and skills on feed formulation, fish processing, and best farm management practices in the operations of their farm business. . The Ekiti State Government can explore the fisheries and aquaculture industries by providing training on fish value chain to the youth, and empowering them with start-up capital at a lower interest rate to engage in fish farming and other related businesses along the fish value chains. This will go a long way in reducing youth unemployment and poverty in the State.

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Effect of Tillage Operations on the Yield of Two Varieties of Maize under Sandy Loam Soil Conditions at FEDPOLNEK Demonstration Farm Owerri Imo State

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Abstract

The effect of tillage operations on the yield of two varieties of maize (white and yellow maize) were studied. The results of the study were statistically analyzed using randomized complete block design (RCBD). The least significant difference was determined at $P < 0.05$ level of probability to the test difference between four main treatments; Ploughing T_1, Harrowing T_2, Ploughing and Harrowing combination T_3 and No-Tillage T_4 with two varieties of maize P_1 and P_2 for white and yellow maize respectively were considered within each tillage operation. The results showed that the dominant soil type of the study area is sandy loam soil. The estimated marginal means for plant height (cm), number of grain per ear, grain weight (g), grain yield (t/ha), showed highest values during ploughing and harrowing combination, followed by ploughing alone compared to other tillage operations for both maize varieties. White maize variety recorded higher height, stem girth, number of leaves, maize weight (g) and maize yield (t/ha); 78.62cm, 4.55cm, 9.78cm, 42.34g and 12.24t/ha respectively during ploughing and harrowing combination compared to other tillage operations as against yellow maize variety. Analysis of variance (ANOVA) was performed to examine the main effects of tillage operations, maize varieties and their interactions on the measured parameters, which showed a significance difference at 0.05% for the parameters. The study therefore recommends ploughing and harrowing combination operation for increase productivity as well as optimize the soil nutrient availability, water retention and soil structure.

Keywords: Tillage, maize yield, tillage operations, treatments, sandy loam soil

Introduction: Tillage operations play a crucial role in modern agricultural practices, influencing soil preparation, nutrient availability, weed control, and overall crop productivity. The selection of appropriate tillage operation is particularly important when dealing with specific soil conditions, such as sandy loam soils. Sandy loam soils are characterized by their coarse texture, which results in rapid water drainage, low water-holding capacity and reduced nutrient retention. These soil conditions present unique challenges for crop cultivation, including maize production. Maize (Zea mays) is one of the most important cereal crops globally, serving as a staple food and feed source. However, its successful cultivation in sandy loam soils requires careful consideration of tillage operations and the selection of suitable maize varieties. Different tillage operations, such as conventional tillage; ploughing, harrowing, ploughing and harrowing combination, and no-tillage have different effects on soil structure, moisture retention, nutrient availability and maize yield. Understanding the impact of these tillage operations on maize yield is crucial for optimizing production in sandy loam soil.

Previous research has shown that the choice of tillage operations can significantly affect crop performance in various soil types. However, there is a need for further investigation specifically focusing on sandy loam soils and their interaction with maize cultivation and their varieties. By evaluating the effects of different tillage operations on the yield of two varieties of maize under sandy loam soil conditions, this study aims to provide valuable insights into the optimization of maize production in such environment. Understanding the influence of tillage operations on maize yield in sandy loam soils can contribute to sustainable agriculture by enhancing productivity, conserving soil resources and minimizing environmental impacts. Additionally, this research can help farmers and agricultural practitioners make informed decisions regarding tillage operations and maize variety selection to maximize yields and profitability.

Maize is considered one of the most important cereal crop due to its demands for consumption and industrial purpose (Abagandura et al., 2017). Low soil organic matter and pests decrease maize production worldwide (Copeland and Crookston, 1992). Farmers use various tillage practices without being aware of the effect of these systems on soil physical properties and plant growth (Gomez et al., 1999). It is essential to select a tillage operation that sustains the soil physical properties required for successful growth of maize in FEDPOLNEK. Therefore, more information is needed on the effect of tillage operations on maize production in FEDPOLNEK. The most limiting factors for sustainable maize (Zea may) production in small holder farm systems of Sub-Sahara Africa like Nigeria are erratic and unpredictable rains and low fertility. The major causes of low soil fertility are low levels of nutrient inputs, continuous cropping, overgrazing, deforestation and poor soil and water conservation measures (Buah et al., 2017). The situation is further aggravated by increased population pressure and limited availability of fertile land.

Given the growing demand for food and feed production in a changing climate, sustainable interventions are critically required to increase maize productivity while conserving the natural resource base and preventing further degradation that has characterized most soils in Nigeria. Most farmers prepare the land by using hand hoe or by ploughing with tractors or draught animals. However, cultivation with the hand hoe is more common. When the soil is subjected to intensive and repeated tillage, it becomes susceptible to high run-off and soil erosion rates and soil deterioration. This results in progressive decline in soil productivity and low crop yield (Gomez et al., 1999). Some of the degraded soils often exhibit a general lack of response to mineral fertilizer addition. The general objective of this study is to examine the effect of tillage operations on the yield of two varieties of maize under sandy loam soil conditions at FEDPOLNEK, Imo State. The specific objectives are as follows; To determine the effect of tillage operations on the yield of two maize varieties; To compare varieties of maize best suitable for study area under different tillage operations. And to make recommendations to the farmer within the study area.

Materials and Methods: **Experimental Site**: The experimental site was located at the Federal Polytechnic Nekede Owerri (FEDPOLNEK) Demonstration Farm which lies within latitude 5^0 26'N and 5^0 26.0672'N and longitude 7^0 2 and 7^0 2.238'E. The area of the land selected was 100m x 100m or 10,000m^2, the land was sub-divided into small plots of 25m x 25m in other to accommodate the planting of the two varieties of maize (white and yellow maize). The planting distance was 0.75m x 0.75m and planting depth 0.05m (5cm). From the emergence of the plant to the shooting out the leaves, measurements were taken. The research site was chosen based on its sandy loam soil characteristics, accessibility and previous cropping history and drainage were considered to ensure the site was representative for such experiment.

Experimental Design: The study was laid out in a randomized complete block design (RBDC) with four main treatments; ploughing alone T_1, harrowing alone T_2, ploughing and harrowing combination $T_{3,}$ and No-tillage T_4, two varieties of maize; white P_1 and yellow P_2 (as the levels) were randomly assigned to the respective tillage treatments with three replications and one location at FEDPOLNEK Demonstration Farm (4x2x3x1) = 24 experimental runs. The size of each plot was (100m x 100m) divided into plot of (25m x 25m) with inter block spacing of 1.5m and inter plot spacing of 1.5m.

Experimental Procedure: The experiment was conducted from 20th March, 2023 to 20th July, 2023 at the FEDPOLNEK. The plots were ploughed on the 20th March, 2023 and the harrow operation was done the next day (21st March, 2023) followed by Ploughing and harrowing combination operation on the 22nd March, 2023. A 45kW (60 Hp) SWARAJ Tractor Model 978FE with three-point hitch system was used to pull the field equipment during the field operations. Disc plough and disc harrow were used for the study; the plough consists of three plane concave disc with a spacing of 680mm while the harrow consists of sixteen gang plane concave and notched concave disc harrow spaced 225mm apart. A constant speed travel of 1.8m/s was maintained for the tillage operations for the soil (sandy loam) as recommended by Ahaneku and Ogunjirin (2005). Also the draft force required for ploughing and harrowing operations were 4.95KN and 3.77KN respectively as opined by Ahaneku and Dada (2013). For No- tillage, planting was dug after slashing the soil surface. Two maize varieties (white, DMR-ESR and yellow, SAMMAZ 15) were used for the study. These varieties were selected because they are predominantly grown in the zone. The seeds were acquired from the National Root Crop Research (NRCR) at Umudike in Abia State. At the commencement of the experiment, tillage depths were measured at 10 random locations on each plot. A steel rule was inserted down into the tilled soil until a characteristic hard pan was reached. The tillage depth was measured from the corresponding reading on the steel rule. For all the operations 4 maize seeds per hole for planting followed by thinning done to 2 plants each per hole for all the treatments. Irrigation was applied manually by watering can. All other agronomic practices were kept normal and uniform for all treatments. Harvesting and threshing was done on 6th July, 2023 and kept in their respective plot for sun drying. Each plot yield was tied in bundle and weighed. The ears were removed from the dry stalks, unsheathed and threshed mechanically with the help of corn Sheller.

Effect of tillage operations on input parameters on white maize.

Note terms:

T_1= ploughing alone T_2= harrowing alone T_3= ploughing and harrowing combination T_4= no tillage

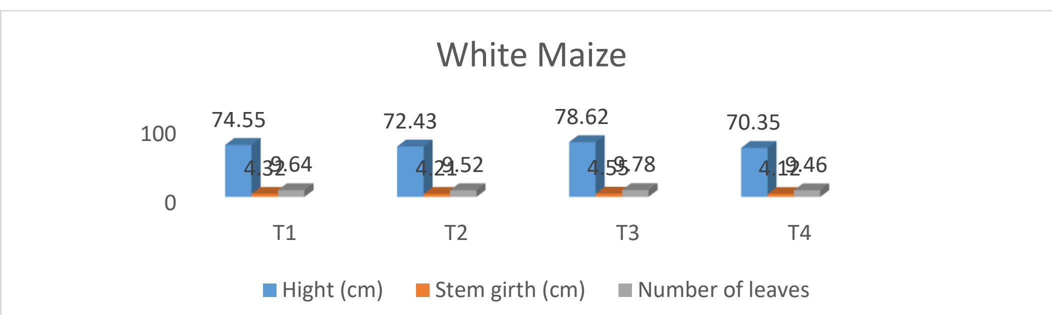

Figure 2.1: Effect of tillage operations on input parameters on white maize.

Discussion: Figure 2.1 revealed that white maize recorded the highest height, stem girth and number of leaves of 78.62cm, 4.55cm and 9.78 respectively at ploughing and harrowing combination operation compared to other operations. This is attributed to effect of the tillage operation which resulted to the higher height, stem girth and number of leaves in ploughing and harrowing operation than other tillage operations under study which is in agreement with Aikins and Afuakwa (2010) and Drakopoulos et al. (2016).

Effect of tillage operations on input parameters on yellow maize

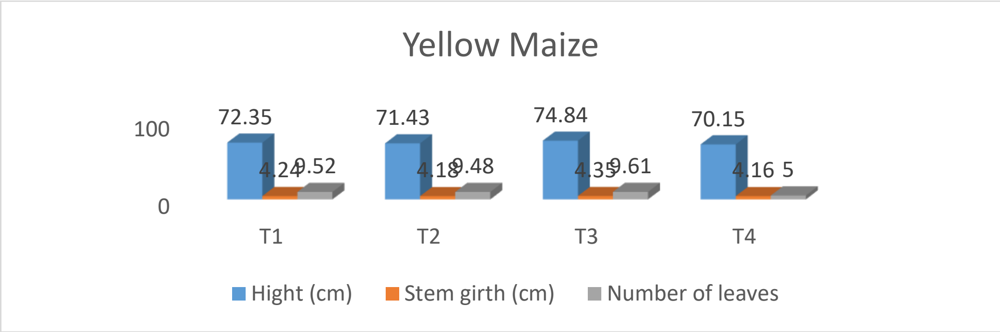

Figure 2.2: Effect of tillage operations on input parameters on yellow maize

Discussion: Figure 2.2 revealed that yellow maize recorded the highest height, stem girth and number of leaves of 74.84cm, 4.35cm and 9.61 respectively at ploughing and harrowing operation compared to other operations. This is attributed to the effect of the tillage operation which resulted to higher height, stem girth and number of leaves in ploughing and harrowing operation than other tillage operations under study which is in agreement with Aikin and Afuakwa (2010) and Drakopoulos et al. (2016).

Effect of tillage operations on maize weight of white maize and yellow maize.

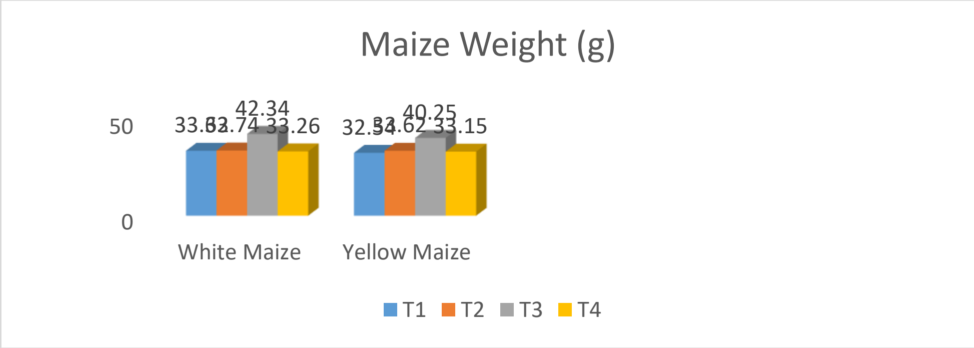

Figure 2.3: Effect of tillage operations on maize weight of white maize and yellow maize.

Discussions: Figure 2.3 revealed that ploughing and harrowing operation recorded the highest maize weight of 42.34g and 40.25g respectively for both white and yellow maize compared to other operations. This is attributed to the effect of the tillage operation which resulted to higher maize weight in ploughing and harrowing operation than other tillage operations under study which is in agreement with Paramu et al. (2016) and Bongomin et al. (2020).

Effect of tillage operations on maize yield of white maize and yellow maize.

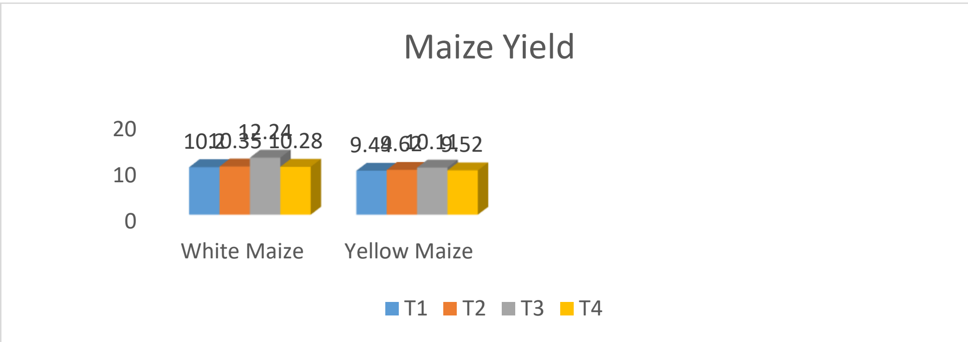

Figure 2.4: Effect of tillage operations on maize yield of white maize and yellow maize.

Discussions: Figure 2.4 revealed that ploughing and harrowing operation recorded the highest maize yield of 12.24 and 10.11g respectively for both white and yellow maize compared to other operations. This is attributed to the higher maize yield in ploughing and harrowing operation than other tillage operations under study which is in agreement with Paramu et al. (2016) and Bongomin et al. (2020).

Effect of tillage operations on plant height at maturity

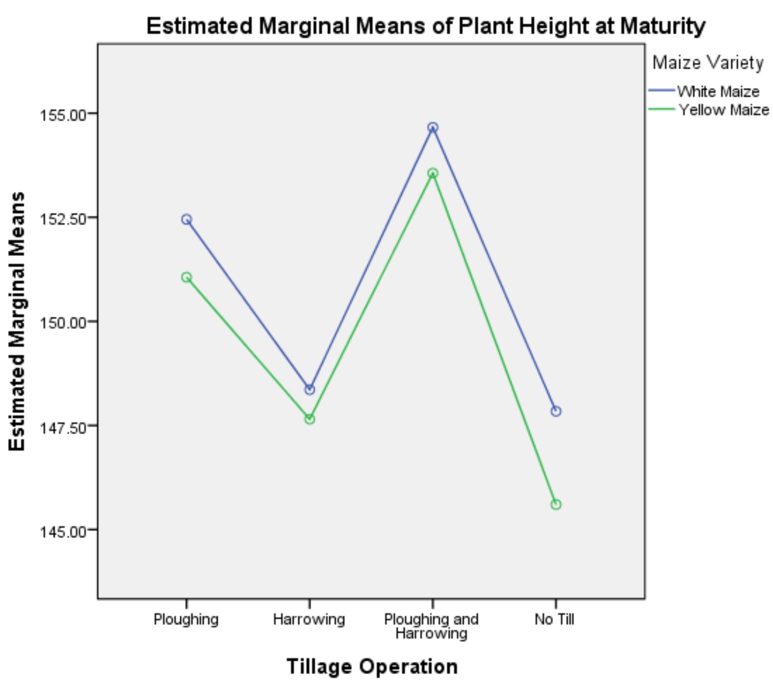

Figure 2.5: Effect of tillage operations on plant height at maturity

From the plot above, considering the various tillage operations, it shows that the plant height when no till was carried out was the lowest and this occurred in both varieties of maize (147.84cm and145.64cm, white and yellow respectively) while it was highest for the ploughing and harrowing combination for both varieties of maize (154.66cm and 153.56cm, white and yellow respectively). Under ploughing alone (152.45cm and 151.06cm respectively) was recorded compared to harrowing only which is (148.36cm and 147.65cm) for white and yellow respectively.

Conclusion: The research on effects of tillage operations on the yield of two varieties of maize under sandy loam soil conditions found that ploughing and harrowing combination operation recorded the best effect on the yield of maize followed by ploughing alone operation, harrowing operation and lastly No-till, this is in line with Paramu et al. (2016); Zero or No tillage treatment resulted in lower maize grain yield than conventional tillage. Also, the finding showed that white maize variety performed better than the yellow maize this may be as a result of specific growing conditions, farming practices; tillage operations and genetic factors.

Recommendations: The study recommends a further study on tillage operations and maize cultivation under sandy loam soil conditions. It encourages future investigation into related areas such as soil health, nutrient management and climate change adaptation. The study's finding can be disseminated through extension services to reach farmers and agricultural stakeholders, promoting the adoption of best practices for tillage operations and maize cultivation in sandy loam soil. The study's findings can inform policy makers and agricultural organizations in formulating policies and guidelines related to tillage operations and maize cultivation in sandy loam soils. It encourages the development of precision agriculture approaches, where tillage operations and maize variety selection can be tailored to specific soil conditions, optimizing resources use and crop productivity.

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Quantifying Soil Fertility Status under Diverse Land Use Practices in Toro Lga, Bauchi State

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Abstract

Quantifying the soil fertility status of a region is crucial for understanding its agricultural potential and guiding sustainable land management practices. This study aims to quantify the soil fertility parameters under Forested and cultivated landuse management patterns in Gumau, Toro Local Government Area of Bauchi State, Nigeria. Soils were sampled at 0- 15 cm depth and 0-10 cm depth for forested and deforested sites respectively using soil auger. Soil fertility parameters were analyzed using standard procedures. Data generated were subjected to descriptive analysis to evaluate frequencies distribution of the soil variables and categorized them into different classes. Independent sample t-test was also used to ascertain the influence of landuse practices on the soil fertility status. The descriptive statistics revealed differences in the variability of each soil property. Coefficient of variation ranged from 4% (pH in water) to 119% (K^+) for cultivated land and from 2% (pH in water) to 61% (Mg^{2+}) for Forested area. Independent sample t-test results revealed $Ca^{2+,}$ K^+ and Na^+ were not significantly different between the studied sites. Mg^{2+} were significantly different at 0.05 level of probability while pH in water and $CaCl_{2,}$ OC, TN, AP and CEC were significantly different at 0.01 level of probability. The independent sample t-test results highlighted the effect of converting forest landuse and consequences of cultivation on the soil fertility status in the studied site. This conversion had advance effect especially on the carbon component of the area. In the face of challenging environment issue, this effect is not acceptable and should be adequately and immediately addressed. Landuse management practices (agroforestry system, no tillage, minimal tillage) that harnesses the potential of the land for sustainable production to curb food scarcity while the forest and soil resources are conserved are therefore recommended

Key words: Land use, soil fertility, forest ecosystem, cultivated land and soil organic carbon

Introduction: Soil fertility serves a crucial factor in determining agricultural productivity and ecosystem health which are prominently affected by land use techniques (Akinnifesi, *et al*., 2016). In order to create and promote sustainable land management strategies and secure agricultural progress, it becomes imperative to comprehend how soil fertility varies across land use practices especially forested areas and agricultural lands. Forest ecosystems typically enhance soil fertility through natural mechanisms such as the buildup of organic matter and the cycling of nutrients, whereas cultivated lands frequently undergo changes that may disrupt these processes (Ogunkunle and Adebayo, 2016). The challenges posed by deforestation, unsustainable farming practices, and climate change have worsened these problems, resulting in diminished soil fertility and productivity. Recent research demonstrates that land use practices have a considerable impact on the chemical, physical, and biological characteristics of soil. For example, studies by Ojo *et al.* (2021) and Obidike-Ugwu *et al* (2021) suggests that clearing forests and engaging in agricultural practices can cause soil degradation, lower organic matter levels, and nutrient loss. Conversely, forest soils are generally better at retaining organic carbon and nutrients, which are essential for supporting biodiversity and enabling crop production (Kumar et al., 2022). While some studies have shown that forests management can increase the nutrient status of a soil (Madong *et al.,* 2009; Adebayo, and Idowu, 2014), others have reported no significant changes or even a decrease in soil quality. (Ray and Thomas, 2012). Although several researches have worked on land use practices influence soil fertility in diverse regions, there is a noticeable lack of research specifically targeting Toro Local Government Area (LGA).

The agricultural activities in Toro LGA primarily consist of subsistence farming, which often employs traditional methods that may not promote optimal soil health. As pointed out by Adamu *et al*. (2023), continuous crop cultivation without proper soil management can lead to a gradual decrease in fertility. Additionally, the growing demand for land resources due to population increase and economic activities intensifies the difficulties associated with maintaining soil fertility. This current situation calls for a thorough evaluation of soil quality indicators, such as pH levels, organic matter content, and nutrient availability, to assess fertility across different land uses. Understanding these dynamics will provide valuable insights for farmers, policymakers, and other stakeholders striving to implement effective land use strategies that enhance soil health and optimize agricultural outputs. Therefore, the objectives of this research is to assess and quantify soil fertility parameters under forest and cultivated land use practices in Gumau, Toro LGA, Bauchi State then provide recommendations for sustainable soil management practices to improve soil fertility and agricultural productivity in the region.

Materials and Methods: Site Description: The study was carried out in Gumau ward of Toro Local Government Area located at the northern tip of Bauchi State. It lies between latitude 10° 14' 52" N and longitude 9° 1' 4" E of the equator with elevation of 230 m (minimum) - 1053m (maximum). It shares common boundaries with Laru village by the south, Anguwan Sanga by the South west, Ruruwai by the west, Anguwan

Kanya by the east, Tashanmalam Sale by the North and pingel by the north east. Gumau was created in 1947 and occupies a total area of about 820.98 square kilometers (Hashiru glamour, unpublished). According to the National Population Commission (NPC, 2006) the total population of Gumau was estimated at 73,894 people. The study area lies within the northern Guinea savanna ecological zone, characterized by a tropical climate with distinct wet and dry seasons and the rain fall is about 1300mm per year, and the temperature is up to 39.6ºC (Udo and Manman, 1993). The predominant land use practices in the region include subsistence farming, livestock grazing, and some commercial crop production.

Data Collection: In order to assess the soil fertility status, soil samples were collected within forested and cultivated areas at Gumau ward of Toro Local Government Area. Each area was divided into seven plots and each plot replicated three times making a total of twenty-one (21) samples from each. Disturbed soil samples were obtained at depths of 0 – 15cm (Forested area) and 0 – 10 cm (Cultivated area).

Data analysis: Soil samples collected were analyzed for pH in water (H_2O) and 0.01M calcium chloride ($CaCl_2$) at 1:2.5 soil/solution ratios, using a pH meter equilibrating for 30 minutes (Jurinak, 1978). Soil organic carbon (OC) was determined using wet method of Walkley-Black (Nelson and Sommer, 1986). Soil nitrogen (TN) and Available phosphorus were analyzed by Kjeldahl method (Bremner, 1982) and Bray II method according to the procedure of Olsen and Sommers (1982) respectively. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were ascertained following the extraction with 1N ammonium acetate (1N NH_4OAC) at pH 7 described by Bremner and Mulvancy (1982). After which Ca^{2+} and Mg^{2+} were determined by an atomic absorption spectrophotometer while Na^+ and K^+ was measured with a Gallen Kamp Flame Analyzer. Cation exchange capacity (CEC) was estimated using ammonium acetate (1N NH_4OAC) at pH 7 as described by Rhoades and Thomas (1982).

Statistical Analysis: The results obtained for this study were subjected to descriptive method of analysis to assess to soil fertility under the two Landuses while independent sample t-test was be used to estimate the significant difference between the study areas. The analysis were done using Microsoft Excel (2018)

Results and Discussions: ***Descriptive statistics of the soil fertility status in relation to cultivated area.***

The result of the fertility status of oil under cultivated landuse management was presented in Table 1. The values recorded for soil pH both in water and calcium chloride ($CaC1_2$) revealed a range from 6.3 to 7.0 (6.61) and 5.5 to 6.5 (5.96) respectively. Soil organic carbon ranged from 0.46% to 0.73% with an average value of 0.62%. Total nitrogen values obtained showed a range of 0.040% to 0.063% and a mean of 0.05%. Available phosphorus (AP) recorded a mean value of 9.25mg/Kg with range of 7.00mg/Kg to 11.38mg/Kg. Regarding the exchangeable bases, the values ranged from 3.40% to 7.20% (Ca^{2+}), 0.64% to 2.984% (Mg^{2+}) , 0.12% to 1.17% (K^+) and 0.16% to 0.20% with a means of 5.31% (Ca^{2+}), 1.73% (Mg^{2+}) , 0.32% (K^+) and 0.17 (Na^+). Cation exchange capacity which is an indication of soil fertility status showed a ranged of 10.60% to 16.40 and a mean value of 13.96%.

The chemical properties of the studied soil showed a CV range of 4% to 119% (Table 1). Soil pH both in water and $CaCl_2$ ranked low with a CV of 4% and 7% respectively. Exchangeable Na^+ (8%) and CEC (15%) also ranked low. Medium CV values were observed under OC, TN, AP and Ca^{2+} while high CV values were obtained under Mg^{2+} and K^+. The range of CV for the area suggested different degree of heterogeneity among the soil properties studied. This result also agreed with the finding of Nayanaka *et al* (2010) and De Oliveira *et al* (2011). The coefficient of skewness and kurtosis of the chemical properties showed that all investigated properties were not significantly skewed or Kurtoic except K^+ (Table 1). Distribution of variables showed that K^+ and Na^+ were both positively skewed and kurtotic. Organic carbon (OC), TN, AP, Mg^{2+} and CEC were both negatively skewed and kurtotic. Soil pH in both water and $CaCl_2$ were positively skewed but negatively kurtotic while Ca^{2+} revealed the same result in reverse order.

Table 1: Descriptive analysis of soil fertility status under cultivated area

pH_w = pH in water, pH_{Ca} = pH in $CaCl_2$, TN = Total nitrogen, AP = Available Phosphorous, K = Exchangeable potassium, Na = Exchangeable sodium, Ca = Exchangeable calcium, Mg = Exchangeable magnesium. CEC = Cation exchange capacity, CV = Coefficient of variation

Significant if the absolute value of skewness or kurtosis is ≥2X its standard error. The standard error of skewness is 0.794 while the standard error for kurtosis = 1.587. *: Significant, ns: non-significant.

Descriptive statistics of the soil fertility status in relation to forested area.: Description of soil chemical properties under forested area in Table 2 revealed different responses to the statistical analysis from the studied soil fertility parameters. Soil pH in water responded with a mean of 6.12 ranging from 6.0 to 6.4 while pH in $CaCl_2$ showed a range value of 5.1 to 5.6 with mean of 5.31. Organic carbon ranged from 0.83% 1.21% with an average of 0.93% while TN ranged from 0.07% to 0.104% with a mean value of 0.08%. Available phosphorus varied from 1.75mg/Kg to 6.13mg/Kg with an average of 3.88mg/Kg. Exchangeable bases and CEC ranged from 2.8% to 4.6% with a mean value of 4.31% (Ca^{2+}), Mg^{2+} from 0.27% to 1.64% (0.87%), K^+ from 0.18% to 0.45% (0.30%), Na^+ from 0.16% to 0.37% (0.22%) and CEC from 8.4% to 11.2% with an average value of 10.03%. Low CV values (<15%) were found for pH in water (2%) and $CaCl_2$ (3%) OC (14%), TN (15%) and CEC (11%). Only K^+ had medium CV (28%), AP (CV=39%), Ca^{2+} (CV=37%) and Na^+ (CV=36%) had relatively high CV while Mg^{2+} showed high CV (61%) in Table 2. Result of the coefficient of skewness and kurtosis obtained revealed that organic carbon, total nitrogen and calcium were significantly skewed and kurtotic. Other measured chemical properties under forested area were not significantly skewed or kurtotic. Distribution of pHw, pHc, OC, TN, $Ca^{2+,}$ K^{2+}, and Na^{2+} were positively skewed and kurtotic. Cation exchange capacity distribution was negatively skewed and kurtotic while AP and Mg^{2+} were positively skewed but negatively kurtotic. Generally, analyzing the descriptive statistics (Tables 1 and 2) was possible to evaluate the frequency distribution and obtain summary statistics in order to categorize the soil fertility status of the studied areas into different categories (Wasiullah and Bhatti, 2007; Ceddia *et al*., 2009).

Cultivated	N	Minimum	Maximum	Mean	SD	CV (%)	Skewness	Kurtosis
pHw	21	6	6.4	6.16	0.127	2	1.137 ns	1.947 ns
pHca	21	5.1	5.6	5.31	0.168	3	0.582 ns	0.052 ns
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mg²⁺ (%)	21	0.27	1.64	0.87	0.533	61	0.364 ns	-1.541 ns
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na⁺ (%)	21	0.16	0.20	0.17	0.014	8	1.424 ns	2.321 ns
CEC (%)	21	10.6	16.4	13.96	2.135	15	-0.616 ns	-0.768 ns

Table 2: Descriptive analysis of soil fertility status under Forested area

pH_w = pH in water, pH_{Ca} = pH in $CaCl_2$, TN = Total nitrogen, AP = Available Phosphorous, K = Exchangeable potassium, Na = Exchangeable sodium, Ca = Exchangeable calcium, Mg = Exchangeable magnesium. CEC = Cation exchange capacity, CV = Coefficient of variation

Significant if the absolute value of skewness or kurtosis is ≥2X its standard error. The standard error of skewness is 0.794 while the standard error for kurtosis = 1.587. *: Significant, ns: non-significant.

Influence of forested and cultivated landuse management practices on the studied soil fertility parameters.: Independent sample t-test at 0.05 level of probability was summarized and presented in Table 3. Soil pH in both water and calcium chloride are higher in cultivated site than the forested site and this may not be unconnected to the type of mineral fertilizer used in the farming operations. Higher organic carbon and total nitrogen values recorded for forested site could be attributed to accumulation of organic materials due to high inputs from root and above ground biomass (Reicosky and Forcella, 1998; Yimer *et al*., 2007). Recorded AP value under cultivated site was about 138% higher than the forested site value. The high value is as a result of mineral fertilizer and organic amendment application, Njoke and Mbah (2012) and Mbah and Onweremadu (2009) also reported similar observation. Exchangeable bases (Ca^{2+}, Mg^{2+} and K^+) and CEC values were higher in cultivated site than forested site although only Mg^{2+} and CEC showed significant difference. Voundi–Nkana *et al*.(1998) reported that application of animal manure, household waste, animal and plant residues which are common management practices under cultivated landuse management are good sources of Ca^{2+}, Mg^{2+}, Na^+, K^+ and P.

Table 3: Means and significant levels of the measured soil fertility parameters in the studied sites

	CULTIVATED	FORESTED	T-test
pHw	6.61	6.15	**
pHca	5.96	5.31	**
OC (%)	0.62	0.93	**
TN (%)	0.05	0.08	**
AP (mg/Kg)	9.25	3.88	**
Ca^{2+} (%)	5.31	4.32	NS
Mg^{2+} (%)	1.73	0.87	*
K^+ (%)	0.32	0.30	NS
Na^+ (%)	0.17	0.22	NS
CEC (%)	13.96	10.03	**

Conclusion: Descriptive statistics and independent sample t-test were used to investigate the effect of forested and cultivated landuse management practices on the fertility status of soil in Gumua, Toro L.G.A of Bauchi State. The descriptive statistics was used to evaluate frequency distribution of soil properties and categorized them into different classes. Descriptive statistics for the study areas revealed differences in variability of each soil fertility parameter. Coefficient of variation which is measure of overall soil variability showed great variation among studied soil parameters. Independent sample t-test results highlighted the effect of converting forest landuse and consequences of cultivation on the soil fertility status in the studied site. This conversion had advance effect especially on the carbon component of the area. In the face of challenging environment issue, this effect is not acceptable and should be adequately and immediately addressed. Landuse management practices (agroforestry system, no tillage, minimal tillage) that harnesses the potential of the land for sustainable production to curb food scarcity while the forest and soil resources are conserved are therefore recommended.

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Valuation of Ecosystem Services in Nigeria: A Review of Importance, Types, Valuation Methods, and Limitations

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Abstract

Forests, as major components of terrestrial ecosystems, account for over 60% of the total biomass and more than 50% of carbon stocks, serving an indispensable function in regulating regional climates and maintaining the global carbon balance. The aim of this paper was to determine the Valuation of Ecosystem Services in Nigeria: a review of Importance, Types, Valuation Methods, and Limitations. The total value of forest ecosystem services based on valuations done between 2000 and 2015 in Nigeria is approximately 1,000,000 Naira/ha. These highly valuable systems are however under threat globally with a loss of 3% of global forests in the last 25 years. This equates to a loss of 11 billion tons of stored carbon. The values resulting from sustainable collections of non-timber (NTFP)), carbon losses and support by habitat are 164,000, 178,000 and 159,000 Naira/ha respectively. The health service reflects a value of 33,000 Naira/ha while the other (still highly significant) services display values below 10,000 Naira/ha. The different techniques for valuing forest resources include; market price valuation, surrogate market approaches, production function approaches, stated preference approaches, and cost-based approaches. The challenges of valuing forest resources in Nigeria include; Lack of data and information, Limited capacity and expertise. In conclusion, the valuation of forest resources in Nigeria is essential for understanding their true worth and making informed decisions regarding their sustainable management. Market-based and non-market valuation methods provide valuable insights into the economic and ecological contributions of forests. However, challenges such as data availability, capacity constraints, and accounting for nonmarket values need to be addressed. By incorporating valuation results into policy-making and promoting sustainable practices, we can ensure the long-term conservation and equitable utilization of Nigeria's forest resources. The study therefore recommended; raised awareness of the importance of ecosystem services among policymakers and the public, developing and implementing valuation methods that are appropriate for the Nigerian context, integrating ecosystem.

Key words: *Biomass, Forest, Habitat, Ecosystem*, Economic.

Introduction: Forest resources are the key components of the natural resources base of any community, region or country and they play a fundamental role in the socio-economic well-being of the people of those communities (Sheil, 2013). **Due to economic development and population growth, forest resources in some regions are being depleted, resulting in ecological challenges and prompting increased attention towards forest conservation (**Wang *et al.*, 2020)**. Forests, as major components of terrestrial ecosystems, account for over 60% of the total biomass and more than 50 % of carbon stocks, serving an indispensable function in regulating regional climates and maintaining the global carbon balance (** Lukina, *et al*., 2021).

Understanding the economic value of these resources is crucial for sustainable forest management and informed decision-making. In this seminar, we will explore the valuation methods used to assess the worth of forest resources in Nigeria (Munasinghe and Lutz, 1993). Forests are plant communities consisting predominantly of trees and other woody vegetation occupying an extensive area of land **(**Wang *et al.*, 2020). Globally, numerous wood forest products, such as fuelwood, play a vital role in various sectors, lumber and non-wood forest products such as wild foods, leave litters, leaves for wrapping, medicinal products and land snails provide rural farming families with several entrepreneurship livelihood opportunities (Brack, 2018).

Forest products are known to be essential sources of income generation for rural farming families for means of livelihood, expansion of farms and diversifying commercial activities (Campbell *et al.*, 2015). The potential benefits include: daily subsistence and survival from forest product gathering, income redistribution and poverty reduction, recreational facilities. Firewood, timber and medicine (Fonta *et al*., 2011).

Importance of Forest Resources in Nigeria

Forests are natural habitats for many animals (Federal Ministry of Environment, 2010). The trees supply oxygen to the atmosphere. They affect the rainfall in a particular region. They also provide us with wood, medicines, food, perfumes, paper, clothes, etc. Trees are the world's largest storehouses of carbon which is important to maintain global temperatures (Crini *et al*., 20202).

Socio-Cultural Aspects

Men carry out the hunting of wildlife while the collection of snails, worms and insects is the activity majorly carried out by women and children (Shecklaton *et al.*, 2013). The forest plants are used to treat diseases of human systems, parasitic infections in children and miscellaneous diseases including medico magical uses (Shecklaton *et al.*, 2013. A lot of fauna resources not accepted for food and those not socially accepted because of taboos are used for traditional medicine (Adjanohoun*et al.*, 2008).

In some parts of Nigeria, for example, palm wine is of paramount importance at most social functions (Okafor, 1979). Among the Igbo of Southern Nigeria, all discussions, prayers, and ceremonies begin with the breaking of cola nuts. Without cola, these occasions are not regarded as serious (Okigbo, 1980).

Table 1: Different Ecosystems Services by category in Nigeria by Region

Region	Category	Ecosystem services
North-West	Provisioning services	Water filtration, timber, fuelwood, non-timber forest products
North-West	Regulating services	Carbon sequestration, erosion control, air purification, climate regulation
North-West	Supporting services	Soil formation, nutrient cycling, pollination
North-West	Cultural services	Recreation, spiritual and cultural values
North-East	Provisioning services	Water filtration, timber, fuelwood, non-timber forest products
North-East	Regulating services	Carbon sequestration, erosion control, air purification, climate regulation
North-East	Supporting services	Soil formation, nutrient cycling, pollination
North-East	Cultural services	Recreation, spiritual and cultural values
North-Central	Provisioning services	Water filtration, timber, fuelwood, non-timber forest products, livestock grazing, crop production
North-Central	Regulating services	Carbon sequestration, erosion control, air purification, climate regulation, water regulation
North-Central	Supporting services	Soil formation, nutrient cycling, pollination
North-Central	Cultural services	Recreation, spiritual and cultural values
South-West	Provisioning services	Water filtration, timber, fuelwood, non-timber forest products, tourism
South-West	Regulating services	Carbon sequestration, erosion control, air purification, climate regulation, water regulation
South-West	Supporting services	Soil formation, nutrient cycling, pollination
South-West	Cultural services	Recreation, spiritual and cultural values
South-South	Provisioning services	Water filtration, timber, fuelwood, non-timber forest products, fisheries, aquaculture
South-South	Regulating services	Carbon sequestration, erosion control, air purification, climate regulation, water regulation
South-South	Supporting services	Soil formation, nutrient cycling, pollination
South-South	Cultural services	Recreation, spiritual and cultural values
South-East	Provisioning services	Water filtration, timber, fuelwood, non-timber forest products, tourism
South-East	Regulating services	Carbon sequestration, erosion control, air purification, climate regulation, water regulation
South-East	Supporting services	Soil formation, nutrient cycling, pollination
South-East	Cultural services	Recreation, spiritual and cultural values

(Source: UNEP-WCMC, 2017)

Economic contributions

Fodder and forage are used to support livestock-cattle, sheep, goats, donkeys and camels both in wet and in dry season (Shecklaton *et al.*, 2013). However, the plant parts such as new flush of leaves, flowers and fruits often produced in the dry season are rich in proteins, vitamins and minerals. Fodder is harvested in the natural forest is utilize effectively for feeding livestock National Agricultural Extension Research and Liaison Services (Mander, 2008).

According to World Commission on Forests and Sustainable Development (2008), fuel wood and charcoal make up 56% of global wood production, and approximately 90% of this is produced in developing countries. Firewood is the most important source of energy for developing countries and the only source of energy for most of the world's rural areas (IEA, 2002). In sub-Saharan Africa, wood supplies about 70% of total energy used and firewood collectors account for over 85% of the wood removed from the forest and woodlands (Contrera, 2010).

Table 2: Contribution of Forest Resources to Nigeria's GDP (in billion USD) 2010-2023

Year	Contribution of forest resources to Nigeria's GDP (in billion USD)
2010	3.2
2011	3.4
2012	3.6
2013	3.8
2014	4
2015	4.2
2016	4.4
2017	4.6
2018	4.8
2019	5
2020	5.2
2021	5.4
2022	5.6

2023	5.8

Source: World Bank (2023)

Table 3 revealed that the Girei Forest Reserve demonstrates significant economic contributions through its ecosystem provisioning services, with an estimated annual monetary value of ₦25,907,400 (Oroka, 2021). This value is derived from various resources, including the hunting of 2,360 guinea fowls, which accounts for 18.2% of the total value, the collection of approximately 8,120 liters of honey (20.2%), and the harvesting of about 55,050 bundles of firewood (21.2%). These figures highlight the vital role that these services play in supporting the local economy. Recent literature emphasizes similar trends in other regions, such as Kenya, where biodiversity contributes over ₦26 billion annually through sustainable practices (Gabe, 2000).

Table 3: Estimated Annual Monitory Value of some Ecosystem Provisioning Services obtained from Girei Forest Reserve

Types of ecosystem provisioning services	Quantity of ecosystem provisioning services obtained per year	Price per unit (₦)	Monitory value per year (₦)	Percentage (%)
Wind honey	8120 liters	1000	8120000	31.3
Sugar cane	4272 bundles	100	427200	1.6
Vegetables	4248 bundles	400	1699200	6.6
Grass cutter	618 pieces	250	154500	0.6
Squirrel	1315 pieces	200	263000	1.0
Guinea fowl	2360 pieces	2000	4720000	18.2
Antelope	42 pieces	4500	189000	0.7
Firewood	55050 bundles	100	5505000	21.2
Grass	2215 bundles	200	443000	1.7
Medicinal plants	7290 kilograms	50	364500	1.4
Building poles	40220 bundles	100	4022000	15.5

(Source: Adedotun and Ogunbode, 2023)

Overview of the Economy

Although recent years have posed significant challenges for Nigeria's economic growth, the country remains the largest economy in Africa and is forecasted to experience recovery and growth. The Nigerian economy was adversely affected during 2015 and 2016 by a decline in global crude oil prices, which was exacerbated by inadequate foreign exchange supply and restrictions that led to production and labor losses in various sectors (Yemi, 2019). Nigeria has made notable strides in diversifying its economy, with the relative contribution of agriculture and primary sectors to GDP decreasing by 16-17%, while the services sector's contribution has increased by 24% (World Bank Group, 2024). This shift is critical as the country grapples with a rapidly growing population, driven by high birth rates and significant urban migration, which has resulted in approximately 53% of the population now residing in urban areas (Owan *et al*., 2020).

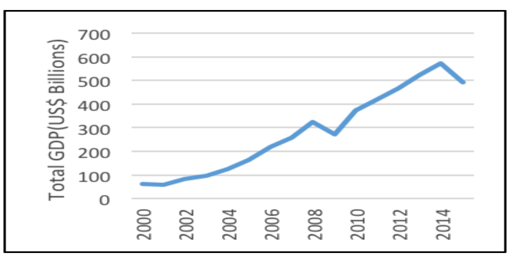

Figure 1

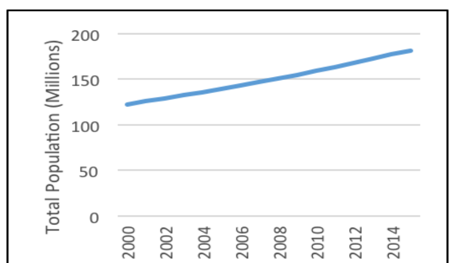

Figure 2

Figure 1: Growth of Nigeria's Gross Domestic Product (GDP) between 2000 and 2015 (Source: World Bank)

Figure 2: Growth of Nigeria's population between 2000 and 2015 (Source: United Nations Environment, 2017).

The value of Nigeria's Forest Ecosystem Services

Ecosystems are highly complex systems of which Nigeria's forest systems are no exception (Owan *et al*., 2020). The quantification of these interconnected and interlinked systems is not always as straight forward as quantifying the service provided (ecological infrastructure) and identifying beneficiaries of services for a given period (World Bank Group, 2024). There are various paradigms which are characteristic of natural ecological systems which must be considered (Owan *et al*., 2020). Recent assessments indicate that the value of sustainable collections is approximately 164,000 Naira/ha, while carbon losses are valued at 178,000 Naira/ha, and habitat support is valued at 159,000 Naira/ha. Health services provided by these ecosystems reflect a value of 33,000 Naira/ha, with other important services displaying values below 10,000 Naira/ha. Overall, the total value of forest ecosystem services in Nigeria, based on valuations conducted between 2000 and 2015, is estimated to be around 1 million Naira/ha (Owan *et al*., 2020).

According to recent literature, the total value of Nigeria's forest ecosystem services is estimated at approximately USD 21.1 billion per year. Regulating Services: Services such as water filtration, climate regulation, and erosion control contribute significantly, with an estimated value of USD 5.4 billion. Supporting Services: These include essential processes like soil formation and nutrient cycling, valued at USD 4.2 billion. Cultural Services: Although they account for the smallest share, cultural services, which encompass recreation and spiritual values, are valued at USD 3.0 billion (Ambe and Onnoghen, 2019; Mengist, *et al*., 2020; Nwakanma, 2022).

Table 4: Total Value of Nigeria's Forest Ecosystem Services per year

Region	Provisioning services (USD billion/year)	Regulating services (USD billion/year)	Supporting services (USD billion/year)	Cultural services (USD billion/year)	Total (USD billion/year)
North-West	1.2	0.8	0.6	0.4	3
North-East	1	0.7	0.5	0.3	2.5
North-Central	1.4	0.9	0.7	0.5	3.5
South-West	1.6	1	0.8	0.6	4
South-South	1.8	1.1	0.9	0.7	4.5
South-East	1.5	0.9	0.7	0.5	3.6
Total	8.5	5.4	4.2	3	21.1

Source: Federal Ministry of Environment (2015)

VALUATION METHODS FOR FOREST RESOURCES

To assist private firms and government policymakers in making informed decisions regarding activities with significant environmental impacts, economists have increasingly focused on developing and applying methods for valuing non-market benefits in monetary terms. Essentially, these techniques seek to express the utility derived from non-market goods and services in market terms, which is believed to provide a reliable reflection of the relative preferences of producers and consumers for various goods and services (Owan *et al*., 2020). These methods have been shown to effectively capture the economic value of non-market benefits, such as improved air quality and biodiversity conservation, thereby supporting more informed decision-making (Guijarro and Tsinaslanidis, 2020; Eaton *et al*., 2023). The resulting values from these methods are crucial for conducting cost-benefit analyses and informing more complex economic models, ultimately supporting sustainable decision-making in environmental policy (Guijarro and Tsinaslanidis, 2020).

Table: 5 Valuation Methods for Forest Resources

Valuation method	Description	Citation
Market price method	This method uses the market prices of forest products, such as timber, fuelwood, and non-timber forest products, to estimate the value of forest resources.	Barbier,& Pearce. (2000).
Cost-based method	This method estimates the value of forest resources by calculating the cost of replacing them.	Pearce & Turner. (1990).
Income-based method	This method estimates the value of forest resources by calculating the income that they generate.	Hanley, & Barbier. (2009).
Stated preference method	This method uses surveys and other methods to elicit people's willingness to pay for forest resources.	Arrow, *et al.* (1993)
Revealed preference method	This method uses people's actual behavior, such as their choices to visit forests or to purchase forest products, to infer their values for forest resources.	Freeman, A. M. (2003).

Timber and non-timber forest products pricing: Valuing timber and non-timber forest products (NTFPs) is an essential aspect of assessing the economic worth of forest resources. Different valuation methods are employed to determine the market value of timber and estimate the economic contributions of NTFPs.

Valuation of Timber:

1. Market Prices: The most straightforward approach to valuing timber is through market prices. Timber prices are influenced by factors such as species, quality, volume, market demand, and supply dynamics (Damnyag *et al.*, 2016).
2. Appraisal Methods: Appraisal methods, such as the stumpage value method or the merchantable volume method, are used to estimate the value of standing timber (Chirwa *et al.*, 2017).

Valuation of Non-Timber Forest Products (NTFPs):

1. Market Surveys: NTFPs encompass a wide range of products, including medicinal plants, fruits, nuts, fibers, resins, and handicrafts. Valuing NTFPs often involves conducting market surveys to assess prevailing prices in local, regional, or international markets (Shackleton *et al.*, 2011).
2. Direct Cost Method: The direct cost method estimates the value of NTFPs based on the costs incurred in their collection, processing, and marketing (Shackleton *et al.*, 2011).

3. Contingent Valuation Method (CVM): CVM is a non-market valuation approach that assesses the economic value of environmental goods and services, including NTFPs (Makanda *et al.*, 2016).
4. Replacement Cost Method: The replacement cost method estimates the value of NTFPs by considering the cost of alternative products or substitutes in the market (Shackleton *et al.*, 2011).

Contingent Valuation Method (CVM)

The Contingent Valuation Method (CVM) is a widely used approach for eliciting individual expressions of value from respondents regarding specified increases or decreases in the quantity or quality of non-market goods. Most CV studies rely on data collected through interviews or postal surveys, as established by Mitchell and Carson (1989). CVM primarily employs two main formats: open-ended and dichotomous choice (DC) (Koumoutsea and Mergos, 2023).

Travel cost method

The Travel Cost Method (TCM) is a widely used economic valuation technique for estimating the recreational value of forest resources (Kaya, 2022).

Key Aspects of the Travel Cost Method

1. **Conceptual Framework**: TCM is based on the idea that the costs incurred by visitors (including travel expenses, time costs, and any entrance fees) reflect the value they place on the recreational experience.
2. **Data Collection**: The method typically involves collecting data through surveys that ask visitors about their travel expenses, the number of trips taken, and their socio-economic characteristics (Kaya, 2022).
3. **Valuation Estimates**: Recent studies utilizing TCM have provided valuable insights into the economic contributions of forest resources ((Kaya, 2022).
4. **Applications**: TCM has been applied in various contexts to evaluate the recreational value of forests. It has been particularly useful in regions where traditional market-based valuation methods are less applicable (Sohrabi *et al*., 2019).
5. **Limitations and Challenges**: While TCM is a robust method for valuing recreational benefits, it does have limitations (Sohrabi *et al*., 2019).

Hedonic pricing method

The Hedonic Pricing Method (HPM) is a widely recognized economic valuation technique used to estimate the value of non-market goods, particularly in the fields of real estate and environmental economics. This method is based on the premise that the price of a marketed good, such as residential property, is determined by its various characteristics or attributes (Sohrabi *et al*., 2019).

HPM is particularly effective in assessing the impacts of environmental factors on property values. For instance, studies have demonstrated that proximity to parks, water bodies, or urban green spaces can significantly enhance property desirability and, consequently, its market value (Nguyen 2020).

Recent advancements in data analytics and geographic information systems (GIS) have enhanced the precision of HPM applications (Liu *et al*., 2024). Additionally, recent studies have begun to integrate HPM with other valuation techniques, such as contingent valuation and stated preference methods, to provide a more comprehensive understanding of the economic value of ecosystem services (Nguyen 2020).

Total economic value assessment

Total Economic Value (TEV) assessment is a comprehensive approach used to estimate the total value of natural resources, including forests, by considering both market and non-market values. TEV assessment takes into account the various goods and services provided by natural resources and quantifies their economic worth.

TEV assessment considers four main components of value:

1. Use Value: Use value refers to the direct benefits derived from the utilization of forest resources. It includes both market values, such as timber and non-timber forest products, as well as non-market values, such as recreation, ecotourism, and cultural services (Nitanan *et al*., 2020).
2. Option Value: Option value relates to the value people assign to the future availability and potential use of forest resources. It reflects the willingness to pay for the preservation of options for future use or the avoidance of irreversible losses (Helles *et al*., 2013).
3. Existence Value: Existence value refers to the value people attribute to the mere existence of forests, irrespective of any direct use or future use (Arias-Arévalo *et al*., 2017).
4. Bequest Value: Bequest value represents the value people place on preserving forests for the benefit of future generations. It reflects the desire to leave a legacy and ensure the availability of forest resources and associated benefits for future societal well-being (Markowski-Lindsay *et al*., 2016).

Challenges In Valuing Forest Resources In Nigeria: Lack of data and information

Lack of data and information presents a significant challenge in valuing forest resources in Nigeria. Insufficient and incomplete data hinder accurate assessments of the economic worth of forests and limit the ability to make informed decisions regarding their management and conservation (Nguyen 2020). However, in Nigeria, there is a lack of up-to-date and reliable forest inventory data. Incomplete or outdated information on forest extent, species composition, and volume of timber stocks hampers accurate valuation efforts (Ayanlade *et al.*, 2017).

Limited capacity and expertise: Limited capacity and expertise pose significant challenges in valuing forest resources in Nigeria. Insufficient technical skills, expertise, and institutional capacity hinder the accurate assessment and valuation of forests (Olalekan, *et al*., 2019). In Nigeria, there is a shortage of professionals with the necessary skills and expertise in forest valuation. This limits the ability to apply appropriate valuation methods and accurately estimate the economic value of forest resources (Ayanlade *et al*., 2017). Effective valuation of forest resources requires robust data management and analysis skills. However, the capacity to collect, manage, and analyze data related to forests is often limited in Nigeria. Insufficient skills in data collection, quality control, and analysis hinder the generation of reliable and accurate data for valuation purposes (Ayanlade *et al.*, 2017).Inadequate institutional capacity within relevant agencies and organizations is a significant challenge in forest valuation. Limited resources, including financial and technical resources, hinder the development and implementation of comprehensive valuation studies (Ayanlade *et al.*, 2017).

Accounting for ecosystem services: According to Druckenmiller, (2022), Ecosystem services are often omitted from climate policy owing to difficulties in estimating the economic value of climate-driven ecosystem changes. Ecosystem services are the benefits and functions that natural ecosystems provide to people. One important aspect of ecosystem accounting is that the physical flows of ecosystem services can be recorded as being used both within the formal economy (and hence captured in GDP) as well outside it (Nguyen 2020).

Economic Valuation of Carbon Sequestration: Economic valuation of carbon sequestration involves assessing the monetary value of the carbon stored in ecosystems and the associated benefits it provides, such as climate change mitigation and ecosystem services. By assigning an economic value to carbon sequestration, policymakers, businesses, and society can better understand the importance of preserving and enhancing carbon sinks. The Social Cost of Carbon (SCC) is a widely used economic tool for valuing carbon sequestration (Nguyen, 2020).

Market-based approaches involve creating a market for carbon credits or offsets. These mechanisms assign a financial value to carbon sequestration by allowing companies or individuals to offset their emissions by investing in projects that reduce or remove carbon dioxide from the atmosphere. The value of these carbon credits is determined through market mechanisms like cap-and-trade systems or voluntary carbon markets. (Vanderklift *et al*., 2019). Nevertheless, economic valuation of carbon sequestration provides valuable insights for decision-makers, enabling them to incorporate the costs and benefits of carbon storage into policy and investment decisions (Li *et al*., 2018). It helps to align economic incentives with climate change mitigation and encourages the preservation and enhancement of ecosystems that act as crucial carbon sinks.

Conclusion: In conclusion, the valuation of forest resources in Nigeria is essential for understanding their true worth and making informed decisions regarding their sustainable management. Market-based and non-market valuation methods provide valuable insights into the economic and ecological contributions of forests. Forest resources underscore their critical importance not only for ecological health but also for economic valuation and sustainability. Various valuation methods, including the Travel Cost Method (TCM), Hedonic Pricing Method (HPM), and Contingent Valuation Method (CVM), provide valuable insights into the economic benefits derived from forests, such as recreational opportunities, environmental quality, and non-market goods.

Recommendations: Raise awareness of the importance of ecosystem services among policymakers and the public. and implement valuation methods that are appropriate for the Nigerian context. Integrate ecosystem services into decision-making processes. Ecosystem services should be considered alongside economic and social factors when making decisions about land use, development, and resource management. Invest in research on ecosystem services. More research is needed to understand the full range of ecosystem services that are provided in Nigeria, as well as their economic and social value.

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Efficacy of Black Walnut against Microbial Infestation in Dried African Catfish African Catfish (Clarias gariepinus) In Jos, Plateau State,

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Abstract

This research was carried out in order to evaluate the anti-microbial activity of Black walnut powder on microbial associated with dried fish African Catfish(Clariasgariepinus). The fresh walnuts were washed with clean water under a running tap.The washed walnuts were left in a plastic container for 30 minutes so the water can drain. The walnut was then broken into pieces to increase surface area for easy drying. The dried walnut was grinded to powder in a mortar with a pestle. The walnut powder was sieved with a fine mesh to achieve fine powder. A portion of the walnut fine powder was reserved for phytochemical analysis. The Black walnut was inoculated on Nutrient Agar (NA) and Potato Dextrose Agar (PDA) and incubated at 28°c for one hour. The fungi isolated were Rhizopus, Saccharomyces cerevisiae and Mucor, they were identified using macroscopic and microscopic features. Black walnut seed powder was used at different concentrations to determine the sensitivity of the Microbial to the powder. The concentrations of the Black walnut seed powder used were 0g, 20g, 40g and 60g. The results obtained showed that the Black walnut seed powder at 20g, 40g and 60g has the best effect on all the Microbial isolated.This implies that Black walnut seed powder can be used effective organid agent to control microbial infestation in dried African catfish (Clarias gariepinus).

INTRODUCTION*:* Fish received increased attention as a potential source of animal protein and essential Nutrients for human diets (Ekpenyong and Ibok, 2012).In addition to its nutritional value, fish play important role in providing incomes and poverty alleviation in both rural and urban areas of many developing countries. Due to the susceptibility of fish to chemical, microbial and physical deterioration, various preservation techniques are put in place to check spoilage (Kiin-Kabir, *et. al.,* 2011). Fish spoilage is a metabolic process that causes fish to be undesirable for human consumption due to changes in sensory and nutritional characteristics. Thus, processing and preservation of fresh fish were of utmost importance to maintain product quality, reduce wastage and prevent economic losses (Kumar, *et. al.,* 2014). In all of the importance of fish, high level of spoilage still occurs in Nigerian as a result of inadequate storage facilities, thus constituting a threat to the development of the fishing industry in Nigeria (Ayeloja, *et. al.,* 2015). Fish are usually dehydrated as a means of preservation, as fish is well-known for its perishability issue. For regions that have easy access to large areas of water, fish is a major source of nutrients for their community. In addition, dried fish differs from place to place and culture to culture, from the type of fish used to the drying methods and ingredients used in the drying process. Stock fish and clip fish are examples of dried fish products from Norway (Bao, *et. al.,* 2020). On the other hand, Asian countries like China, Bangladesh, and Japan are also significant contributors to the dried fish industry (Freire, *et. al.,* 2016). However, modern studies have developed more efficient methods to dry the fish, especially convection (Bantle, *et. al.,* 2010). Before the fish is dried, salt is added to the fish for maturation. For ideal osmotic dehydration to occur, the head and backbone of the fish are removed, and the remaining flesh is folded in a specific way before it is covered with salt for 3–4 weeks (Bantle, *et. al.,* 2013). Fish is one of the most important sources food and income to many people in developing countries (Osarenren and Ojor,2014). Fish industry is vital to Africa supporting annual export worth about $3bn.(Mbah, et. al.,2012).

Over the years, fishery sector has been a source of income and livelihood for millions of people around the world, Nigeria account for 30-40 post-harvest losses for landed fish catches thus, prompting the subjection of landed fish catches to a variety of processing methods, such as smoking and drying.(Hassan, et. al.,2014) reported that about 60% and close to 80% of the population in many developing and developed countries, respectively, consume fish as main source of animal protein. The rising cost of many animal protein sources now make consumers to be more interested in fish as a source of dietary protein (Ayeloja, *et. al.,* 2017). Smoked dried fish with low moisture content provides food particularly. Dried smoked C. gariepinus is highly relished item of many traditional dishes in Nigeria. Smoked fish is a good alternative to fresh fish which is not available all the time. Also, provided it is well processed, it is a good product as the nutritional values of the smoked and fresh fish are not significantly different (Adeyemi, et al., 2013). In many countries including Nigeria, aquaculture is currently limited to fish production because farmers have limited knowledge of other aquatic organisms and low production capacity. It is currently the fastest growing livestock industry in the world (FAO, 2014). The gap in the demand and supply is being met through importation. Due to insufficiency of domestic production, importation of fish and fish products accounts for more than half of fish supply in the country. Aquaculture has the potential to become a sustainable practice that can supplement capture fisheries, eliminate fish importation and significantly contribute to feeding the world's growing population. Fish production is a good source of employment, food security, income generation, from local and foreign exchange, ecotourism and improve health. In the recent past there has been considerable consumer demand for food products with natural organic preservatives (Testa, *et. al.,* 2019) because of its potential human health benefit. Natural products such as essential oils, spices, and herbal extract are preferred preservatives because of their biodegradability, low cost and toxicity, and biocompatibility (Fatoki, *et. al.,* 2009). The antioxidant, flavoring, and antimicrobial properties of aromatic compounds derived from natural plants have been reported to enhance nutritional quality and shelf life of food products (Sarkar, *et. al.,* 2014).

Juglans nigra, commonly known as black walnut, has been reported to possess antibacterial properties against various bacteria. The antibacterial effect of Juglans nigra can be attributed to the presence of bioactive compounds such as juglone, tannins, and phenolic compounds (Kumar, et. al.,2015). These compounds have shown inhibitory activity against a wide range of bacterial pathogens. Kumar, *et. al*.,2015 reported that natural or green antimicrobial, flavoring, and antioxidant properties of essential oil, spices, and herbal extracts can be exploited in synergy with other processing techniques such as heating, to bring about desired inactivation of enzymes, harmful microbes, and chemical deterioration (Liu, et. al., 2012). Hence the need to develop a product of smoked catfish marinated with Juglans nigra . The beneficial effect of phenolic compounds naturally occurring in M. oleifera seed meal is recognized for their positive effect on human health and their beneficial physiological and biological properties which are antihypertensive, anti-inflammatory, anticarcinogenic, antiallergenic, antimicrobial, and antiarthritic activities are well documented (Liu, *et. al.,* 2012). Hence the need to develop a product of smoked catfish marinated with Juglans nigra seed meal which could increase their nutritional qualities hence consumer demand because of their antimicrobial properties.

The damage caused by bacteria and fungal on smoked Clarias gariepinus often leads to a huge economic losses. Bacterial and fungal contamination can have negative effects on smoked Clarias gariepinus, compromising its quality, safety, and shelf life. This is attributed to loss of value especially nutritional value. More so, the fish viability is reduced, owing to depletion of the stored food materials in the fish by bacterial disease. Most of preservatives in use today are synthetic chemicals compounds, which have many side effects on the handler and environment(Abolagba and Uwagbai.,2011). Bacteria such as Staphylococcus aureus, Proteus, Bacillus, Micrococcus, were the most common microorganism associated with smoked fish, Customers mostly assess the quality of fish by considering the appearance, smell and palatability of the fish when cooked hence it is necessary to produce good quality and safe smoked fish free from harmful microbial load (Abidemi-Iromini, *et. al.,* 2019). The need to protect smoked fish from disease is imperative when the crucial role it plays in insuring food security, income generation and employment .Thus, the findings of this research work will help to profer organic solution to dried and stored African catfish (Clarias gariepinus).Specifically, this study intends to address the following research objectives: determine the phytochemical compound of Black walnut.; determine the optimum concentration of Black walnut (Juglans nigra) marinade for maximum Anti Bacterial effectiveness.; determine the optimum concentration of Black walnut (Juglans nigra) marinade for maximum Anti Fungal effectiveness.; identify prominent Bacteria encountered in smoked fish product.

Materials and Methods: Scope of the Study: The study was limited to the use of different levels of seedmeal of Juglans nigra against bacteria and fungus of Clarias gariepinus for some days and the percentage of bacteria and fungus at different concentration. The experiment was conducted in the laboratoryof FederalCollegeofForestry, Jos, PlateauState. The site of the study is located at latitude 9° 54' in the Savannah North of Northern Guinea. Temperature of the areais usually between 21 and 25 degrees Celsius. Due to its high altitude,the state climate is usually cool. Average annual rainfall is 1,260mm (Adeyemi, 2012).

Sample Collection: A total of 75 pieces of table sized African catfish (*Clarias gariepinus*) were purchased from bukuru park fish market in Jos Metropolis. Fresh walnut seed (*Juglans nigra*) was bought from the Farin ‘Gada Vegetable market also in Jos. 12 transparent 1liter-capacity plastic containers with lids, were use in storing the fish for six weeks. Openings were made on sides of the container and covered with net to allow for ventilation and keep other pests out.

2.3 Preparation of walnut

The fresh walnuts were washed with clean water under a running tap. The washed walnuts were left in a plastic container for 30minutes so the water can drain. The walnut was then broken into pieces to increase surface area for easy drying. The broken walnut was placed on a cookie sheet with parchment paper which were spread evenly to ensure that they were all well aerated before putting them into the pre-heated oven at 80 to 100°C for 4 to 5hours for the walnut to completely dry. The dried walnut was grinded to powder in a mortar with a pestle. The walnut powder sieved with a fine mesh to achieve fine powder. A portion of the walnut fine powder was reserved for phytochemical analysis.

Fish Preparation*:* The 75 C. *gariepinus* of ±300g were quickly transported to the biology laboratory at the Federal College of Forestry Jos. The fish were dispatched by pithing. Pithing is a method of killing fish, including catfish, by destroying the brain through penetration with a pointed instrument. The process is considered humane as it causes immediate loss of consciousness and death of the fish. The process involves using sharp object, such as a pithing rod, pin to puncture the fish's brain through the top of the head, just behind the eyes, effectively rendering the fish unconscious and killing it. After a through wash, the fish were degutted and randomly grouped into 6 (5 groups for treatment and one group as control). The groups of fish were dipped into the different concentrations of walnut marinade for 3 hours before smoking in a smoking kiln, and further drying in an electric oven to bring down moisture content to below 10 percent. After cooling to room temperature, each fish was weighed and the average weight recorded.

Preparation of Marinade: Walnut seed powder at 0g, 20g, 40g, and 60g were added to 1liter of distilled water to form the control,1st, 2nd, and 3rd concentrations respectively.The samples were tagged according to marinade concentrations; "0g/L, 20g/L, 40g/L, and 60g/L. and placed in transparent plastic containers covered with lids. Openings were made on opposite sides of the container and sealed with nets to keep insects out and allow for ventilation. The treatment and control are stored in a cool, dry, and quiet place to be observed. Each of the three labelled concentrations were replicated three (3) times.

Microbial Analysis: Experimental work area: The working tables were swabbed with ethanol to disinfect them. All the wares were washed and air-dried after which they were sterilized in hot air oven at 160ºC for 1 hr. Culture media was prepared according to manufacturers' specifications and distilled water used for serial dilution were sterilized in an autoclave at 121°C for 15 min before use. For bacteria isolation and identification, Nutrient Agar was used, representative colonies emerging from the plates were grouped according to their cultural characteristics and their micro-morphology.

Microbial Count Indices : The counting of the bacteria colonies which evolve after incubation were expressed in colony forming unit (CFU)/g. The following indices were employed for the diversity study.

Shannon−Wiener Index (H)= −

Simpson (D)= P = n/N,

where n is the of individuals of one particular species found, N is the total number of individuals found.

Data analysis: Data generated were subjected to descriptive statistics. Means treated for statistical differences using one way ANOVA with the aid of SPSS 21.0 for the statistical analysis.

Results and Dicussion: Phytochemical Analysis of Black Walnut: The phytochemical Analysis of walnut indicates presence of active antibacterial agent such as tanniuns, alkanoid and staroids at high levels, indicating that walnut has antimicrobial and antibacterial properties.

Table 1: Aqueous Phytochemical Analysis of Black Walnut.

1	Saponins	-
2.	Flavounoids	+
3.	Tanniuns	++
4.	Alkaloids	++
5.	Terenoids	+
6	Staroids	+
7	Amino acid	++
8	Cardiaee glycosides	+
9	Anthroquinones	-

Key -:

+	Present
-	No detected
++	Moderate present

Source: Authors computed results (2024)

4.2 Microbes present in dried C. gariepinus during storage with time (42 days)

Table 2, shows the microbes present in dried C. gariepinus during the period under research. The result reveals that no fungi or bacteria were found in C. gariepinus treated with walnut fruit powder. However, the untreated C. gariepinus was found to be attacked by fungi (Rhizopus and Mucus) and bacteria (Yeast)

Table 2: Microbes present in dried *C. gariepinus* during storage with time (weeks)

Isolates	Walnut fruit powder (g)			
	20	40	60	Control
Fungi				
Rhizopus	-	-	-	+
Mucus	-	-	-	+
Bacteria				
Yeast	-	--	-	+

+ =Present; - =Absent

Source: Authors computed results (2024)

Bacterial and Fungal Counts of *Clarias gariepinus*: Figure 1 showed the microbial-bacterial and fungal counts of *Clarias gariepinus*. The untreated (control) fish recorded the highest mean Fungi (Rhizopus and Mucus) count of 4.95 X10^4 and 4.70 x 10^4 CFU/g respectively. Similarly, the least bacterial (Yeast) count of 4.35 X10^4 CFU/g was also recorded for the control.

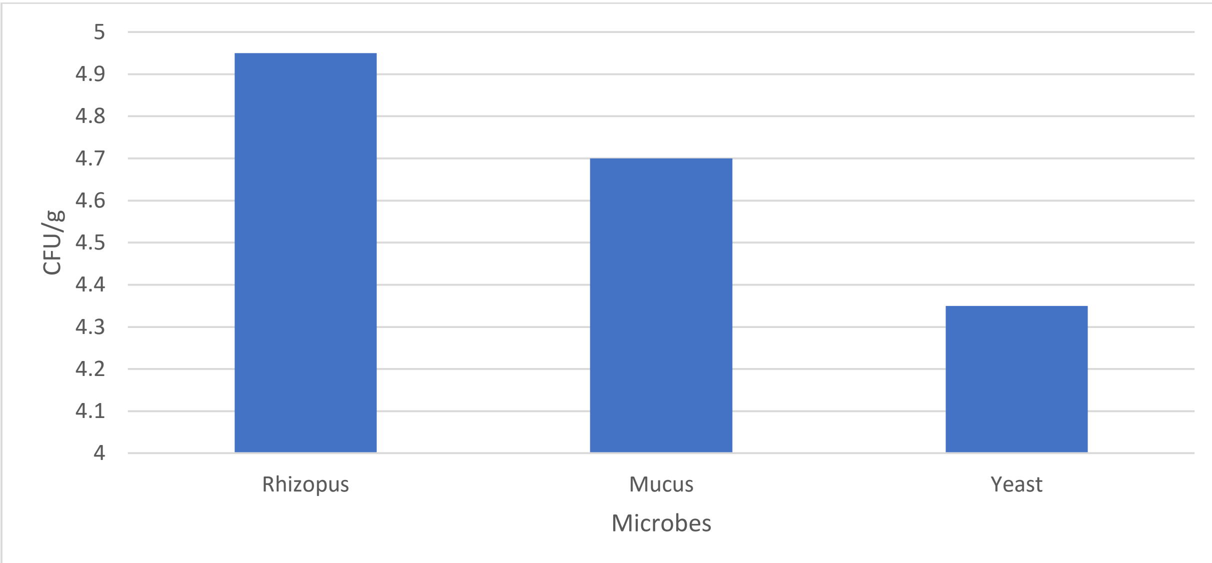

Figure 1: Bacterial and Fungal Counts of dried *Clarias gariepinus*

Source: Authors computed results (2024)

Discussion: In this study, evaluation of efficiency of seed meal *Juglans nigra* against the bacteria and fungus disease smoked dried fish Clarias gariepimus was carried out. The total plate counts for both bacteria and fungi did not exceed the range of specified microbiological limits recommended for fish and fishery products by International Commission on Microbiological Specification for Foods (ICMSF, 1986). The protocol of ICMSF recommends a maximum bacterial count of 5 x 105 CFU/g for good quality product and a maximum count of 107 for marginally acceptable quality products (Nwachukwu and Madubuko, 2013).

The biochemical test carried out on isolates from these smoked Clarias gariepimus showed the presence of *Rhizopus, Mucus* and Yeast which according to Ramos, (1999) that isolation of pathogenic and spoilage organisms raises public health concerns about safety in consuming smoked fish products from our markets and cause a high rate of spoilage leading to shorter shelf/storage life of the product. Meanwhile, organisms that cause food-borne diseases have been reported to include *E.coli,Bacillus* species, *Clostridium botulinum*, molds, fungi and yeast (Osakue *et al,* 2016).The microflora, *Rhizopus, mucus and yeast* encountered in smoked fish studied are common microflora associated with fish and are the same as those reported in smoked *Clarias sp*. in Benin metropolis by Abolagba *et al* (2011) and Odu *et al* (2012) on smoke-dried mangrove oysters (*Crassostrea gazar*) sold in Port Harcourt. The storage of the smoke-dried *C. gariepinus* treated with walnut fruit powder showed no significant growth of microorganisms throughout the storage period. The presence of *Rhizopus, mucur and yeast* in the control samples studied could be from the handling process; this calls for treatments and standard hygiene during fish handling and processing by the processors. There was no significant increase in the bacterial load of the dried fish samples the contamination of the samples by microorganisms did not increase indicating that the treatments were effective in storing the smoked fish. The highest total bacterial count of 4.95 x 10^4 cfu/g of the fish sample was lower than the maximum recommended value of bacteria counts for good quality fish products, which is 5×10^5 cfu/g according to International Commission on Microbiological Specifications for Foods (ICMSF 2002) and < 10 cfu/g by the Microbiological Guideline for Ready-to-eat-Food (2007). Contamination may have been introduced during smoking and preparation for storage. Olaleye and Abegund (2015) stated that the presence of fungi and bacteria in food may be because food handlers failed to observe basic sanitary rules. There was no growth of fungi in the samples, indicating the safety of the products. This showed that the walnut fruit powder could prevent the growth of spoilage organisms.The quality attributes observed may be due to the fact that the samples were properly treated and stored, thereby preventing the samples from exposure to oxygen and micro-organisms that can adversely affect the quality of the samples. However, since there was no significant difference in the overall acceptability of the smoked fish throughout the storage period, it implies that, there was no any major difference in the quality of the fish; this indicates that the quality of the smoked fish was preserved effectively with the application of walnut fruit powder studied. Walnut fruit powder had an antibacterial effect of J*uglans nigra* seed meal on marinated smoke mud African catfish.

Recommendations: Based on the result of this findings, it can be recommended that; Walnut fruit powder can be used as an organic antimicrobial agent for the preservation of African catfish Clarias gariepinus. Further studies is recommended at lower concentration to ascertain at which level would the fungi and bacteria be more infected.

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ARABLE CROP FARMERS' ADAPTATION MEASURES TO CLIMATE CHANGE IN OHAJI/EGBEMA L. G. A., IMO STATE, NIGERIA

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Abstract

This study assessed arable crop farmers' adaptation strategies to climate change in Ohaji/Egema L. G. A., Imo State, Nigeria using research survey design. The study objectives were: ascertain the socio-economic characteristics of farmers in the study area, ascertain the farmers perceived effects of climate change, identify the adaptation strategies to climate change used by farmers, and identify the constraints that militate against the use of adaptation strategies to climate change by farmers. The study used descriptive statistics to analyse survey data. Results of the study indicated that majority of the farmers are females (60.8%) and mean age of arable crop farmers in the study area was 49 years. The survey result also showed that mean number of years spent in school was twelve years implying that they finished secondary school and could read, write and access information; access to extension service was low in the study area (31.5%). The study revealed that farmers have the knowledge of climate variability and always use adaptation strategies in the study area. The survey result also discovered that the perceived effects of climate change in the study area were reduced yield, reduced income, loss of nutrients due to leaching, increased cost of inputs, high rate of spoilage of farm produce, etc. The research findings further revealed the adaptation measures adopted by arable crop farmers in the study area as use of cover crop/mulching, use of improved/tolerant varieties, mixed cropping, use of disease/pest resistant varieties, use of organic manures, etc. Constraints that militated against the use of adaptation measures include poor extension services, low farm income, high cost of farm inputs, inadequate weather information, etc. Based on the result of this study, the following recommendations are made: extension services should be strengthened to enlighten farmers about climate change adaptation strategies, in addition, affordable climate change adaptation technologies should be developed for arable crop farmers to adopt, and climate change adaptation funds should be made available to the arable crop farmers to enable them purchase appropriate technology necessary for climate change adaptation.

***Keywords**: Arable crop, climate change, adaptation strategies, perceived effect*

Introduction: Nigeria with over 216 million people (National Bureau of Statistics (NBC, 2022)), is the most populated country in Africa and the sixth in the world. It is the tenth-largest producer of crude oil in the world and achieved lower-middle-income status in 2014 (World Food Programme (FAO, 2020). However, around 84 million Nigerians, representing about 37 percent of the total population, live below the poverty line ((Global Network against Food Crises [GNAFC] 2020). Conflict and insecurity, rising inflation and other economic shocks and the impact of the climate crisis continue to drive hunger in Nigeria – with 26.5 million people across the country projected to face acute hunger in the in the years ahead (Global Network Against Food Crises [GNAFC] 2020 and Food and Agriculture Organization [FAO] 2020). This is a staggering increase from the 18.6 million people food insecure at the end of 2023 (FAO, 2020) Sono, Wei and Jin (2021) noted that countries in Sub- Saharan Africa, including Nigeria are more vulnerable to the vagaries of climate because of their geographical location, wide spread poverty, low incomes, and low institutional capacity, weak response to climate change effects as well as their heavy reliance on climate-sensitive or rain – fed agriculture.

Recent studies have indicated serious changes in Nigeria's weather patterns and environmental conditions, these changes include: increase in temperatures; heavy rainfall; delayed and shorter rainy seasons; longer rainy seasons; unreliable rainfall patterns; significant decline in amount of rainfall from the normal averages, drought and flooding (Tasie (2021) and Henri-Ukoha and Adesope (2020) which have negatively impacted the lives and livelihoods of smallholder farmers. Climate change has been identified as one of the greatest challenges to the persistent low agricultural productivity amidst myriads of efforts by government and other stakeholders to control it (Nwaiwu *et. al*., 2013 and Orebiyi, *et al*., 2014). These trends in climate change and variability are projected to continue due to increased concentrations of greenhouse gases in the atmosphere (Food and Agriculture Organization [FAO] 2020). Appropriate adaptation to climate change has been recognised as a viable opportunity available for both farmers and the agencies and professionals working with them for raising farmers' yields and incomes in ways that are environmentally sustainable (Abraham et al. 2014). Recent researches have demonstrated that without appropriate adaptation strategies the changing climate can be challenging for agricultural production and food security, but with the implementation of adaptive farming measures and practices, potential challenges to achieving smallholder farmer household food security and income can be significantly reduced (Elijah, Osuafor and Anarah, 2018). Climate variability has brought Nigeria's agricultural system under serious threats and stress. Ohaji/Egbema LGA in Imo State is not left out. A place once known as the food basket of the State is lagging behind due to climate crisis, cattle herdsmen menace and oil bunkering activities (increase in greenhouse gases and land pollution). This implies that food and nutrition security in the area and beyond are under serious threat as arable crop production is a significant aspect of agricultural activities in the area (Kanu and Onyekwere, 2023). Extreme climatic events such as excessive rainfall, droughts and floods, land pollution due oil bunkering or kpor fire and forest fires have become a regular occurrence which results in tragic crop failure, increased hunger, malnutrition, pests and diseases and reduced agricultural productivity (Orebiyi, *et al*., 2014). In the study area, agricultural production is largely non-mechanized; therefore weather and climate variables assume prominence in every stage of production. Farmers depend largely on climate signals as major determinants of their farming activities. Farmers had encountered series of loses as a result of change in climate (Orebiyi, *et al*., 2014). Though, crops like cassava, yam and maize are known to tolerate drought to a reasonable extent, are still adversely affected by the variability in climate. All stages of crop production are affected by the variations in climate. Unfortunately, scientists have it that variations in climate may not be avoided entirely because of inability of countries like Nigeria to stop the emission of green house gases. Therefore the basic way to mitigate it is by building up resilience or adaptation strategies to help farmers cope with the effect of this change. How the arable crop farmers in the study area are adapting to climate change and the adaptation measures used are not known. Bearing the commercial and nutritional importance of arable crops in the study area, it becomes very imperative to inquire as well as identify the climate – smart coping measures used by these farmers in the study area. This will surely help them to cope with the variability in climate thereby enhancing their production activities, income and welfare of farmers. It is against this background that this paper assessed the adaptation measures to climate change on arable crop production in Ohaji/Egbema and the climate - smart measures used by the farmers. Considering the above, it is pertinent to assess farmers' adaptation strategies to climate change in Ohaji/Egbema LGA, Imo State, Nigeria. To achieve this, the following research objectives guided the study; ascertain the socio-economic characteristics of the arable farmers in the study area; describe the arable crop enterprise types; ascertain farmers perceived effects of climate change; assess the adaptation measures to climate change used by farmers; Identify the constraints militating against the use of adaptation strategies to climate change by farmers.

Methodology: Study Area: The study was conducted in Ohaji/Egbema LGA in Imo State, Nigeria. Ohaji/Egbema is an agrarian and oil rich local government area of Imo State, Nigeria with headquarters in Mmahu – Egbema. Ohaji/Egbema is made up of seventeen autonomous communities. Ohaji/Egbema LGA lies in the South/Western part of Imo State and shares boundaries with Owerri in the East, Oguta in the North and Ogba/Egbema/Ndoni in Rivers State in the South/West. The people of Ohaji/Egbema are blessed with vast fertile land for agriculture and wildlife, and are mostly farmers, hunters and fishermen.

The study used primary and secondary data. Primary data were generated through questionnaire administered to farmers. Secondary data was based on published and unpublished literature. All the arable crop farmers in the study area formed the population of the study. Sample for the study was drawn through a multistage sampling technique. In the first stage, ten communities were randomly selected from the seventeen autonomous communities. In the second stage, twelve respondents were randomly selected from each of the ten communities. This gave a total of one hundred and twenty farmers who served as respondents for the study.The objectives of the study were achieved using descriptive statistics such as frequency, percentages and mean. To identify adaptation strategies to climate change used by farmers, the respondents were asked using a three-point Likert-type scale of always = 3, rarely = 2, never = 1 and to indicate the scale that agreed with their opinion. The mean computation was achieved and a discriminating index was arrived at by dividing the value of the rating scales by the number of scales, thus: (R+O+N)/3 = 3+2+1/3 = 2.0 (discriminating index). Choosing an interval 0.5, upper limit of 2+ 0.5 = 2.5, lower limit = 2- 0.5 = 1.5. All items with $X \geq 2.5$ were considered 'always' while $X < 2.4$ but $X \geq 1.5$ were considered 'rarely' and $X < 1.5$ were considered 'never'.To analyze farmers' perceived effects of climate change, the respondents were asked to indicate their perceived effects of climate change from a list of possible effects of climate change obtained from literature and personal observation measured on a three point Likert-type scale of high = 3, moderate = 2, low = 1.

The mean computation will be achieved with the formula: X=f(X)/N

Where:

X = the value by which farmers perceived effects of climate change are to be judged.

f = frequency

∑X = sum of the various perceived coefficient obtained

N = sample size

Grand mean = Sum of means/no. of items

Standard deviation = ∑f(X-X)/N

A discriminating index was arrived by dividing the sum of the value of the rating scales by the number of scales, thus: (H+M+L)/3 = (3+2+1)/3 = 2.0 (discriminating index). Choosing an interval 0.5, upper limit of 2+ 0.5 = 2.5, lower limit = 2 - 0.5 = 1.5. All items with $X \geq 2.5$ were considered 'high' while $X < 2.4$ but > 1.5 were considered 'moderate' and $X<1.5$ were considered 'low'.

RESULTS AND DISCUSSION

Socio-economic Characteristics of arable crop farmers in Ohaji/Egbema LGA

Table 1: Mean and percentage distribution socio - economic characteristics of arable crop farmers in Ohaji/Egbema LGA

S/N	Variables	Mean/percentage (%)
1.	**Age (years)**	**49.0**
2.	**Sex (Percentage of females)**	**60.8**
3.	**Marital Status (Married in percentage)**	**88.0**
4.	**Education (No. of years spent in school)**	**12.0**
5.	**Household Size (No. of people)**	**8**
6.	**Farming Experience (Years)**	**17**
7.	**Membership of cooperative group (percentage of membership)**	**62.5**
8.	**Farm Size (hectares)**	**1.2**
9.	**Extension Visit (percentage of access)**	**31.5**
10.	**Annual farm income (Naira)**	**832,000**

Source: Field Survey, 2024

Table 1 shows the socio – economic characteristics of arable crop farmers in the study area. The results showed that the average age of the farmers' respondents was 49 years. This implies that the farmers were in their active and productive years and could withstand the strenuous processes of climate change adaptation in arable crop farming. Thus, the farmers would therefore be expected to show positive disposition in willingness to use adaptation strategies. This finding agrees with that of Orgu, et al. (2024) who reported that young and middle aged farmers are full of energy to provide what is needed in climate change adaptation and arable crop farming.

The result in Table 1 further showed distribution of farmers by sex which indicates that most (60.8%) of farmers were females. The result showed that female farmers dominated arable crop farming in the study area. The survey result also showed the marital status of the farmers (88.0%) and depicts that most of the farmers were married. They will favourably be disposed to embrace technologies that would raise their standard of living such as adaptation strategies to climate change. This finding is in line with that of Tasie (2021), who opined that married women have high responsibility and expectation to meet household demand and could easily adopt technologies that reduce impact of climate change. The result in Table 1 indicates that the average number of years spent in school was twelve years. This shows that the farmers' respondents attended secondary school and were educated enough to easily understand the role technologies play in their farming activities and climate change adaptation which might affect their willingness to use them to increase yield in the study area.

The result revealed that the mean household size of farmers' respondents was eight (8) persons per household. This could be an advantage in terms of supply of free or cheap farm labour. This finding is in agreement with the finding of Ayanlade et al. (2023), who asserts that large household size would increase farm labour supply needed to boost arable crop farming and climate change adaptation to enhance productivity. On farming experience, the result indicated that the mean farming experience as 17 years. This shows that the farmers had been in arable crop production for a long time to know there is climate change and may have been adapting to climate change. The numbers of years in arable crop production should have exposed them to crop production management practices and climate change mitigation and adaptation strategies to boost yield. This finding agrees with that of Orgu, et al. (2024), who opined that the number of years in farming helps to manage the consequences of climate change. The result in Table 1 showed that most of the farmers (62.5%) belong to social organisations (cooperative societies). Social organisations are channels of creating awareness and disseminating vital information about adaptation to climate change and also helps to the pooling of resources together by members to boost output, increase farm revenue and farmers welfare. This finding in tandem with that of Ahmadu and Ewansiha (2023), who averred that cooperative membership help in dissemination of information about climate change and improved technologies to cushion the effect of climate change. The study revealed that only 31.5% of the farmers had extension visits and the visits were not regular. This implies poor agricultural extension services in the study area and this has the potential of depriving farmers' access to the requisite information and knowledge of improved inputs and innovation on climate change adaptation strategies. This finding agrees with Tasie (2021), who avowed that agricultural extension services have capacity to boost farmers' adaptive capacity to climate change. Lastly, Table 1 avowed that the annual mean farm income of respondents was 832,000 naira. This indicates that arable crop farmers in the study area have relatively high annual farm income which could help the farmers in adoption of innovation and climate change adaptation financing.

Arable crop farmers' enterprise type

Table 2 Distribution of arable crops farmers based on crop enterprise type

Arable Crop	Frequency	Percentage (%)
Cassava	120	100.0
Maize	120	100.0
Vegetables	120	100.0
Yam	58	48.3
Cocoa yam	45	40.0

Source: Field Survey, 2024 Multiple responses recorded

Table 2 showed that all the farmers (100%) cultivated cassava, maize and vegetables. The choice of these crop enterprises could be as a result of the minimal labour requirement and the reduced stress involved in there agronomic practices. These crops can be mixed cropped (co – cultivation) and intercropped with other crops. Farmers practice mixed cropping and intercropping to reduce the risk of crop failure due to environmental and climatic stress. This finding agrees with the finding of Eze (2016), who asserts that mixed cropping is a guard against crop failure.

Arable crop farmers perceived effects of climate change on arable crop farming

Table 3: Perceived effects of climate change on arable crop farming

EFFECTS	High	Moderate	Low	Std Dev.	MEAN	DECISION
Reduced crop yield	80(66.7)	29(24.2)	11(9.2)	1.4	2.57	High
Reduced income	74(61.7)	32(26.7)	14(11.7)	1.3	2.50	High
Loss of farm land to erosion	34(28.3)	37(30.8)	39(32.5)	0.8	1.79	Moderate
Loss of nutrients due to leaching	57(47.5)	41(34.2)	26(21.7)	1.2	2.33	Moderate
Increased pest and disease infestation	50(41.7)	25(20.8)	45(37.5)	1.6	2.67	High
Stunted growth of crops	59(49.2)	40(33.3)	20(16.7)	1.1	2.31	Moderate
Increased water scarcity and drought	52(43.3)	40(33.3)	35(29.2)	1.4	1.93	Moderate
Increased cost of seedlings and other inputs	51(42.5)	39(32.5)	30(25.0)	1.2	2.18	Moderate
High rate of spoilage of farm produce	50(41.7)	35(29.2)	35(29.2)	1.3	1.32	Low
Late maturity of crop	49(40.8)	45(37.5)	26(21.7)	1.4	2.19	Moderate
Changing planting/harvesting dates	71(51.2)	32 (26.7)	17 (14.2)	0.98	2.45	Moderate
					2.02	Moderate

Table 3 showed the distribution of the farmers based on perceived effects of climate change. The Table indicates that reduced yield (X = 2.57), reduced income (2.50) and increased pest and disease infestation (2.67) are the greatest effects of climate change in the study area. The Table implied that some of the perceived effects are high and some moderate. The effects of climate change, therefore brings about the low productivity of arable crops in the study area which leads to low income and low standard of living. This result supports the findings Eze (2016) and Albert and Okidin, (2014), who in their separate studies assert that climate change had brought about low yield of crops.

Adaptation measures to climate change

Table 4: Arable crop farmers' adaptation measures to climate change in Ohaji/Egbema LGA

Adaptive Strategies	Always	Rarely	Never	Std dev.	Mean	Decision
Use of cover crop/mulching	80(62.5)	30(25.0)	10(8.33)	0.7	2.63	Always
Use of improved/tolerant varieties	79(65.8)	32(26.7)	9(7.5)	0.9	2.67	Always
Mixed cropping	80(66.67)	25(20.8)	15(12.5)	0.8	2.54	Always
Livelihood diversification	83(69.2)	27(22.5)	10(8.33)	0.7	2.60	Always
Use of disease/pest resistant varieties	85(42.5)	30(29.2)	5(21.7)	0.9	2.67	Always
Intercropping	83(69.2)	27(22.5)	10(38.33)	0.7	2.60	Always
Changing planting/harvesting dates	80(66.57)	25(20.8)	15(12.5)	0.9	2.54	Always
Frequent weeding	75(62.2)	40(33.3)	5(4.2)	0.8	2.58	Always
Switching to non-farm activities	78(39.2)	31(25.8)	11(29.2)	0.8	2.56	Always
Planting early maturing varieties	82(68.3)	29(24.2)	9(7.5)	0.7	2.61	Always
Increase in the use of family labour	75(62.5)	30(25.0)	15(12.5)	0.9	2.50	Always
Changing the time of land preparation	77(64.2)	29(24.2)	14(11.7)	0.8	2.53	Always
Use of Organic manures	75(45.8)	38(31.7)	7(16.7)	0.9	2.57	Always,
Use of Pesticide/herbicide	74(61.7)	31(25.8)	15(15.5)	0.7	2.50	Always

Table 4 reveal the adaptation measures adopted by arable crop farmers in Ohaji/Egbema LGA. All the listed measures or technologies were always used by most the farmers as adaptation strategies to cushion the effects of climate change to boost farm output, increase farm income and better their living conditions of the arable crop farmers. This is attributed to the understanding that people sought and have access to information from different sources. This finding is in agreement with Tasie, 2021), who in the study of arable crop farmers' adaptation practices to climate change risks in Rivers State, Nigeria, outlined many adaptation strategies to climate change farmers use to reduce the impact of climate change on the arable crop farming.

Constraint to Farmers Adaptation Strategies to Climate Change

Table 5: Distribution of farmers based on constraints to adaptation to climate change

Constraints	*Frequency	Percentage (%)
Poor extension service delivery	115	95.8
Low farm income	117	97.5
High cost of farm inputs	110	91.7
Poor access to weather information	112	93.3
Lack of credit facilities	116	96.7
High cost of farm labour	95	79.2
Inadequate knowledge of climate change	97	80.8
Poor access to improved agric. technology	101	84.2
Inadequate capital	104	86.7
Poor infrastructural facilities	87	72.5
Land tenure system	84	70.0

*Multiple responses

The result in Table 5 showed the constraints to adaptation to climate change among the arable crop farmers in Ohaji/Egbema LGA. The result in Table 5 indicated that all the constraints were serious constraints because of the high percentage of response for each constraint. The Table revealed that low farm income (97.5%), lack of credit facilities (96.7%), poor extension services (95.8%) and poor access to weather information (93.3%) were the major constraint facing farmers adaptation to climate change in the study area. This finding is in consonance with the study of Eze (2016), who opined that smallholder farmers have very low resource and finance base and as such they are vulnerable to climate variability and lack the capacity to adapt to climate change and also have less likelihood of accessing weather information or capacity to develop technologies on their own.**Conclusion;** This study investigated arable crop farmers' adaptation measures to climate change in Ohaji/Egbema LGA. The study adopted survey research design and showed that farmers have the knowledge of climate variability and that there were perceived effects of climate change on arable crop farming such as reduced yield, reduced income, etc. and the farmers always use various measures like use of cover crop/mulching, resistant crop varieties, mixed cropping, intercropping, etc. to adapt to the changing climate in the study area. Constraints that militated against the use of adaptation measures include poor extension services, low farm income, high cost of farm inputs, inadequate weather information, etc.**Recommendations:** Based on the result of this study, the following recommendations were made: (1) extension services should be strengthened to enlighten farmers about climate change adaptation measures (2) In addition, affordable climate change adaptation technologies should be developed for resource-poor farmers to adopt (3) climate change adaptation financing should be intensified as a critical pathway to invest in the climate adaptation and resilience efforts of climate vulnerable farmers of the study area and (4) climate and weather information from relevant agencies like Nigerian Meteorological Agency (NiMet) should be disseminated to the farmers through relevant public and private agencies.

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Influence of Selected Tree Species on Key Soil Properties for Sustainable Land Management

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Abstract

*This study examines the impact of different tree species on select soil properties in Nekede, Owerri North, Imo State, Nigeria. Three tree species – mango (Mangifera indica), cashew (Anacardium occidentale), and African rosewood (Pterocarpus mildbraedii) – were evaluated for their effects on selected soil chemical and physical properties. Surface soil samples were collected from a two-meter radius around each tree trunk across three locations: the Federal Polytechnic campus, Umuerim, and Umukotocha. Laboratory analysis revealed significant differences (P < 0.05) in soil pH between soils near the selected tree species – 4.99 for cashew, 5.02 for mango, and 5.06 for rosewood – and control soils (4.64). Additionally, soils around the trees showed significantly elevated levels (P < 0.05) of organic carbon (OC), nitrogen (N), phosphorus (P), and potassium (K) compared to control soils. Notably, African rosewood had a stronger influence on OC and N concentrations than cashew or mango. Species diversity did not significantly impact pH, P, or K levels. No significant effects of tree species were observed on the soil's physical properties. In conclusion, the tree species studied significantly influenced soil chemical properties but had minimal ef*fect on physical soil attributes.

Keywords: African rosewood, Cashew, Mango, Tree species, Soil, Soil properties

Introduction: Sustainable land management amid climate change, rapid land degradation and population growth is a panacea to continues food production and security. In recent times, farmers in Nekede have been confronted with the growing challenge on how to optimize available land resource to achieve sufficient food production without causing further harm to environment and disrupting the ecosystem while adapting to climate change. Many scholars have reported that tree plantation systems have the potential to be a land-management alternative, for conserving soil, maintaining soil fertility and increasing soil productivity (Brady and Weil, 2016). It is therefore important to explore possible viable options including agroforestry. Tree species are known to affect soil by absorbing water and nutrients from the soil and adding litter to the soil (Prescott and Vasterdal, 2013). Some studies have demonstrated that tree species diversity can lead to higher mineral soil carbon stocks and pH (Guckland et al., 2009) or increase soil carbon stocks and the C/N ratio (Dawud et al., 2016). Other studies have shown that litter decomposition and mineralization results in increased presence of plant essential nutrients particularly, the primary nutrient elements. Hillal (2004) explained the effect of plant species on the physical properties of the soil including structure and hydrological properties. This study aims at investigating the effects of tree species on the immediate soil environment and compare the response of soils to different species. The essence of the comparison is to determine the best of all the economic trees in the study area for agroforestry as land management approach.

Materials and method: This study was carried out in Nekede, Owerri North, Imo State, Nigeria. Nekede is located approximately at latitude 5.4207^{0}N and longitude 7.0767^{0}E is characterized by a humid tropical climate, with an average rainfall of 2500mm of which 80% occurs between May and July. The rest of the year is relatively dry. The soil type is ultisols and the texture is sandy loam. Three tree species – mango (*Mangifera indica*), Cashew (*Anacardium occidentale*) and African rosewood (*Pterocarpus mildbraedii*) – were selected for evaluation of their effects on certain key chemical and physical properties of surrounding soils. The trees were selected from three different locations – Federal Polytechnic campus, Umuerim, and Umuokotocha. Surface soil samples were collected from a two-meter radius around each tree trunk across the three locations. The control samples where taken 50 m away from the trees. The samples were labelled and sent to the laboratory to determine pH, organic carbon content, primary nutrients content, bulk density, porosity and particle size distribution. Certain physical properties such as moisture content and infiltration rate were determined in the field. Materials and equipment used for sampling include soil auger and core sampler, meter tape, hand trowel and soil bags. Data collected was subjected to analysis of variance using GenStat.

Result and Discussion: Effect of Tree Species on Selected Chemical Properties: As shown in **table 1** below, laboratory analysis revealed significant differences (P < 0.05) in soil pH between soils near the selected tree species – 4.99 for cashew, 5.02 for mango, and 5.06 for African rosewood – and control soils (4.64). This agrees with Guckland *et al.* (2009) that tree species diversity can lead to higher mineral soil pH. This can be attributed to litter fall, decomposition and mineralization of basic cations which have the capacity to raise soil pH. This could be different if samples were collected down the profile since tree plants absorb water and nutrients at the low horizons. Organic carbon was seen to be significantly higher in soils around the selected trees compared to the control. Rosewood had the highest (1.747%) reservoir of organic carbon, followed by Mango (1.7%), cashew (1.397%), and control had the least (0.57%). A number of factors could account for the higher OC recorded around the tree species soil environment including quantity and quality of litter, microbial activities, moisture and microclimate. Litter amount and quality determines organic carbon content of the soil (Hansson *et al*., 2013). Rosewood, being deciduous in nature would shed its leaves in a season which leaves appreciable amount of litter around the plant. This explains why the soil around it had the highest OC content.

Nitrogen content was also seen to follow the same pattern as OC with rosewood producing the highest value (0.177%), followed by mango (0.157%), cashew (0.143%) and control (0.053%). Phosphorus was significantly higher in the soils around the selected trees with rosewood producing the highest value of 9.63 mg/kg and control, the least value (3.68 mg/kg). Just like the rest of the chemical properties investigated, potassium was significantly higher around the trees than the control soils. The highest potassium value (0.31 cmol/kg) was recorded for the soil obtained around mango trees and the least value (0.083 cmol/kg) was recorded for the control. All the selected tree species bear fruits and have seeds. The seeds are known to contain potassium and phosphorus among other minerals. When the fruits drop, they decay alongside their seeds and release potassium and phosphorus amongst other minerals. This could account for the higher phosphorus and potassium values recorded around the trees environment.

Table 1. Effect of Tree Species on Selected Chemical Properties of Soils in Nekede

Treatment	pH	OC (%)	N (%)	P (mg/kg)	K (cmol/kg)
Cashew	4.987	1.397	0.1433	7.63	0.207
Rosewood	5.057	1.747	0.1767	9.63	0.260
Mango	5.023	1.700	0.1567	8.58	0.310
Control	4.643	0.570	0.0533	3.68	0.083
$LSD_{(0.05)}$	**0.2653**	**0.3320**	**0.05516**	**2.098**	**0.0663**

OC = Organic Carbon, N = Nitrogen, P = Phosphorus, and K = Potassium

Effect of Tree Species on Selected Physical Properties of Soils: Table 2 below shows the results obtained for the selected physical properties under investigation. Statistical analysis failed to reveal any significant differences in the means of the physical properties. Bulk density, porosity, moisture content, infiltration rate were statistically similar in all the soil sampled. The results obtained on bulk density and porosity could be attributed to the fact that the soils of the area under investigation have similar textural class (sandy loam). According to Hillel (2004), soils with similar textural class show uniform bulk density and porosity regardless of tree cover. Moisture content and infiltration rate are dynamic and can be affected by recent precipitation. This could have affected the results obtained as sampling was done shortly after rainfall in the area.

Table 2. Effect of Tree Species on Selected Physical Properties of Soils in Nekede

Treatment	Bulk Density (g/cm^3)	Porosity (%)	Moisture Content (%)	Infiltration Rate (cm/hr)

Cashew	1.873	0.290	9.49	93
Rosewood	1.843	0.303	10.58	89
Mango	1.770	0.327	9.13	94
Control	1.860	0.300	9.09	95
$LSD_{(0.05)}$	**0.2534**	**0.0945**	**5.173**	**8.231**

Conclusion and recommendation: The tree species studied significantly influenced soil chemical properties such as pH, OC and the primary nutrients content of the soil, but had minimal effect on physical soil attributes. As the results have shown, African rosewood tree had greater influence on the soil compared to cashew and mango. It is not clear why it so. Therefore, why it may be rational from the study to use rosewood for agroforestry in the area, further studies should be carried out to ascertain the veracity of the findings.

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Climate Change Mitigation through Forest Resource Management: Strategies and Roles of Rural Women in Vwang District, Jos South LGA, Plateau State

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Abstract

The forest continues to face depletion and approaches to its management have not involved women the way they would have desired. Already, women are playing significant roles in the collection and management of forest products and indirectly contributing to climate change mitigation efforts however, these have not been adequately documented. Hence, this study evaluated rural women's involvement in forest resource management in Vwang district of Jos South LGA, Plateau State, addressing the limited recognition and documentation of their roles in climate change mitigation. Utilising a multistage sampling method, data was collected from 305 respondents and analysed using SPSS version 23.0. Findings indicated that a majority of women (64.3%) were farmers and an estimated 260 (85.3%) were actively participating in the management of forest resources. The most commonly managed forest resources in the study area included leafy vegetables (81.9%), spices (51.5%) and fuel wood (30.4%) The most popular management practice in Vwang district was soil and water conservation (40.0%), agroforestry accounted for 33.1% while reforestation and afforestation was 18.8%. Income generation was the primary motivation for forest resource management, cited by 62.3% of women, while 27.6% were driven by conservation concerns. However, poor pricing was identified as a significant challenge (43.9%), limiting economic benefits and potentially discouraging sustainable practices. Women play a crucial role in forest resource management, but face economic barriers and limited formal recognition. Recognizing women's roles in forest policies and expanding education on sustainable practices would strengthen conservation efforts and mitigate climate change.

Keywords: Climate Change, Forest Resources, Management, Women, Plateau Stat

Introduction: Globally, forest play an important role in the livelihood of rural people in general. Rural communities depend on forest resources such as fuelwood, fodder and non-timber forest products for their survival (Pouliot and Treue, 2013). Women are primary users of forest resources in many rural areas, they collect wild vegetables, fruits, firewood and medicinal plants. Often times, they rely on these resources for income generation and sustenance (Clair, 2016). Despite rural women's reliance on and significant role in forest resource management, they often face substantial barriers that limit their effectiveness in contributing to climate change mitigation. Gender inequalities, socio-economic challenges, and restricted participation in decision-making processes hinder their ability to sustainably manage forests and actively engage in climate solutions (Eneji, Ajake, Mubi & Husain, 2015). Furthermore, deforestation, over-exploitation of resources, and climate change present critical threats to forest sustainability (Coleman & Mwangi, 2013; Johnson, 2003). These challenges disproportionately impact rural women, whose livelihoods are closely tied to forest ecosystems (Meyiwa, Maseti, Ngubane, Letsekha & Rozani, 2014).

Evidence shows that a lack of targeted support and training programs restricts women's capacity to adopt sustainable forest management practices and implement strategies that could mitigate climate change (Argawal, 2009; Juma, Omondi & Kareri, 2021). Empowering rural women through capacity-building initiatives and integrating their perspectives in forest governance are essential steps in strengthening climate change mitigation efforts and ensuring resilient forest ecosystems that support both local livelihoods and global climate goals (Banerjee, Hussain, Tuladhar, & Mishra, 2019). A number of forest resource management strategies have been developed and implemented to enhance sustainable use and conservation of forest resources thereby addressing climate change. These strategies often emphasise community-based management, participatory approaches, and the integration of traditional knowledge with modern conservation practices. However, the effectiveness of these strategies in addressing the unique needs and challenges faced by rural women remains a critical area of concern (Freshwater Mollusk Conservation Society, 2016; Lal, 2012).

In Nigeria, as in many parts of the world, women's involvement in the forest sector extends far beyond fuel wood and fodder collection; they play crucial roles in sustaining and managing forest resources and are primary users of forest products (Duru, Aro & Oladipo, 2022). However, many afforestation programs have failed due to the neglect of women's needs, despite their pivotal role in these efforts. Women contribute significantly to maintaining and restoring the environment, with ecofeminism suggesting that women's close relationship with nature fosters a nurturing approach toward environmental stewardship (Tiondi, 2001; Williams, 2004). To address climate change mitigation, it is essential to integrate women into forest management strategies, as sustainable forest practices are crucial in sequestering carbon and reducing greenhouse gas emissions. Women's involvement in sustainable forest management can enhance climate resilience and reduce climate impacts, particularly in rural communities that rely on forests for livelihoods (Ume, Opata & Onyekuru, 2021). Yet, current forest management strategies often overlook the unique challenges faced by rural women. This study evaluates these strategies, identifies the barriers women encounter, and proposes inclusive recommendations to ensure women's active participation in sustainable forest management, ultimately contributing to climate change mitigation and improved rural livelihoods.

Methodology: Study Area: This study was carried out in Vwang district of Jos South LGA of Plateau State.

Study Design and target population: The s**tudy design** was descriptive and the target population for this study were rural women between ages 18 and 60years. A semi-structured questionnaire was designed to collect primary data from study participants.

Sampling Preocedure: A multistage sampling method was used; at first stage, the four wards under Vwang district were sampled using simple random sampling by balloting, second stage involved a random selection of 3 villages from each of the wards. A systematic sampling was used at the third stage to sample every 4th house. The fourth and the last stage involved simple random sampling through balloting of one woman per house.

Sample Size

This was calculated using the Fischer formula

$n = \frac{z^2 pq}{d^2}$

Where n = minimum sample size
z = confidence limit
p = 33% (Shuaibu 2015: proportion of women who were harvesting and managing forest resources)
q = complimentary probability (1-p)
d = degree of accuracy (0.05)
n= 305
Prevalence of women who practice forestry through nursery development in Igalamela/ OdobuLGA, Kogi state

Questionnaire distribution: This was done proportionately using the percentage of household in each ward based on 2006 population census household figures for Vwang District. Vwang/Fwei ward had the highest representation 85(27.9%), followed by Chugwi 83(27.2%) participants. Turu A represented 71 (23.3%) of the study participants while Turu B was 66(21.6%).

Statistical analysis: Data entry was conducted using Excel, and data analysis was performed using SPSS version 23.0. The analysis included descriptive statistics such as means, standard deviations, frequencies, and proportions. The results were summarised using tables and charts.

Results: The average age of respondent was 33.6±8.3years, the predominant age group of the women was 30-39 years accounting for 41.0% of the women. Average family size was 6.8±4.0 and average number of children 3.1±1.9. A proportion of 11.5% of the women had no formal education. The result showed that 56.7% of the women were married were largely farmers **(**64.3%) and 89.5% earn a monthly income of less than ₦50, 000 (see Table 1).

Table1: socio-demographic characteristics of Respondents

Characteristics	Frequency n=305	Percent
Age		
<20	8	2.6
20-29	89	29.2
30-39	125	41.0
40-49	74	24.3
50+	9	3.0
Education		
None	35	11.5
Primary	100	32.8
JSS	103	33.7
SSS/vocational	46	15.1
Training college	19	6.2
University	2	0.7
Marital status		
Single	54	17.7
Married	173	56.7
Divorced	16	5.2
Widowed	41	13.4
Separated	20	6.6
Occupation		
Farming	196	64.3
Trading	148	48.5
Forest products	94	30.8
Hairdressing	23	7.2
Teaching	10	3.3
Others	28	9.2
Income (₦)		

<50,000	273	89.5
50000-99000	31	10.2
≥100000	1	0.3

An estimated 69% of the women recognised herbs as a forest resource, other forest resources identified by respondents included fuel wood (68.5%), trees (62.2), mushrooms (46.6%), bush meat (43.3%) and animals (43%) (See Figure 1).

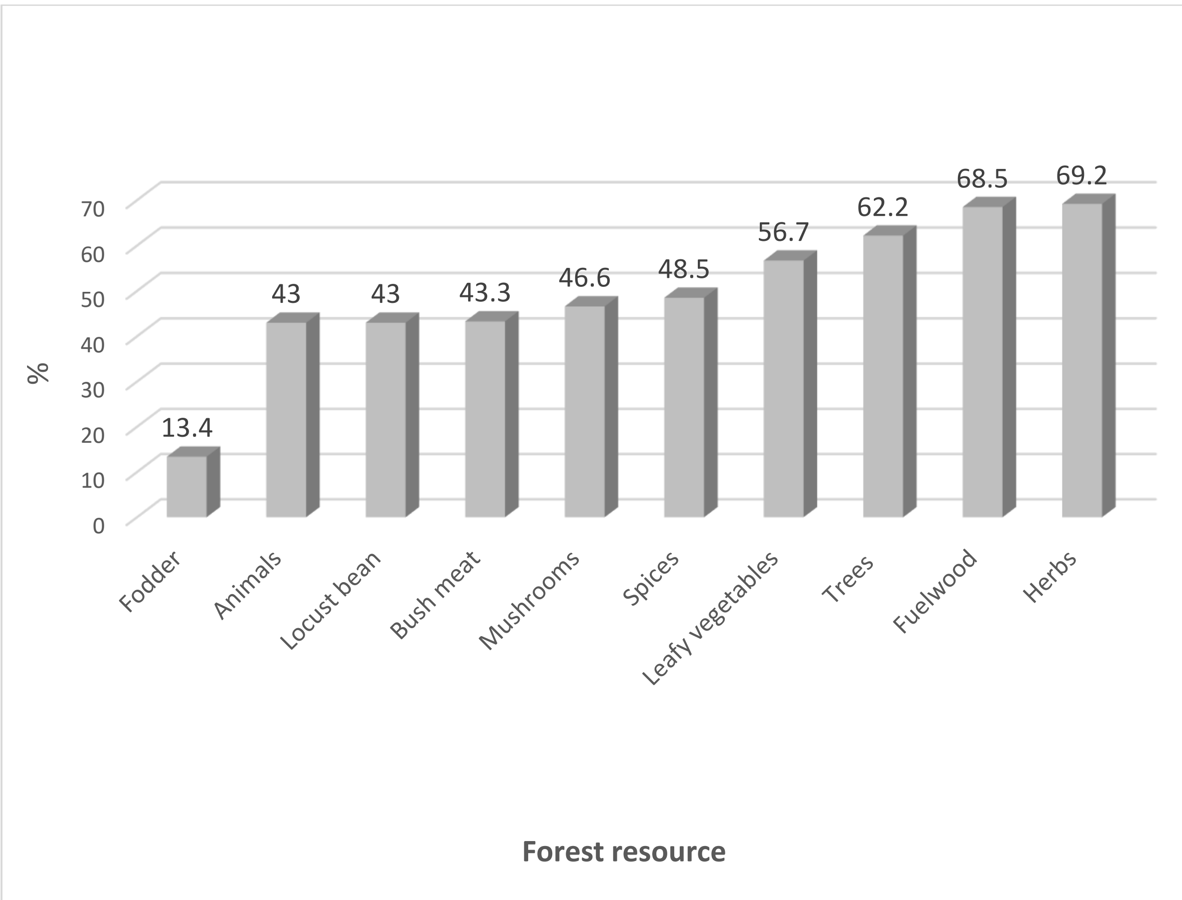

Figure 1: Major forest resources in the study area

The proportion of women who were harvesting and managing forest resources as shown in figure 2 was 85.3%. (See table 2).

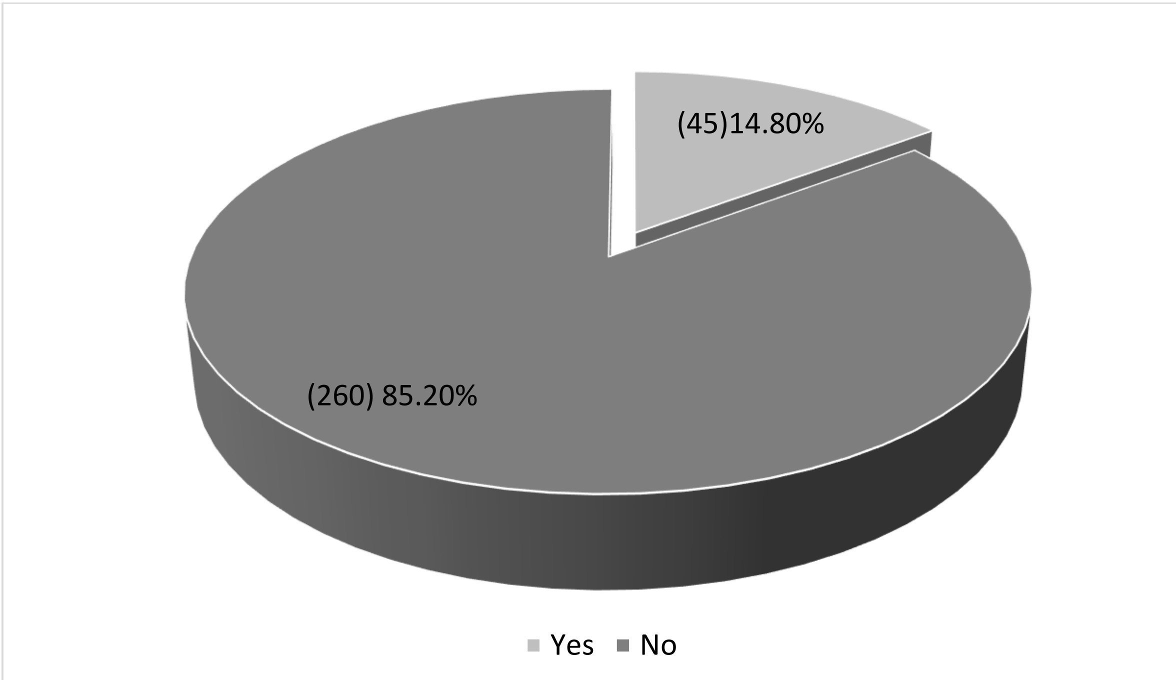

Figure 2: Proportion of women who were harvesting and managing forest resources

Table 3 presented the forest resources that were managed in the study area, leafy vegetables were predominant (81.9%) ,followed by spices 51.5% then follow by fuel wood 30.4% followed by fodder 27.7% and the least being managed was mushroom (5.4%.).

Table 3: Forest resource that is being managed in the study area

Forest resource n=260 (Multiple choice)	Frequency	Percent
Mushroom	14	5.4
Leafy vegetables	213	81.9
Spices	134	51.5
Fuel wood	79	30.4
Locust bean	35	13.5
Fodder	72	27.7

The result in Table 4 showed that the most popular management practices in Vwang district was Soil and water conservation (40.0%). This was followed by agroforestry which constituted 33.1%, others were; reforestation and afforestation (18.8%), integrated pest management (15.8%). Silvicultural activities such as pruning, thinning, terracing, shading was 11.2% and fertilizer application was 8.1%. Selective harvesting (6.9%) and sustainable yield management (6.9%) were the least practiced.

Table 4: Management strategies employed by women in Vwang

Management Practices n=260 (Multiple choice)	Frequency	Percent
Soil and water conservation	104	40.0
Agroforestry	86	33.1
Reforestation and afforestation	49	18.8
Integrated pest management	41	15.8
Silvicultural activities	29	11.2
Fertilizer application	21	8.1
Selective harvesting	16	6.2
Sustainable yield management	16	6.2

The reasons for women's participation in the management of forest resources varied. A significant portion, 62.3%, cited income generation as a primary motivation. Additionally, half of the women (50%) indicated that household food needs drove their involvement. Preservation and conservation of resources were important for 27.6% of the participants, while 9.2% engaged in NTFP management for medicinal purposes.

Table 5: Reasons for participation in forest management

Reasons n= 260 (Multiple choice)	Frequency	Percent
Income generation	164	62.3
Household food	130	50.0
Preservation and conservation	72	27.6
Medicinal purpose	24	9.2

The most critical challenge encountered by the women was poor pricing of the forest resources accounting for 43.9%, followed by seasonality of the produce (33.1%). This was followed by lack of training, lack of capital and lack of tools for processing the produce at 15.0%, 13.9% and 11.9 respectively.

Table 6: Challenges in managing forest resources

Challenges	Frequency	Percent
Poor pricing of the produce	114	43.9
Seasonality of produce	86	33.1
Lack of training	39	15.0
Lack of capital	36	13.9
Lack of tools for processing	31	11.9

Discussion: The results of this study indicated that a large majority of the women were farmers, which aligns with the agricultural nature of the study setting and the primary occupation of rural people. This finding supports other studies showing that women in rural areas, particularly in developing countries, play a significant role in food production (Butt, Hassan, Mehmood & Muhammad, 2010; Ogunlela & Mukhtar, 2009). The respondents had an average age of 33.6 years, with a standard deviation of 8.3 years, showing that the population was relatively young. The largest age group of respondents was women between 30-39 years old, making up 41% of the participants, suggesting a focus on women in their most productive and economically active years (Sumberg & Okali, 2013).

A noteworthy 11.5% of women had not received formal education, revealing potential obstacles to accessing information and resources, which could impact their involvement in forest management. More than half of the women were married, and on average, families consisted of 6.8 members, and each family had an average of 3.1 children, which is typical for the study area's family structure (Sharma & Badodiya, 2016). The study's findings revealed that most of the women were engaged in farming, aligning with the agricultural focus of the study area and the primary occupation of rural residents. This result supports previous research showing that women in rural areas, particularly in developing nations, play a substantial role in food production, and it highlights their deep connection to the natural environment, including critical forest resources. This dependence on and interaction with forests position rural women as key players in climate change mitigation efforts. By sustainably managing these resources, women can help preserve carbon-sequestering forests, reduce greenhouse gas emissions, and support resilient ecosystems essential for both environmental health and sustainable agriculture. (Raney, 2011; Obayelu, Ogbe & Edewor, 2020; Amusan, Akokuwebe & Odularu, 2021). A significant majority of the women earn a monthly income of less than ₦50,000, indicating that they are low income earners and rely mostly on subsistence activities.

The high percentage of women involved in harvesting and managing forest products in this study underscores their critical role in forest stewardship, which directly supports sustainable management practices, community reliance on ecosystems, and climate change mitigation. Their active participation is essential not only for maintaining forest health but also for enhancing the livelihoods of their families and communities, as healthy forests are key carbon sinks that help reduce greenhouse gas emissions. This involvement also empowers women by creating opportunities for income generation and fostering leadership in resource management, strengthening both socio-economic resilience and environmental sustainability in the face of climate change. (Zaku & Moor, 2022).

The findings revealed diverse range of motivations driving women's participation in the management of forest resources. Income generation stands out as the predominant reason, with 62.3% of women involved in forest product activities for economic benefits. This suggests that forest product serve as a crucial source of livelihood for many women, likely contributing to household income and financial independence. It highlights the economic importance of forest resources in rural communities, where formal employment opportunities may be limited and corroborates the works of Kar & Jacobson (2012). Half of the women (50%) also manage forest products to meet household food needs, indicating that these product are an essential component of food security for these families. In subsistence-based economies, reliance on forest products for daily sustenance underscores the importance of preserving these resources to ensure ongoing food supply and food security (Meyiwa et al., 2015).

Preservation and conservation motivations, expressed by 27.6% of the women, indicate a rising awareness of the importance of sustainable forest resource management, not only to support long-term environmental health but also as a critical element in climate change mitigation. These women recognise the lasting value of protecting forest ecosystems, which play a vital role in carbon sequestration and reducing greenhouse gas emissions, ensuring the availability of forest products for future generations. Additionally, 9.2% of the women rely on forest resources for medicinal purposes, highlighting the cultural and traditional significance of these resources in healthcare, particularly in areas with limited modern medical access. This reliance emphasises the essential role of forest products in supporting health and well-being in resource-dependent communities (Banerjee et al., 2019).

However, significant challenges affect sustainable forest management, including poor pricing, which undermines fair compensation for harvested resources, weakening women's economic stability and discouraging sustainable practices. Seasonality also presents a constraint, as the availability of forest resources fluctuates throughout the year, leading to periods of scarcity that impact consistent income and food security for these communities (Duru, Aro & Oladipo, 2022). Addressing these economic and seasonal barriers could empower women to adopt more resilient and climate-conscious management practices, thereby enhancing forest conservation efforts and supporting both livelihoods and climate change mitigation (Ajani, Onwubuya & Mgbenka, 2013).

Conclusion: This study highlights the crucial role that women play in forestry and agriculture, specifically in the management of forest resources, which is essential for both food security and climate change mitigation. The predominantly young and economically active women are central to food production and forest stewardship, with most engaged in farming and forest resources related activities. Their involvement in forest resources harvesting is driven primarily by economic needs, as forest resources are essential for household income and food security. However, challenges such as low pricing and the seasonality of forest resources limit the economic benefits and sustainability of forest resources practices. Additionally, low formal education rates among the women present barriers to accessing resources and information that could restrict access to resources and knowledge that could enhance their impact on climate-resilient forest management

Recommendations: Access to fair markets and pricing for forest products should be established through community-led market initiatives and cooperatives to improve fair pricing of forest products, ensuring women earn equitable incomes and empowering women's economic role in climate-conscious forest management. Government and agricultural stakeholders should provide training in sustainable harvesting, forest conservation, and income diversification to strengthen women's role in sustainable forest management, which is crucial for climate change mitigation. Stakeholders should promote the cultivation of high-demand NTFPs to ensure a consistent supply of food all year round by encouraging the establishment of community gardens and agroforestry projects that could supplement forest harvesting thereby enhancing household food security. Government and NGOs should recognise and formalise women's roles in forest management through gender-inclusive policies, which would improve women's access to resources, elevate their leadership in conservation, and enhance their contributions to climate change mitigation.

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Effect of *Trichoderma spp.* in Enhancing Germination Rates in Rice Plants

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Abstract

A study was carried out to evaluate the effect of Trichoderma spp. in enhancing germination rates in rice plants. Trichoderma viride 5 kg, rice seeds (local & improved) 70% ethanol, 5% sodium, hypochlorite, sterile distilled water, polythene bags digital scale, weighing meter, ruler, NPK fertilizer, compost manure, watering cane, sprayer, oven were provided. One hundred rice seed grains were selected for each treatment (improved and local varieties) to sum a total of 400 seeds. The seed germination rate (%) was determined as the average number of seeds that germinate over the 1-10 days period in the experiment. The inoculation of rice plants with Trichoderma spp. increased the rate of seed germination percentage compared with the untreated rice. Findings from this study indicated that Trichoderma sppp. has the potential to enhance the rate of germination and yield in rice seeds, besides reducing loses due to delayed germination.

Keywords: *Trichoderma spp.*, Germination Rate, Rice Plants, Enhancing.

Introduction: The production of rice is faced with many challenges amongst which are availability of water and adequate use of fertilizer for crop growth and yield (Vakili *et al.,* 2015). The ever - increasing population of the World has necessitated the development of intensive agricultural technologies to sustain soil fertility which is essential in achieving and maintaining high crop yields over a period of time (Makinde *et al.,* 2007). Many disadvantages of widespread use of chemical fertilisers include increase in soil acidity, mineral imbalance and soil degradation and even farmers nowadays do not prefer chemical fertilizers (Bedada *et al.,* 2014). In composting microorganisms decompose organic substrate aerobically into carbon dioxide, water, minerals and stabilised organic matter (Harman, 2006). Compost is added into the soil to improve nutrients and water-holding capacity (Vakili et al. 2015). Recently, researchers observed that addition of cow dung to biomass generated from palm oil industries improves the physical and chemical properties including nutritional composition of compost. Palm oil biomass mixed with cow dung in the ratio of 1:3 significantly improved the compost quality with respect to various parameters such as pH, electrical conductivity and C:N ratio (Yadav et al. 2013). Thus, cow dung may not only act as a substitute for chemical fertilizers because it supplements organic matter, but also as a conditioner for soil (Vakili et al. 2015). *Trichoderma* is a genus of filamentous ascomycete fungi that are among the frequently isolated soil microorganisms (Bedada *et al.,* 2014). However, these fungi have been widely used as bio control agents and they can also enhance germination stimulate plant growth and suppress plant diseases by one or more different, direct or indirect mechanisms. The success of *Trichoderma* in the rhizophere is due to their high reproductive capacity to survive under very unfavourable conditions such as drought, efficiency in the utilization of nutrients, capacity to modify the rhizophere and strong aggressiveness against plant pathogenic fungi (Harman, 2006). Trichoderma species has been widely used as biological control agents in agricultural field. Trichoderma species has been reported effective for a range of crop diseases mitigation caused by pathogens, especially fungal plant pathogens. This study was carried out to evaluate the effect of *Trichoderma spp.* in enhancing germination rates in rice plants.

Materials and Methods: The study was carried out at the new botanical garden of the Gombe State University, Gombe. Gombe lies within 10.30 N latitude and 11.07 E longitude with an average temperature of 29.50C. *Trichoderma viride* 5 kg, rice seeds (local & improved) 70% ethanol, 5% sodium, hypochlorite, sterile distilled water, polythene bags digital scale, weighing meter, ruler, NPK fertilizer, compost manure, watering cane, sprayer, oven were provided. One hundred rice seed grains were selected for each treatment (improved and local varieties) to sum a total of 400 seeds. In addition, a control treatment was used in which *Trichoderma* were applied to it. 6-10 grams of *Trichoderma* powder per kilogram of seed was mixed before sowing. *Trichoderma* powder was applied to the field by mixing 1kg of *Trichoderma* formulation in 100 kg of (FYM) and covered for seven days with polythene. the heap was Sprinkled with water intermittently. The mixture was turned after every 3-4 days interval and then broadcast in the field. Within 4-5 days of inoculation, the compost with *Trichoderma* successfully development was indicated by a whitish layer which is the growing fungal mycelium (Singh *et al.,* 2010). The site of the experiment was splinted into four subplots with four varieties of rice exposed to two treatments with their respective controls and a total number of 20 replicates. Rice seedlings were placed in soil with different treatments (*Trichoderma* + compost and soil with NPK fertilizer) and a control treatment for each rice varieties. The seed germination rate (%) was determined as the average number of seeds that germinate over the 1-10 days period in the experiment. Germination rate was computed using the formula proposed by International Research Rice Institute IRRI (2011);

$$\text{Germination rate (germ. rate)} = \%\, no.of\ seeds\ germinated/no.of\ \ seeds\ in\ the\ \ plot \times 100$$

Data was collected on rice growth components i.e. germination rate was measured at day three, five, seven and ten days after sowing (DAS). All the measurement was taken on a clear sunny day between 8:00am - 10:00am and data were recorded on weekly basis.

Results: The study revealed the significance of *Trichoderma spp.* as growth promoter in both varieties of rice. The study observed that the inoculation of rice plant with *Trichoderma spp.* increased the rate of seed germination percentage compared with the untreated rice. Germination percentage was high in the rice plant treated with *Trichoderma spp.* (about 55%) compared to the rice plant treated under NPK fertilizer having (about 35 %), for T. control and NPK control for all rice varieties showing the highest germination rate about (35 %) and (30 %) respectively. It was observed that this fungus has a significant effect on early seedling emergence in the growth performance of rice plant as shown in Table 1.

Table I: Effect of Trichoderma, NPK and Control and pv (< 0.05) on number of tillers

VARIETY	TREATMENT	1 WAP	2 WAP	3 WAP	3 WAP	4 WAP	5 WAP
JAMILA	F. CONTROL	0.00± 0.00	0.00± 0.00	0.00±0.00	1.00±1.00	2.33±0.57	4.00±1.00
	FERTILIZER	0.00± 0.00	0.00±0.00	1.00±0.00	2.66±0.57	4.00±0.00	5.66±0.57
	T. CONTROL	0.00±0.00	0.00±0.00	1.33±1.15	3.66±0.57	5.33±1.52	6.66±1.52
	TRICHODER.	0.00±0.00	0.00±0.00	1.00±1.00	3.00±1.00	4.66±2.08	7.00±2.00
NERICA	F. CONTROL	0.00±0.00	0.66±0.57	2.00±1.00	3.33±0.57	4.00±1.00	5.33±1.52
	FERTILIZER	0.00±0.00	1.33±1.52	3.00±1.00	3.66±1.52	5.00±2.00	6.33±3.21
	T. CONTROL	0.00±0.00	1.00±1.00	2.66±1.52	4.66±2.08	6.66±2.08	8.66±2.08
	TRICHODER.	0.66±0.57	3.00±1.00	4.66±1.52	6.66±2.08	9.00±1.73	11.66±2.08
SIPPI	F. CONTROL	0.00±0.00	0.66±0.57	2.00±1.00	3.33±0.57	4.33±1.52	6.00±1.73
	FERTILIZER	0.00±0.00	1.33±1.52	2.66±2.08	4.33±1.52	5.66±2.08	6.33±2.30
	T. CONTROL	0.33±0.57	1.33±1.52	3.00±1.73	5.00±1.00	6.33±1.52	7.66±2.08
	TRICHODER.	0.66±0.57	2.00±1.00	3.66±1.15	5.33±0.57	7.00±1.00	9.33±1.00
TARNATSI	F. CONTROL	0.00±0.00	0.00±0.00	0.00±0.00	1.00±0.00	1.66±0.57	3.00±1.00
	FERTILIZER	0.00±0.00	0.00±0.00	0.00±0.00	1.66±0.57	2.66±0.57	4.66±0.57
	T. CONTROL	0.00±0.00	0.00±0.00	0.00±0.00	1.33±0.57	3.33±1.52	4.00±2.64
	TRICHODER.	0.00±0.00	0.00±0.00	0.33±0.57	2.33±0.57	4.66±0.57	7.00±1.00
PV	VARIETY	0.04	0.00	0.00	0.00	0.00	0.00
	TREATMENT	0.00	0.06	0.30	0.00	0.00	0.00
	INTERACTION	0.10	0.35	0.73	0.41	0.69	0.67

Keys: WAP = Weeks after planting, Improved varieties = Nerica and Sippi, Local varieties = Jamila and Tarnatsi

Discussion: *Trichoderma* is one of the fungal genera in agriculture best known for promoting germination, improving growth and for biological control of plant diseases (Benítez *et al.,* 2004). This genus colonizes roots and provides signaling to147the plants to trigger the production of growth regulators and to induce systemic resistance to pathogens (Sharma *et al.*,2017). The early germination, better plant architecture, higher panicle number, longer panicle length, and increased plant height recorded from the *Trichoderma* inoculated rice plants than the NPK treated rice was in corroboration with the findings of Diánez - Martínez *et al.* (2016) which reported similar results. Seed priming allows the early DNA transcription and RNA and protein synthesis which repair the damaged parts of the seed and reduce metabolic exudation and ultimately improve seed germination characteristics and the seedling emergence (Islam *et al.,* 2012). Anwar *et al.* (2013) reported that rice seeds respond to seed priming in the early part of the germination stage and stated that it can increase seed germination rate percentage and germination speed. Plant-growth-promoting fungi (*Trichoderma)* are supported by having more access to organic matter in the soil, while inorganic fertilizers can have a detrimental effect on these soil microbes, e.g., by altering the soil pH (Debbarma *et al*., 2015).

Conclusion: *Trichoderma sppp.* has the potential to enhance the rate of germination and yield in rice seeds, besides reducing loses due to delayed germination. *Trichoderma spp.* also contribute to plants' growth and development traits regardless the variety used whereas treatments with NPK fertilizer seen to have detrimental effects especially when rain is insufficient.

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A Study on the Tree Species Diversity of Billiri Local Government Area, Gombe State, Nigeria

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Abstract
A study was conducted on the tree species diversity of Billiri local government area, Gombe state, Nigeria was with the aim of evaluating the tree species diversity with their diversity and relative density. Systematic random sampling method was used to sample the tree species in order to generate data. Twelve (12) families and twenty - eight (28) tree species were identified. The tree species Azadirachta indica had the highest density value (3.468), while density lowest value was recorded in Vitex doniana, Ficus syncomorus, Anacardium occidentalis and Tectona grandis with (0.662). Azadirachta indica had the highest relative density value (23.467%), while the vitex doniana, Ficus syncomorus Anacardium occidentalis and Tectona grandis had the lowest relative density value (0. 422). However, Vitex doniana, Ficus syncomorus, Anacardium occidentalis and Tectona grandis required high conservation measures.

Keywords: Tree Species, Diversity, Density, Relative Density, Billri.

Introduction: Trees provides human with an array of products that play important roles in human general well-being and economic life (Omofonmwan and Osa-Edoh, 2008). They provide goods and services, including food, water, shelter, nutrient cycling and cultural and recreational values (Malaka, 2011). Trees also store carbon, provide habitat for a wide range of species and help alleviate land degradation and desertification. Trees were estimated to provide approximately 6 billion people with food, medicines, fuel and other basic necessities (Millennium Ecosystem Assessment, 2005). About 6% of the earth's land area was once covered by trees but due to the explosive use of land for agriculture, dam construction, urbanization and industrialization, these trees are cut down (Malaka, 2011). The role of population in deforestation is a contentious issue (Sands, 2005). The impact of population density on deforestation has been a subject of controversy. Poverty and overpopulation are believed to be the main causes of excessive loss of trees (Omofonmwan and Osa-Edoh, 2008). Therefore**,** this study is focused on the tree species diversity of Billiri local government area, Gombe state, Nigeria.

Materials and Methods; The study was conducted at Billiri Local Government Area (LGA), Gombe State. Billiri LGA lies within Latitude 9°50' and 11°09''N and Longitude 9.833°and 11.150°E. It covers an area of 737km² and is 50 km away from Gombe the capital city. The vegetation was extensively surveyed in other to determine the patterns of trees species diversity across various landscapes, (systematic line transects) was used to generate data on the tree's diversity. Using Bullock, (1996) method, two parallel line transects of 1000m in length were established and the distance between the transect line was 500m, using GPS, ranging pole, flagging tape and meter tape. Sampling plots of 50 x 50m was laid in alternate direction along each transect at an interval of 200m, thus summing up to 4 sample plots per 1000 m transect and a total of 8 sample plots. Complete enumeration of trees species per plot was carried out and the trees were identified by their local and botanical names by the help of an experienced tree identifier. In few cases where a tree species cannot be identified; specimen of such tree was collected, preserved and taken to the herbarium section of Biological Science Department of Gombe State University, Nigeria for proper identification. Tree species diversity was estimated using the species density and relative density as described by Sugar *et al*. (2003).

$$Density\ (D) = \frac{\text{Number of individuals of a species in all the sample plots}}{\text{Total number of sample plots studied}}$$

$$Relative\ Density\ (RD) = \frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}}$$

Results
Twelve (12) families and twenty - eight (28) tree species were identified at Billiri LGS during the study (Table 1). The tree species *Azadirachta indica* had the highest density value (3.468), while density lowest value was recorded in *Vitex doniana, Ficus syncomorus, Anacardium occidentalis and Tectona grandis* with (0.662) each respectively. *Azadirachta indica* had the highest relative density value (23.467%), while the *vitex doniana, Ficus syncomorus Anacardium occidentalis* and *Tectona grandis* had the lowest relative density value (0. 422) respectively (Table 2).

2.748

Table 1: Families and Species of Tree Identified at Billiri Local Government Area Gombe State, Nigeria.

S/N	Families	Species
1.	*Caesalpinoceae*	*Senna siamea*
		Bauhinia rufescens
		Isobalina doka
		Piliostigma reticulatum
		Deterium microcarpus
2.	*Mimosaceae*	*Acacia sieberiana*
		Acacia nilotica
		Prosopis afiicana
		Parkia biglobosa
3.	*Moraceae*	*Ficus polita*
		Ficus plataphylla
		Ficus thonningi
		Ficus syncomoros
		Ficus spp
4.	*Palmae*	*Phoenix dactylifera*
		Hyphaena thebaica
		Borassus aethiopum
5.	*Meliaceae*	*Khaya senegalensis*
		Azadirachta indica
6.	*Com002Fbretaceae*	*Combretum nigricans*
		Anogeissus leiocapus
7.	*Anacardiaceae*	*Anacardium occidentalis*
		Mangifera indica
8.	*Myrtaceae*	*Psidium guajara*
9.	*Balanitaceae*	*Balanite aegyptica*
10.	*Bombacaceae*	*Adosonia digitata*
11.	*Papilionoiceae*	*Delonix regia*
12.	*Verbenaceae*	*Vitex doniana*

Table 4.3: Density and Relative Density of trees identified at Billiri Local Government Area Gombe State Nigeria.

Discussion: The highest species recorded from the families; *Mimosoideae* followed by *Caesalpiniodeae* and *Moraceae* was in agreement with the findings of Zhigila *et al.* (2016) which reported highest value for the sub-families *Caesalpiniodeae* and *Mimosoideae* in Kwashabawa Communities of Zamfara State Nigeria. The families were known as native species in most Savannah wood land in Africa. A similar observation was reported by Lucky *et al.* (2017) in North-Eastern Nigeria. The tree species with the highest density value (3.468) was *Azadirachta indica* (3.468) indicating that *Azadirachta indica* is the most abundant species, it might be due to the fact that *Azadirachta indica* is an invasive trees species which reproduces in large quantity and are dispersed by birds and bats that eat its fruits and its seedlings could germinate and grow in dense shade this species was widely distributed as a beneficial tree in the drier parts and was in consistent with the findings of Idris *et al* (2016). The lowest density value (0.662) was recorded in *Vitex doniana*, *Ficus sycomorus*, *Anacardium accidentalis* and *Tectona grandis*, there were deforested due to their economic importance and medicinal value. The highest relative density value (23.467%) was in *Azadirachta indica*, while the lowest value (0.422) was on the following species; *Vitex doniana*, *Ficus sycomorus*, *Anaccardium occidentalis* and *Tectona grandis* There were effected by land clearing for building, agriculture and other developmental activities taken place.

Conclusion

Twelve (12) families and twenty - eight (28) tree species were identified, tree species *Azadirachta indica* had the highest density, while density lowest was recorded in *Vitex doniana, Ficus syncomorus, Anacardium occidentalis and Tectona grandis*. *Azadirachta indica* also had the highest relative density, while the *vitex doniana, Ficus syncomorus Anacardium occidentalis* and *Tectona grandis* had the lowest relative density. There is need for afforestation programs, threatened tree species must be protected from extinction.

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		Density					**Relative Density**		
		Sites					Sites		
s/n	Species	I	II	III	IV	Total	I	II	III
1	*Acacia nilotica*	0.281				0.281	1.902		
2	*Anacardium occidentalis*		0.062			0.062		0.422	
3	*Acacia sieberiana*	0.312				0.312	0.845		
4	*Adansonia digitate*	0.531	0.531		0.25	1.312	4.791	4.791	
5	*Anogeisus leiocarpus*	0.093				0.093	0.634		
6	*Azadirachta indica*	1.25	1.843	0.125	0.25	3.468	8.436	12.473	0.845
7	*Balanite aegyptiaca*	0.343		0.156		0.500	2.325		1.057
8	*Borassus aethopum*	0.312	0.531	0.903		0.937	2.114	3.593	0.634
9	*Calotropis procera*	0.903				0.903	0.634		
10	*Delonix regia*				0.187	0.187			
11	*Ficus polita*	0.093	0.218			0.312	0.626	1.479	
12	*Ficus plataphylla*	0.093				0.093	0.634		
13	*Ficus sycomorus*	0.531	0.25			0.981	3.593	1.691	
14	*Ficus thonningi*		0.312			0.312		2.114	
15	*Fardberbia albida*	0.281			0.593	0.875	1.902		4.016
16	*Hyphaene thebaica*	0.062	0.062	0.031	0.031	0.187	0.422	0.422	0.211
17	*Hura crepitans*		0.093			0.093		0.634	
18	*Isobalina doka*		0.093	0.218		0.312		0.634	1.479
19	*Khaya senegalensis*	0.0937	0.468			0.562	0.634	3.171	
20	*Mangifera indica*	0.156	0.312			0.468	1.057	2.114	
21	*Parkia biglobosa*	0.875	0.8125	0.312	0.187	1.937	5.919	5.496	2.114
22	*Piliostigma reticulatum*			0.062	0.156	0.218			0.422
23	*Prosopis Africana*	0.218				0.218	1.479		
24	*Psidium guajava*		0.218	0.062		0.281		1.479	0.422
25	*Senna semea*	1.031				1.031	6.976		
26	*Techtona grandis*				0.062	0.062			
27	*Vitex doniana*		0.062			0.062		0.422	

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Sources of Climate Change Information Among Tomato Farmers in Kura Local Government Area of Kano State, Nigeria

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Introduction: The impacts of climate change have been experienced globally, especially in the tropics. These have triggered a wide variety of physical and biological changes across the world with negative effects on agriculture, humans, and the environment (Intergovernmental Panel on Climate change [IPCC], 2014). It is important to note that while the vulnerability to climate change impacts is higher in lower-middle- and low-income countries, particularly Africa, the readiness to improve resilience ranks very low in such countries (ND-GAIN, 2021). A recent report, for example, shows that Nigeria is one of the top ten of the most exposed countries to the effects of climate change, with about 6% of its land area estimated to be exposed to extreme weather events (World Bank, 2019).

Climate change impact is significant in this category as some regions of the country already suffer about a 20% decline in the cycle of growing days (Ebele and Emodi, 2016). Moreover, many forest resources are also gradually going extinct due to climate change impacts (Onyekuru and Marchant, 2016). The current format used for raw climate data makes it unclear how or even if they can be used at the farm scale. Use of past and future climate information offers the potential to enhance agricultural resilience to climate change through improved agricultural decision making, such as preparing for expected adverse or favorable conditions. Skills in climate model outputs have improved over time, and more recently, a set of climate change scenarios known as representative concentration pathways has been adopted by climate researchers to provide a range of possible futures for the evolution of atmospheric composition and implications on various sectors (Zahid and Iqbal, 2015; Deb *et al*., 2018).

While tomato industry is growing significantly worldwide, climate change poses many challenges. For example, temperature has a direct impact on growth and development of the crop and could significantly affect it yield. Tomatoes are an essential source of human nutrition and now globally recognised for nutritional security given its richness in micronutrient contents and improved awareness on healthy eating among people in recent times. In spite of numerous potentials of tomatoes economically, socially and nutritionally, still farmers in the study area are face with uncountable challenges such as poor information on climate change poor quality inputs, absence of precision agriculture, poor markets and price fluctuation, poor storage and processing facilities, etc. In view of the above, the study aimed at assessing sources information on climate change among tomato farmers in Kura local government area of Kano state, Nigeria. Specifically, the study intends to achieve the following objectives: Describe the respondents' level of knowledge on climate information in the study area; Describe the respondents' level of accessibility to extension agent in the study area; Describe tomato farmer's sources of information on climate change; Identify types of climate change information received by respondents in the study area; Identify the constraints faced by tomato farmers in accessing climate change information.

Methodology: This study was conducted in Kura Local Government area of Kano State, Nigeria. Major towns and villages in Kura LGA includes Dalili, Dukawa, Karfi, Kura, Gundutshe, Dan Hassan, Rigar Duka, Tanawa and Kurunsumau. The geographical coordinates of Kura LGA are 11° 46' 17" North, 8° 25' 49" East with an elevation of 447m above sea level. The LGA occupies an area of 202.7 km^2 with a population density of 1,161/km² and is characterized with an average temperature of 32ºC. The LGA has a population 235,300 predominantly occupied by members of the Hausa/Fulani ethnic group (National Population Commission, 2022) projected at 3.2% growth rate of 2006 National Population Census. The hottest month of the year in Kura is April, with an average high temperature of 101°F and low of 73°F. The cool season lasts for 1.8 months, from December 2 to January 27, with an average daily high temperature below 89°F. The coldest month of the year in Kura is January, with an average low temperature of 55°F and high temperature of 87°F. The *wetter season* lasts *4.5 months*, from *May* to *October*, with greater than *40%* chance of a given day being a wet day. The month with the most wet days in Kura is *August*, with an average of *24.2 days* with at least *0.04 inches* of rainfall. On the other hand. The *drier season* lasts *7.5 months*, from *October* to *May* (*Weather Park, 2023*).

The study used multi-stage sampling procedure in the selection of respondents. In the first stage, all the districts of the LGA were selected. In the second stage, five (5) wards in Kura LGA were proportionately and purposively selected. In the third stage, 15 tomato farmers were randomly selected from each of the five (5) wards to give a total number of 75 respondents. Questionnaire was used as an instrument for data collection. The questionnaire was designed based on the objectives of the study and comprises both open and close ended questions. Descriptive statistics was used to achieve the research objectives.

Results and Discussion: The result in Table 1 depicts respondents' level of knowledge on climate change in which 64.0% had moderate knowledge on climate change. This finding implies that some tomato farmers in the study area are aware on the changes in weather and climate. The finding agreed with that of Sanneh (2022) who reported that most of tomato farmers in Gambia had awareness of climate change impact.

Table 1: Distribution of Respondents Based on their Level of knowledge on Climate Change Information (n = 75)

Level of Knowledge	*Frequency*	*Percentage*
Low	14	18.7
Medium	48	64.0
High	13	17.3

Source: Field Survey, 2022

Respondents' Access to Extension Agents and Frequency of Extension Visit: As shown in Table 2 majority (60.0%) of the respondents have no access to extension agents while substantial proportion (40.0%) had access to extension agent. Access to extension agents implies ability of the farmers to receive information on Good Agronomic Practices (GAP) which in turns helps in improving the productivity and wellbeing of the farmers. In addition, access to extension is expected to enhance farmers' level of awareness on climate change. Although, extension contact was relatively low in the study area as more than half of the respondents had no access to extension agents. This buttressed the results in Table 2 where most of the farmers had moderate knowledge on climate change issues in the study area. The finding is closely related with that of Emenyonu *et al.* (2020) who found that majority of the respondents had no access to extension agents in Anambra State, Nigeria. The finding in Table 2 also shows that more than half (56.7%) of the respondents received extension visit annually. This implies that frequency of extension visit was not evenly distributed in the study area.

Table 2: Distribution of Respondents Based on their Access to Extension Agent and Frequency of the Extension Visit (n = 75)

Variable	Frequency	Percentage
Access to Extension Agents		
Yes	30	40.0
No	45	60.0
Frequency of Extension Visit (n= 30)		
Weekly	1	3.3
Fortnightly	4	13.3
Monthly	2	6.7
Quarterly	4	13.3
Semi-annually	2	6.7
Annually	17	56.7

Source: Field Survey, 2022

Respondents' sources of information: The finding in Table 3 reveals that 25.3% and 24.0% of the respondents sourced their information from radio and extension agent, respectively. Respondents that sourced their climate change information from co-farmers, television, inputs dealers, constitute 18.7%, 13.3% and 10.7%, respectively. The result is an indication that there is a social tie among the respondents in the study area. The result agreed with Agesa *et al.* (2019), who reported that, main source of information on climate change for the farmers in Yatta sub-County, Ghana was through extension officers with most of them identifying more than one source of information.

Table 3: Distribution of Respondents Based on their Source of Information (n = 75)

Variable	Frequency	Percentage*
Source of Information		
Extension agent	28	37.33
Inputs dealers	19	25.33
Radio	49	65.33
Television	31	41.33
Internet	14	18.67
Co-Farmers	34	45.33
Cooperatives	13	17.33

Source: Field Survey, 2022 *Multiple responses

Type of climate change information received by the respondents

As shown in Table 4, the key types of climate change information received by the respondents were on changes in weather condition (37.3%), flooding (21.3%) and increase in pest infestation (14.7%) among others. This finding translates that most of the farmers in kura LGA identifying multiple type of climate change information. The result agreed with Recha *et al*. (2017) who reported that, food security, water and other key natural resources may be threatened by climate change in Taharaka, Eastern Kenya.

Table 4: Distribution of Respondents Based on the Type of Climate Change Information Received (n = 75)

Type of climate change information received	Frequency	Percentage*
Changes in weather conditions	51	68.00
Seasonal variability changes	32	42.67
Flooding	35	46.67
Excessive increase in temperature	13	13.33
Increase in pest infestation	31	41.33
increase in disease infection	12	16.00
Impeding food insecurity	14	18.67

Source: Field Survey, 2022 *Multiple responses

Constraints faced by Tomato Farmers in Accessing Climate Change Information : The major constraints faced by tomato farmers in accessing climate change information include lack of access to extension services (66.7%), inadequate information about climate change (58.7%) and poor access to modern climate change adaptation strategies (56%) which were ranked 1st, 2nd and 3rd, respectively. The 4th and 5th constraints were inadequate knowledge about appropriate measures and poor internet services respectively. The result is in line with Agrawal and Perrin (2009) who reported that the major problems faced by farmers were lack of access to modern climate change adaptation strategies and lack of access to extension services in Lorenzoni of the United Kingdom. Similarly, Adishi and Oluka (2018) observed that in Nigeria, adequate information and adaptation strategies should be provided to farmers in order to curtail the effect of climate change on crop production.

Table 5: Distribution of Respondents Based on their Constraints to Climate Change Information (n = 75)

Constraints	Frequency	Percentage*
Poor access to extension services	50	66.7

Lack of adequate information about climate change	44	58.7
Poor access to modern climate change adaptation strategies	42	56.0
Inadequate knowledge about appropriate measures	41	54.7
Poor internet services	39	52.0
Inadequate infrastructure such as electricity	36	48.0
Low level of education	35	46.7
Gender issues	29	38.7

Source: Field Survey, 2022 *Multiple responses

Conclusion: The study concluded that tomato farmers had awareness on climate change and most sourced climate change information through radio, fellow farmers and television in the study area. In addition, the study also concluded that the major constraints to climate change information include lack of access to extension services, lack of adequate information about climate change and lack of access to modern climate change adaptation strategies. The study therefore recommends the operationalization of private extension services and promotion of climate change programmes in radios and other media to improve farmers' awareness. In addition, smart adaptation strategies should be promoted to enhanced farmer's resilience to climate emergencies in the study area.

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Mitigating Post-Harvest Losses of Tomatoes in Barkin-Ladi Local Government Area, Plateau State, Nigeria: An Examination of Handling Techniques.

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Abstract

This research examines strategies to minimize post-harvest tomato losses in Barkin-Ladi Local Government Area, Plateau State, Nigeria. The study aimed to determine the factors contributing to post-harvest tomato losses, analyze the impact of socio-economic factors on these losses, and identify barriers to implementing effective post-harvest handling strategies. A survey of 140 tomato farmers in Barkin-Ladi Local Government Area used structured questionnaires and interviews. The result of the findings revealed that Sun drying is the most common post-harvest handling practice (70.5%), Storage facilities (87.9%) and packing/packaging (41.7%) are major concerns and that educational level significantly influences farmers' involvement in tomato production. Chi-Square analysis reveal that although educational level influences farmers' involvement in tomato production, surprisingly, it does not significantly mitigate post-harvest handling constraints. The study revealed key challenges that persist in the handling post-harvest loss as poor extension services, harvesting/field handling, and transportation persist. This study suggests that agricultural education and training initiatives can equip farmers with the knowledge to adopt cutting-edge technologies and optimal practices, enhancing their overall well-being, and advocates for enhanced tomato quality through effective sorting, grading, and handling procedures. Enhance agricultural education, capacity building, and extension services. Invest in storage facilities, packing systems, and training on best practices.

Key words: Post-Harvest Losses, Tomato Production, Handling Techniques, and Food Security.

Introduction: Tomatoes are one of the most widely consumed fruits globally (FAO, 2022), with over 180 million metric tons produced annually. Nigeria, being the 14th largest producer worldwide, accounts for approximately 2.3 million metric tons of tomato production per year (FAOSTAT, 2022). As a significant contributor to the country's agricultural sector, tomato production plays a vital role in ensuring food security and economic stability for rural communities (Oladipo et al., 2020). In Nigeria, tomato production is a major source of income for many farmers, particularly in the northern regions where the crop is predominantly grown (Usman et al., 2020). The country's tomato industry provides employment opportunities for thousands of people, from farmers to processors and traders. Tomato production also contributes significantly to Nigeria's GDP, with the crop valued at over ₦100 billion annually (CBN, 2020). Tomatoes are not only an economic powerhouse but also a nutrient-dense food, rich in essential vitamins, minerals, and antioxidants. A medium-sized tomato (122g) is an excellent source of energy, protein, fiber, vitamin C, vitamin A, potassium, and lycopene, a powerful antioxidant with anti-cancer properties, providing approximately 22 kcal of energy and 28% of the daily recommended intake of vitamin C (Slimestad et al., 2020). The major tomato-producing states in Nigeria include Kaduna, Kano, Jigawa, and Plateau, with Barkin-Ladi Local Government Area being one of the key production hubs (Oladipo et al., 2020). The region's fertile soil, favorable climate, and abundant water supply make it an ideal location for tomato cultivation.

However, despite the importance of tomato production in Nigeria, post-harvest losses continue to hinder the full potential of the industry, particularly in Barkin-Ladi Local Government Area, Plateau State. Post-harvest losses, estimated to range between 20-50% of total production (Kummu et al., 2021; Olayinka et al., 2022), result from inadequate handling techniques, inefficient transportation systems, and limited knowledge of proper preservation methods. This study aims to investigate the mitigating strategies for post-harvest losses of tomatoes in Barkin-Ladi Local Government Area. Specifically, the research seeks to identify the primary modes of conveying tomatoes from farm to market, determine the causes of post-harvest losses in tomato production and identify constraints hindering the adoption of better post-harvest handling strategies.

Statement of the problem: Tomato production in Barkin-Ladi Local Government Area, Plateau State, Nigeria, is plagued by high post-harvest losses (20-50% of total production), resulting from inefficient handling techniques, inadequate transportation, and limited knowledge of preservation methods. This leads to economic losses, food insecurity, reduced productivity, limited market opportunities, and negative impacts on rural livelihoods. The lack of effective mitigation strategies and limited research on the specific challenges facing this region exacerbate the problem. This study aims to address this knowledge gap by examining handling techniques, identifying effective strategies to reduce post-harvest losses, and understanding the causes, socio-economic factors, and constraints influencing these losses. The overall objective is to develop practical solutions to improve tomato productivity, food security, and economic stability for rural communities.

Research Objectives: The general objective of the study is to examine the handling techniques of post-harvest losses of tomatoes in Barkin-Ladi Local Government Area, Plateau State, Nigeria. To identify the causes of post-harvest losses in tomato production, To examine the influence of Socio-economic characteristics on post - harvest losses and

Identify the constraints of adopting better strategies on handling post-harvest losses.

Test of Hypothesis

H_0: There is no significant relationship between educational level and constraints to post harvest handling practices of tomato production.

H_a: There is significant relationship between educational level of respondents and constraints to post harvest handling practices of tomato production.

Methodology: The study was conducted in Barkin-Ladi Local Government Area, Plateau State, Nigeria, with its headquarters in Barkin-Ladi town (latitude 9°32'00" N, longitude 8°54'00E). Spanning 1,032 sq, the area had a population of 175,267 according to the 2006 census. It borders Jos-South LGA to the east, Bokkos LGA to the south, and Mangu LGA to the west. The region receives rainfall from April to June, averaging 1,125 mm annually. The soil is generally deep, well-drained, and diverse, including sandy, loamy, clay, and patchy silt loam, supporting various crops such as maize, potatoes, beans, rice, groundnuts, sorghum, and yam. The study targeted four high tomato-producing districts (Gashishi, Zabot, Gindi Akwati, and Kura Falls) out of 14. A purposive sampling method selected 35 respondents from each village, aided by an extension agent, yielding a total sample size of 140. Primary data were gathered through structured questionnaires and interviews conducted by extension agents. Descriptive statistics (means, percentages, standard deviation, frequencies) and multiple regression analyses were employed.

Results and Discussions

Table 1: Post Harvest handling Practices

Post harvest process	Frequency (140)	Percentage
Sun drying	69	70.5
Sorting	23	14.1
Grinding & Boiling	33	24.1
Refrigerating	15	0.8

Sources: Field Survey, 2024 Multiple Selection

The results presented in Table 1 reveal the post-harvest handling practices employed by tomato farmers in Barkin-Ladi Local Government Area. Sun drying is the most common method used (70.5%), likely due to its simplicity and low cost. Sorting is employed by only 14.1% of farmers, indicating a lack of emphasis on quality control. Grinding and boiling (24.1%) may help reduce losses, but its effectiveness depends on proper handling and processing. Notably, refrigeration is used by only 10.7% of farmers. These findings suggest an over-reliance on sun drying, potentially leading to losses. The low adoption of sorting and refrigeration practices compromises tomato quality. This aligns with Olayinka et al. (2014), who found that sun drying is a common method used by tomato farmers in Nigeria, but noted its limitations in preserving quality. To address these challenges, improving access to cold storage facilities, promoting proper sorting and grading techniques, and exploring alternative drying methods (e.g., solar dryers) are recommended.

Table 2: Socioeconomic factors influencing farmer's involvement in tomato production.

Coefficients[a]

Model		Unstandardized coefficients B	Std. error	Standardized Coefficients Beta	T	Sig
1	**(constant)**	3.634	.944		3.849	.000
	Sex	.271	.249	.117	1.090	.278
	Age	-.111	.151	-.114	-.739	.461
	Marital status	.211	.171	.128	1.231	.221
	Household size	-0.172	.186	-.133	-.924	.358
	Educational level	2.175	.069	.246	2.541**	.012
	Farming Experience	0.084	.279	.042	.303	.763
	Farm size	-0.052	.224	-.032	-.230	.819
	Source of income	0.024	.162	-.015	-.147	.883

Source: Field Survey, 2024

Multiple regression analysis was conducted to identify the factors affecting farmers' participation in tomato production. The results were R = 0.351, $R^2 = 0.123$, and Adjusted $R^2 = 0.059$, indicating that the model accounts for 12.3% of the variability in farmers' involvement.

The unstandardized coefficients (B) are Sex (0.271, positive), Age (-0.111, negative), Marital Status (0.211, positive), Household Size (-0.172, negative), Educational Level (2.175, positive), Farming Experience (0.084, positive), Farm Size (-0.052, negative), and Source of Income (0.024, positive).

Only educational level was statistically significant (p = 0.012), while household size (p = 0.358), farming experience (p = 0.763), farm size (p = 0.819), and source of income (p = 0.883) were not significant. The findings indicate that educational attainment increases the likelihood of farmers engaging in tomato production. This finding is consistent with Oladejo and Adebayo (2014), who suggested that education improves farmers' capacity to adopt innovative technologies, manage their farms effectively, and make informed decisions.

Table 3: Constraints faced in post-harvest handling practices of tomato

Post harvest process	Frequency	Percentage
Storage facilities	94	87.9
Packing & Packaging	78	41.7
Transportation	26	11.7
Market Handling	19	9.2
Harvesting & Field Handling	42	23.8
Poor Extension Service	32	29.2

Source: Field Survey 2024 **Multiple responses**

Table 3 reveals that storage facilities (87.9%) are the most pressing concern, followed by packing/packaging (41.7%), harvesting/field handling (23.8%), poor extension services (29.2%), transportation (11.7%), and market handling (9.2%). Notably, inadequate storage facilities and packing/packaging are primary concerns, while poor extension services and harvesting/field handling issues persist. Transportation and market handling are relatively less significant.

This finding aligns with Olayide, Ibrahim and Ogunsumi (2013), who reported that inadequate storage facilities, poor handling practices, and limited extension services are major constraints facing tomato farmers in developing countries.

Table 4: Chi-Square Analysis of the Relationship between Educational Level and Constraints to Post-Harvest Handling Practices in Tomato Production

Chi-Square Test		
Educational level	chi-square	51.841
	df	.40
	sig	.099

(X^2= 51.841, P=0.099

Table 4 presents the results of the Chi-Square analysis examining the relationship between educational level and constraints to post-harvest handling practices in tomato production. The result shows that Chi-Square value (X^2) is 51.841, Degrees of Freedom (df) 4 and Significance level (P-value) 0.099. The Chi-Square test results indicate that the relationship between educational level and constraints to post-harvest handling practices in tomato production is not statistically significant (P = 0.099). Since the P-value exceeds the conventional significance level of 0.05, we accept the null hypothesis (H_0) that there is no significant relationship between educational level and constraints to post-harvest handling practices. This suggests that educational attainment may not be a determining factor in mitigating post-harvest handling constraints in tomato production.

Conclusion: This study investigated the post-harvest handling practices and losses of tomatoes in Barkin-Ladi Local Government Area, Plateau State, Nigeria. The findings revealed significant constraints hindering the tomato industry's potential, including inadequate storage facilities, poor packing and packaging, limited extension services, and inefficient transportation systems. The study's results underscore the importance of addressing these challenges to enhance tomato productivity, food security, and economic stability for rural communities. Specifically, improving storage facilities, promoting proper handling and packaging techniques, and strengthening extension services can significantly reduce post-harvest losses. Contrary to expectations, the analysis revealed no significant relationship between educational level and constraints to post-harvest handling practices (P = 0.099). This suggests that educational attainment may not be a determining factor in mitigating post-harvest handling constraints in tomato production.

Recommendations: Farmers should improve tomato quality by sorting and grading, using solar dryers, storing in shade or breathable bags, handling gently to avoid bruising, and attending post-harvest training. The Ministry of Agriculture should create agricultural education and training for farmers, allocate resources for capacity building, emphasize innovative technologies, enhance extension services, establish vocational training centres, provide modern farming courses, and collaborate with NGOs and the private sector for better resources and expertise. The Minister of Agriculture should focus on investing in storage facilities, expanding rural storage, improving packing systems, and training on best practices to enhance tomato production and reduce losses. The government should develop a comprehensive support system for farmers by implementing targeted training programmes focusing on post-harvest handling practices, strengthening extension services to provide technical support, and promoting access to technology and innovative solutions

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Antimicrobial and Molecular Docking Studies of Methanol Leaf Extract of *Allamanda cathartica* Against *Pseudomonas aeruginosa*

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Abstract

Pseudomonas aeruginosa is an opportunistic pathogen which affects immunocompromised patients. The pathogen is resistant to most antibiotics which are effective against other micro-organisms and this calls for the need for a new and effective drug discovery in the scientific world against it. The aim of this research work was to carry out antimicrobial and molecular docking studies of methanol leaf extract of Allamanda cathartica against P. aeruginosa. The experimental groups include 25, 50, 100, 200 mg/mL of the plant extract and 5 mg/mL of penicillin standard drug as the control. The result of the antimicrobial activity showed that methanol leaf extract of the plant sample inhibited the growth of P. aeruginosa at a zone of 12.7±0.15 mm diameter by 25 mg/mL extract, 16.7±0.25 mm by 50 mg/mL extract, 20.0±0.17 by 100 mg/mL extract, 23.3±0.25 mg/mL by 200 mg/mL extract and 13.50±0.26 by 5 mg/mL penicillin standard drug. The molecular docking studies showed that androst-5,15-dien-3ol acetate and campesterol gave higher docking scores of -10 and -7 than penicillin standard drug, with docking score of -6.9. Two other compounds from the plant extract (gamma sitosterol and stigmastrerol) with docking scores of -6.8 and -6.8 expressed close docking scores with pecinillin. Based on the results expressed by this plant sample, methanol leaf extract of A. cathartica contains promising compounds that could serve as drugs against P. aeruginosa.

Keywords: *Allamanda cathartica*, Antimicrobial, *Pseudomonas aeruginosa*, Zone of Inhibition, Minimum Inhibitory Concentration (MIC), Minimum Bactericidal Concentration (MBC)

Introduction: *Pseudomonas aeruginosa* is a gram-negative bacterium commonly found in water, soil, vegetation and hospitals. The pathogen is known as an opportunistic human pathogen, causing infections in people with underlying health conditions (Mooney *et al*., 2022). *P. aeruginosa* infection can range from mild to severe, and they can occur in various parts of the body. **It is known as the leading cause of morbidity and mortality in cystic fibrosis patients and as one of the leading causes of nosocomial infections (infections acquired from hospitals) (**Moradali *et al*., 2017**).** *P. aeruginosa* can cause respiratory infections, especially in people with cystic fibrosis (CF) or chronic obstructive pulmonary disease (COPD). In cystic fibrosis patients, the bacterium can colonize the lungs, leading to chronic lung infections (**Malhotra *et al*., 2019**). The pathogen can cause urinary tract infections (UTIs) in people with urinary catheters or other urinary tract abnormalities. The urinary tract infections caused by this pathogen can be challenging to treat due to the resistance ability of this pathogen to many antibiotics. *Pseudomonas aeruginosa* can infect wounds, burns, and surgical sites, especially in healthcare settings and in moist environments (Abdi *et al*., 2024). The pathogen is often resistant to antiseptics and disinfectants, making it a highly challenging pathogen.

The ability of *P. aeruginosa* to thrive in diverse environments increases *P. aeruginosa* reservoirs and the possibility for exposure, leading to higher incidence of infections (Wood *et al*., 2023). This pathogen has been isolated from hot tubs, humidifiers, and soils (Howard and Inglis, 2003), while in the hospitals, it has been isolated from respirators, physical therapy pools, sinks, and mops (Pollack, 2003). Patients have also been reported to serve as sources of infection in hospitals (Wood *et al*., 2023). Due to its high versatile and virulent nature, the pathogen is responsible for many serious infections, particularly in immunocompromised hosts (Osmon *et al*., 2004).

A. cathartica (L.) is an ornamental plant in the *Apocynaceae* family. It is an evergreen, vine like woody shrub, which may reach a freestanding height of about 2 meters or more. It is native to South and Central America. The all-year-round production of its bright flowers has made it a popular ornamental (Fabiyi *et al*., 2013). *A. cathartica* is commonly referred to as Allamanda, Golden trumpet, Yellow Bell, Buttercup flower. It is called by different names in different regions such as Allokananda and Fok kaia in Bangladesh, Bunga Terompet in Indonesia, Allamonda, nkutu and ako-dodo (Yoruba) in Nigeria (Iyamah and Idu, 2015).

The extract of *Allamanda* has been indicted in treatment of snake bites, because of its anti-haemorrhaging properties (Knowles, 1993). Various medicinal properties have been attributed to the plant, few of which include its purgative effect, anti-venom, ascites as well as anti-inflammatory and constipation causing properties (Petricevich and Abarca-Vargas, 2019). The aqueous extract of the plant has been reported to be used for the treatment of malignancy, bacterial and fungal diseases and relief from acute abdominal pain. Fartyal (2016) reported the antimicrobial activities of the extracts against *Candida albicans*, *Tricophyton mentagrophyte*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Proteus mirabilis*. Till this present moment, no report has been published on the effect of methanol leaf extract of *A. cathartica* and its molecular docking studies against *P. aeruginosa*. This research, therefore, focused on the effect of the methanol leaf extract of *A. cathartica* against *P. aeruginosa* and its molecular docking studies.

Materials and Methods: Materials : Plant Material: The leaves of *A. cathartica* was obtained from Sherri Hills, Jos South Local Government Area of Plateau State. A sample of the plant was deposited at the herbarium of Federal College of Forestry, Jos, for proper identification, where a voucher number (FH-11735) was obtained.

Equipment and Reagents: Incubator (11400-3), autoclave (MSLPS18), waterbath (Model: H H-420 PEC), 70% methanol, H_2SO_4, $FeCl_3$, ammonia, chloroform, benzene, sodium hydroxide, ninhydrin, benedicts reagent, hydrochloride, ammonium chloride, Molisch reagent, test tubes, distilled water etc. The softwares used for the molecular docking include Chimera (1.14-win 64), Pyrex (version 0.8) and Discovery studio (DS-2021).

Strain of *P. aeruginosa*: The strain of the organism (*P. aeruginosa*) was obtained from National Verterinary Research Institute (NVRI), Vom and was kept in a slant culture of cold nutrient agar in the Biology laboratory, Federal College of Forestry, Jos.

Methods: Extraction of Plant Sample: The fresh leaf sample was harvested and washed under running tap water until it was free of dirts. The sample was drained-off water and air dried at room temperature on the slab in Chemistry laboratory. It was pulverized using mortar and pestle and sieved to obtain finely divided sample. The sample was then stored in an air-tight container until when needed.

Sub-Culture and Inoculation: The organism was isolated from the pure culture and sub-cultured onto a nutrient agar using streak method under sterile conditions. The sub-cultured isolate was then kept in an incubator at 37^0C for 24h to enable for resuscitation of the organism. The sub-cultured plate was used for inoculation of the organism on the test plates after microscopic confirmation.

Antimicrobial Activity: The antibacterial activity of methanol leaf extract of *A. cathartica* against *P. aeruginosa* was carried out at the Biology Laboratory, Federal College of Forestry, Jos using the method described by Eghomwanre *et al*. (2016). This was done by using the hole-borer disk diffusion method. The plant extract was prepared into different concentrations (25 mg/mL, 50 mg/mL, 100 mg/mL and 200 mg/mL and 5 mg/mL penicillin). The bacteria isolate was then suspended in the Mueller - Hinton agar plates in nutrient agar under sterile condition. A cork-borer was sterilized by autoclaving at 121^0C for 15 minutes. The pure culture of the organism was taken from a slant bottle and used to inoculate agar sample which was then used to inoculate the different treatments using streak method. The cork was then used to bore holes on the agars under sterile condition after which 1 mL of each treatment of the extract and standard drugs were filled into each of the holes. The growth of the *P. aeruginosa* from the different concentrations of the plate was examined and the zone of inhibition measured to see which concentration has better growth inhibition.

Determination of Minimum Inhibitory Concentration (MIC): The determination of the minimum inhibitory concentration of *A. cathartica* was carried out using the broth dilution method, as described by Ibekwe *et al*. (2001). A Muller-Hinton broth was used to prepare a two-fold dilution of the extract. Extract stock solution was prepared at a concentration of 20 mg/mL and used to prepare 10, 5 and 2.5, 1.25 mg/mL respectively through serial dilution. Exactly 0.1 mL inoculum of the pathogen was then inoculated onto the tubes and the content incubated at 37^0C for 24 hours. The plates were observed for any growth of the pathogen and the least concentration of the extract without growth was taken as the minimum inhibitory concentration.

Determination of Minimum Bactericidal Concentration (MBC): Minimum bactericidal concentration of the extract was carried out using the method described by Parvekara *et al*. (2020). The different concentration tubes in the MIC that did not show bacteria growth, i.e no turbidity was observed, were sub-cultured onto nutrient agar. The tubes were then incubated at temperature of 37^0C for 24 hour to examine them for any possible turbidity. The least concentration with no bacteria growth was tagged minimum bactericidal concentration.

Molecular Docking Study: Molecular docking was carried out to examine the affinity of the different compounds for the active site of the protein (*P. aeruginosa*). The method described by Ali *et al*. (2017) was used. The 3-dimensional (3-D) structure of the compounds in the plant sample from a GC-MS screening was docked against the 3-dimensional (3-D) structure of the *P. aeruginosa* protein.

Protein and Ligand Preparation: The protein with a PDB ID of 1RO5 was retrieved from protein data bank (www.rcsb.org) and prepared by removing non-standard molecule and water molecules and adding charges and ions with the use of Chimera (version 1.1.4). The ligands were downloaded in their sdf format from PUBChem repository website (www.pubchem.ncbi.nlm.nih.gov) and prepared by converting them from their structural data file format (SDF) to PDB format using chimera.

Docking of Protein with Ligands: The prepared protein was uploaded to Pyrex software and converted to pdbqt format while each of the ligands were also uploaded to pyrex and converted to pdbqt format, the preferred format by pyrex. The protein and ligands were forwarded onto Vina Wizard and their grid box dimensions adjusted (X = 50.4727, Y = 45.7641 and Z = 46.2850). The vina wizard was allowed to pick 8 exhaustive binding pockets and allowed to commence the docking.

Statistical Analysis: Data collected from the zone of inhibition for each of the concentrations were subjected to analysis of variance (ANOVA) with the use of Statistical Package for Social Sciences (SPSS), Version 23. One Way Analysis of variance (One Way ANOVA) was used to test the statistical difference between the zone of inhibition of the pathogen for each of the treatment and that of the standard drug and where statistical difference occurred between the means, Tukey's test was employed in separating the means. All *p*-values were taken to be significant at $p \leq 0.05$.

Results and Discussion: Results: Antimicrobial Activity: The result of the antimicrobial activity of *A. cathartica* is presented in Figure 1. The result showed that significant difference ($p \leq 0.05$) occurred among the different concentrations of the plant sample against *P. aeruginosa*. The 25 mg/mL extract cleared the organism at a zone of 12.7±0.15 mm diameter which is significantly different from the zone of inhibition observed in 50 mg/mL (16.7±0.23). At concentrations of 100 mg/mL and 200 mg/mL with mean values of 20.0±0.17 and 23.3±0.25 respectively, the result showed significant difference between them. However, the result of the standard drug (5 mg/mL ampicillin) showed a mean value of 13.5±0.26 which is statistically different from the different concentrations of the plant extract except for that of 25 mg/mL whose results are statistically similar.

Figure 1: Zone of Inhibition of *P. aeruginosa* by Methanol Leaf Extract of *A. cathartica*

Minimum Inhibitory Concentration: The result of the minimum inhibitory concentration of the plant extract is given in Table 1. Based on the effectiveness of the extract at 25 mg/mL, the minimum inhibitory concentration was tested at range of 5 mg/ml to 0.625 mg/ml. the result showed the presence of the pathogen at 5 mg/ml and 2.5 mg/ml, but not at 1.25 mg/ml. therefore, the MIC of the plant against *P. aeruginosa* is 1.25 mg/mL. The result of the minimum bactericidal concentration showed that no turbidity was observed at 1.25, 0.625 and 0.3125, therefore, the minimum concentration with no further bacteria growth is 1.25 mg/mL and it was taken as the minimum bactericidal concentration.

Molecular Docking of *A. cathartica* against *P. aeruginosa*: The result of the molecular docking (Table 2) showed that the compounds in the methanol leaf extract of *A. cathartica* bound favourably well with the active site of *Pseudomonas aeruginosa*. In relation to the standard drug (penicillin), whose binding affinity to the protein is -5.9, two compounds (Androst-5,15-dien-3ol acetate and Campesterol) gave higher binding affinity than penicillin, indicating its possible drug-likeness ability for the treatment of *P. aeruginosa*. Androst-5,15-dien-3ol acetate gave a docking score of -10, while campesterol gave a docking score of -7. Other compounds with high binding affinity include stigmasterol (-6.8) and gamma-sitosterol (-6.8).

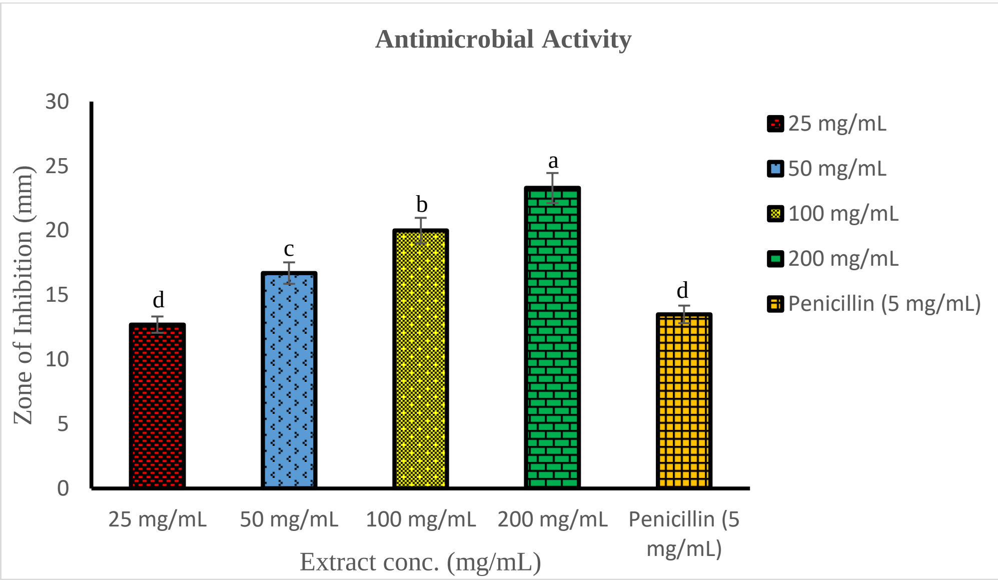

Table 1: MIC and MBC of *A. cathartica* against *P. aeruginosa*

Extract Concentration (mg/mL)	MIC	MBC
5 mg/mL	+	
2.5 mg/mL	+	
1.25 mg/mL	Nil	Nil
0.625 mg/mL	Nil	Nil
0.3125 mg/mL	Nil	Nil

Table 2: Molecular Docking Interaction of the Ligands and *P. aeruginosa*

Protein interaction with Ligand	Binding Affinity
P. aeruginosa _Androst-5,15-dien-3ol acetate	-10
P. aeruginosa _Campesterol	-7
P. aeruginosa _Penicillin	-6.9
P. aeruginosa _Gamma-Sitosterol	-6.8
P. aeruginosa _Stigmasterol	-6.8
*P. aeruginosa*_Delta Tocopherol	-6.2
P. aeruginosa _Pentadecanoic acid	-6

P. aeruginosa _gamma-tocopherol	-6
P. aeruginosa _ 1,6-Dimethyl-9-(1-methylethylidene)-5,12- dioxatricyclo[9.1.0.0(4,6)]dodecan-8-one	-6
P. aeruginosa _ Methoxyacetic acid, 10-undecenyl ester	-5.8
*P. aeruginosa*_ n-Hexadecanoic acid	-5.6
P. aeruginosa _1,2-Epoxy-5,9-cyclododecadiene	-5.6
P. aeruginosa _3-Octyne-6-methyl	-5.3
P. aeruginosa _ 9,17-Octadecadienal, (Z)-	-4.8

N.B: the negative sign preceding the binding affinity indicates an exothermic reaction

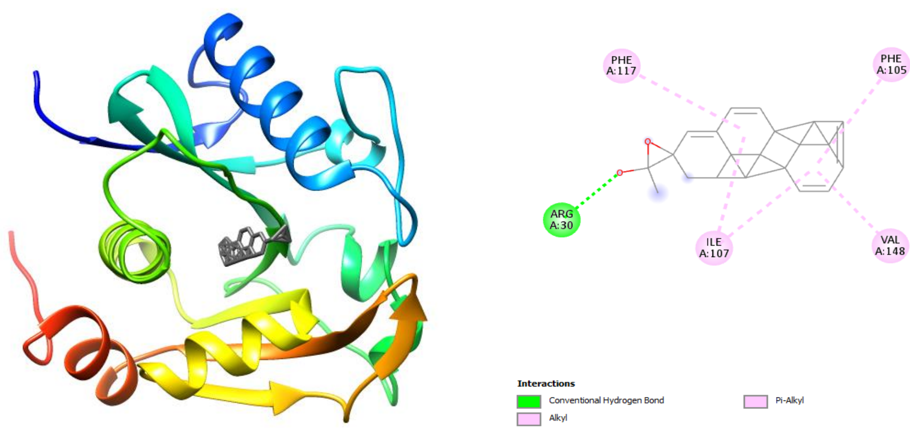

Figure 1: 3D and 2D structures of androst-5,15-dien-3ol acetate interaction with amino acids in the binding pocket of p. aeruginosa

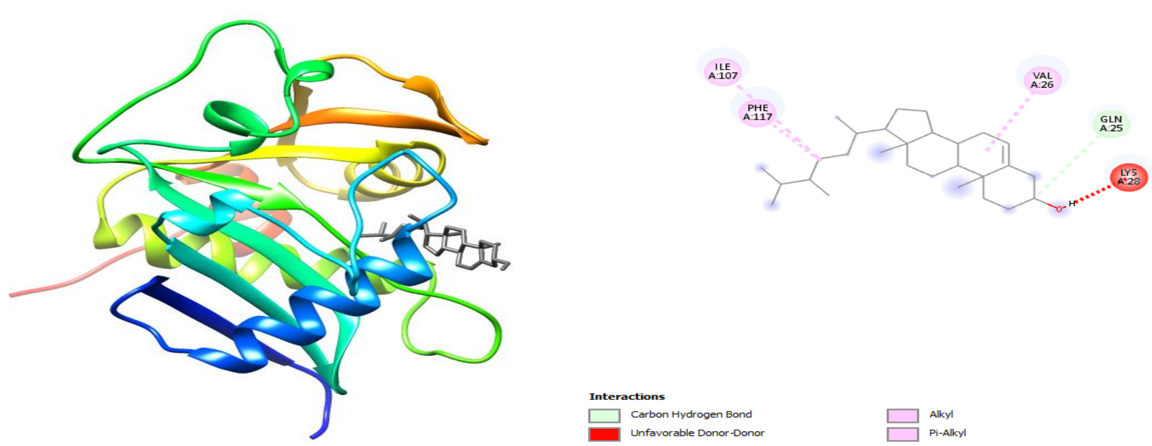

Figure 2: 3D and 2D structures of campesterol interaction with amino acids in the binding pocket of *P. aeruginosa*

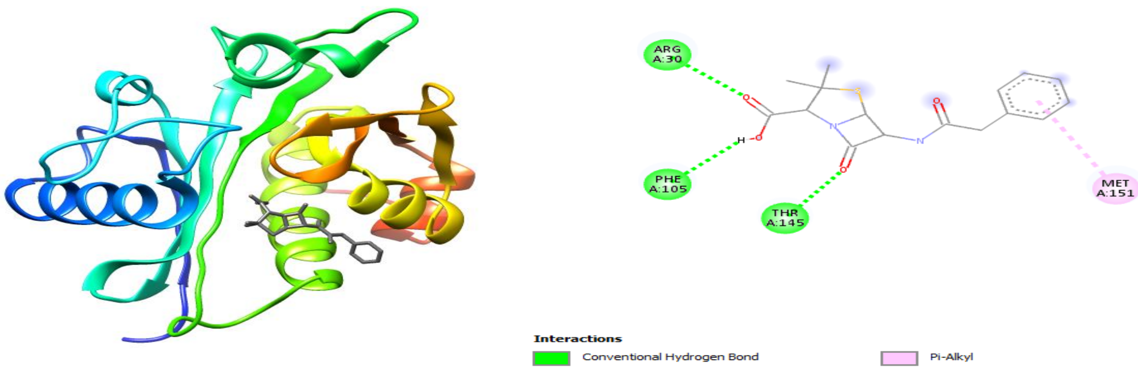

Figure 3: 3D and 2D structures of penicillin interaction with the amino acids in the binding pocket of *P. aeruginosa*

Discussion: *P. aeruginosa* is a nosocomial pathogen that is responsible for a range of infections and it is of importance due to its resistance ability to many antibiotic drugs. In view of the nosocomial nature of this pathogen, attacking immunocompromised patients and its drug resistance ability, it is ineluctable to search for new anti-pseudomonal compounds from natural sources like plants that are effective and non-resistance to the pathogen. The major medicinal component of plants is the phytochemicals as they contain secondary metabolites which are non-nutritive chemicals (Obidola *et al*., 2019) but play medicinal roles in the body. These phytochemicals include alkaloids, flavonoids, tannins, saponins, cardiac glycosides and a host of others. Some of these phytochemicals have been reported for their antimicrobial activity (Alrasheed *et al*., 2023; Pinto *et al*., 2023). Plants such as *Vernonia blumeoides* have been reported for their effect against *P. aeruginosa* (Aliyu *et al*., 2016). The presence of phytochemicals in the methanol leaf extract of *A. cathartica* is an indication of the possible medicinal functions possessed by the plant. Plant samples have been reported to contain phytochemicals varying from alkaloids, tannins, saponins, phenols, anthraquinones, etc. the methanol extract of the plant expressed the presence of alkaloids, flavonoids, tannins, phenols, terpenoids, steroids, quinones and beta-cyanins which are biologically active against microorganism (Wintola and Afolayan, 2015). These phytochemicals have been reported to be present in various plant samples (Wintola and Afolayan, 2015).

The antimicrobial activity of the plant sample showed a dose dependent manner, with the lowest dose having a pathogen clearance of 1.27±0.15, while the highest dose of the extract showed a clearance of 2.03±0.25. This antimicrobial activity of the plant extract could be as a result of the various phytochemicals that are present in the plant sample. Phytochemicals such as alkaloids, flavonoids, saponins, phenols and tannin have been reported for their anti-pseudomonal activity (Wintola and Afolayan, 2015). Previous studies reveal that the number of flavonoids play vital role in the inhibition of biofilm by combating the quorum sensing molecules (Aliyu *et al*., 2016). The effect of these phytochemicals could be as a result of the bioactive compounds present in them which have the ability to resist growth of this pathogen. The result of the molecular docking is also an indication of the possible drug-likeness potential from this plant. Compounds such as Androst-5,15-dien-3ol acetate, Gamma-sitosterol, stigmasterol, campesterol showed good binding affinity with the protein of *P. aeruginosa*. This result is similar to that of Aliyu *et al*. (2016) in which natural compounds such as N-decanoy and N-decanoyl from *Vernonia blumeoides* showed high binding affinity with the protein of *P. aeruginosa.*

Conclusion: Conclusively, the investigation on the presence of phytochemicals on the methanol leaf extract of *A. cathartica* showed the presence of important phytochemicals which have been reported for antimicrobial activity. The activity of this plant sample might have been due to the presence of bioactive compounds in the plant or it could be due to the synergistic effect of the compounds present in the plant. Interestingly, a bioactive compound of the plant (Androst-5,15-dien-3ol acetate) was actively bound to the active site of the protein more than the standard drug. Some other compounds also gave higher binding affinity than the standard drug.

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Economic analysis of composting poultry waste to mitigate environmental pollution in Cross River State, Nigeria

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Abstract

The study examined the economics of composting poultry waste to mitigate environmental pollution in Cross River State. A simple random sampling technique was used to select two (2) poultry farms each from the three (3) senatorial districts namely; Northern, Central and Southern senatorial districts. Data were collected through structured questionnaires, personal interviews and direct field observations. A budgetary analysis using the Benefit-Cost Ratio (BCR) was carried out to evaluate the feasibility and potential return on investment of composting poultry waste, while poultry waste was subjected to a laboratory analysis before and after composting to determine parameters such as carbon-to-nitrogen (C:N) ratio, temperature, pH and moisture content. The results indicated an estimated BCR of about 1.14, indicating that composting poultry waste is profitable. The C:N ratio, temperature, pH and moisture content of composted poultry waste were higher than that of un-composted poultry waste implying that composted poultry waste is environment friendly. The study recommends that poultry farmers should invest in composting waste.

Keywords: *Economics, composting, environmental, pollution*

Introduction: Poultry production contributes significantly to global food supply, but it generates substantial waste, mainly in the form of manure, which can lead to environmental pollution and public health risks if not managed properly. Henchion *et al.,* (2019) notes that the future global demand for animal-based protein will increase by 50 percent in 2050 with a consequence of increased concerns for both food security and environmental sustainability. One of the reasons is attributed to the fact that animal derived foods emit higher levels of greenhouse gases (GHG) than plant or crop-based foods. Tilman and Clark (2017) observe that such emissions are linked with climate change. Nwanta and Adeyemo, (2018) posits that intensive animal production and large scale slaughtering of animals for food in largely substandard poultry farms has resulted in an increased challenge of poultry waste management. Excessive production of waste from poultry farms and its improper disposal has led to air pollution and contamination of agricultural farmlands and eventually surface and water groundwater pollution and this has become a major public health concern to the society. The growth of the poultry industry has led to the generation of vast quantities of waste, including manure, feathers, and bedding materials. The improper management of these wastes can pose significant environmental risks. Ineffective disposal practices, such as runoff into waterways or indiscriminate dumping, can lead to water and soil contamination, jeopardizing ecosystems and human health. Akanni and Benson, (2018) notes that although most of these wastes are excellent sources of organic and inorganic nutrients that are of value if managed and recycled properly, they also pose potential environmental and human health concerns. Nahm, (2019) posits that intensive poultry production is a major contributor to emission of Greenhouse gases (GHG), acidification and eutrophication. Jamara (2020), in support of this view posits that the disposal of raw poultry manure without further treatment is deleterious, not safe and poses serious environmental problems such as obnoxious odour, leaching of toxic elements as heavy metals, methane emissions, eutrophication of waterways, nutrient imbalances, phytotoxicity and dissemination of pathogens and weeds.

Globally, there is growing interest in the use of organic manures due to depletion in soil fertility. Waste generated from poultry can be a good source of soil fertility, as it can produce organic fertilizer, biogas, or electricity. The resulting organic fertilizer can be sold to farmers, reducing their dependence on chemical fertilizers and improving soil health. Thus, reducing greenhouse gas emission which is largely responsible for the negative effects of climate change.

The practice where poultry farm waste is disposed of by burying, incineration, rendering or land filling is flawed with high cost intensity, labour intensiveness, production of environmental pollutants and obnoxious odour. Therefore, it is imperative to seek a more economically viable practice of poultry waste management for environmental sustainability. Composting provides a suitable alternative in this regard. Composting is a “spontaneous simple, natural, exothermic, bio-oxidative, aerobic decomposition process of organic materials” and it is hygienic, economic and ecologically sound system of waste management (Jamara, 2020).

Mahmud, (2023) notes that composting can be used to reduce the volume and odour of poultry waste, while also creating a valuable soil amendment. By composting poultry waste, farmers can help to reduce the risk of nutrient pollution and greenhouse gas emissions, while also creating a valuable resource for their crops.

Studies have been carried out to investigate poultry waste management measures. Onyia *et al.,* (2022) studied the economics of poultry waste management policy in South East, Nigeria, and concentrated on exploring the determinants of poultry waste control policies. An investigation into the economics of butchery waste management in metropolitan Port Harcourt, Nigeria, by Onoja *et al.,* (2020), only identified the poultry waste management system to include burning, composting, incineration and payment for waste disposal as the major poultry waste disposal measures. Onu *et al.,* (2019) identified the different waste management methods and factors affecting them. Baba *et al.,* (2018) using gross margin analysis in the study of economics of composting poultry farm waste, observed higher net profits in some of the treatments carried out. The study posits that with the continuity of the composting process round the year more economic benefits would be attained. The study concluded that besides the primary objective of environmental friendly and safe disposal of poultry litter, a secondary valuable end product in the form of organic manure was also produced. None of these studies except Baba *et al.,* (2018) whose study was conducted in India, made efforts to look at the economics of composting poultry waste to mitigate environmental pollution. More so, if such studies exist, they are lacking in Cross River State. Therefore, an investigation into the economics of composting poultry waste becomes a compelling necessity.

Materials and Methods: The study was carried out in Cross River State, Nigeria in 2024. There is a significant concentration of poultry in Cross River State. The simple random sampling technique was used to select two (2) poultry farms each from the three (3) senatorial districts namely; Northern, Central and Southern senatorial districts. Data were collected through structured questionnaires, personal interviews and direct field observations. Data collected include composting materials, cost of materials, and revenue including a laboratory analysis of poultry waste before and after composting to compare their characteristics. Prices of materials were obtained based on the current market prices in the study area during the 2024 production season. The prices were taken as follows;

- Cost of composting bin at ₦51,850.00 per bin
- Cost of carbon source (poultry waste) at no cost
- Labour wage rate (loading, remixing, unloading) at ₦2,000.00 per man day
- Cost of transportation at ₦3,200.00 per day
- Value of end product of compost at ₦3,750.00 per kg.

The study was conducted within one cycle (3 months) of composting poultry waste per 34 kg of compost bin and projected for a 5 year period. The per 34 kg establishment cost, maintenance cost were obtained. A straight line depreciation method was used to get the actual value of the fixed cost of the assets during the 2024 production season. A discount rate of 5% was used to represent the interest rate or opportunity cost of capital. The justification for the choice of 5% is because of the preferred rates of interest for agricultural investments, which is usually lower than the market rates of interest.

Analytical technique: A budgetary analysis using the Benefit-Cost Ratio (BCR) was carried out to evaluate the feasibility and potential return on investment of composting poultry waste. BCR compares the expected benefits to the expected costs. It is determined by first deriving the present values of benefit and cost as follows;

$$Pv\_B = \sum (B_t/(1+r)^t) \quad 1$$

Where;

Pv_B = Present value of benefit (₦)

r = Discount rate (%)

t = Time period (No. of years)

$$Pv\_C = \sum (C_t/(1+r)^t) \quad 2$$

Where;

Pv_C = Present value of cost (₦)

r and *t* are as explained.

$$BCR = Pv\_B/Pv\_C \quad 3$$

Where;

BCR = Benefit Cost Ratio (₦)

Pv_B and *Pv_C* are as explained.

Decision rule; BCR > 1, implies that benefits exceed costs, indicating a viable project. BCR < 1, means that costs exceed benefits, suggesting that the project is not viable and should not be embarked upon. BCR = 1, shows that benefits equal costs, indicating a break-even point.

Poultry waste was subjected to a laboratory analysis before and after composting to determine parameters such as carbon-to-nitrogen (C:N) ratio, temperature, ph and moisture content. This is necessary to evaluate the environmental consequences of composted poultry waste.

Result and Discussion: Economics of composting poultry waste

The benefit cost analysis for composting poultry waste per 34kg at 5% discount rate for a five year period is shown in table 1. Results indicate an estimated benefit-cost ratio of approximately 1.14, which is greater than one. It implies that for every one naira invested in composting poultry waste, about ₦1.14 will be received in benefits. It further suggests that the investment is expected to generate a 14% return on investment since benefits outweighs the costs by 14%. This result indicates that composting poultry waste is viable since profit can be made after factors of production have been paid for. The result agrees with Baba *et al.* (2018), whose study found that composting poultry waste is profitable.

Table **1**: Benefit-cost analysis for composting poultry waste

Year	Output (kg)	Price (₦/kg)	Revenue (₦/kg)	Cost (₦/kg)	Discount Factor (5%)	Discounted Cost (₦)	Discounted Revenue (₦)
1	34	3750	127.5	117	0.9524	111.43	121.43
2	34	3850	130.9	113	0.9070	102.49	118.73
3	34	3850	130.9	116	0.8638	100.2	113.07
4	34	4000	136	120	0.8227	98.72	111.89
5	34	4100	139.4	118	0.7835	92.45	109.2

BCR = 1.136

Source: Data analysis, 2024

Composting poultry waste to mitigate environmental pollution: The characteristics of un-composted poultry waste and composted poultry waste are shown in table 2. The analysis shows that composted poultry waste has a higher carbon-to-Nitrogen (C:N) ratio, temperature, pH and moisture content compared to un-composted poultry waste. A high C:N ratio balances nitrogen levels, regulates microbial activity and enhances decomposition. This will help to reduce the risk of nutrient pollution and greenhouse gas emissions and create a valuable resource for crops. The result corroborates with Mahmud, (2023). The high temperature of composted poultry waste suggests that pathogenic activities are regulated and nitrogen stabilization induced, which in turn reduces the volume and odour of poultry waste. The level of pH affects microbial activity, influences nutrient availability and impacts pathogen survival. The high pH of composted poultry waste will enhance phyto-remediation of the soil and prevent seepage. High moisture content of composted poultry waste implies enhancement of biodegradation of organic pollutants, thus reducing environmental pollution.

UCPW	15-25:1	10-27	6.5-7.5	30-50
CPW	20-30:1	54-60	6.5-8.5	50-60

Source: Laboratory analysis, 2024
UCPW- Un-composted poultry waste
CPW- Composted poultry waste

Table 2: Characteristics of un-composted and composted poultry waste

Type	Carbon-to-Nitrogen (C:N) ratio	Temperature (^{0}C)	pH	Moisture content (%)

Conclusion: The study concludes that besides the high benefits relative to the costs involved in composting poultry waste, composting is environment friendly and a safe method of disposing poultry waste. Therefore, poultry farmers should invest in composting poultry waste to increase their revenue stream and reduce environmental pollution.

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Copper Fractions in Relation to Soil Development of A Toposequence in A Tropical Environment

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Abstract

*Copper is an essential element that is required by plants for their growth and development and to complete their life cycle. The objectives of this study are to examine copper fractions and their relationships with selected soil properties. The study site is in Tumu-Sarari area, on the fringes of the Jos Plateau, Nigeria. Field work involved a purposive sampling approach. The study site was stratified based on topographic characteristics. One soil profile pit was dug to represent average soil conditions in each topographic unit. Sequential extraction processes were used to analyze the water soluble, exchangeable, particularly sorbed/carbonate bound, Fe-Mn oxide bound, organic matter bound, and residual bound Cu fractions for laboratory analysis. The outcome showed that the copper fractions' magnitudes occur in the following order: residual > carbonate bound > organic matter bound > Fe and Mn bound > exchangeable fraction > water soluble. The water soluble and exchangeable fractions which constitute the available forms of copper are at optimum levels and range from 0.70 to 1.69 mg/kg. Copper fractions associated with water soluble, organic and carbonate did not have significant relationship with selected soil properties. However, there was a significantly and positively correlation (r = 0.70**, 0.78** respectively) between exchangeable copper fractions, clay content and soil textural class. In addition, there was a significant negative correlation (r = -0.74, -0.86 respectively) between Fe and Mn associated copper fractions, clay content and soil textural class. Moreover, sand content and copper fractions linked to Fe and Mn oxides have a highly substantial positive association. This can be because sand content affects soil aeration. In the same vein, residual copper percentages and sand concentration exhibit a strong positive correlation (r = 0.76*).*

Keywords: *micronutrients; copper; toposequence; topography; Jos Plateau*

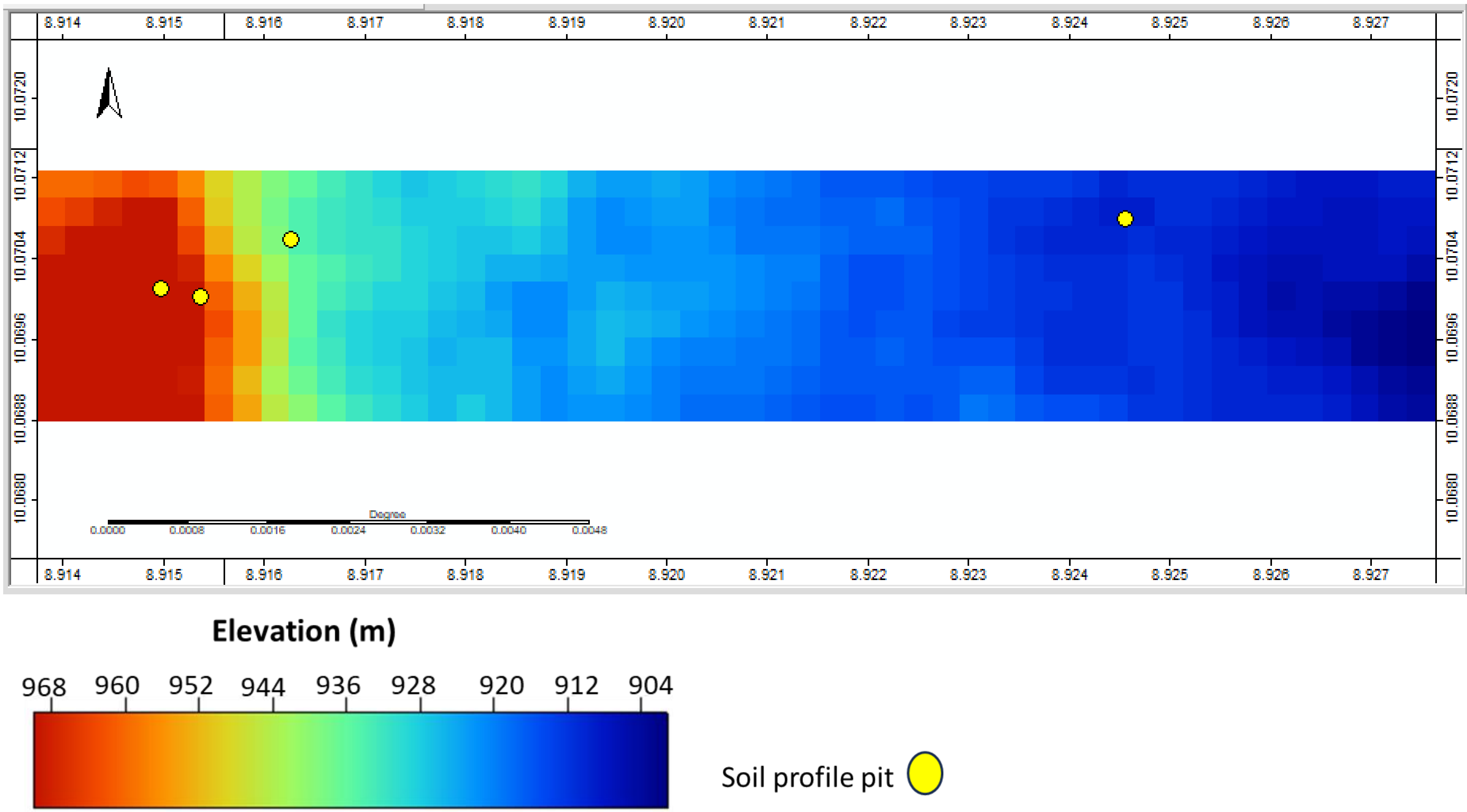
Introduction: Soil characteristics is largely dependent on the parent material from which the soils are generated as conditioned by topography over periods of time and these in turn will affect the amount and distribution of total and extractable Cu in the soil profile. However, a variety of pedological variables, including chemical, biological, and physical ones, can change the profile distribution of Cu (Adriano, 2001). According to Purves (2003), soil contamination by substances like copper, lead, and zinc seems to be mostly irreversible. Because of their cumulative nature and lack of biodegradability, metallic pollutants are hazardous even in very small concentrations (Tembo *et al*., 2006). Although the soil serves as a sink or filter, heavy metals in soil have lengthy residence durations, in contrast to other environmental compartments including the atmosphere and water (Lombi *et al*., 1998).

The availability of copper (Cu) to plants varies widely and occurs in several forms. Okoli *et al*. (2019) have reported the presence of Cu in several chemical pools, including those that are water soluble, readily exchangeable, adsorbed, precipitated with secondary minerals, and bonded to primary minerals. The change in soil texture, pH, calcium carbonate (CaCO3), organic matter, and other soil factors determines the kind and quantity of different forms of Cu (Kabala and Singh, 2001). Chelation is the process by which copper is bonded to organic matter in soil (Jassal *et al*., 2016). Complexation with clay-humus particles and/or the development of insoluble humic complexes typically reduce the solubility of Cu in soil (Sharma *et al*., 2015). Until now, not much has been done with respect to investigating the relationship of the various chemical fractions of copper with respect to hill slope soil development in the Tumu Sarari locality of the Jos Plateau, Nigeria. Consequently, the objective of this study is to examine copper fractions and their relationships with selected soil properties.

Materials and Methods: **Field work**

The study site is in Tumu-Sarari area, on the fringes of the Jos Plateau, Nigeria. The climate is tropical continental, and the geology of the area consists of basement complex and younger granites (Directorate of Overseas Surveys, 1977). The elevation characteristics of the study site are presented in Figure 1 and topographic characteristics of the area is presented in Figure 2. Field work involved a purposive sampling approach. The study site was stratified based on topographic characteristics; one soil profile pit was dug to represent average soil conditions in each topographic unit. Morphological properties were described using guidelines in the soil survey manual (Soil Survey Division Staff, 1993). Soil samples were obtained from each genetic horizon and the geographic coordinate of each profile pit is latitude is 10.070100° and longitude 8.914970°; latitude 10.070010° and longitude 8.915360°, latitude 10.070580° and longitude 8.916260°; latitude 10.070790° and longitude 8.924550° for summit, backslope, foot slope and toe slope positions respectively.

Laboratory Analysis: Salbu *et al*.'s (1998) sequential extraction method was used to estimate the Cu fractions. Copper fractions examined were water soluble, exchangeable, and carbonate-bound, organic matter-bound, Fe-Mn oxide-bound, and residual fractions. Following McLean's (1982) procedures, the pH of the soil was measured in both distilled water and a 0.01M CaCl2 solution at a ratio of 1:2.5 for the soil to water or solution. The hydrometer approach, as described by Gee and Bauder (1986), was used to determine the particle size distribution. Organic matter was determined using the dry combustion method.


8.914
8.915
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8.924
8.925
8.926
8.927
10.0720
10.0712
10.0704
10.0696
10.0688
10.0680
Degree
0.0000
0.0008
0.0016
0.0024
0.0032
0.0040
0.0048
Elevation (m)
968
960
952
944
936
928
920
912
904
Soil profile pit

Figure 1: Map of study area showing elevation and location of profile pits

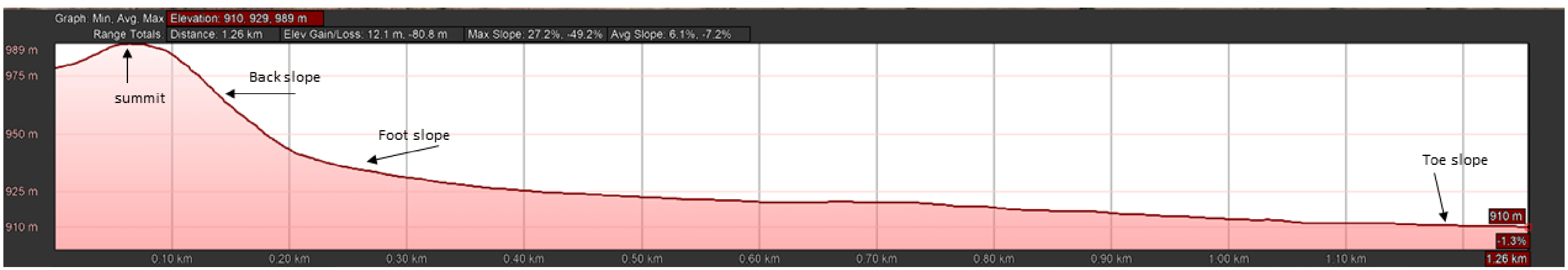

Figure 2: Topographic characteristic of the study area

In the dry combustion method, which is based on loss on ignition, soil samples that have been oven dried are put in a crucible and burned for at least three hours at 550 +/- 25°C in a muffled oven. After 30 minutes of cooling in the desiccator, the sample-filled crucible is weighed and the weight loss is then used to compute the organic matter (Ivezić et al., 2016).

Statistical Analysis: Soil data were analyzed using descriptive statistics. The relationship between soil characteristics and copper percentages was evaluated using correlation analysis.

Results and Discussion: Soil Morphological Characteristics: Soil morphological characteristics of the study area is presented in Table 1. The soil is very shallow at the summit and back slope positions but moderately deep at foot and toes slope positions. Furthermore, horizonal development is rudimentary at the summit and back slope positions. Only the A horizon is observed at the back slope position, and erosional process could have limited further horizonal development. Consequently, the soil in the summit and back slope positions is classified as Entisols. Similarly, Norton *et al*. (2003) after a study of hill-slope soils concluded that dynamic erosion and deposition are significant factors affecting soil development on the landscape. According to Owonubi (2017), topography also affects how much precipitation is absorbed and held in the soil, how quickly soil is lost to erosion, and how soil develops as a result of the deposition of eroded materials.

The soil structure type in the study area is sub-angular blocky. The grade and size of the structure indicates that the structure is well developed. This could be due to the fact that agricultural activities on these soils began only in the recent past (about 3 years), hence the influence of anthropogenic activities on soil structural development has been low. Soil colour in the study area is generally yellowish red with hues ranging from 2.5 to 7.5. Munsell colour values are usually lower in the A horizon, most likely as a result of higher levels of organic matter content. The observe colour characteristics are typical of soil of the northern guinea savanna area as noted by Owonubi (2017). Soil consistencies for the air-dry moisture states in the A horizons are generally hard to very hard. For the summit and backslope positions, soil consistencies for moist and wet moisture states are friable and non-sticky slightly plastic. This implies that the soil would be suitable for tillage activities at these moisture states. However, A horizons of the foot and toe slope positions have very friable, slightly sticky, and slightly plastic soil consistencies most likely as a result higher clay content at these slope positions. Consequently, tillage activities would best take place at the moist moisture states.

Table 1: morphological characteristics in various slope positions

Profile	Horizon	Depth (cm)	Structure	colour	air-dry	moist	wet
					Soil Consistence		
SUMMIT							
1	Ap	0-10	strong platy breaking to sub-angular blocky	7.5YR 3/2	slightly hard	friable	non- sticky, slightly plastic
	AC	10 -25	strong sub-angular blocky	7.5YR 3/3	very hard	friable	sticky, slightly plastic
	C	> 25					
BACK SLOPE							
2	A	0-26	strong sub-angular blocky	7.5YR 3/2	hard	friable	non-sticky, slightly plastic
	R	>26					
FOOT SLOPE							
3	A	0 -12	strong sub-angular blocky	2.5YR 2/4	hard	very friable	slightly sticky, slightly plastic
	B	12 -60	strong sub-angular blocky	7.5YR 4/6	very hard	very friable	slightly sticky, plastic
	BC	60 - 90	strong sub-angular blocky	7.5YR 4/6	very hard	very friable	slightly sticky, slightly plastic
	C	> 90					
TOE SLOPE							
4	A	0 - 15	strong sub-angular blocky	2.5YR 2/4	very hard	very friable	slightly sticky, slightly plastic
	B	15 - 65	strong sub-angular blocky	5YR 5/3	Extremely hard	very friable	slightly sticky, plastic
	BC	65 - 90	strong sub-angular blocky	2.5YR 4/2	very hard	very friable	non-sticky, non-plastic

Physical and Chemical Soil properties: Results on soil physical characteristics is presented in Table 2. Clay content tends to increase from summit to toe slope positions and from A to B or BC horizons. Erosional processes are likely to influence movement of clay materials in suspension through runoff downslope. On the other hand, illuviation processes and in-situ soil weathering due to higher rate of absorption and retention of precipitation at the foot and toe slope positions are probably responsible for higher clay content in the B horizons. As a result, the toe slope location has sandy clay loam soil texture, while the summit has sandy loam soil texture. The research area's soils have a mean bulk density of 1.69 g/cm3 with a range of 1.34 to 2.09. Density values generally tend to increase with increase in soil depth. Taking into consideration bulk density values and soil texture characteristics, soil of the foot and toes slope positions have higher degree of compaction that would affect root growth.

The distribution of soil pH and pH-buffer capacities is presented in Table 3. Mean soil pH in the study area is 5.65 with minimum and maximum values of 4.98 and 6.36 respectively. Consequently, soil reaction ranges from slightly to moderately acidic of A horizons at the summit to upper slope positions. However, at the foot to toe slope positions the soils are moderately to strongly acidic. This could be due to leaching of basic cations out of the soil profile as a result of absorption and retention of greater amounts of water from precipitation and overland flow from summit positions. The pH values are however within the range observed by Owonubi (2017) for basement complex soils in the northern guinea savanna. Though Olowolafe (2003) and Fasina and Adeyanju (2006) had noted that the low pH values in these soil types could in addition be attributed to acidic nature of the basement complex rocks from which the soils were derived.

Table 2: Physical soil characteristics and organic matter distribution in soils of various slope positions

Slope Position	Profile	Horizon	Depth	Bulk Density	Clay	Silt	Sand	Gravel	Textural Class	Organic matter
Summit	1	Ap	0-10	1.32	18	16	66	39	Very gravelly sandy loam	4.74
		AC	10 -25	2.09	22	10	68	37	Very gravelly sandy clay loam	3.98
		C	> 25	Nd	nd	nd	Nd	nd	nd	
Back slope	2	A	0-26	1.39	16	12	72	48	Very gravelly sandy loam	5.44
		R	> 26	Nd	nd	nd	Nd	nd	nd	
Foot slope	3	A	0 -12	1.34	14	22	64	11	Sandy loam	5.45
		B	12 -60	1.73	26	12	62	7	Sandy clay loam	3.84
		BC	60 - 90	1.79	30	14	56	10	Sandy clay loam	3.69
		C	> 90	Nd	nd	nd	Nd	nd	nd	
Toe slope	4	A	0 - 15	1.86	26	26	48	10	Sandy clay loam	4.65
		B	15 - 65	1.97	44	14	42	38	Very gravelly clay	5.24
		BC	65 - 90	1.69	26	12	62	48	Very gravelly sandy clay loam	5.75

Note: nd = not determined, Units of depth = cm, bulk density = g/cm^3, clay silt, sand, gravel, organic matter = %

Table 3: Copper fractions (mg/kg) in soils of various slope positions

Slope Position	Profile	Horizon	Depth	W	E	O	C	Fe and Mn	R
Summit	1	Ap	0-10	0.138	0.563	6.225	3.013	7.563	63.700
		AC	10 -25	0.188	0.938	8.025	4.550	3.800	59.400
		C	> 25	Nd	nd	nd	nd	nd	nd
Back slope	2	A	0-26	0.013	0.763	6.350	2.850	6.538	52.500
		R	>26	Nd	nd	nd	nd	nd	nd
Foot slope	3	A	0 -12	0.138	0.775	4.875	1.713	5.588	38.500
		B	12 -60	0.063	0.900	4.450	2.713	5.075	42.400
		BC	60 – 90	0.038	1.050	6.200	2.825	4.500	48.700
		C	> 90	Nd	nd	nd	nd	nd	nd
Toe slope	4	A	0 – 15	0.450	0.888	4.375	2.238	2.200	38.400
		B	15 – 65	0.100	1.175	4.613	2.713	2.050	29.400
		BC	65 – 90	0.363	1.325	5.963	2.138	4.525	49.400

Note: W = water soluble Cu, E = exchangeable Cu, O = organic matter bound Cu, C = carbonate bound Cu, Fe & Mn = iron and manganese oxide bound Cu, R = residual Cu.

Organic matter content in soil of the study area is high (> 3.0) and range from 3.69 to 5.75 mg/kg. The content of organic matter in these soils could have been higher in the surface soils if the soils of the summit to foot slope position had not been brought under cultivation for the first time 3 years ago. Brady and Weil (1999) had noted that soil cultivation hastens the rate of oxidation of soil organic matter thereby leading to its depletion.

Copper Distribution in Soils: Table 3 displays the distribution of copper fractions in the soils of the study area. The magnitude of the copper fractions occurs in the order: Residual > Fe and Mn bound > Carbonate bound > Organic matter bound > Exchangeable fraction > water soluble. In contrast, Okoli *et al* (2019) in a study noted reported that Fe and Mn bound copper fractions were the most dominant. Furthermore, studies by Kabala and Singh (2001) indicate that the order of magnitude of the various copper fractions is dependent on soil type and land use. The readily available fraction according to Okoli *et al* (2019) constitute the water soluble and the exchangeable fractions. Together using the rating provided by Buchholz (2004), the content of readily available copper in these soils is high. Closely following the readily available fraction is the copper fraction that is associated with organic matter. This fraction is moderately available as the copper in the organic matter is released into the soil after mineralization. Organic matter has been reported to significantly influence soil nutrient dynamics especially in tropical Nigerian soils (Chude *et al*., 2012). Consequently, copper fractions in the residual, and Fe and Mn bound are categorized as unavailable and weathering processes would have to release copper in these fractions to the soil. Studies of some urban soils by D¥Bkowska-Naskrêt *et al*., (2016) showed that copper occurred mostly low bioavailable fractions. Furthermore, Jassal *et al*., (2016) noted that organically bound copper ranged from 0.06 to 1.60 mgkg^{-1} and accounted for 3.66% of total soil copper in some salt affected soils.

Relationships between copper fractions and some selected soil properties are presented in Table 4. Copper fractions associated with water soluble, organic and carbonate did not have significant relationship with selected soil properties. However, there was a significant ($P < 0.05$) positive high degree of correlation between exchangeable copper fractions and clay content and soil textural class. This is not unlikely as Weil and Brady (2017) noted that clays are significant soil constituent influencing cation exchange capacity. Also, there was a significant ($P < 0.05$) negative correlation between Fe and Mn associated copper fractions and clay content and soil textural class. This could be due to the fact that these soils are relatively young and soil development would tend to favour the production of silicate clays rather than Fe and Mn oxide which are more dominant in highly weathered soils (Weil and Brady, 2017). Furthermore, there is a highly significant positive correlation between copper fractions associated with Fe and Mn oxides, and sand content. This could be due to the influence of sand content on soil aeration. The influence of sand content on soil aeration has been underscored by Weil and Brady (2017). Similarly, there is a significant ($P < 0.05$) positive correlation between residual copper fractions and sand content. This could be connected to significant amounts of copper bearing minerals in the sand fractions. Primary minerals make up the majority of the sand and silt fractions in most soils, according to Huang and Wang (2005).

Table 4: Correlation between copper fractions and selected soil properties

	Clay	Silt	Sand	Textural class	Organic Matter	pH
Water soluble	0.029	0.502	-0.301	0.206	0.245	0.226
	0.941	0.169	0.432	0.594	0.526	0.559
Exchangeable	0.687	-0.301	-0.474	0.775	0.136	-0.100
	0.041	0.431	0.198	0.014	0.727	0.798
Organic	-0.323	-0.584	0.618	-0.216	-0.196	-0.114
	0.397	0.099	0.076	0.577	0.614	0.771
Carbonate	0.031	-0.596	0.297	0.161	-0.545	-0.570
	0.937	0.090	0.438	0.679	0.129	0.109
Fe and Mn oxide	-0.742	-0.221	0.809	-0.860	0.107	0.502
	0.022	0.569	0.008	0.003	0.784	0.169
Residual	-0.570	-0.419	0.758	-0.520	-0.221	0.154
	0.109	0.262	0.018	0.152	0.568	0.693

Cell Contents Pearson correlation
P-Value

Conclusion: The study shows the relationship between copper and selected soil properties of the study area. The readily available fraction which constitutes the water soluble, and the exchangeable fractions were rated as optimum in these soils. However, of major concern is the organic bound fraction which serves as a reserve should the readily available fractions but might be depleted over time through continuous cropping as it is being practiced in the area. Consequently, to sustain the copper content and improve the fertility of these soils; prudent soil organic matter management through the uses of conservation tillage, green manure, crop rotation and application of biochar and other organic amendments is imperative.

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A Review of the Nutrient Requirement of Fish for Sustainable Fish Production in Nigeria

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Abstract

Fish production is a major industry in many countries, Nigeria inclusive. The industry has great potentials for growth as the demands for fisheries product increases and the supply for natural resources decreases. Like in other forms of animal production nutrition plays a critical role in fish production because it influences not only production cost but also fish growth, health and waste production. Researches over many decades have expanded the scope of knowledge of the nutritional requirements of culture species. The knowledge of the nutritional requirements of fish will help close the food security gaps with regards to the deficit in fish supply. This study provides an overview of the nutrient requirements of culture fish species for sustainable fish production in Nigeria. The study discussed nutrient requirement for fish on the basis of dietary protein requirements, amino acid requirements, Carbohydrates/Energy requirements, lipid requirements, Vitamins requirements and Mineral requirements. The study concludes that fish farmers must know the nutritional requirements of fish species in order to develop nutritious, cost effective diets and meet those requirements with balanced diet formulations, appropriate feeding practices for maximum profits and sustainable fish production

***Keywords**: Fish, Nutrient requirement, Sustainable Production.*

Introduction: In the wild, fish obtain food naturally from aquatic environment; this food may be phytoplankton or zooplanktons, insects, seeds and small fish. However, under culture condition the natural feeds are not adequate for optimum growth therefore there is need for supplementary feeds to help fortify the naturally available diet with extra protein, carbohydrate, lipid, minerals and vitamin (Béné *et al*., 2016; Alatise and Okoye, 1979; Lim and Dominy, 1989).The quality and quantity of feed used in fish culture are the major factors in determining profitability because feed represents the largest single expenditure in semiintensive or intensive culture operations. Economical production depends on availability of least-cost nutritionally balanced diet (Lim and Dominy, 1989). In Nigeria the high cost of feed imputs is a major problem of fish farmers in intensive and semi-intensive fish farming culture system (Ayinla, 1988; Fagbenro and Davis, 2003). Nutrition is critical in fish production since it accounts for 40-80% of production cost (Igeofagha, 1979; Eyo, 1990; New, 1993; Prendagast *et al.*, 1994). Lall (1991) and Helfrich and Craig (2002) indicated that proper nutrition is one of the major factors influencing ability of fish to attain genetic potential for growth, reproduction and longevity. Efficient production and growth of fish in the culture systems depends entirely on feeding complete feed at appropriate rate with due considerations to the dietary requirements of the fish which should not be exceeded (Craig & Helfrich, 2017; Ayinla, 1991). Formulated or artificial diets may either be complete or supplemental. Complete diets supply all the nutrients (proteins, carbohydrates, fats, vitamins and minerals) necessary for the optimal growth and health of fish. Generally, the basic nutrient composition of fish feed include protein (18-50%), lipid (10-25%), carbohydrate (basal diet) 15-20%, ash (< 8.5%), phosphorus (< 1.5%), water (< 10%), vitamins and minerals (Aquasend, 2024; Mohanta, 2022; Lall and Dumas, 2015; National Research Council, 2011).

Amongst these nutrients energy forms the bulk or basal diet while protein constitutes the most expensive item in formulated diets. These key nutrients determine the scale of production of a fish diet while the rest of the nutrients promote the efficiency of utilization of these two nutrients (FAO, 2023; Annune and Oniye, 1993). Fish are normally provided with complete diets when reared in high density indoor systems or confined in cages and cannot forage freely on natural feeds (Helfrich and Craig, 2002). However, supplemental (incomplete, partial) diets are fed only to help support the natural food (insects, algae, small fish) that are naturally available in fish ponds or outdoor raceways. Supplemental diets do not contain full complement of vitamins and mineral, although they are used to help fortify the naturally available diet with extra protein carbohydrate and lipids (FAO, 2022; Helfrich and Craig, 2002).

The main objective of fish feed formulation is to put together raw materials (feed ingredients) that will provide nutritionally balanced feed for fish. This is actually aimed at providing nutrients for rapid fish growth so as to enhance optimal production at low feed cost (Ayinla, 1991; Annune and Oniye, 1993). The formulation of fish diets therefore needs an understanding of the nutrient requirement of different fish species in relation to age, feeding habits, production objectives and physical state; and nutrient composition of the feed stuffs and the level of associated anti-nutritional factors and feed contamination in such feed stuff.

Dietary Protein Requirement for fish: Fish require much higher dietary crude protein, 16-60%; EIFAC (1971); 20-60% Hastings (1976); 35-55%; NRC (1993); 24-27% Tacon (1987); 30-56% Lim and Dominy (1989) and 18-50% Helfrich and Craig (2002) and lower dietary energy in comparism to other animals (Lim and Dominy, 1989). Thus protein requirement is given high priority in any nutritional study since it is the single nutrient that is needed in the largest quantity for growth and development and also because it is the most expensive ingredient in the diet (Lovell, 1988 and NRC, 1993). This implies that fish feeds should be carefully formulated to ensure that the protein fraction does not exceed the optimum level required by the fish in order to minimize wastage. The protein requirements of fish vary for each fish species and with each life state (Wang *et al*., 2023). Lim and Dominy, 1989; Alcestes and Jory, 2000). Helfrich and Craig (2002) also indicated that wide variations in protein requirements of fish were due to differences in species (genetic composition), size of fish, water temperature, culture management (water exchange/water quality), feed allowance/rate, stocking rate, amount of non-protein energy, quality of the dietary protein. Helfrich and Craig (2002) indicated that proteins are composed of carbon (50%), nitrogen (16%), oxygen (21.5%) and hydrogen (6.5%). The proteins are needed to supply amino acids and to make enzymes and hormones (Ensminger and Olentine, 1978). Helfrich and Craig (2002) however stated that protein is used for fish growth if adequate level of fats and carbohydrates are present in the diet. If not protein may be used for energy and life support rather than growth.The quality of protein is principally influenced by its amino acid composition. The findings of Helfrich and Craig (2002) indicated that protein level in aquaculture feeds generally average 28 – 32% for cat fish and 32 – 38% for tilapia. Fry and fingerling fish require a diet higher in protein (which may frequently exceed 50% crude protein), lipids, vitamins and minerals and lower in carbohydrates because they are developing muscles, internal organs and bone with rapid growth (Wang, *et al*., 2016). Alcestes and Jory, 2000).

Sub-adult fish require more calories of fats and carbohydrates for basal metabolism and a smaller percentage of protein for growth. Adult fish require lesser amount of protein however the amino acid which make up that protein need to be available in certain ratios. Maintenance diets may contain as little as 25 – 35% crude protein (Francis-Floyd, 2004) and food for grow-outs often approach or exceed 40% crude protein. Brood stock animals also require high protein and fat levels to increase the reproductive efficiency (Alcestes and Jory, 2000). However, the reports of Ayinla and Bekibele (1992), Alcestes and Jory (2000) and Francis-Floyd (2004) vary with the report of Ayinla (1988) which indicated that fingerling stages of *Clarias gariepinus* required 31 – 34% crude protein; juveniles 31 – 34% crude protein; adults, 40% crude protein and broodstock, 40% crude protein. Degani *et al.* (1989) and Michiels and Henken (1985) also reported 40% crude protein requirement for broodstock of *Clarias gariepinus*.

Amino Acid Requirements for fish: All fish species require the 10 essential amino acids namely arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Feed stuff deficient in any of the 10 essential amino acids cause depressed appetite and consequently depressed growth rate of fish (Kemigabo *et al*., 2018). Ayinla, 1988; Ayinla and Bekibele, 1992). Among all the amino acids lysine and methionine are often the first limiting amino acids. Fish feeds prepared with plant protein (particularly soybean are typically low in methionine. Thus, extra methionine must be added to plant protein sources as supplements to augment the inadequacy and to promote optimal growth and good health. It is also important to note and match the protein requirements and amino acid requirements of each fish species reared for attainment of optimal growth (Helfrich and Craig, 2002). Lall (1991) reported the level of amino acids in channel catfish (Clarias) and *Oreochromis niloticus* thus: phenylalanine 5.0 (1.2); tryptophan 0.5 (10.12); histidine 1.5 (0.4); arginine 4.3 (1.0); lysine 5.1 (1.2); valine 3.0 (0.71); isoleucine 2.6 (0.6); leucine 3.5 (0.8); threonine 2.5 (0.5) and methionine 2.3 (0.6) respectively. Ayinla (1988) reported the essential amino acid requirements of *Clarias gariepinus juveniles* thus: arginine (5.8); histidine (3.9); isoleucine (5.3); leucine (12.3); lysine (8.6); methionine and cystine (-); phenylalanine and tryrosine (3.8); threonine (4.9); tryptophan (-) and valine (3.5). In certain cases, the presence of non essential amino acids in diets represents a sparing effect which reduces the need for fish to synthesize them. (Lim and Dominy, 1989). The indispensible amino acid phenylalanine is readily converted to dispensible tyrosine in fish. Thus its dietary level requirement is dependent on tyrosine concentration (Wilson and Halver 1986).

Studies on utilization of several dietary sulphur compounds in channel catfish showed that D-L methionine was utilized as effectively as L-methionine by channel catfish (Robinson *et al.,* 1978). Wilson *et al*. (1978) also reported that channel catfish fed a tryptophan deficient diet (0.05%) for eight weeks had significantly poorer weight gain and feed conversion efficiency than individuals fed diets containing as low as 0.12% tryptophan (0.5% dietary protein). Eyo (1988) reported that 0.2% L-Soybean diet gave the best growth performance in *Clarias anguillaris*. Similarly, Eyo and Olatunde (1998) demonstrated that D-L methionine can substitute L-methionine in soybean diet for mud fish *Clarias anguillaris* fingerlings. Viola *et al.* (1982) reported that supplementation of soybean meal with both methionine and lysine improved Carp diets Robinson *et al.* (1980) reports on growth study of channel catfish fingerlings indicated that tyrosine can replace or spare 50% of the total phenylalanine requirements. NRC (1983) however indicated that since most protein sources used in practical fish feed contain adequate levels of phenylalanine and tyrosine, the sum of the two amino acids normally exceed dietary needs. Oresegun and Alegbeleye (2001) reported that the supplementation of 0.2% methionine improved the FCR and PER of diet containing 20% cassava peels fed to tilapia (*Oreochromis niloticus*).

Carbohydrates/Energy Requirements for fish: Carbohydrates (starches and sugar) are the most economical and inexpensive sources of energy for fish diets. Carbohydrates are included in aquaculture diets to reduce feed costs and for their binding activity during feed manufacturing. They are also used due to their natural abundance. In fish, carbohydrates are stored as glycogen that are mobilized when necessary to satisfy energy demands Hien *et al*., 2022; Annune and Oniye 1993; Helfrich and Craig, 2002). Helfrich and Craig, (2002) indicated that fish have lower dietary energy requirements because they exert relatively less energy to maintain position and move in water than do mammals and birds and because they excrete most of their nitrogenous wastes as ammonia (through the gills) instead of urea or uric acid thus loosing less energy in protein catabolism and excretion of nitrogenous wastes (Goldstein and Forster; 1970). Fish also have a lower dietary energy requirement because they do not have to maintain a constant body temperature. Therefore maintenance energy requirement and heat increament are lower for fish than for land animals; with the implication that carbohydrates are not efficiently used by fish (Lovell, 1988; Helfrich and Craig 2002). Helfrich and Craig (2002) stated that mammals can extract about 4Kcal of energy from 1gram of carbohydrate whereas fish can only extract 1.6Kcal from the same amount of carbohydrates. Helfrich and Craig (2002) further indicated that up to 20% dietary carbohydrates can be used by fish as earlier indicated by Lovell (1988).

Most research efforts towards provision of adequate feed for fish have been centered on manipulation of dietary protein used in feed formulation. Generally, fish nutritionists have given priority to meeting the requirements for protein, major minerals and vitamins thereby allowing energy, to take care of itself (Lovell, 1988). Lovell (1988) further stressed that fish uses protein efficiently as a source of energy, it was also maintained that a high percentage of digested energy in protein is metabolisable in fish than land animals. However, a ration poor in carbohydrate entails the use of either lipid or protein to provide necessary calories (Cowey and Sargent, 1972).

Lipids Requirement for Fish: Lipids are non-protein calorie sources which are often neglected in fish feed preparation, they are generally more digestible than some carbohydrates (Hilton, 1982). Due to the high energy content of fats they can be utilized to partially spare or substitute for protein in aquaculture feeds (Helfrich and Criag, 2002). The protein sparing effects of lipids varies between species but appear to be optimal at about 15 – 18% of the diet (Sinyangwe *et al*., 2017; De-Silva *et al.,* 1995). Lipids supply about twice the amount of energy as proteins and carbohydrates and typically lipids comprise about 15% of fish diets, lipids supply essential fatty acids (EFA) and serve as transporters of fat-soluble vitamins. Eyo (2003) indicated that lipids and fatty acids perform three different functions in the organism, as they serve as energy carriers, metabolic regulators and structural elements in the cell. Helfrich and Craig (2002) indicated that a recent trend in fish feed is to use higher levels of lipids in the diet. They further asserted that increasing lipids can help reduce the high costs of feeds by partially sparing protein in the feed, it was also noted that problems such as excessive fat deposition in the liver can decrease the health and market quality of fish. Helfrich and Craig (2002) indicated that simple lipids include fatty acids and triacylglycerols and that fish typically require fatty acids of the Omega 3 and 6 (n – 3 and n-6) families for maximum growth and efficient utilization.

Vitamins Requirements for Fish: Vitamins are organic compounds necessary in the diet for normal fish growth and health. They are not often synthesized by fish and thus must be supplied in the diet (Helfrich and Craig, 2002). Many vitamins function as co-enzymes (Cowey and Sargent, 1972). Vitamins are normally categorized into two groups namely: the water – soluble and fat soluble vitamins. Fishes are extremely sensitive to vitamin deficiencies. Deficiency of each vitamin has certain specific symptoms with retarded growth being the most common deficiency symptom (Helfrich and Craig, 2002). Other signs common to several vitamin deficiencies were identified as abnormal skin pigmentation, ataxia, hypersensitivity haemmorrhage, fatty livers and increased susceptibility to bacterial infection. Supplemental vitamins which comprises of all the aforementioned vitamins are usually part of commercially formulated diets for intensively cultured fish with the exception of inositol and biotin which are usually found in sufficient quantities in fish feed ingredients (Helfrich and Craig, 2002). Lall (1991) summarized the dietary vitamin requirements for optimum growth of Channel catfish thus: vitamin A, 5,500-iu; D,500-4,000iu; E. 50-100; K.10; Thiamin 1-20mg; Riboflavin 9-20mg; Pyridoxine 3-20mg; Pantothenic acid 10-50mg; Niacin 14mg; Folic acid 5mg; B12 0.02mg; Choline 400; Inositol; not required (N.R.); C (N.R.) or 100mg.

Mineral Requirement for Fish: Minerals are inorganic elements necessary in the diets for normal body functions. There are two (2) categories of minerals, macro-minerals and micro-minerals. Macrominerals are required in large quantities. Common macro-minerals include sodium, chloride, potassium and phosphorus. These minerals regulate the osmotic balance and aid in bone formation and integrity. Micro-minerals (trace minerals) include manganese, iron, zinc, copper, iodine, cobalt and selenium. Micro minerals exist as components of enzyme and hormone systems (Helfrich and Craig, 2002). Fish can absorb many minerals directly from the water through their gill membranes and skin, this phenomenon allows them to compensate to some extent for mineral deficiencies in their diet. Thus their minerial requirements are reduced (Helfrich and Craig, 2002). The dietary requirements for several minerals by Channel catfish include calcium <0.1% (Lim and Dominy, 1989), Phosphorus 0.45%, (Lovell *et al.,* 1978); Magnesium 0.05% (Gatlin *et al.,* 1982), Zinc, mg/kg 20-150, (Gatlin and Wilson, 1983).

Twenty milligrams per kilogram (20mg/kg) is the basal requirement for Zinc, however, 150mg/kg is recommended in practical fish feeds to compensate for mineral and phytate binding of zinc. Selenium, 0.25 mg/kg; Manganese, 2.40mg/kg; Copper, 5.00mg/kg and Iron, 30.00mg/kg (Gatlin and Wilson, 1983; 1984; 1986a; 1986b; 1986c). Gallagher (1993) indicated that dietary supplementation is necessary in some fishes. Since there is no information on mineral requirements for Tilapia the requirements for channel catfish could be used for both *O.niloticus* and *Clarias gariepinus* (Lim and Dominy, 1989). Blood meal, bone meal, fish meal, limestone, red pepper and wood ash were reported by Aduku (1993) as natural sources of macro and micro minerals used in feed formulation for animals.

Conclusion: The knowledge of the nutrient requirement of fish will enable fish farmers to feed their fish adequately with the required nutrients thereby ensuring that the fish they produce are not malnourished, and hence attain qualitative growth. Farmers are also able to maximize profits with good returns on investments. Presently in Nigeria, fish feed accounts for about 80% of production cost due to the effects of the removal of fuel subsidy, consequent high inflation, and high transportation cost. Feed wastage is also reduced to the barest minimum through the application of the knowledge of the nutrients required by fish for maximum production.

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Comparative Phytochemical and Nutritional Properties of Some Vegetables in Jos Metropolis, Plateau State

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Abstract

Vegetables are rich sources of nutrients that contain bioactive compounds, commonly available and of high yield which can be eaten raw or as processed product. This study was conducted to assess the phytochemical and nutritional content of carrot, cucumber and radish using standard method of analysis. The assessed phytochemicals (Saponins, Phlobatanins, Flavonoids, Terpenoids, Cardiac glycosides, Phenols, Amino acid and Tannins) were all present in carrots, while cucumber and radish did not have all the assessed phytochemicals present indicating that carrot had the highest phytochemicals. The nutritional composition assessed include crude carbohydrate, crude protein, crude lipids, moisture contents, total ash and fiber content. The nutritional composition assed were present in all the vegetables with carrot having the highest crude carbohydrate, cucumber the highest crude protein and moisture content while radish had the highest crude lipids, total ash and fiber content. Consumption of these vegetables should be encouraged due to their varying and complimenting nutritional and phytochemical composition. **Keywords:** Carrots, Cucumber, Nutritional, Phytochemical, Radish, Vegetable.

Introduction: There is a converse relationship between fruit and vegetable consumption and the incidence of various illnesses, including cardiovascular diseases, cancers, and inflammation disorders (El-Beltagi *et al*., 2022). Vegetables are one of the most important components of our daily diet as they enrich the body with important vitamins and minerals. They also serve various medicinal functions in the body system. Vegetables play a vital role in human nutrition and health by providing nutrients, vitamins, antioxidants, phytosterols, and dietary fiber (Poobalan *et al*., 2019). The medicinal properties of vegetables include antioxidant, antimicrobial, antidiarrheal, anthelmintic, antiallergic, antispasmodic and antiviral activities (Kumar *et al*., 2023). Phytochemicals are plant-based group of bioactive chemical compounds which help plants in resisting microbial attacks and also consumption by insect and other animals (Kumar *et al.,* 2023). Phytochemicals, which encompass various bioactive compounds such as flavonoids, phenols and alkaloids contribute to plant's defense system and have been linked to human health benefits (Smith *et al.,* 2023). Vegetables are recognized for their notable water content and introduce a refreshing element to diets and harbor phytochemicals boasting potential antioxidant properties.

The carrot (*Daucus carota* subsp. sativus) is a root vegetable, usually orange in colour, though purple, black, red, white, and yellow cultivars exist (Singh *et al*., 2021). *Daucus carota*, native to Europe and Southwestern Asia was reported to originate from Persia. The plant was originally cultivated for its leaves and seeds. It is well known for its strong antioxidant content, particularly carotenoids, which have been linked to cancer-fighting effects (Ikrama *et al*., 2024). Carrot is one of the vegetables celebrated for its richness in beta-carotene and other vital vitamins such as vitamin C and K, thiamin (B1), riboflavin (B2), pyridoxine (B6) and folates (B9), necessary for metabolism of carbohydrates, proteins and healthy growth (Singh *et al*., 2021). Radish is a crop plant that is known, botanically, as *Raphanus sativus* L., a species belonging to the genus *Raphanus* and the family *Brassicaceae* (Manivannan *et al*., 2019). Various cultivars of radish have been divided into distinct kinds based on the shape of its edible roots as well as intended uses (El-Beltagi *et al*., 2022). **Radish is considered a root due to starch and compound storage ability of the root. Radish possess some characteristics which are unique to some phytochemical features. The presence of anthocyanin pigments, for instance, provide the root red colour while isothiocyanates contribute to the pungent flavor and distinctive taste.** The root is usually consumed in salads, but it can also be cooked or salted together with other vegetables. **Radish is low in calories and a good source of calcium, magnesium, copper, manganese, potassium, vitamin B_6, vitamin C, and folate.** Cucumber, (*Cucumis sativus*) is a creeping plant of the gourd family which is widely cultivated for its edible fruit. *Cucumis sativus Linnaeus*) is commonly known as cucumber and is native to India (Javid *et al*., 2024). It belongs to one of the most well-known members of the *Cucurbitaceae* family. Cucumber fruits are almost cylindrical in shape, elongated, have tapered ends, and can grow up to 62 centimeters (24 in) in length and 10 centimeters (4 in) in diameter (Zhang *et a*l., 2019). Leaves, flowers, seeds, fruits, and bark of cucumber are rich in many phytoconstituents, which are biologically active and produce specific pharmacological effects (Sahu and Sahu, 2015). Glycosides, alkaloids, phenols, terpenoids, steroids, tannins, saponins, carotenoids, resins, and flavonoids are some of the chemical components found in the cucumber fruit (Agatemor *et al*., 2018). Carrot, radish and cucumber are well known vegetables in Plateau State due to the suitability of the weather for their cultivation. They are consumed in many house-holds and sold to neighbouring states as a means of livelihood for the farmers. Although, the phytochemical and proximate composition of cucumber (Agatemor *et al*., 2018) has been worked upon and published, comparative phytochemical and nutritional properties of carrot, radish and cucumber is yet to be published.

Materials and Method: Materials : The materials used for this work include carrots, radish, cucumber, water bath (Model: HH-420), filter paper, funnel, electric blender (Model: CB 8231), Ferric Chloride, H_2SO_4, NaOH, Aluminium chloride, ethanol, ammonia, beakers, conical flasks, spatula, watering bottle, crucibles etc. All chemicals and reagents were of standard and analytical grades and were obtained from Sigma-Aldrich, United Kingdom.

Sample Collection and Preparation : The vegetable samples (cucumber, carrot and radish) were purchased from Farin Gada market and transported to Federal College of Forestry, Jos. The fresh vegetables were taken to a horticulturist for identification, after which the samples were taken to the chemistry laboratory of Federal College of Forestry where they were washed with distilled water, slice into tiny pieces and dried under room temperature after which the dried vegetable samples were ground and put in a plastic bag and labeled properly for further analysis.

Extraction of the Samples for Phytochemical Analysis: Exactly 50 g each of pulverized carrot, cucumber and radish sample were weighed and percolated in 100 mL of distilled water in air-tight container for 24 hours. Each of the sample was filtered with a muslin cloth and funnel before using whatman No. 1 filter paper. The samples were then concentrated over a water bath to get rid of the solvent, and the crude extract was then obtained.

Phytochemical Analysis: The crude extracts of carrots, cucumber, and radish were subjected to qualitative screening for identification of the various chemical constituents which are saponins, tannins, cardiac glycosides, steroids, flavonoids, anthraquinones, and alkaloids. The phytochemical analysis was done according to standard method by (Trease and Evans (1989*),* Soforowa (1993).

Nutritional Analysis of the Vegetables: Nutritional analysis of the vegetables was determined according to the method of Association of Official Analytical Chemist Method (AOAC), while nitrogen-free was determined by a conversion factor (AOAC, 2000).

Resul: Phytochemical Constituents: The result of the phytochemical screening of the vegetables is shown in Table 1 below. The table shows that saponins and terpenoids are absent in cucumber, while phlotabanins, phenols and cardiac glycosides are present in trace amount, with flavonoids, amino acids and tannins being moderately present. Carrots expressed moderate presence of saponins, cardiac glycoside, amino acids and tannins. Phlobatanins, terpenoids and phenols are present in little amount while flavonoids is present in high amount. Radish expressed moderate presence of saponins, phlobatanins and flavonoids, trace amount of terpenoids, and amino acid with the absence of cardiac glycosides, phenols and tannins.

Table 1: Phytochemical Composition of Cucumber, Carrots and Radish

Phytochemicals	Cucumber	Carrots	Radish
Saponins	-	+ +	+ +
Phlobatannins	+	+	+ +
Flavonoids	+ +	+ + +	+ +
Terpenoids	-	+	+
Cardiac glycosides	+	+ +	-
Phenols	+	+	-
Amino acids	++	+ +	+
Tannins	++	+ +	-

Key: + = trace presence; ++ = moderately present; +++ = highly present; - = absent

Nutritional Composition: The result of the nutritional composition of the vegetables are given below (Table 2). The carbohydrate content showed significant difference. The result showed that carrots has the highest meant value of carbohydrates (39.65±0.05), while cucumber gave the lowest mean value (21.03±0.03). The crude protein content of the three vegetables showed significant differences ($p > 0.05$), with the highest mean value in carrots, while cucumber (16.48±0.04) and radish (18.53±0.03) gave lower mean values. Radish (2.46±0.02) alone gave a significant difference in the lipid content, in comparison with carrot (1.16±0.04) and cucumber (1.39±0.03), while the former and later are not significantly different from each other. The moisture composition was highest in cucumber, with a mean value of 32.01±0.04, followed by that of radish (22.71±0.06) and the lowest in carrots (21.14±0.02b). Significant difference was, however, not observed in carrots and radish but the two vegetables were found to be significantly different from cucumber. The ash and fibre content were more expressed in carrot and radish respectively with mean values of 14.33±0.05 and 17.85±0.02 respectively. Cucumber, however, gave the lowest mean value of 8.65±0.06 for ash content, while carrots gave the lowest mean value of 10.85±0.03 in moisture content respectively.

Table 2: Nutritional Composition Cucumber, Carrots and Radish

Nutritional	Cucumber	Carrots	Radish
Carbohydrates	21.03 ± 0.03^{c}	39.65 ± 0.05^{a}	26.17 ± 0.34^{b}
Protein	16.48 ± 0.04^{c}	22.2 ± 0.08^{a}	18.53 ± 0.03^{b}
Lipid	1.39 ± 0.03^{b}	1.16 ± 0.04^{b}	2.46 ± 0.02^{a}
Moisture	32.01 ± 0.04^{a}	$21.14\pm0.02b^{bc}$	22.71 ± 0.06^{b}
Ash	8.65 ± 0.06^{c}	14.33 ± 0.05^{a}	11.05 ± 0.03^{b}
Fibre	12.32 ± 0.02^{b}	10.85 ± 0.03^{c}	17.85 ± 0.02^{a}

Means within the same row having similar superscript alphabets are not significantly different

Discussion: Vegetables are group of plants that are encompassed with essential nutrients which are consumed for nutritional and health purposes. Vegetable are rich in phytochemicals which serve various [illegible]licinal purposes in the body. [illegible]es consumed raw or cooked. Among the common vegetables in Jos, Plateau State are cucumber, carrots and radish, whose phytochemical and nutritional values vary, thereby, informing consumers of which vegetable will provide more nutrients and phytoconstituents among these three. Phytochemicals are majorly secondary metabolites which are synthesized by plants to serve as antimicrobial, antifungal that serve the purpose of their survival and fecundity. These secondary metabolites displayed different biological activities, such as antimicrobial, anti-inflammatory, cardioprotective, antiviral and anticancer properties (Elekofehinti *et al*., 2021).Based on the result obtained in this research work, cucumber contained the least phytochemical among the three vegetables. The presence of flavonoids in moderate amount, with cardiac glycosides and plobatanins in trace amount showed that cucumber contains little phytoconstituents. The result of the phytochemical constituent of cucumber is in agreement with that of Agatemor *et al*. (2018) who reported the presence of flavonoids, tannins, cardiac glycosides. However, contrary to his result, saponins and terpenoids are absent in the extract of the fruit of cucumber as observed in this research work. The distinctions between these two results might be as a result of the differences in soil types, environmental factors as well as genetic factors (Kumar *et al*., 2023; Tiwari and Cummins, 2013). The presence of flavonoids, phenols and tannins showed the potentials of cucumber to serve as an antioxidant, mediating the effect of reactive oxygen and nitrogen species in the body (Muniyandi *et al*., 2019). The presence of cardiac glycosides could imply the potential of fruits in regulating heart beats through the activity of its sodium potassium pump in its Na^{+}/K^{+}-ATPase activity (Karaś *et al*., 2020).

Carrots has the highest number of phytochemicals and it is the most abundant among the three vegetables. The presence of tannins, flavonoids, saponins, cardiac glycosides and phenols in the ethanol extract is similar to the published work of Nimmyel and Lohdip (2022) who reported that aqueous acetone extract of carrot showed the presence of tannins, flavonoids, saponins, cardiac glycosides, phenols but absence of terpenoids. A similar study also revealed the ethanolic extract of carrot to have the highest flavonoid content which is similar to the report in this study (Tanveer, 2019). Saponins have also been reported for its effect against microorganism, thereby serving as antimicrobial activity against both gram (+) and gram (-) microorganisms (Elekofehinti *et al*., 2021). Saponins have been reported to serve various pharmacological properties such as anti-inflammatory, antiviral, cardioprotective, immunoregulatory and anticancer (Cheng *et al*., 2016). Terpenoids are group of compounds found in essential oil which are responsible for various biological functions. The presence of terpenoids in these vegetable could be responsible for some biological activities as terpenoids have been reported to serve as anticancer (Potocnjak *et al*. 2018), anti-allergic (Kobayashi *et al*., 2016), antibacterial (Guimaraes *et al*., 2019) and as antioxidant (Wang *et al*., 2019). Radish also recorded the presence of important phytochemicals such as flavonoids, saponins, phlobatanins, amino acids and terpenoids. This result is similar to that of Riaz *et al*. (2023) who examined the presence of flavonoids, tannins, saponins, terpenoid. In comparison, the amount of carbohydrates and protein content of carrots may imply a higher energy supply to the body than cucumber and radish. Carbohydrate is a source of pure form of energy to the body, providing adequate monosaccharides, disaccharides, oligosacchardies and polysaccharides that can be oxidized to form adenosine triphosphate (ATP) (Awuchi and Amagwula, 2021). However, high carbohydrate content could lead to hyperglycemia, a condition not favourable to diabetic and obese individuals. The proximate composition result of cucumber is in contrary to that of Agatemor *et al*. (2018) in which he obtained 94.2±0.08 (moisture), 3.01±0.07(crude protein), 1.02±0.01 (fibre), 0.94±0.24 (ash), 0.55±0.13 (lipid), 0.28±0.09 (carbohydrates). The reason for the differences could have been as a result of the direct analysis of the fresh cucumber by Agatemor *et al*. (2018), whereas, dried sample was used by this research work. The proximate result of carrots is similar to the published work of Gazalli *et al*. (2013) who reported a moisture content of 8.78±0.17, ash content of 5.05±0.32, protein of 6.16±0.06, fat of 2.43±0.12, crude fibre of 24.66±0.83.

Conclusion: The study on the phytochemical screening and nutritional properties of carrot, cucumber and radish showed the presence of the phytochemicals in the vegetables sample. All the phytochemicals assessed were present in carrot sample while in the cucumber sample, saponins and terpenoids were absent and in radish cardiac glycoside, phenol and tannins were also absent. This indicates that in the three vegetable samples assessed, carrots had the highest phytochemical content followed by radish and then cucumber. In the nutritional composition of the vegetable samples, carrot had the highest crude carbohydrate while cucumber had the highest crude protein and moisture content. Radish had the highest crude lipids and fiber content. The health benefits of consuming these vegetables are due to the presence of these bioactive compounds and the nutritional composition in the vegetables. Based on this finding, consumption of carrots, cucumber and radish should be encouraged due to their nutritional and phytochemical properties which are of health benefits.

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Preliminary Early-Stage Screening of Sorghum (*Sorghum bicolor* L.) Genotypes Seedlings for Enhanced Drought Tolerance in Nursery Environments in Jos Plateau.

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Abstract

This research project was carried out at the Federal College of Forestry in Jos, in September 2023, to assess the drought tolerance of some six sorghum (Sorghum bicolor. L) genotypes at the seedling stage in the nursery. The Sorghum genotypes were planted in PVC pipes filled with potting mixture and subjected to either moisture stress or non-moisture stress conditions. The experiment spanned 45 days, during which various parameters such as germination percentage, seedling height, number of leaves per plant, and length of primary root were measured. Under moisture-stress conditions, the experimental material received initial watering for the first 10 days, followed by discontinued watering. The non-moisture stress group, on the other hand, was consistently watered to field capacity throughout the 45 days. Data analysis included simple descriptive statistics, such as percentages and means, and the results were presented using a bar chart to depict the performance of different Sorghum genotypes during the experiment. Preliminary findings suggest that, for fodder and animal feed production, Kaura and Mori showed resilience in maintaining leaves under moisture stress. Takanda and Kaura emerged as promising genotypes based on root length and their ability to withstand moisture stress. However, further research employing statistical analysis tools and field trials is essential to consider factors like crop yield, disease resistance, and local environmental conditions for the optimal selection of the most effective Sorghum genotype.

***Keywords:** Drought, Tolerance, Seedling stage, Genotype.*

Introduction: Sorghum (*Sorghum bicolor* (L.) Moench] is the fifth most important cereal grain after maize, rice, wheat and barley in the world (FAOSTAT, 2017). It has been cultivated for centuries as a staple food crop in most of sub-Saharan Africa and Asia. It has extensive adaptation and tolerates high temperatures and drought stress (Derese *et al.*, 2017). It grows under high radiation, inadequate and erratic rainfall and in soils of poor structure, low fertility and low water holding capacity. Considering recent climate changes, sorghum production could reduce the expected food shortages (Abdalla and Gamar , 2011). In developing countries, including Nigeria, more than 500 million people consume sorghum as their principal food source (Burke *et al*., 2013). Sorghum is a gluten-free cereal used as a whole grain or processed into flour to provide essential nutrients including carbohydrates, protein, vitamins and minerals, and nutraceuticals such as antioxidants, phenolics and cholesterol-lowering waxes (Taylor *et al*., 2006). In Nigeria, a total of 4.34 million tons of sorghum is being produced per annum. The mean yield level in the country is estimated at 2.4 t ha−1. The crop is the major food cereal after maize and tef in terms of number of growers, area coverage and grain production in the country (FAOSTAT, 2017). It is utilized in various forms, such as for making the local bread, 'Injera', and for the preparation of local beverages such as, 'burkutu' 'tela' and 'areki'. Grain from some sorghum varieties is cooked as a roasted or boiled grain. Sorghum stalks are used as feed for animals and as housing and fencing material. The crop is highly adapted to the lowland and drier parts of Nigeria. Despite its ability to grow in the arid and semi-arid areas of sub-Saharan Africa including in Nigeria, the yield and quality of sorghum are affected by a wide array of production constraints such as the use of low-yielding traditional varieties, which keep its productivity low. Drought, infestations by *Striga hermonthica* and soil salinity are the major stresses that limit sorghum production and productivity in the world (Zhu-Salzman *et al.*, 2004). Among these, drought stress and Striga damages are the most important production constraints to sorghum production in Nigeria (Derese *et al.*, 2017; Gebretsadik *et al.,* 2014). Drought is a major constraint in sorghum production worldwide and is considered the most important cause of yield reduction in crop plants (Sabadin *et al,*. 2012; Besufekad and Bantte, 2013), especially in water-limited areas of the world including parts of western and southern Africa. Striga infestation is often linked with poor soil fertility, resulting in poor harvests and consequently hunger (Ejeta, 2007). The impact of *Striga* is more pronounced in areas under moisture and nutrient stresses (Burke *et al.,* 2010).

In dryland areas, high seedling mortality rates are common due to drought and heat stress, particularly during early stages of plant growth like germination, emergence, and establishment (Abreha *et al.,* 2022). Sorghum losses often occur post-emergence but before seedling establishment (Queiroz *et al.,* 2019). Drought significantly impacts these early developmental stages, affecting starch synthesis and energy production by increasing respiration, which reduces seedling vigor and germination (Queiroz et al., 2019). Sorghum varieties exhibit variable responses to drought, with higher osmotic potential environments favouring a greater germination rate index (GRI) and lower potentials prolonging mean germination time (MGT) (Khan *et al.,* 2022; Bayu *et al.,* 2005). Sorghum is vital in arid and semi-arid regions, where it outperforms other cereals like maize and wheat (Duodu *et al.,* 2003; Reddy *et al.,* 2004). Selecting drought-tolerant sorghum varieties suited to low-moisture conditions is critical for sustained production. Farmers often prefer local sorghum landraces for their high biomass yields, which serve as animal fodder, fuel, and construction material during off-seasons. This study aims to identify top-performing local sorghum varieties in terms of germination, growth, and drought tolerance in controlled conditions.

Materials and Methods: Study site: The experiment was conducted in the Federal College of Forestry Jos Screen house in the nursery. The area lies between the southern limit of the Guinea Savannah ecological zone. Temperatures range between 10^0C and 32^0C, and the main annual rainfall is about 1400mm. The experimental field is situated at 09^{0}56'N and 08^{0}53'E at an altitude of 1,217M above sea level, within the Northern Guinea Savannah ecological zone of Nigeria (Kowal and Knabe, 1972).

Source of Experimental Material: Sorghum (*Sorghum bicolour* (L.) Moench) genotypes seeds: Kaura, Mori, Bendo, Yel -yel, Para-Para and Takanda ,were sourced from sorghum growing areas of Tula area of Gombe State.

Screen-house-evaluation: Six seeds from each of the six different Sorghum genotypes were sown in uniformly cut polyvinyl chloride (PVC) pipes, used as pots, each measuring 45 cm in length and 10 cm in diameter. Each pot was filled with 4.0 kg of loamy soil, as described in Table 1, and irrigated daily to field capacity for three days before sowing. After seedling emergence, the seedlings were thinned to four per pot and arranged in a completely randomized design with three replications. The experiment was initially watered at a rate of 0.6 liters per pot daily for the first 10 days, after which watering was discontinued. Observations were conducted for a total of 45 days. Following the cessation of watering, growth and morphological traits were recorded biweekly as indicators of drought tolerance. Measurements of the number of leaves (NOL) were taken biweekly, while plant height (PH) and root length (RL) were measured on the 45th day. Below-ground measurements followed a modified version of the procedure described by Harrington *et al.* (1994) and Obeng-Bio *et al.* (2011). Each pot containing seedlings with its soil was carefully submerged in a 100-liter bowl filled with water to loosen and wash the roots. The seedlings were then transferred to a 25-liter container of water to ensure complete removal of soil particles. The root length (cm) was measured using a meter rule from its point of its nodal origin . Observations and data collection were recorded accordingly.

Observations and Data Collections: Morphological observations and data were recorded on any two (2) randomly selected seedlings in each pot. This would be done for both experimental materials under moisture-stressed and non-moisture-stressed conditions, as follows:

1. Germination percentage (G%): This was done by dividing the number of germinated seeds by the total number of seeds planted by 100. Seed Germination percentage (%) = (Number of germinated seeds / Total number of seeds) x 100.
2. Plant height (PT): This would be done by taking measurements from the soil surface to the highest point of the arch of the uppermost leaf whose tip is pointing down in cm.
3. Number of leaves per plant (NOL): This was determined by counting the total number of leaves on each of the two sampled plants starting from the lowest one (the coleoptile leaf which has a rounded tip) up to the last leaf that is arched over (tip is pointing down), and divided by two per pot.
4. Root Length (RL) root length was measured from the collar region to the tip of the longest root and expressed in centimeters (cm).

Data Analysis : All data collected was analyzed using descriptive statistics and presented using a bar chart to illustrate the plant response parameters to imposed experimental conditions.

Results: Variations in Germination Response of Genotypes in Non-moisture and Moisture-stressed Condition: The result of the mean performance of the sorghum genotypes evaluated under both the moisture and non-moisture-stressed environments are presented (Figure, 1)

Non-moisture-stressed environment: These results highlight significant variations in the germination percentages among different genotypes , indicating genetic differences in their ability to germinate under the non-moisture stressed conditions as presented in Figure 1. Kaura showed a 26.7% germination rate, Mori exhibited a high rate of 90%, Bendo displayed an 86.7% rate, and Yel-Yel achieved a perfect 100% germination. Para-para reached 66.7%, and Takanda matched Mori with a 90% germination rate.

Moisture Stressed Environment: During the experiment under moisture stress, Kaura demonstrated a 60% germination rate, Mori showed a higher rate of 86.7%, and Bendo achieved an 83% germination rate. Yel-Yel had a perfect 100% germination rate, while Para-para reached 56.7%. Takanda also achieved a 100% germination rate under moisture-stressed conditions.

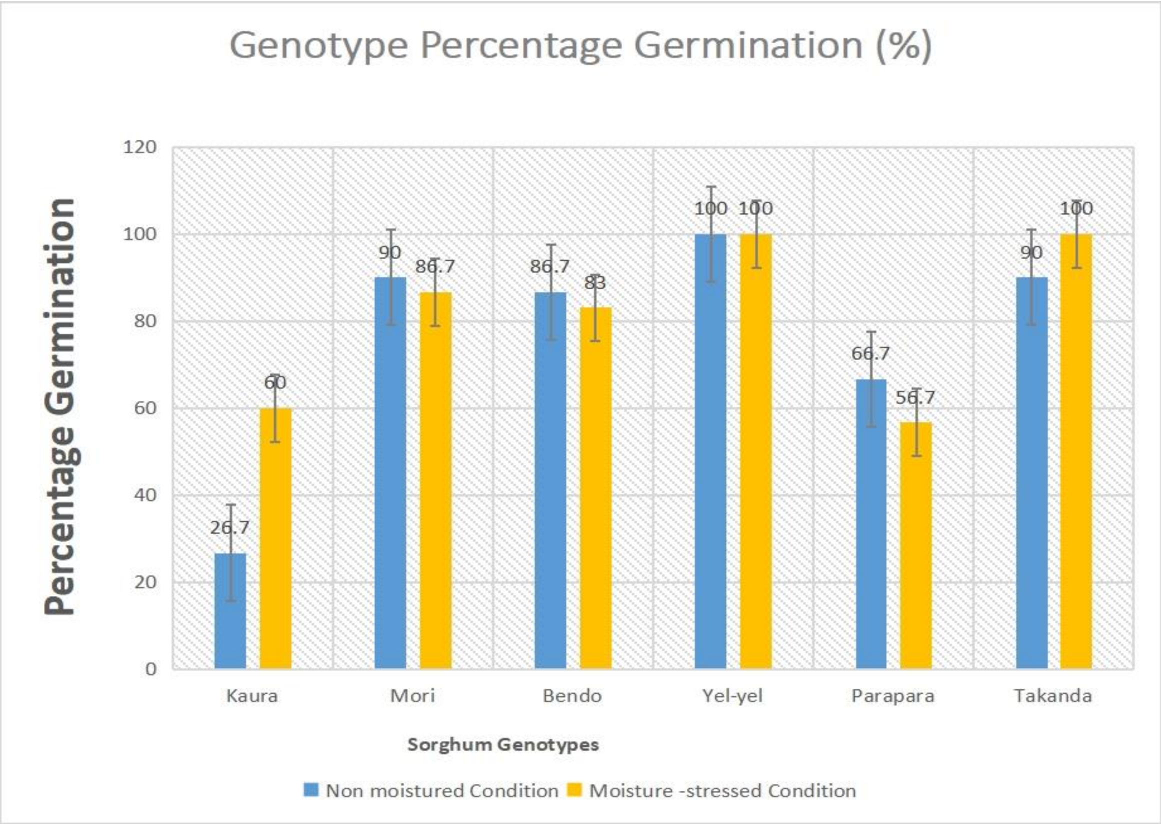

Figure 1: Germination Percentage (%) Variations of Six Sorghum Genotypes Under Non-Moisture and Moisture-stressed Conditions in The Screen house During The Experimental Period in Jos.

Variations in Genotype Response to Plant Height Under Non-moisture and Moisture-stressed Condition

Plant Height Under Non-Moisture Condition: The results indicate that Yel-yel (29.3 cm) recorded the tallest plant height, suggesting strong vertical growth, followed by Kaura (28.8 cm) and Mora (28.3 cm). Bendo (28.0 cm) showed slightly shorter height, while Takanda (25.0 cm) exhibited moderate height. Para-para (23.3 cm) had the shortest plant height among the genotypes. See Figure 2.

Plant Height Under Moisture-stressed Condition: In a moisture-stressed environment, Kaura exhibited the shortest plant height at 23 cm, suggesting it is more sensitive to moisture stress. Para-para followed closely with a height of 21 cm, also indicating high sensitivity. Takanda reached 25 cm, showing moderate tolerance to moisture stress. Yel-yel recorded a height of 26.3 cm, indicating some resilience but with moderate impact from moisture stress. Mori and Bendo showed the greatest tolerance, both reaching a height of 28.3 cm, suggesting they are the least affected by moisture stress. See Figure 2.

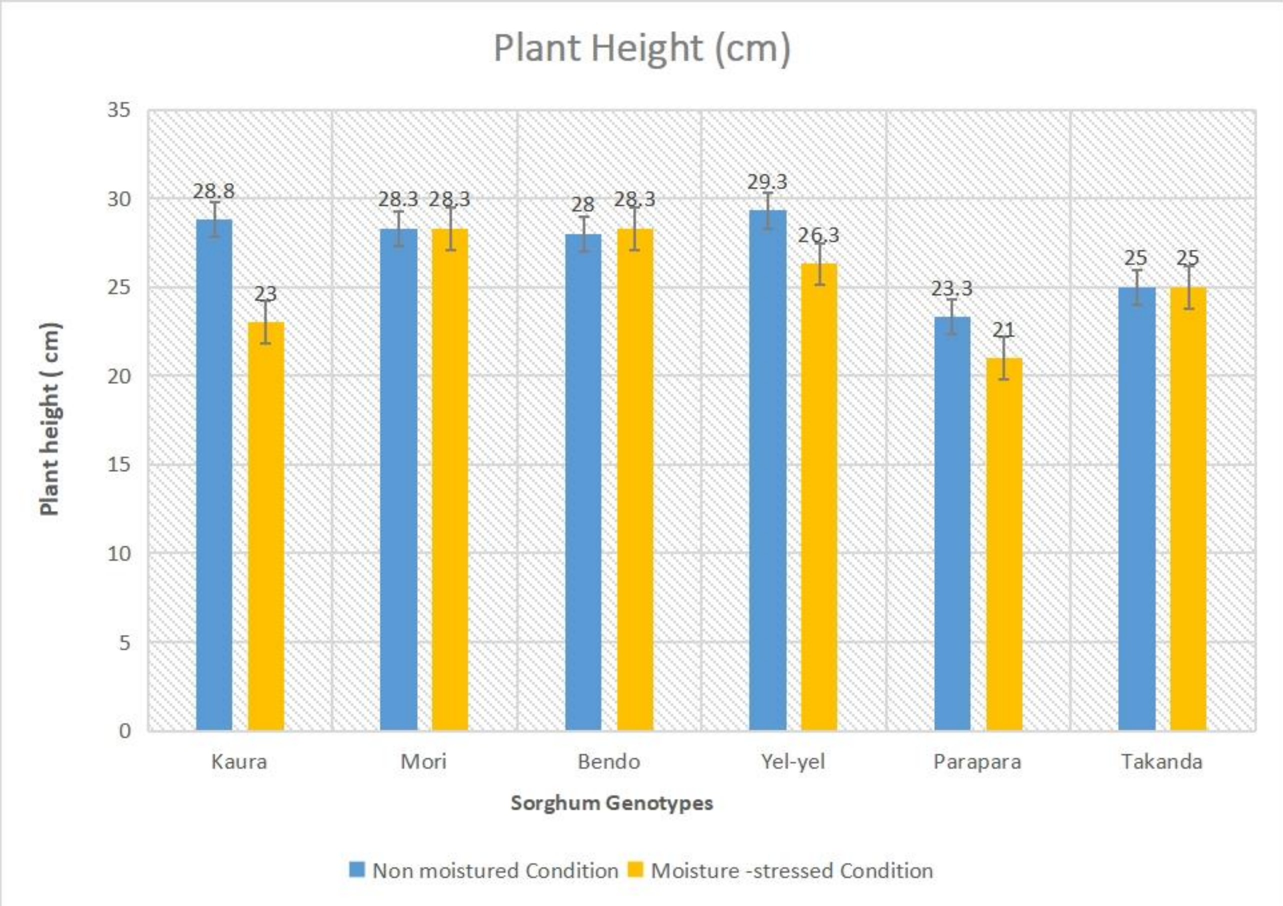

Figure 2: Mean Plant Height of Six Sorghum Varieties Under Non-Moisture and Moisture-Stressed- Conditions in the Screen House During The Experimental Period in Jos.

Variations in Genotype Response to Root Length Under Non-moisture and Moisture-stressed Condition

Plant Root Length Under Non-Moisture Conditions: The sorghum genotypes showed root lengths ranging from 18.9 cm to 28.0 cm. Yel-Yel had the longest mean root length at 28.0 cm, followed by Kaura (26.1 cm), Mora (25.7 cm), and Bendo (25.3 cm). Takanda had the shortest root length. See Figure 3.

Plant Root Length Under Moisture Conditions: The result revealed that under moisture-stressed conditions, Takanda exhibited the longest root length (29.3 cm), suggesting strong adaptability, followed by Kaura (28.9 cm), Mora (28.4 cm), and Bendo (28.1 cm), which also displayed resilience. Yel-Yel (26.6 cm) and Para-para (24.9 cm) showed shorter roots, indicating potentially lower adaptability to moisture stress. See Figure 3.

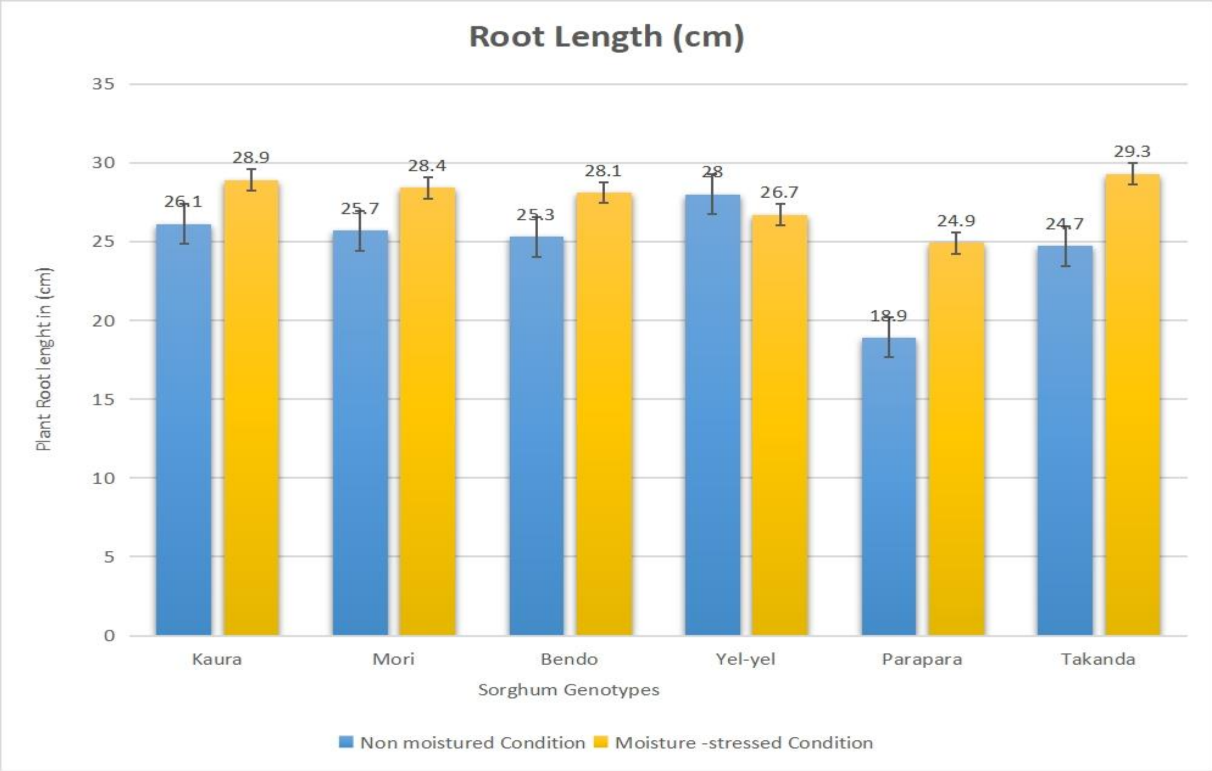

Figure 3: Mean Root Length of Six Sorghum Genotypes Under Non-Moisture and Moisture-Stressed Conditions in The screen house During The Experimental Period in Jos.

Genotype Response to Plant Number of Leaves (NOL) Under Non-moisture and Moisture-stressed Conditions: Plant Number of Leaves Under Non-Moisture-Stressed Conditions: Under non-moisture-stressed conditions, genotypes Kaura, Mori, and Para-para each produced an average of 2.66 leaves. In contrast, Bendo, Yel-yel, and Takanda averaged 3 leaves, showing slightly higher leaf production. See Figure 4.

Plant Number of Leaves Under Moisture-stressed Conditions: The results indicated that in a moisture-stressed environment, genotypes Kaura, Mori, Yel-Yel, Para-para, and Takanda each maintained an average of 3 leaves, demonstrating resilience to water scarcity. Bendo had a slightly lower average of 2.7 leaves, suggesting some impact from moisture stress, although the difference is relatively minor. Overall, the consistent leaf counts in these varieties indicate their adaptability to moisture-limited conditions. See Figure 4.

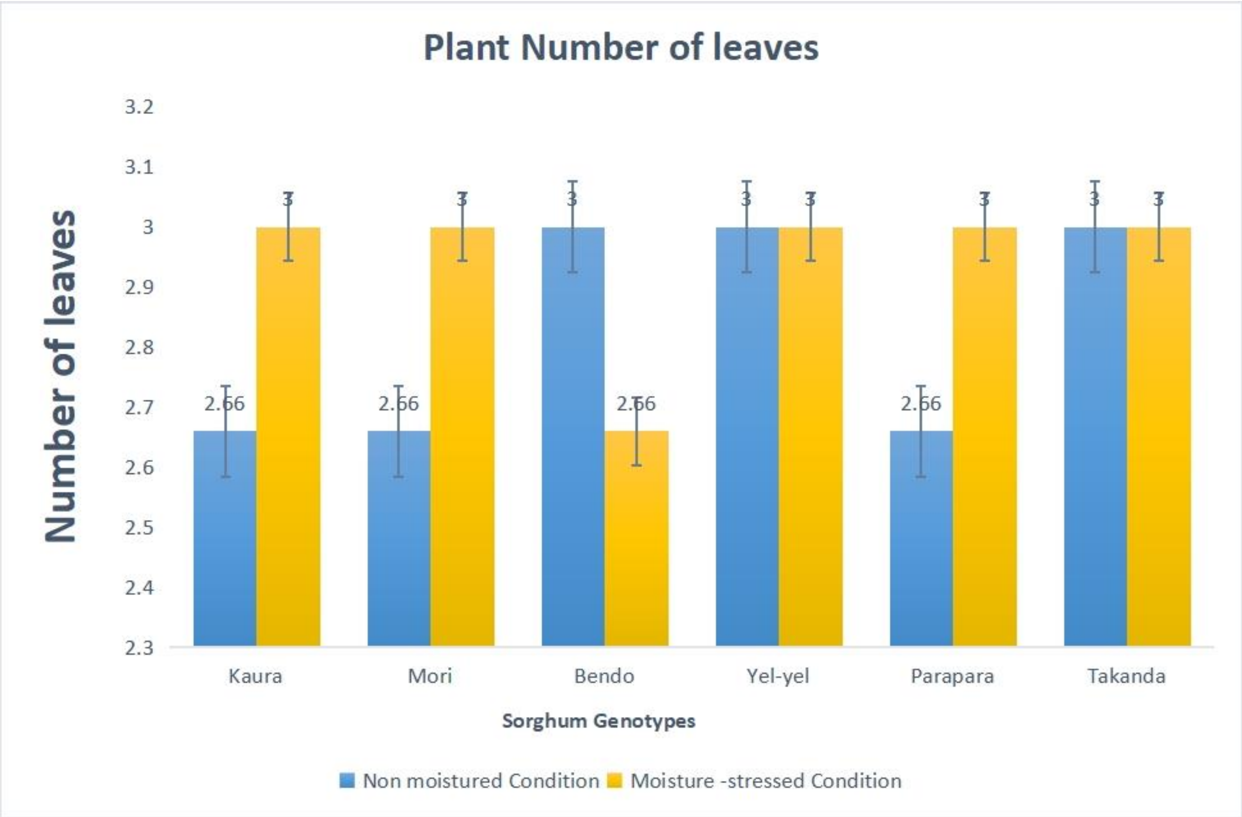

Figure 4: Mean Number of Leaves For Six Sorghum Genotypes Under Non-Moisture and Moisture-Stressed Conditions In The Screen house During The Experimental Period in Jos.

Discussion: The preliminary screening of sorghum (*Sorghum bicolor* L.) seedlings for drought tolerance in nursery environments is crucial for identifying genotypes capable of withstanding water scarcity, a significant agricultural challenge. Our findings reveal notable variations in growth parameters, such as plant height, root length, and leaf number among different sorghum varieties under drought conditions. This supports the findings of Cantao *et al.* (2008), and Liu *et al.* (2017), which indicate that certain physiological and morphological traits can serve as reliable indicators of drought resistance during the seedling stage. Genotypes Takanda and Yel-Yel demonstrated superior drought tolerance by maintaining a higher number of leaves and longer root lengths than other varieties. This suggests that these genotypes have developed adaptive strategies to cope with limited moisture, enhancing resource utilization during stress, consistent with the concept of water-use efficiency (WUE) as a physiological indicator of drought adaptability (Martin *et al.*, 1999; Ray *et al.*, 1999; Liu *et al.*, 2017). Their ability to sustain growth in adverse conditions underscores their potential for cultivation in arid and semi-arid regions, where sorghum is a staple crop.In contrast, Bendo exhibited reduced leaf numbers and shorter root lengths, indicating a higher sensitivity to drought stress. While differences in growth parameters were not drastic, they highlight the genetic variability in drought response among the evaluated sorghum genotypes. Such variations are critical for breeding programs aimed at enhancing drought resilience, aligning with the findings of Nwadike *et al.* (2022; 2023).The study underscores the importance of early-stage screening in nursery environments. Evaluating physiological traits under controlled conditions enables the effective identification of promising genotypes for further development and field testing, facilitating the selection of varieties that thrive under water-limited conditions.

Recommendations: Based on the results presented, the following recommendations are suggested: cultivating Kaura and Mori in moisture-stressed environments is recommended for fodder and animal feed production.Genotype Takanda and Kaura can be considered potential parents for breeding programs based on root length. Further research employing statistical analysis tools and field trials is needed to evaluate factors such as crop yield, disease resistance, and local environmental conditions for optimal variety selection.

Conclusion: Evaluating sorghum genotypes for drought tolerance at the seedling stage has provided valuable insights into their adaptability and resilience to moisture stress. The findings emphasize the importance of selecting genotypes with longer root systems and consistent leaf growth as promising candidates for enduring moisture scarcity. However, it is essential to recognize that selection should not rely solely on a single trait. Therefore, further research and extensive field trials are recommended to facilitate a comprehensive selection process for sorghum varieties in moisture-stressed regions. These efforts will contribute to developing more resilient and productive sorghum varieties, addressing the challenges posed by drought and climate change, and enhancing food security in affected environments.

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Response of Wild Edible Plant Black Nightshade (Solanum nigrum L.) accession to Diverse Nutrient Sources in Jos, Plateau

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Abstract

The study evaluated the growth and yield response of Solanum nigrum L. *(Black Nightshade) to diverse nutrient sources during the 2022 cropping season in Jos, Plateau State, Nigeria. Using a Randomized Complete Block Design (RCBD) with eight treatments (varied applications of cow dung and NPK fertilizers), we aimed to identify optimal nutrient sources and application rates for enhancing growth parameters such as plant height, leaf yield, branch number, and fruit yield. Results showed that treatments using both organic (cowdung) and inorganic (NPK) fertilizers had beneficial effects on growth, with mixed sources generally promoting a higher yield and plant population. However, significant differences p=0.05 levels of probability, in growth and yield characteristics were mostly observed in total plant population per plot rather than individual growth parameters. This study underscores the potential of integrating organic and inorganic fertilizers to support sustainable cultivation of* Solanum nigrum*, offering practical recommendations for farmers seeking to maximize yield and maintain soil health. Further research is recommended to assess the long-term effects of these nutrient sources and to establish their economic viability in the area.*

***Keywords**: Accession, Fertilizer, Wild Edible Plants (WEP), Weeds, Indigenous Vegetables*

Introduction: While humanity depends on a diverse array of cultivated crops, only a handful of staple crops account for the majority of the global food supply. Notwithstanding this, the contribution of minor species should not be underestimated. Researchers have focused mainly on staple crops and paid little attention to minor species. One such specie is *Solanum nigrum* L. (Black nightshade) (Callistus *et al.*, 2014).*Solanum nigrum* is a short-lived perennial shrub that belongs to the Solanaceae family. It is popularly called Glossy Night Shade in English or simply black nightshade or blackberry nightshade, and Odu in Yoruba.Black nightshades (*Solanum nigrum* L. and related species) are commonly found as weeds in nitrogen-rich soils across arable lands, gardens, rubbish heaps, in moderately light and shade environments and disturbed areas from sea level to mountainous regions (Ademuyiwa *et al*., 2018; Edmonds and Chewya,1997). Despite their weedy status. In certain local communities, these plants are utilized as leafy herbs, vegetables, sources of fruit, and for various medicinal applications, thereby classifying them as wild edible plants (WEPs) or indigenous vegetables (Beluhan and Ranogajec,2010). Indigenous vegetables, which are species growing wild without cultivation or domestication, are often considered underutilized due to limited data (Weinberger, 2007). These plants are either native to a region or have become integral to local traditions and culture over time (Maundu *et al.*, 1999; Weinberger, 2007).The nightshade is a species of flowering plant in the genus Solanum. Its ripe berries and cooked leaves of edible strains are used as food in some locales and have a high nutritional value, providing an important source of Ca, Fe, proteins, Vit A, and fiber among other nutrients (Husselman and Sizane, 2006). The plant parts are used in traditional medicine. A tendency exists in the literature to incorrectly refer to many of the other "black nightshade" species as "*Solanum nigrum*".

The domestication and cultivation of *Solanum nigrum* and similar wild edible plants remain a low priority, largely due to limited knowledge and documentation of their identification, nutritional composition, uses, and management (Frison *et al.*, 2006; Vincetti *et al.*, 2008). These resources are underutilized, as traditional leafy vegetables are often classified as minor crops and receive minimal attention in crop improvement and agronomic research, partly due to a lack of data on their yields and market potential (Mwafusi, 1992). This neglect has contributed to a significant narrowing of the food base in many traditional societies.Propagation of *Solanum nigrum* remains unclear, as these vegetables, though sometimes grown from seeds in local communities, remain scarce, partly due to limited understanding of their response to various manure sources. Ogbonna (2008) identified declining soil fertility and soil degradation has been reported as a major barrier to sustainable crop production (Dunjana *et al.*,2023). Furthermore, the rising costs and scarcity of inorganic fertilizers have compounded the challenges faced by agricultural practices in many regions of Nigeria.

Underutilized vegetable species hold significant potential for enhancing food security, nutrition, and environmental sustainability; however, they remain under-exploited. In traditional communities, best practices for cultivating these plants are often poorly documented, leading to a lack of evidence. Soils with low nutrient levels require amendments to enhance crop production, with organic fertilizers being a viable option as they improve soil structure and microbial mass while providing nutrients through mineralization (Dunjana *et al.*,2023). However, minerals from organic sources are typically released slowly, often not becoming available until after the first season. Conversely, while inorganic fertilizers are favored by farmers for their rapid availability to plants, they are often costly and can be harmful to soil health and human well-being (Arisha and Bardisi, 1999). this study aims to evaluate the response of *Solanum nigrum* L to its growth and yield as this can inform increased awareness , improvement and enhance crop yield outcomes.

Materials and Methods.: Study Area: Field experiments was conducted during the 2022 cropping season within the teaching and research field of the Forestry Research Institute of Nigeria (FRIN), Federal College of Forestry, Jos Plateau State. The experimental field is situated at 09°56'N, and 08°53'E at an altitude of 1,217M above sea level. Within the Northern Guinea Savanna ecological zone of Nigeria (Kowal and Knabe, 1972).

Soil Analysis of Site: The soil attributes of the experimental plots were carried out to determine their physical and chemical characteristics.

Sourcing of Experimental Material: About 1kilogram seeds of African black nightshade were collected from farmers in the Gembu metropolis of Sardauna Local Government Area of Taraba State.
Experimental Treatments, Design and Layout: The experiment were laid out in a Randomized Complete Block Design (RCBD) with eight treatments. Each treatment had 3 replicates, each with 8 experimental units to ensure a sufficient number of plant samples for the duration of the trial. The treatments were: Control (M0); 5 kg Cow dung/ha (MI); 10 kg Cow dung/ha (M2), 15 kg Cow dung/ha (M3), 2 kg cow dung + 2 kg NPK/ha (F*M), 5 kg NPK/ha (F1), 90 kg NPK/ha (F2), and 100 kg NPK/ha (F3). N was supplied in the form of N-P-K (20:10:10). The cow dung manure were obtained from the Yanshanu cattle market in Jos north and proper curing was ensured and followed pulverization and sieving .The length of each bed was 1m × 1m and a border of 0.75m and a general setback of 0.75m around the experimental field.
Cultural practices: The land was cleared manually, to remove all the vegetative cover and unwanted materials raked out from the filed. The beds were constructed manually through the use of an Indian hoe. 10g of nightshade seeds were weighed out and sown per bed according to the planting methods of broadcasting. The cured cow-dung organic fertilizers treatments were applied once, immediately after planting bed preparation while inorganic fertilizers were applied in two split application at 2 weeks after planting (WAP) and at 4WAP. Weed were controlled using hoe weeding and hand pulling to minimize any damage. Harvesting was carried out manually by picking matured leaves and young shoots at 5WAP, 7WAP and WAP9 and followed by destructive sampling method of uprooting the whole plant at the end of the experiment at 10WAP.
Data Collection and Analysis: Five (5) plants were sampled per plot for data collections , the number of leaves and branches per plant of nightshade at harvest also number of fruits per hectare and fruit yield (kg/ha) and dry matter yield (kg/ha) according to methods described by (Lemma, 2002):

1. Plant height (cm): Plant height were recorded by measuring the height of 5 randomly selected plants in each plot from the ground to the main apex.
2. Number of Primary branches: plant primary branches were counted at maturity from 5 randomly selected plants in each plot.
3. Fruit yield (kg):The sum of fruit weight per plot from successive harvest (kg) will be taken and converted to ton per hectare.
4. Leaf yield (kg):The sum of leaf weight per plot from successive harvest (kg) were taken and converted to kilogram per hectare (kg/ha).
5. Dry matter: sum of all yields collected at dry weight in kg were added and converted to kilogram per hectare (kg/ha).

All data collected were analyzed and presented as well as subjected to Analysis of Variance (ANOVA) (Gomez and Gomez,1984), and treatment means comparison will be done using Fisher's list significance difference (HSD) at 5%, using SAS computer software (SAS, 2009) and presented later as data is still being analyzed.

Results

Means of Growth and Yield Characteristics of black Night shade evaluated during the trial under different fertilizer sources are presented table 1 bellow:
Plant Height : The mean of plant height under different fertilizer sources and rates showed were not significant with treatment 5 kg NPK/ha (F1) with the least value and the highest mean value was recorded for 5 kg Cow dung/ha (M1).
Mean Number of leaves : The mean of plant number of leaves under different fertilizer sources and rates showed were not significant with treatment combination of organic and inorganic fertilizer (F*M) 62.67 and (F2) had the highest mean value 61.67.

Plant Branches: The mean of plant branches under different fertilizer sources and rates showed no significant difference . control recorded the least value of 5.67, with fertilizer combination having the highest mean value of 10.00.

Mean Fruit Yield: The mean of fruit yield (g/plot) were not significantly difference the least mean value was recored for control 10.67 and the highest mean value for 18.33 was against 15 kg Cow dung/ha .

Mean Fresh Weight : The mean of fresh weight yield (g/plot) under different fertilizer sources and rates showed no significant difference .The highest mean value of 403.3g/plot was recorded for 5 kg Cow dung/ha, while the least value recorded for control with the least value of 136.67g/plot.

Dry Matter Yield: The mean of dry matter yield (g/plot) under different fertilizer sources and rates showed no significant difference 5 kg Cow dung/ha (M1) fertilizer had the highest mean value of 103.67g/plot, the least value recorded for control 27.33g/plot.

Total Plant Population Per Plot: The total population of plant per plot under different fertilizer sources and rates were significantly different across all treatments..

Table 1: Means of Growth and Yield Characteristics of Black-nightshade Evaluated During the 2022 Trial Under Different Fertilizer Sources and Rates

Discussions.

Although , the means recorded for all treatment were relatively high indicating that treatment had effect on the plant . how ever, the mean performance of Black Night shade under difference fertilizer sources and rates revealed that there was no significant different in all treatment means while significant difference was recorded only for plant population per plot.
This shows that the difference manures sources and rates can be used for raising the Black night shade plant.

Recommendation: Based on the result above the application of 5 kg/ha, 10kg/ha of organic manure and a combination of both sources in equal proportion could be recommended for the cultivation of black night shade especially when high plant population density is the objective.
Conclusion: The experiment conducted during the 2022 farming season to assess the growth and yield performance of *Solanum nigrum* (black nightshade) demonstrated that a balanced approach using mixed nutrient sources is highly beneficial for its cultivation in the Jos Plateau, where soil health is a key concern. The findings showed that various fertilizer sources and application rates, whether used alone or in combination, can effectively support black nightshade growth. This information provides valuable guidance for local farmers, encouraging sustainable agricultural practices that enhance both productivity and nutritional quality of this important wild edible plant. Future research should focus on the long-term impacts of these nutrient applications and evaluate their economic feasibility for smallholder farmers in the area.

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Treatments	PH Means	NL Means	NB Means	NF Means	FWT Means	DWT Means	PP/Plot Means
2 kg cow dung + 2 kg NPK/ha	51.73	62.67	10.00	14.67	231.70	46.33	206.67ab
5 kg NPK/ha	51.03	51.00	8.00	11.00	333.67	100.67	191.33ab
90 kg NPK/ha	59.40	61.67	8.00	11.67	385	103.67	194.33ab
100 kg NPK/ha	52.00	38.67	7.67	12.67	361.67	111.67	186.67ab
5 kg Cow dung/ha	77.07	58.33	7.67	14.67	403.33	44.33	295.33a
10 kg Cow dung/ha	61.17	45.00	8.00	12.67	366.67	73.33	284.33a
15 kg Cow dung/ha	71.37	46.00	8.00	18.33	283.33	56.67	268.67ab
Control	52.10	58.00	5.67	10.67	136.67	27.33	94.33b
HSD	Ns	Ns	ns	ns	ns	ns	*
SE±	5.53	14.01	2.23	4.51	168.83	54.87	51.72

***NB: Means with the same letter on same columns are not significantly different at* p=0.05 levels of probability .**

PH-**Plant Height :** NL-**Number leaves;** NB-**Number of branches ;**NF-**Number of fruits ;**FWT- **Fresh Weight;** DWT- **Dry Weight ;** PP- **Plant Population**

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Towards Boosting Food Security and Living Standard in Benue State: An Assessment of the Role 0f Third Fadama Project in Buruku Lga

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Abstract

Food security is at the forefront of the basic requirement for human survival and also doubles as one of the indices of economic development globally. This paper using primary and secondary data as bases for empirical and qualitative analysis examines the Fadama Project in Buruku Local Government of Benue State against the background of its contributions in the area of agricultural development and poverty reduction among the farmers in Fadama User Groups. A total of 190 structured questionnaires were administered using multi-stage sampling technique among members and no- members of farmers in Fadama Users Group. Frequency tables and simple percentages were used in analysis of data from the questionnaire and field surveys while Pearson correlation was adopted in hypotheses testing. The study also conducted Focus Group Discussion and Key informant's interview under the auspices of the Department of Agriculture and State officials of Fadama Project in Benue State at the Local Government Secretariat. The Study found that the Fadama project has significantly contributed in boosting agricultural operations in the study area through yearly engagement in the provision of improved seedlings, fertilizer, storage and processing facilities alongside extension services. The study also found that food security has been significantly improved through the periodic interventions by Fadama Project, which has provided a boost in the farmers' productivity and raised income levels, which in turn has significantly improved on food availability, accessibility and affordability. The study recommends greater commitment to the success of Fadama project through expansion in the scope of benefiting farmers. The study also recommends involvement of farmers in the planning, policy and other aspects of the Fadama Project since they double as beneficiaries and field players.

Keywords: *Fadama project, Agriculture, Food security, Agro processing and Poverty reduction*

Introduction: The global food scenario has progressively become a painting of ill-defined food production and supply system on a fixed arable land keenly contested by population growth which hit 8.2 billion benchmark in July 2024 and is expected to clock 10.2 billion by 2030 at its current 3.2 percent annual growth rate, (United Nations, 2024). According to Galanakis (2024) and Asaasuen et al (2024) there are many other issues of natural and socioeconomic affiliations which have increasingly placed profound difficulty on the food production and supply chain especially in developing countries. Among them include seasonal changes, geopolitical and religious conflicts as well as ethno-cultural and violent land use disagreements, poverty and consumer preferences. These have individually and collectively aggravated poverty levels in Sub-Saharan Africa including Nigeria and many other parts of the world leading to expanded scopes of food shortages and general economic under-development, (Oko et al, 2022; Olanrewaju & Balana, 2023). As a response strategy to the foregoing, the Federal Government of Nigeria under President Umaru Musa Yar' Adua instituted the Fadama Project and captioned it as the First National Fadama Project in 1990. According to Olawole and Olawatayo (2019), this project was initially designed primarily to provide irrigation schemes with some states comprising Bauchi, Gombe, Jigawa, Kano, Kebbi, Zamfara and Sokoto as core states, while the Federal Capital Territory and others were categorized as facility states. Due to groundbreaking success from this first Fadama Project, the Federal Government in 2003 launched the second (2nd) Fadama Project which was basically community driven with expanded scopes of funding under the tripartite arrangement involving the World Bank and Federal Government. Continued success of the programmed led to the eventful launch of the (3rd) Third Fadama Project with an expanded geographical spectrum covering all the 36 states of the federation and FCT with full assumption of the status of key instrument to stimulate agricultural growth and improve food security among the rural population, (Chakib & Adetunji, 2022).

Against the background of its establishment objectives, the Third National Fadama Project has recorded spectacular achievements across Nigeria. For instance, in a study on the impact of National Fadama III on economic development in Akwa Ibom State, Ubong et at (2024) using structured questionnaire on Fadama Users, Group and Non Fadama Users respectively categorized as Fadama beneficiaries and non-beneficiaries found and reported that there is great contrast in the financial fortunes of FUG and non Fadama beneficiaries. It is further proved that the Akwa Ibom Fadama III operations have established a microfinance Bank, which undertakes soft loan facilitates to farmers thereby boosting crop production under the four (4) priority crops: Cassava, Rice, Sorghum and Tomatoes. In Imo State, the Third National Fadama Programmed has benefited members of Fadama Users Groups through improved seedlings and fertilizer support as well as other agricultural imputes. According to Aja et al (2024) in their study of Fadama III within the context of sustainable land management practices among Fadama User Groups in Imo State using 128 farmers as sample size and frequency tables as well as simple percentage reported that Fadama has made enormous positive impacts but most often the counterpart funding on the part of government comes in late, which limits the extent to which benefits would have been maximized by farmers.

Within the Federal Capital Territory, the Third Fadama Project has greatly alleviated poverty levels through increased food production, which provides both for food security and sales for income. According to Adeboyo etal (2023) in their study on the Third Fadama Project and its impact on poverty, using 413 structured questionnaires in 6 Area Councils of the Federal Capital Factory, the project has since its inception provided a boost in crop yields through its improved seedlings and fertilizer support, This measure has translated to high output among beneficiaries of the Fadama Project thereby enhancing their financial statuses as they produce also on commercial scale, thereby providing for domestic consumption and sales in local markets. In the same view, the Third Fadama Project has benefited Fadama User Group. Members in Lagos and Niger state respectively through modern agricultural inputs and improved food security as the benefitting farmers increasingly produce crops with greater ease and output, while output has significantly received a boost, (Alawole & Oluwatayo, 2019; Chidawa etal, 2021).

Further northwards in Kaduna State, the Third Fadama project has made spectacular landmarks on the living standard of beneficiaries in Kaduna and Sokoto States. In a study, Murtala and Iris (2022) examined the comparative benefits accruing to Fadama User Groups herein-after referred to as FUG in Kaduna and Sokoto States using a sample of 245 beneficiaries randomly drawn from 12 communities in the two sates using Pearson Product Movement Correlation. Results showed that FUG beneficiaries benefited significantly through assets requisition by courtesy of the Federal Government of Nigeria, World Bank and donor agencies, which went a long way in enhancing their agricultural productivity and livelihoods. It is against the background of the foregoing that this study ventures into the Third Fadama operations in Buruku Local Government Area of Benue State relative to its contribution towards improving on the food security situation and living standard among the masses.

Statement of problem: Nigeria's growing population which stands at 218.5 million people in 2022 and 233.9 as at 16:00 hours GMT on the 15th of October, 2024 and still counting depends predominantly on food supply from agricultural productivity among the country's farmers who though have enormous numerical advantage over the non-farmers, are weakened by endemic poverty. It is imperative to state here that poverty anywhere in the world among producers translates to capital deficiency and low productivity in both agriculture and industry. This scenario has accordingly led to gross under-utilization of the agricultural potentials comprising water bodies, forests, arable lands and fadama areas with corresponding low output in the fishing, agrarian and forestry sectors as well as livestock. This odd state of affairs has greatly intensified poverty to its degenerating levels of the cyclical status and inherent side effects of increasing magnitude of criminality and other social vices in the Nigerian state generally and and Benue State. The introduction of Fadama Project in phases by the federal government has increasingly improved livelihood among framers across the country, with farmers in Buruku LGA also in full participation within the spectrum of the Third Fadama Project activities. This study is therefore a timely and appropriate measure to assess the extent to which farmers in Buruku have also benefited from the project relative to food security and living standard.

Objectives of the study: To identify areas of direct assistance by the Third Fadama Project and how these have impacted on agricultural output among FUG farmers in Buruku Local Government Area.**;** To examine the impact of the Third Fadama Project on farmer's income in the study area.**;** To examine the impact of the Third Fadama Project on living standard among farmers in FUG.**;** To assess the impact of Fadama Project iii and food security situation among farmers in FUG.

Methodology: This study administered 130 structured questionnaires among FUG farmers and non-FUG farmers using purpose random sampling. Additionally a session of focus Group Discussion was organized at the Department of Agriculture at the local government secretariat, in which FUG farmers and officials of the Fadama Project at the state level participated. This provided the needed primary data whereas secondary data were sourced through journal articles and other textbooks. On the other hand, Person correlation statistics was employed in testing hypotheses 1,3 and 4 while 't' test was used in testing hypothesis 2, Similarly this study used frequency tables and simple percentage in analyzing data on socioeconomic and demographic affiliations of respondents.

Results and analysis: This segment of the study presents findings and their analysis based on techniques already stated under methodology.

Demographic and socioeconomic characteristics of reswpondents: Data on demographic and socioeconomic profile of sampled respondents were obtained and are presented in Table 1.1.

Table 1.1 Demographic and socioeconomic profile of respondents

Variables	Frequency	Percentage
Gender**:**		
Male	89	68.46
Female	41	31.53
		99.99
Age:		
20-30	07	5.38
31-40	20	15.38
41-50	45	34.61
51-60	41	31.53
60 & above	17	13.07
	130	99.97
Marital status:		

Married	68	52.30
Single	40	30.76
Separated	22	16.92
		~~99.98~~
Education:		
No. Formal Education	21	16.15
Primary Level	60	46.15
Secondary Level	38	29.23
Tertiary Level	11	8.46
	130	99.99
Farming Status		
FUG farmer	70	53.84
Non FUG farmers	50	46.15
Total	130	99.99

Source: Field survey, Aug 2024

Table 1.1 indicates that 68.46 percent of the respondents were male whereas 31.53 percent were of the female gender. The table also indicates that 5.38% were aged between 20-30 years whereas 15.38 percents and 34.61 percent were aged between 31-40 years and 41-50 years respectively. Similarly, the table indicates that percent of sampled respondents were within the age bracket of 51-60 years whereas -----of them fell with the age bracket of 61 years and above. Again, the table indicates that 52.30 percent of the respondents were married whereas 30.76 percent were single and 16.92 percent were separated for various reasons. Table 1.1 Further indicates that 16.15 percent of the sampled farmers had no formal education whereas 46.15 percent had attained the primary level of education and 29.23 percent schooled up to secondary school level with 8.46 percent of the sampled population having attained tertiary education. On farming status, the table indicates that 53.84 percent of the sampled respondents were members implying that they were not beneficiaries.

Testing of hypotheses: **Hypothesis 1** There is no significant relationship between Fadama 111 project and agricultural output among FUG farmers."

Table 2.1 Test of relationship between Fadama 111 project and agricultural output among FUG farmers.

Variables	N	Person corr.	Sign (2 tailed)
Fadama 111 project FUG agricultural output	130	0.422	0.000

Correlation is significant at 0.01 level

Source: 1BM SPSS Extract, August 2024

Table 2.1 indicates a positive correlation of o.422 implying significant relationship under two tailed test. This means that agricultural output among FUG farmers trail along the paths of Fadama Project 111 at all times. The strength of the association is however only moderates, which points to the homogeneity of other factors that also affect agricultural productivity, such as climate and socioeconomic forces. Thus, the hypothesis which states that, there is no significant relationship between the Third Fadama Project and agricultural output among FUG farmers in the study area is hereby rejected in favor of the alternative hypothesis, which states that there is a significant relationship between the Third Fadama Project and the agricultural output of FUG farmers in the study area.

Hypothesis 2 "There is no significant difference between the annual agricultural output of FUG and non-FUG farmers in Buruku LGA."

Table 3.1 Test of difference in annual agricultural output between FUG and non-FUG farmers in Buruku LGA

Variable	Means	T	DF	Sig(2 tailed)
Average annual output of FUG farmers Average annual output of non-FUG farmers	3,345,600 1,255,200	10.357	399	0.000

Source: Extracts from IBM SPSS, August 2024

Table 3.1 indicates the average annual output of FUG farmers and non-FUG farmers representing N3, 345,600 and ₦ 1,255,200 respectively. The result shows a t-value of 10.357 with probability of 0.000<0.05. The t—test value of 10.357 is statistically significant at 0.05 level of significance where (p=0.000<0.05). Thus, the mull hypothesis which denies the existence of a significant difference between the annual agricultural output between FUG farmers and non-FUG farmers is hereby disproved and accordingly rejected in favor of the alternative hypothesis, which states that there is a significant difference between the average annual agricultural output of FUG and non-FUG farmers.

Hypothesis 3 Fadama projet III has no significant impact on the living standards of FUG farmers in Buruku LGA.

Table 4.1 Test of links between Fadama III projects and living standard of FUG farmers in Buruku LGA

Variables	M	Person corr.	Sign (2 tailed)
3rd Fadama project Living standards of FUG farmers	130	0.697	0.000

The correction is significant at 0.01 level

Source: IBM SPSS Output, August 2024

Table 4.1 indicates a strong positive correlation coefficient of 0.697 which in significant at 0.01 level under 2-tailed test. This implies that there is a strong positive association between the Third Fadama Project and living standard among the FUG farmers in the study area. In other words, the Third Fadama Project and living standard among FUG farmers move together in the same direction at all times. Therefore the hypothesis, which states that the Third Fadama Project has no significant impact on living standard is hereby rejected in favor of the alternative one, which states that Third Fadama Project has a significant impact on living standard of FUG farmers in Buruku LGA.

Hypothesis 4 Fadama III Project has no significant impact on food security in Buruku LGA : Food security in a function of its availability, accessibility and afford ability. Given the in cumbrances associated with measuring food security especially against the background of daily intake of calories recommended by Food and Agricultural Organization, this study adopts daily intake of meals in line with the popular three (3) square meals per day as basis for rating food security among FUG and non-FUG farmers, (Deretal, 2020; Balakrishna etal, 2022).

Table 5.1 Food security status based on 3 square meals per day among FUG and non-FUG farmers.

Farmers statuses	*No. of Meals per day*	*Expt.freq*	*Observed freq*	*Percentage*
FUG members	1 square	Nil	Zero	Zero
	2 square	70	26	37.14
	3 square	70	44	62.85
	Total	**70**	**70**	**99.99**
Non-FUG members	1 square	60	16	26.26
	2 square	60	38	63.33
	3 square	60	06	10.00
	Total	**60**	**60**	**99.99**

Source: Field survey, August 2024

Table 5.1 represents responses from sampled respondents on their routine feeding per day. The table indicates that among the FUG farmers, none operate on one meal per day. The table also indicates that 37.14 percent of FUG farmers go on two meals per day whereas 62.85 percent of them go on three (3) square meals per day, on daily basis. The table furthermore indicates that among the farmers who are not members of FUG, 26.66 percent operate on one (1) square meal per day whereas 63.33 and 10 percents, respectively go on 2 meals per day. From the table, it is clear that an overwhelming majority of the FUG farmers enjoy 3-square meals a day as against an overwhelming minority within the non-FUG farmers taking 3 square meals daily. The table therefore shows that the Third National Fadama has significant impact on food security in the study area.

Hypothesis 4 Third National Fadama Project has no significant links with food security in Buruku LGA.

Food security is function of its availability, accessibility and affordability by the masses in Date and sufficient quantities at all times. Accordingly, this study subjected the three variables to correlation test FUG famers, Results are presented in Tables 5.1.1, 5.1.2 and 5.1.3 respectively.

Table 5.1.1 Test of relationship between Third Fadama Project and food availability

Variables	N	Person corr.	Sign (2 tailed)
Fadama project 111 Food availability	130	0.488	0.000

The correlation is significant at 0.01 level

Source: IBM SPSS output, August 2024

Table 5.1.2 Test of relationship between Fadama projects III and food accessibility

Variables	N	Person corr.	Sign (2 tailed)
3rd Fadama project Food accessibility	130	0.733	0.000

The correlation is significant at 0.01 level

Source: IBM SPSS output, August, 2024

Table 5.1.1 indicates a moderate positive correlating coefficient of 0.488 which is significant at 0.01 level. This correlation is though positive, it points to the possibility of other factor that also significantly affect food availability besides the fadama project. Similarly, Table 5.1.2 indicates a strong positive correlation coefficient of 0.733, which implies that there is strong relationship between the third fadama project and food accessibility among the FUG farmers, in which high levels of fadama intervention leads to corresponding increase in the magnitude of food accessibility among the farmers as test result show that the two variables move together at all times in one direction.

Furthermore, Table 5.1.3 shows a strong positive correlation coefficient of 0.872, which implies a significant link between fadama operations and food affordability in the study area. This means increasing fadama support to FUG farmers leads to corresponding or proportional increase in the farmers ability to afford food supply in line with the dietary needs of their families at all times. Thus, Table 5.1., 5.1.2 and 5.1.3 respectively indicate that the Third National Fadama Project has significantly improved food availability, accessibility and affordability among farmers of Fadama beneficiary groups.

Consequent upon these tables, and Tables 5.2, the hypothesis which denies the existence of a significant impact of the Third Fadama Project on food security in Buruku L.G.A., is hereby rejected in favor of an alternative hypothesis which contends that the Third Fadama Project has significant impact on food security in Buruku L.GA.

Discussion of Findings: This study examined the Third National Fadama Project within the context of its role in boosting food security and living standard among farmers in Buruku L.G.A of Benue state. The study found that the project has made spectacular landmarks in the area of material and financial assistance to the farmers which translated to increased agricultural output. This finding aligns with earlier findings of Arigor et al (2024) who studied the impact of the Third Fadama Project on rice farming in Abakaliki, Ebonyi State and reported that Fadama assisted agricultural inputs have significantly yielded to a boost in the crops output from 217,825 tons to 316, 275 tons. In the same vein, Koyenikan and Ikharea (2014) had examined the Third Fadama Project in Edo state and reported that women participation in the project led to increased productivity in numerous crops including fruits and vegetables under market gardening in the three senatorial districts of the state. In further advantage, this boost in agricultural output implies increased food availability.

This study also revealed that the Third Fadama Project has provided significant boost in the income of FUG farmers. This finding aligns with earlier finding by Bature et al (2013) who studied the Third Fadama Project in Federal Capital Territory within the context of the income of beneficiary farmers. Their study revealed that the value of productive assets among FUG farmers increased significantly following the Third Fadama intervention. Similarly, Ogunjobi et al (2024) studied sustainable agriculture within the context of financial support by the Third Fadama Project in Akure, Ondo State and reported that FUG farmers have enjoyed substantial financial benefits in the forms of direct cash grants and sale of agricultural products in the open markets.

This study furthermore revealed that the Third Fadama project has significantly enhanced the living standard of FUG farmers through multiples of ways including the acquisition of productive assets like processing machineries, which they use in partial processing of their harvest thereby enhancing their value. This finding is in harmony with the findings of Ominikari et al (2017) In which they studied the Third Fadama Project in Bayelsa State against the background of its benefits to farmers, problems of beneficiaries and possible solutions. The study reported that FUG farmers have their living standard significantly improved through routine support from the Third National Fadama Project food supply, job creation and an expanded scope of local industrial activities of agro-based businesses. The study however reported delays in the disbursement of counterpart funding and environmental challenges associated with climate variability.

Finally, this study revealed that the Third National Fadama has contributed in the area of improved food security in Buruku LGA through fixing food availability, accessibility and affordability. This finding also aligns with finding of Onoyemeakpo (2024) who studied public policy and rural development reflecting on the contributions of the Third Fadama Project. The study reported that the project has served as a way of improving cash flows among farmers who used same to boost their agricultural statuses. Similarly, Olubunmi (2024) studied climate change and food security in Nigeria against the noble contributions of the Third National Fadama Project. The study reports that sustainable development has been a priority area for the Fadama project under which food security is aggressively pursued. In the same vein, Njoku and Fadiji (2022) studied effects of Third Fadama Project on food security in Abuja and reports that the expanded scope of agricultural inputs by courtesy of Fadama has significantly increased the level of food security in Gwagwalda, Bwari and Amarc communities of the Federal Capital Territory.

Conclusion: This study has x-rayed the Third Fadama Project in Buruku LGA and found that the project has made significant contributions in the area of financial and material support to FUG farmers. On the other hand, the study found that this support has yielded much gain as it has translated to significant increases in agricultural output among the farmers, thereby improving on their financial standing, food security and living standard. Given this scenario, all stakeholders of agriculture need to work in collaborative terms to support the National Fadama Project as an imperative response strategy for sustainable agriculture and overall economic development in the study area and beyond.

Recommendations: The Third National Fadama should upgrade to Fadama Project IV with and expanded scope of agricultural support involving greater financial and material commitment.**;** The Third National Fadama project should put in place an effective project monitoring team that works basically in rural areas to assess the level of operation among FUG farmers in the study area and beyond.

Figure1: Third Fadama Project state officials and beneficiary farmers during routine visit to Buruku LGc's Department of Agriculture.

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Assessment of Extension Workers' Access and Use of Information and Communication Technology (Ict) In Zone Ii of Jigawa State, Nigeria.

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Abstract

The study examined extension workers access and use of information and communication technology (ICT) in ADP Zone-II, Jigawa State, Nigeria. A multistage sample procedure was used in selecting 76 respondents and data were obtained using structured questionnaire and analyzed using both descriptive and inferential statistical tools. The mean age of the respondents is 41 years. Majority are males (100.0%), married (78.9%) with tertiary education (76.2%). Mean working experience of 17 years, household size of 18 persons and monthly income of ₦88,514.24k. Majority were members of cooperative societies (79.8%). Available ICT used are mobile phone (93.4%), Radio (88.2%) and Laptops (65.8%) respectively. The socio-economic factors influencing ICT usage are Educational level (-1.970), and knowledge of ICT (2.821). Only radio (100.0%), mobile phone (84.4%), television (84.8%), internet (65.7%) and newspaper (55.6%) were accessed by the respondents. Major constraints identified were high cost of ICT equipment (85.5%); inadequate electricity (80.3%), high cost of internet facility (72.4%) among others. Conclusively, ICT tools are available and its usage has been accepted by majority of the respondents in the study area. It was recommended that there is need for the extension workers to continue to form cooperative movement to pool their resources to acquire ICT facilities by themselves in the study area, rather than depending on Government. ICT development partners, NGOs should be involved to assist the respondents' access to ICT tools.

Keywords: *Extension-Workers, Access, Information, Communication, Technology*

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Introduction: Different kinds of Information and Communication Technology (ICT) tools have been developed, put to several tests and launched globally, with records of varying degrees of success. Some of these tools were developed with the main objectives of helping farmers to improve their livelihoods through increased agricultural productivity and income generation, or by reducing risk factors inherent in crop and animal production Okeke et al. (2020). ICTs are those tools or applications that aid information exchange, data collection, collation, and analysis (Sheikh et al, 2003). It can revolutionize the farming sector (Lokeswari, 2016) and as such can be of immense benefit to all Nigerian farmers. ICTs can be used for the provision of accurate, timely, relevant agricultural information and services to the farmers and this will help in a great way to facilitate an environment for a more productive agricultural sector (Sheikh *et al.,* 2003). According to Lokeswari (2016), the challenges of traditional agriculture can be addressed and overcome significantly by ICT utilization that play an important/vital role in uplifting the livelihoods of the rural farmers. ICT has helped in the growing demand for new approaches to farming and other relevant agricultural activities. It has equally helped in empowering the rural people by providing better access to natural resources, improved agricultural technologies, effective production strategies, markets, banking, financial services, etc. (Lokeswari, 2016). Effective use of ICT tools by extension workers depends on the proper farmers' orientation, knowledge, and attitude in using these tools. There is no doubt that information and communication technology has emerged as a useful and more reliable agricultural information transferring tool to enhance the agricultural developmental process (Sobalaje and Adigun, 2013). There are already existing research works on extension workers and ICT which include; adoption and utilization of ICT through farmers (Wole-Alo and Oluwagbemi, 2020), Information and Communication Technology roles in improving women farmers access to agricultural/agribusiness services in Orlu Agricultural Zone of Imo State, Nigeria (Agbamu, 2007).
Useful information flow from Research Institutes, Universities, as well as relevant authorities in the area using the right Social methods, is very important, if the utilizers of the information must make meaning out of it and respond as intended. The inaccessibility of information by extension workers, has been identified by various scholars (Sharma, 2016; Oyekunle, 2017, Arokoyo, 2012), as one of the major factors, militating against development of agriculture in Nigeria today. The use of effective Social to promote agricultural development is being advocated for by stakeholders, as, it has been identified, that, no development programme can succeed without the effective use of Social (Chiazoka *et al.,* 2021). The need for more effective agricultural extension has been a considerable demand and one that will bring numerous benefits, thus, the importance of ICT to a nation's economic growth and development cannot be overemphasized since it is a catalyst necessary for the overall capacity building of extension workers for Agricultural development (Amin, 2013). Due to the challenges of hunger, unemployment as well as poverty, and the continuous increase in population, which characterize the Nigerian nation, the need to ensure food security through agricultural sector is being agitated by various levels of government. It is believed that, if Nigeria, as a nation, can again get it rightful place in Agriculture, most of its present problems will be solved (Tuedon *et al.,* 2021).This is because, agriculture, in the past, has proven, not only to feed the country, but generate revenues for the government to carry out its various developmental programmes, in addition to providing employment opportunities for the citizen. It is thus, no wonder that today; several steps are being taken to fast track agricultural development in the country.

The former Minister of Agriculture during an interview granted to the Daily Trust, a national daily in Nigeria, "the current one extension agent to over 3000 farmers" ratio (1:3000) in Nigeria is not encouraging. Hence the need for a robust extension system that will fill in the wide gap already created by the inadequacy of traditional extension systems" Ragasa, (2015). World food Program of the United Nations is also aware that, the development of ICT has nearly all people in the world turn their heads to various kinds of Social technology which work fast and efficiently in the attempt to obtaining pieces of information. Moreover, it seems that people cannot find themselves daily without the sort of technology which they believe as the key factor in getting important information (WFP, 2017). In the work of agricultural supervision, ICT has now been developed; it refers to one mechanism in the development of Social networks to disseminate new innovations in agriculture which is effectively programmed (Arokoyo, 2011). ICT is beneficial to put agricultural based research and development organizations and disseminators of innovation. Furthermore, ICT serves as a system that encourages the mechanism of managing, disseminating, documenting, researching, and synergizing agricultural innovations which developers of agriculture need to establish continuous development (Agbamu, 2006). Nevertheless, several problems have militated against effective use of cyber extension by extension workers in carrying out their jobs in the development of agriculture in the global competition by hindering effective information passage by extension workers. Therefore, several attempts must be made to empower extension worker with the appropriate Social tools of ICTs and Social media with regards to improving their job performance. ICT has been used by the World Food Programme (WFP) to boost information flow to local insurance companies and microfinance institutions and gradually supporting farmers to start paying for insurance in cash with supervision to empower the primary actors for the sake of creating a conducive business environment and increasing their awareness to the importance of information through the emerging ICT. Capacity building of farmers can be achieved through ICT which avails both extension agents and rural farmers' access to information readily and create an atmosphere that will help build sustainable assets in farming for a better life of rural people. ICT is an innovation designed to deliver agricultural information Social to farmers in a quick manner, enabling them to obtain fast, appropriate, and relevant information regarding their needs (Ifeoma *et al.,* 2021).The specific objectives of this study are to: Describe the socio-economic characteristics of the extension workers in the study area. Assess the level of ICT awareness by extension workers in the study area.; Identify the types of ICT access by the extension workers.; Determine the factors access influencing ICT in the study area.; Identify the constraints to the use of ICTs among extension workers in the study area.

METHODOLOGY: Study Area: Jigawa State is one of thirty-six States that constitute Federal Republic of Nigeria. It is situated in the North western part of the country between latitudes 11.00°N to 13.00°N and longitudes 8.00°E to 10.15°E. Kano and Katsina State border Jigawa to the West, Bauchi State to the East and Yobe State to the Northeast. To the North, Jigawa shares an international border with Zinder region in the Republic of Niger, which is a unique opportunity for cross-border trading activities. According to population projections, the State had a total population of over 5.8 million inhabitants (National Bureau of Statistics [NBS], 2018). About 80% of the population is found in the rural areas and is made up of mostly Hausa, Fulani and Manga (a Kanuri dialect) (Jigawa State Government, 2016). The State has a total land area of approximately 22,410 square kilometres. Its topography is undulating land, with sand dunes of various sizes spanning several kilometres in parts of the State. Its total forest covers is about 5% and this is due to rainfall characteristics and deforestation activities primarily for fuel wood. Jigawa State is predominantly an agrarian State with over 80% of the population involved in Agriculture (Jigawa State Government, 2016). The rain-fed crops grown in the State include millet, sorghum, cowpea, rice, sesame, groundnut, cotton, and watermelon. Dry season crops include sugarcane, hot pepper, okra, tomatoes, onions and spinach. The major livestock kept in the State include, small ruminants (sheep and goat), poultry and cattle. The main rivers are Hadejia, Kafin Hausa and Iggi Rivers with a number of tributaries feeding extensive marshlands in North-eastern part of the State. Hadejia–Kafin Hausa River traverses the State from west to east through the Hadejia-Nguru wetland and empties into the Lake-chad basin.

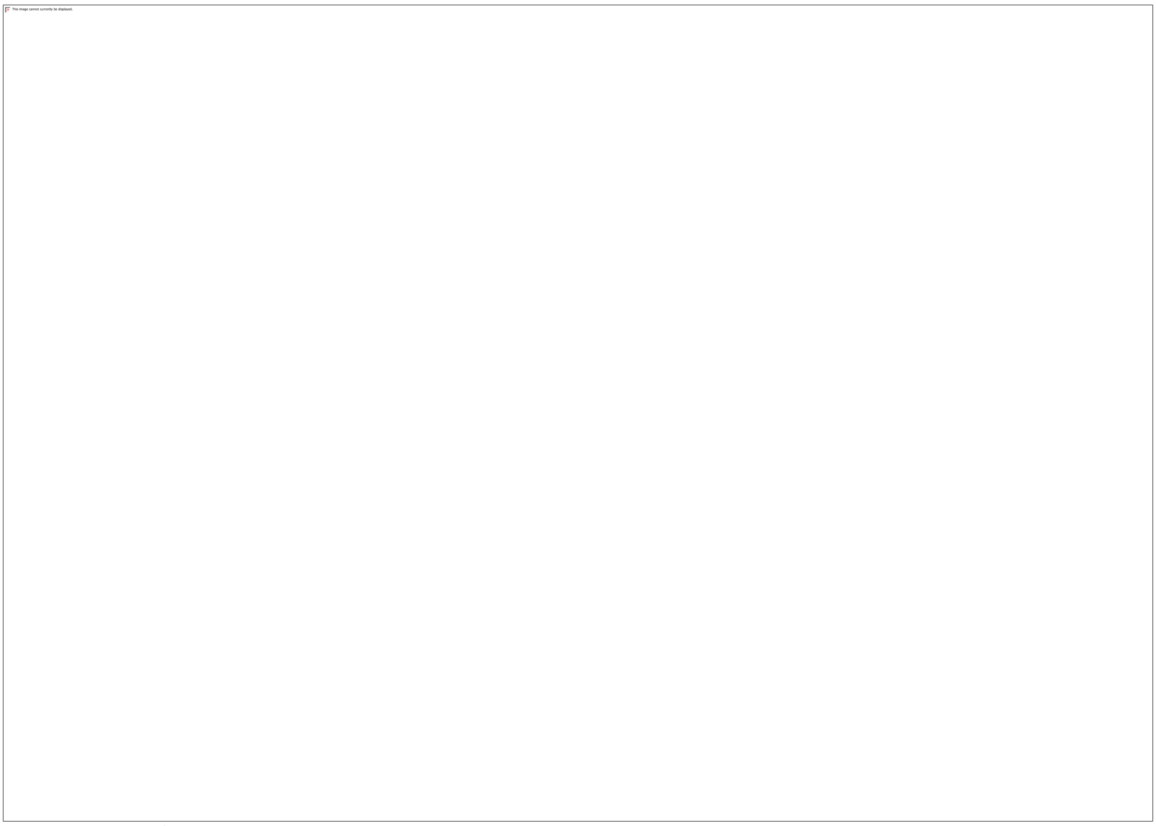
Jigawa State, with its capital at Dutse is currently made up of 27 local government areas and is administratively classified into four (4) zones by Jigawa State Agricultural and Rural Development Authority (JARDA). The zones are as follows:

Zone 1: Birnin Kudu, Gwaram, Buji, Jahun, Kiyawa, Dutse and Miga LGAs

Zone 2: Gumel, Maigatari, Garki, Ringim, Taura and Gagarawa LGAs

Zone 3: Hadejia, Guri, Birniwa, MalamMadori, Auyo, Kirikasama, Kafin Hausa and Kaugama LGAs

Zone 4: Kazaure, Yankwashi, Roni, Babura, SuleTankarkar and Gwiwa LGAs (JARDA, 2006). The highest proportion of extension workers is estimated to fall under Zone II of the state Agricultural Development Programme (ADP) i.e. in the North central part of the state (JARDA, 2006). Thus, zone II was purposively selected for the study.



Source: Ministry of Land and Survey.2023
Fig1.0 Map of Jigawa State Showing the Study area

3.2 Sample size and Sampling Procedure

Multistage sampling procedure was used to select a sample size of 76 extension workers. In the first stage, Gumel Agricultural Zone II was selected. In the second stage four LGAs within the zone were purposively selected, these areas are: Gumel, Maigatari, Taura, and Garki.

The third stage involved purposive selection of three communities from each of the four local government areas. Communities include: Zango, Gumel, Gusau, Ajaura, Kiri, Taura, Kanya, Doko, Garki, Jajeri, Maigatarin Kudu, MaigatarinArewa.

In the fourth stage Yamane formula (1967) was adopted to calculate the sample size after obtaining a comprehensive list of the estimated population of 76 extension workers in the study area from JARDA.

However, assuming 95% confidence level and sampling of 5% error. It is expressed as

n = N/ [1+N (e) 2]…………………………(1)

Where,

n = sample size

N = the population size

e = the level of precision.

n = 76/1+0.245

n = 76/1.245 = 61.04

n = 61.

However, Bowley's proportion allocation formula was used to establish the sample size at each stratum or community. This is expressed as;

ni = nNi/N…………………………(2)

Bowley's proportion Formula is easy to use and it is more scientific in selecting sample size across the entire zone without any form of biasness.
Where,
ni = sample size for the i^{th} stratum
n = total sample size
Ni = population for the i^{th} stratum
N = Total population
In the final stage, a sample random selection was carried out by balloting to proportionately select the calculated sample size in each community as shown in the table 1: 25% of the proportion was used for this study.
Table 1: sampling frame and sample size of the extension workers in JARDA Agricultural Zone II

JARDA Agricultural zone	Local Government Area	Community	Estimated population (sample frame)	Sample selected size
Gumel Agricultural Zone	Gumel	Zango Gumel Gusau	06 08 05	
	Taura	Ajaura Kiri Taura	05 08 08	
	Garki	Kanya Doko Garki	06 04 10	
	Maigatari	Jajeri Maigatarin- kudu Maigatarin- Arewa	05 05 06	
Total	4	12	76	61

Source: Field Survey, 2023

Method of Data Collection
The study was employed both Primary and secondary data with the aids of a well-structured questionnaires and interview schedule from the respondents in line with the objectives of the study. Analytical Techniques The descriptive statistic tools such as mean, percentage, frequency counts and rank ordering was used to achieve Objective (i), (ii), (iv) and (v) Inferential statistics such as logistic regression model was used to achieve objective (iii).

The data obtained from the field was analyzed using descriptive and inferential statistics. The descriptive statistical tools include mean, percentage, frequency counts and rank ordering was used. Whereas, for the inferential statistics, Binary logistic regression analysis was used.

Descriptive Statistics

Model specification:

The various analytical techniques used in this study is specified as follows:
Descriptive statistics are concerned with scientific methods for summarizing, presenting and analysing data as well as drawing valid conclusion and making reasonable decision on the basic of such analysis (Kundiri 2020). For this study, the descriptive statistics like mean, percentage, frequency distribution, and rank ordering was used.
Percentage: the ratio that equate the second number ratio to 100.
Percentage (%) =xX 100... (1) n
Where
% = percentage
x = individual observation
n = total observation or sample size
Arithmetic Mean: is defined as the set of score divided by the number of score. Mathematically Written as:
$X = \sum X_1 + X_2 + X_3 + ...X_n$ .... (2) n
Where;
∑ = summation notation
Xi = individual observation
I = 1, 2, 3 .... n

n= total number of observations

Frequency Distribution: Frequency distribution is the tabulation of a given collection of data in an order with its frequency attached to each value or group of values (Kundiri, 2020).

Binary logistic regression model

i. Logistic regression is a regression model where the dependent variable is considered as dichotomous/binary variables coded 0 and 1(Brian & Sabine, 2004). The model uses maximum likely-hood estimation (MLE) procedure. The advantage of this is that, the probabilities are bound between 1 and 0. Logit regression conceptually gives maximum estimates, overcome the shortcomings associated with linear model of regression and provide estimates that are consistent and efficient (Gujrati, 2004). This model was used to determine the factors influencing the use of ICTs among extension workers'.

The general form of the model is specified as follows

$F(X_1, X_2, X_3, X_{4,} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. X_8)$.Explicitly specified, the equation becomes;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n + e_i \text{.......................................} (i)$$

Where;

Y = the observed use of ICTs Dichotomous variable; 1=if an extension personnel used ICTs in disseminating innovation; otherwise =0)

$\beta 1 - \beta 8$ =Regression coefficients

X_1= marital status, (dummy variable; married = 1; otherwise=0)

X_2 = age, number of years supplied by the respondents measured in (years)

X_3 = educational qualification, number of years of formal education

(0 = no education, 1 = primary, 2 = secondary 3 = tertiary)

X_4 = household size (number)

X_5 = work experience, measured in (years)

X_6 = income from enterprises measured in Naira (₦)

X_7 = gender; male or female; (dummy variable- male =1; otherwise=0)

X_8 = effectiveness of ICT use (1=effectiveness, otherwise=0)

β_o =Constant term

e=Error term (implicit)

RESULTS AND DISCUSSION

Socio-economic characteristics of the Extension Workers access to ICT

The socio economic variables identified for this study include; Age, Household size, Education level, working experience, Marital Status, membership of cooperative, income level of the respondent.

Table 1: Socio-Economic Characteristics of the Respondents

Independent Variable	Frequency	Percentage
Age		
25-34	8	10.5
35-44	48	63.2
45-54	19	25.0
55-64		1.3
Gender		
Male	76	100
Female	0	0
Level of education		
Secondary	2	2.6
HND		20.2
Tertiary		76.2
Marital status		
Married	60	78.9
Single	16	21.1
Divorce	0	0
Widower	0	0
Working experience		
>=21	7	9.2
1-5	6	7.9
6-10	25	32.9
11-15	16	21.1
16-20	22	28.9
21-25	0	0
Household size		
>=16	1	1.3
1-5	16	21.1
12-15	14	18.4
16-20	30	39.5
>21	15	19.7
Monthly income		
<=₦ 50000	21	21.2
₦ 50001-₦100000	68	68.7
₦ 100001-₦ 150000	6	6.1
₦ 150001-₦ 200000	1	1.0
₦ 200001-₦ 250000	3	3.0
Cooperative Membership		
Regular	79	79.8
Non regular	20	20.2

Source: Field survey, 2023

Age of Extension workers access to ICT**:** The result in table 2 indicates that majority of the extension workers are between the ages brackets of (35-44) years with a proportion of (63.2%). This indicates that most of the extension agents were old and are therefore old enough to take decision on the use of ICTs. Sheik *et al.,* (2003) found that the age of individuals affects their mental attitude toward new ideas and hence influence adoption in several ways.

Gender of Extension workers access to ICT: Sex is an important variable in Agricultural production and the role assigned to the sex by the society is known as gender. The sex of the extension agents influence the decision he/she makes concerning adoption of new technologies. Majority (91.1%) were males while 8.1% were females this indicate that the extension agents were predominantly males in the study area. Thus, Female extension agents are generally perceived to face more constraint on the field given the fact that, farming communities were predominantly Muslims in which direct involvement of women as extension agents is not accepted in some communities in the study area.

Educational level of Extension workers access to ICT

It is evident from Table 1 that Majority 76.2% had attendant tertiary education, while 20.2% attended HND, 1.0% attended primary and 2.6% attended secondary school. The result indicate that majority of the extension workers have first degree. This is in tandem with the findings of Arokoyo (2005) he identified high level of illiteracy as a serious constraint to ICT utilization among extension service delivery.

Marital status of the Extension workers: Marital status of a population may be defined as the population of single, married, widowed and divorced people within it (Kundiri, 2020).It could be tied up to the house hold size and may likely affect the level of responsibility and labour. Majority 78.9% were married while 21.1% are single however, 91.1% of extension workers are male. According to Haruna (2011), settled men and women with responsibilities are willing to seek innovations that will increase their living standard.

Working Experience of the Respondents: Table 1 revealed that most of the extension workers fell in the range of 32.9% which are above 40years others includes 9.2% were range between >21 also, 7.9% range between 1-5 this indicates that most of the extension workers fell in the range of 32.9% which are above 40years and have vast experienced in extension activities.

Household size of the Respondents: Table 1 shows the household size were <5 persons with a proportion of40.4% also, 6-10persons

Have a proportion of 53.4% while 6-10 persons have a proportion 18.4% the result shows that54.4% of the extension workers family size ranging from 16-20,there accessibility might be lower as they have order needs of their family.

Monthly income: Table 1 revealed that the monthly income of 1.3% were range between <₦10000 while 35.5% ranges between >₦50000 Also,3.0% ranges between ₦20000-₦250000 and 18.4% ranges between ₦30000- ₦40000 while 43.4% ranges between₦ 40000-₦50000,this indicate that most of the extension workers' income ranges up to₦50,000 above this can affect extension workers' as their monthly income cannot afford them to obtained ICT facilities in order to achieved their basic needs and delivered responsibilities assigned to them.

Cooperative Membership: Association is form when individuals recognize common and desirable needs among themselves (Olukosi, 2007). The result from Table 1 revealed that majority (79.8%) belong to either one cooperative or the other while the remaining 20.2% doesn't belong to any association.According to Arokoyo,(2012) membership of associations enhances dissemination of ICT information. Therefore, more Extension workers are likely to adopt the ICT technologies.

Available ICT usage to the Extension workers: The result from table 2 indicates that 71.7% of the extension workers have availability of internet while 28.3% have none; however 6.1% have not availability of software while 93.3% have ICT availability.. This table shows that the majority of the extension agents have availability of internet at 71.1% while cell phone at 100% and social networking at 83.8%

Table: 2 Available ICT usages to the Extension workers

Variables	Frequency	Percentage
Mobile phones		
Yes	71	93.4
No	5	6.6
Radio		
Yes	67	88.2
No	9	11.8
Laptops		
Yes	50	65.8
No	26	34.2
Telephone		
Yes	5	6.6

No	71	93.4
Emails		
Yes	4	5.3
No	72	94.7
Videos		
Yes	2	2.6
No	74	97.4

Source: Field survey, 2023

Socio Economic Factors influencing access to ICT
Results from table 2 showed the binary logistic regression of factors influencing access to ICT or non between some selected dependent variables and availability of ICT access as independent variables. Also, R^2 Value of 66.4% which implies that variation in availability of ICT access was explained by the independent variables in the model .the p-value which measure the significant of the parameter was found to be significant at 1% confirmed to by p-value of 2.821.This indicate that the independent variables significantly affecting the availability of ICT access. This shows that they have positively contributed to the availability of ICT.

Table: 3 Socio Economic Factors influencing access to ICT

Variables	**B**	**S.E**	**Wald**	**Sig**	**Exp(B)**
Age	.630	.789	.637	.425	1.877
Gender	-.353	1.145	.095	.758	.703
Level of éducation	-1.970	.713	7.640	.006	.139
Marital statuas	.043	.637	.004	.947	1.044
Working expérience	-.043	.327	3.500	.061	.542
Household size	-191	.219	.761	.383	.826
Monthlyincome	.269	.627	.184	.668	.826
Lowcost of ICT equipment	-2.679	1.980	1.831	.176	.069
High educationlevel	-1.578	1.121	1.982	.159	.206
Knowledge of ICT	2.821	.903	9.234	.002	15.554
Closeness of ICT facilities	1.157	.704	2.702	.100	3.181
Frequent use of ICT	-991	1.002	.978	.323	.371
Constant	7.573	6.31	1.437	.231	1944.830
R^2 Value	.664				
Adjusted R^2	49.8				

Source: Field survey, 2023 *significant at p<0.01%

Type of ICT accessed by the respondent

Table 4 indicate the type of ICT assessed by the extension workers, the result shows 99% of the extension workers assessed radio, however 99.0% have no assessed to fax machine while 1.0% have assessed. Also, 84.8% assessed mobile phone while 15.2% were not, however 75.8% assessed Photocopier while 24.2% were not, also 65.7% have assessed telephone while 34.3% were not. those are the type of ICT assessed by the extension workers, because of high and easy accessibility.Ani (2007).

Table: 4 Type of ICT accessed by the respondent

Variable	Frequency	Percentage**(%)**
Radio		
Yes	99	100
No	0	0
Mobile phone		
Yes	84	84.8
No	15	15.2
Television		
Yes	84	84.8
No	15	15.2
Internet		
Yes	65	65.7
No	34	34.3
Newspaper		
Yes	55	55.6
No	44	44.4
Magazine		
Yes	33	33.3
No	66	66.7
Telephone		
Yes	34	34.3
No	65	65.4
Copier		
Yes	24	24.2
No	75	75.8
Fax machine		
Yes	1	1.0
No	98	99.0
TOTAL	891***	100

Source: Field survey, 2023 Multiple response exist ***

The constraints of access to ICT in the study area

Table: 5 results of the constraint shows that the extension workers have higher cost of ICT equipment at 85.5% were 15.5% were not. Inadequate electric supply were at 80.3% while 19.7% have no inadequate electricity supply, therefore weak communication were 34.2% while 15.8% were not, distance of ICT facilities 84.2% however the poor technical knowhow were 57.6% therefore poor training 83.8% while 57.6% high cost of ICT access were 83.8%. distance of ICT facilities affect ICT usage, poor technical know-how among the extension agent discourage ICT usage Omotayo, (2005) .

Table: 5 Constraints of access to ICT by Extension workers

Variable	Frequency	Percentage**(%)**Ranking	
High cost of ICT equipment			
Yes	65	85.5	1st
No	11	14.5	
Inadequate electricity			
Yes	61	80.3	2nd
No	15	19.7	
High Cost of Internet access			
Yes	55	72.4	3rd
No	21	27.6	
Poor training			
Yes	54	71.1	4th
No	22	28.9	
Fear of ICT usage			
Yes	43	56.65th	
No	33	43.4	

LowEducational level			
Yes	56	56.65th	
No	43	43.4	
Low Economic status			
Yes	39	51.36th	
No	37	48.7	
Weak communication			
Yes	26	34.2	7th
No	50	65.8	
Poor Technical Knowhow			
Yes	24	31.6	8th
No	52	68.4	
Distance location of ICT facilities			
Yes	12	15.8	9th
No	64	84.2	
TOTAL	780***	100	

Source: Field survey, 2023 **Multiple response exist *****

RECOMMENDATIONS: Based on the findings of this research they following recommendations are made; Agricultural extension services in Gumel zone II of Jigawa should incorporate the use of ICTs especially the contemporary ICTs such as internet, mobile phones, Email, Radios and Television etc for proper information dissemination to the farmers. ICT training programmes should be organized for the training of extension workers on abounds in the use of ICT facilities for extension service delivery in the study area. There is need for improvement in rural infrastructure particularly, electricity supply and some of the remote villages should be well connected to the national grid in the study area **;** Agricultural Extension workers should be encouraged to form cooperative societies in the state in order to pool their resources to acquired ICT equipment by themselves, rather than inter dependence on Government**;** Government should employed young graduates extensionists that could**;** Deliver extension service effectively and efficiently.

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Phytochemical Assays and Antibacterial Effects of *Agave tequilana* ON *Salmonella typhi* and *Echerichia coli.*

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Abstract

*The occurrence of drug resistant pathogenic strains remained an increasing concern to the pharmaceutical world. This was occasioned by adaptation resulting from continuous exposure to orthodox drugs by thy illness causal microbes. This study consequently focused on phytochemical screening and antibacterial effects of ethanolic leaf extracts of Agave tequilana on Salmonalla typhi and Escherichia coli, using standard procedures. The secondary metabolites obtained were tannins (1.57 ± 0.01 mg/g), saponins (0.91 ± 0.01 mg/g), phenols (1.57 ± 0.01 mg/g), flavonoids (1.53 ± 0.01 mg/g), glycosides (1.18 ±0.01 mg/g), antraquinones (1.05 ±0.00 mg/g), steroids (1.06 ±0.01 mg/g) and commarins(0.62 ±0.01 mg/g). The sensitivity response of the test organisms to control drug was significantly (p<0.05) over the leaf extract across the concentrations. The leaf extract showed moderate antibacterial potentials at 500mg/ml and 250mg/ml for E.coli and at 500mg/ml for S. typhi. However at <250mg/ml and < 125mg/ml weak antibacterial potentials were recorded for S. typhi and E. coli respectively. The minimum inhibitory concentrations (MICs) and minimum bactericidal concentrations (MBCs) of ELEAT on were 125mg/ml and 250mg/ml respectively for test microbes. However, the ratio of MBC/MIC indicated bactericidal effects on the test organisms. The findings showed ELEAT had antibacterial potential which could provide useful alternative to orthodox drugs, while indicating afforestation need to ensure its sustainable management.***. *Keywords:*** *Ethanolic, Phytochemical, Agave tequilana, Minimum Inhibitory Concentration, Bactericidal,*

Introduction: A report by the World Health Organization (WHO) indicated the primary use of drugs from herbal sources by more than 80% of people in the world, especially those living in rural areas. Plant materials remain a valuable resource to address the rising challenges of human health on a sustainable basis. Traditional medicine involving the use of medicinal plants, plays a vital role in meeting the basic health needs in most developing countries (Habtom and Gebrehiwot, 2019). The medicinal values of these plants lie in some chemical active substances that produce specific physiological actions on the human body, animals and microorganisms. Natural products derived from plants may possess a new source of antimicrobial agents with possibly novel mechanisms of action. They are effective in the treatment of infectious diseases while simultaneously mitigating many of the side effects associated with synthetic drugs. Therefore, it is of great interest to carry out a screening of these plants in order to validate their use in folk medicine and to reveal the active principle by isolation and characterization of their constituents. Systematic screening of them may result in the discovery of novel active compounds (Nas *et al*., 2017).. One of the importance of Forestry is availability of huge ethno-botanical resources which are underutilized as alternate medicine sources, through phytochemical and antimicrobial investigations. These could be made for the formulation of naturally deployed option against common medical challenges around (Salih *et al.* 2019).

Phytochemicals are naturally occurring chemicals, otherwise known as secondary metabolites in plants that confer a protective function to plants against bacteria, viruses, fungi, damage by free radicals, insects and herbivores that feed on them, and any other environmental threat (Molyneux, 2007; Curan, 2017). Plants have the ability to counteract the damaging effects of free radical production through the use of some plant chemicals known as antioxidant phytochemicals. These phytochemicals interfere with oxidative process by scavenging free radicals, and acting as electron donors thereby neutralizing their oxidative activity that could lead to disease conditions (Shirazi, 2014; Baba, 2015). Anti-oxidative phytochemicals present in medicinal plants such as flavonoids and phenols participate in the management of diseases especially those caused by free radical damage, by preventing the oxidative damage caused by them(Baba, 2015). *Salmonella typhi* is a gram-negative, rod-shape facultative anaerobic bacterium belonging to the family enterobacteriaceae. It is a pathogenic gram negative bacterium predominantly found in the intestinal human. It timely is due to an outer membrane consisting largely on lip polysaccharides (LPS) which protect the bacteria environment Pier (2004). *Salmonella* is the causative agent of *salmonellosis*. bacterium *Escherichia coli* commonly abbreviated as *E-coli* is a gram-negative, rod-shaped bacterium that is commonly found in the low intestine of warm blooded organisms (endotherms). Most *Escherichia coli* strains are harmless, but some serotypes can cause serious food positing in humans. The harmless strains are part of the normal flora of the gut and can be beneficial to their host by producing vitamin K2. *Escherichia coli* and other facultative anaerobes constitute about 0.1% of gut flora and fecal-oral transmission in the major route through which pathogenic strains of the bacteria cause diseases (Feng *et. al*., 2002).

The lack of portable pipe borne water has left citizens to source for surface water options with attendant poor hygienic conditions, leading to incidences of intestinal track diseases. According to Shemishere *et al*., (2018), treatments of these health challenges remain herculean, due to huge cost incurred, inaccessibility to orthodox medications (which are chemical based substances with numerous adverse side effects). Increasing incidence of drug resistance of pathogenic microbes to shelf drugs (Shemishere *et al.*, 2018). Oladeji (2016), reported that there are about 1000 medicinal plants in Nigeria whose potential are yet to be investigated. Agave belongs to the family Agavaceae, with the genus consisting of about 200 to 300 species(Garcia, 2011; Tripathi *et al*., 2023). It naturally grows in northern and central America although some species are found growing as introduced in several countries of Africa and Asia. They are used as food, source of fiber, or ornamental. Agave is a rosette plant with short stems having fleshy, pointed and erect leaves. Many useful industrial products such as twines, rugs, ropes, brushes, paper boards and craft papers have been derived from the fibre and the residual by products.

A. americana extract has been reported to possess comparative wound healing potential (Misra and Varma, 2017). Antimicrobial effects have been reported of *A. cantala*, showing toxicity and lethality against *Biomphalaria glabrata*, as well as against *Plasmopara viticola*, a fungus responsible for powdery mildew disease in grapes. The extract of *A. cantala* was sprayed onto the leaves and an increase in polyphenol oxidase enzyme and polyphenolics was observed which reduced the fungal infection (Alemán-Nava *et al*., 2018). The insecticidal potentials was reported of undiluted juice of *A. tequilana*, killing 31% of whitefly, while 12% diluted juice killed 100%, and *P. redivivus* nematodes (Herbert-Doctor *et al*., 2016).

The study on the phytochemical and antimicrobial potentials of some species of Agave have been reported. Pandey *et al* (2019) indicated extracts of *Agave americana* showed 50 % cell-death of MCF-7 (human breast adenocarcinoma) cancer cell in 12 h at 5 µg/ml. Salazar-Pineda *et al*(2017), gave an illustration for the first time of the Antibacterial and Anti-inflammatory activity of extracts from *Agave cupreata* against some clinical isolates of *Staphylococcus* with methicillin-resistant. Ade-Ajayi *et al* (2011), highlighted a preliminary report on phytochemical and antimicrobial trials of *Agave sisalana* Perrine juice (waste) against some microbial strains such as *Shigella dysenteriae, Bacillus atrophaeus, Enterococcus faecalis, Pseudomonas aeruginosa*, and *Candida albicans*. Rodríguez-Zapata *et al* (2024), reported Phytochemical analysis and amoebicidal effects of different Agave Species, indicating morphological change occasioned by cell death with nuclear alterations, presence of rounded cells with protuberances/perforations in the membrane and cells that appeared to have exploded. The root, sap and juice of Agave are used to make medicine. Agave has been taken by mouth for constipation, indigestion, flatulence, jaundice, cancer and diarrhea; to promote labor; and to promote urine production. Therefore, renewed efforts at finding suitable and non-toxic ecofriendly options for various human diseases, and the acclaimed potency of this plant in the management of various diseases, stimulated present interest to screen the methanol extracts of *Agave tequilana* for phytochemical profiles and antibacterial effects of on *Salmonella typhi* and *Echerichia coli.*

Materials and Methods: The study was carried out at the Federal College of Forestry Jos, Plateau State Nigeria is Located in Northern Guinea Savanna between Latitude 8^0 20N and Latitude 9^0 30East it has average elevation of about 1,250m above the sea level and stands at height of about 600m above the surrounding plains.(University of Jos Meteorology Station 2010). Leaves of *Agave tequilana* was collected and identified in College Herbarium. The materials were washed with distilled water and dried for six weeks under shade to maintain it compositional integrity (Ncube *et al.,* 2008; Chomini *et al.*, 2020). The dried materials were pulverized separately using pestle and mortar and separately stored in air tight glass until required for analysis.

Preparation of Ethanolic extract: Twenty five grams (25g) of the pulverized leaf substrate were dissolved in 100mls of ethanol and allowed to stand for 24 hours, thereafter filtered, using whatsman filter paper. The filtrate obtained was evaporated to dryness, using hot air oven at thirty seven (37ºC) and stored in a refrigerator (4ºC) until used.

Percentage Yield Extract: The percentage yield extract were calculated using the formula below

$$\%\, yield = \frac{x_2 - x_1}{WSE}\, X\, 100\%$$

Where : X_1 = Weight of empty beaker; X_2= Weight of beaker + final dried extract

WSE = Weight of sample before extraction (Ardzard *et al.,* 2009).

Phytochemical Analysis: The presence of some secondary metabolites in pulverized plant materials were determined by using Standard methods (Parkh *et al.,* 2011). This involves:-

Test for Saponins : One gram (1.0g) of the leaf extract was dissolved in 10 ml of distilled water, shaken vigorously for 30 seconds and allowed to stand for 30 minutes. A honey comb-like froth formed for more than 30 minutes indicated the presence of saponins.

Test for Terpenoids:: Half gram (0.5 g) of the leaf extract was dissolved in 2.0 ml of Chloroform, followed by addition of 3.0ml of conc. H_2SO_4. A reddish brown coloration at the interface revealed the presence of terpenoids.

Test for Flavonoids: This involved sodium hydroxide test. Five drops of aqueous NaOH was added to 5 ml of each extract, a yellow coloration shows the presence of flavonoids.

Test for Tannins: Into 1.0ml of the leaf extract in a conical flask was added 2.0ml of $Fec1_3$. A dark green colour gave a positive test for tannins (Ikeyi *et al*., 2013).

Test for Alkaloids : Two drops of the Dragendorffs Reagent were added to 2.0ml of the extract. A rose red precipitate indicates the presence of alkaloids. While Wagner's Test with 2 drops of the Wagner's Reagent were added to 2.0 ml of the extract. A brown/reddish brown precipitate indicates the presence of alkaloids.

Test for steroids : Into a test tube containing 0.5 g of the sample was added 2.0 ml of acetic anhydride. This was followed by addition of 2.0ml H_2SO_4. A color changed from violet to blue-green indicated the presence of steroids (Ghamba *et al.*, 2014).

Routine Protocol of Sterilization and Disinfection of Work Surfaces and Standardization of Test Organisms. : All test tubes and petri dishes used were sterilized by autoclaving at 121ºC for 15 minutes. Wire loop and cork-borer were sterilized by flaming in Bunsen burner until they become red hot. The work bench surfaces were disinfected using dettol and cotton wool. Hands were washed with soap and dettol (Ardzard *et al.,* 2009). Cultures of test bacteria (*Escherichia coli* and *Salmonella typhimurium*) were obtained from National Veterinary Research Institute (NVRI) VOM, Jos South LGA, Plateau State. Their identities were confirmed using cultural morphological and biochemical tests (Akinnibosun *et al.,* 2009). The bacteria isolates were maintained on nutrient agar at 4ºC. The test bacteria were sub-cultured using appropriate media and identified by biochemical and serological tests. The pure cultures was inoculated in 10 ml of nutrient broth in sterile McCartney bottles and incubated at 37°C overnight. The broth culture was adjusted to a suspension density equal to 0.5 McFarland turbidity standards (Andrews, 2001), with cell density equivalent to 1.5×10^6 colony forming units (cfu)/ml. (Albert *et al,* 1991; Olajubu *et al*., 2012). Nutrient agar (NA) was prepared according to manufactures instruction (Oxoid CM003, 28g in 1 litre of distilled water). 28g of NA was weighed into a conical flask; 1000ml of distilled water was added and capped. The medium was shaken to dissolution and sterilized at 121°C for 15 minutes. (Ardzard *et al.,* 2009).

Determination of Antimicrobial Activities: The antimicrobial effects of ethanolic leaf extract *of Agave tequilana* were determined using agar well diffusion methods according to Ardzard *et al.,* (2009). Sterilized nutrient agar was poured into Petri dish and allowed to set. Five wells (6mm in diameter) were made equidistance to each other in the plates, using a sterile cork borer and one well at the center of the medium. Nutrient agar was added to seal the bottom. Up to 100µl (0.1ml) of each concentration of the extracts (500mg/ml, 250mg /ml, 125mg/ml, 62.5mg/ml and 31.25mg/ml) were respectively introduced into the well using sterile pasteur pipette and 0.1ml of the control (Gentamycin, 1.7mg/ml) was introduced into the well at the centre. Nutrient agar plates were swabbed using sterile wire loop with the broth culture of the respective bacteria isolates. They were allowed to diffuse at room temperature for 2 hours before incubated at 37ºC for 24hours. As a measure of the antibacterial activity of the extracts, the mean diameter zone of inhibition (in mm) measured using a transparent ruler.

Determination of Minimum Inhibitory Concentration (MIC): The Minimum Inhibitory Concentration of the leaf extracts against the test organisms was determined using agar diffusion method on the test organisms (Cheesbrough, 2000, Chomini *et al*., 2020). The test was performed at five levels of concentration of the leaf extract (100, 50, 25, 12.5, 6.25 mg/ml), employing double dilution of extract infusion broth or malt up to the fifth dilution. The MIC test was carried out, using broth dilution methods by (Cowan and Steel, 1985). This was reported as the lowest concentration of the various extracts that inhibits the growth of the tube isolates. The bacteriological peptone was poured to test tube in appropriate defined volumes. Tube contained only 1.0ml of the stock concentration. 10ml of the various concentrations of the extracts was added into each of the test tubes numbered 2 to 6, using pasture pipette to achieve even dilution and distribution of extract within the broth. The content was mixed thoroughly. 1.0ml of the mixture was withdrawn from tube 2 and transferred into tube 3, and from 3 to 4, 5 and 6. They were evenly mixed and incubated at 37ºc for 24 hours. Tubes with turbidity showed microbial growth while those which were clear (no turbidity) do not have microbial growth. This was reported as the minimum inhibitory concentration (as the lowest concentration that prevented even growth) (Cheesbrough, 2000; Cheruiyot *et al*., 2009).

Determination of Minimum Bactericidal Concentration (MBC): The MBC was determined by sub-culturing all the test tubes in each set that show no turbidity or visible growth during MIC test. A loop full of content for the tube showing no microbial growth after sub-cultured by streaking over the surface of already set nutrient agar was an indication of bactericidal effects of the extract (Cheesbrough, 2000). The test tubes were incubated for 24hours at 37ºC. The MBC was recorded as the lowest concentration that shows no growth or absence of growth after sub-culturing was considered as the MBC (Cheruiyot *et al.,* 2009).

Statistical analysis: Data obtained were subjected to analysis of variance, using SPSS version 16, to determine the level of significance. Significant means were separated using least significant difference.

RESULTS: Percentage yield of plant extracts and Phytochemcial screening: The preliminary % yield of ethanolic leaf extracts of *Agave tequilana* (ELEAT) was 8.0% (Table 1). The phytochemical analysis of ELEAT showed the presence of tannins (1.57±0.01mg/ml), saponins (0.91±0.01mg/ml), phenols (1.57±0.01mg/ml), flavonoids (1.53±0.01mg/ml), Glycosides (1.18±0.01mg/ml), Antraquinones (1.05±0.00mg/ml), steroids (1.06±0.01mg/ml) and Commarins (0.62 ±0.01mg/ml). (Table 2). However, alkaloids were not screened.

Antibacterial Activities and Indices: *Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC)* **:** The minimum inhibitory concentration (MIC) of ELEAT against *Salmonella typhi* and *Escherichia coli* was 125 mg/ml each after 24 hours of incubation (Table 4), while the minimum bactericidal concentrations (MBC) was 250mg/ml for both organisms. The antibiotic power, AP(MBC/MIC) evaluated was 2.0 each for *S. typhi* and *E. coli* respectively, which clearly meant that the test concentrations of the leaf extracts gave a bactericidal effects on the test organisms (Table 5).

Sensitivity Tests: The sensitivity response of the test microorganisms to the ethanolic leaf extracts of *Agave tequilana* (ELEAT) varied with microbes as well as concentrations of leaf extract. *Salmonella typhi* gave average zone of inhibition (AZI) values of 5.3±0.06, 3.3±0.06, 2.0±0.00, 1.0±0.00 and 0.5±0.00cm less than 8.0±0.01, 6.30±0.06, 1.6±0.10, 0.8±0.03 and 0.0±0.00cm for *Escherichia coli*, under 500 mg/ml, 250 mg/ml, 125 mg/ml, 62.5 mg/ml and 31.25mg/ml concentrations of the leaf extracts respectively. The control drug (Gentamycin) recorded 25.0 and 21.3mm AIZ values for *E. coli and S. typhi* respectively (Table xxx). The effects of the test drug and the leaf extracts were significantly different on the sensitivity of the test bacteria (Table 3).

Table 1: Showing the Percentage yield of plant extracts of *Securidaca longipenduculata*

Plant part	Solvent	Percentage yield (%)

Leaf	Ethanol	8.00

Table 2: Phytochemical Constituents of Ethanolic leaf Extracts of ***Agave tequilana***

Phytochemical	**Observation**	(mg/g)
Tannins	+++	1.57 ±0.01[a]
Saponins	+	0.91 ±0.01[b]
Phenols	+++	1.57 ±0.01[c]
Flavoniods	+++	1.53 ±0.01[d]
Glycosides	+	1.18 ±0.01[e]
Antroqunone	+	1.05 ±0.00[f]
Steroids	+	1.06 ±0.01[g]
Commarins	+	0.62 ±0.01[h]

Key: + = present, − = Absence,

Table 3: Average zones of inhibition (mm) of different Concentrations of Ethanolic leaf extracts of Test *Agave tequilana* on *Salmanella typhi* and *Escherichia coli*

S/no	**Extract concentration (mg/ml)**	**Test Organism** *Salmonella typhi*	***Escherichia coli***
1	500	5.30±0.06[a]	8.00±0.01[a]
2	250	3.30±0.06[c]	6.30±0.06[a]
3	125	2.0±0.00[e]	1.60±0.06[b]
4	62.5	1.00±0.00[d]	0.80±0.03[b]
5	31.25	0.50±**0.00**[d]	0.00±0.00[b]
6	Control drug (Gentamycin)	21.30±0.15[b]	25.00±0.30[c]

Table 4: Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of leaf extracts of *Hura crepitans* on the test organisms

Test organism	**Incubation Time (hours)**	**Leaf extract concentration (mg/ml)** 500	250	125	62.5	31.25	**Remark**
	Minimum Inhibitory Concentration			**MIC**			
Salmonella typhi	24	-	-	-	+	+	125
Escherchia coli	24	-	-	-	+	+	125
	Minimum Bactericidal Concentration			**MBC**			
Salmonella typhi	24	-	-	+	+	+	250
Escherchia coli	24	-	-	+	+	+	250

MIC = Minimum Inhibitory Concentration, MBC = Minimum Bactericidal Concentration; + = Growth, - = No Growth

Table 5: Antimicrobial Indices Effects of *Agave tequilana* on the Test Organisms

Test Microbe	MIC (mg/ml)	MBC (mg/ml)	MBC/MIC	Antimicrobial Indices Remark
Salmonella typhi	125	250	2.0	Bactericidal
Escherichia coli	125	250	2.0	Bactericidal

MIC = Minimum Inhibitory Concentration, MBC = Minimum Bactericidal Concentration, MBC/MIC = Ratio of Minimum Bactericidal Concentration to Minimum Inhibitory Concentration (antibiotic power (AP)

Discussion: Many workers have reported different yields from different plant extracts such as 7.5%, 13.5%, and 20%, for *Aframomum melegueta*, *Piper guineense* and *Xylopia aethiopica* (Ogbonna *et al*., 2013); 8.96% and 14.66% from *Ipomoea triloba* n-hexane and ethanol leaf extracts (Alozie *et al.*,2022). Shemishere *et al* (2020) observed the yield of plant extracts as a function of solvent types and soaking time. The presence of the secondary metabolites such as tannins, phenols, flavoniods, phenols, glycosides, steroids, anthraquinones, saponins and commarins was similar to Tannins, Flavonoids, Saponins, steroids, quinones, glycosides and commarins observed by Velázquez Ríos et al (2019). This was in addition to Terpenoids and Cardiac Glucosydes, from the ethanolic syrup extract of *A tequilana*. The results of phytochemicals assayed from plants are reported to depend on plant species, vegetative parts, provenance, extractant used, etc (Felhi *et al*., 2017). These phytochemicals are known to exhibit medicinal as well as physiological activities (Shreshtha *et al*., 2015). The quantitative screening of the leaf extract of *Agave tequilana* gave different values that were relatively lower than those reported some workers from other botanicals (Abai and Ekanem, 2020). The pattern of inhibition obtained in current study was similar to the results Igiri *et al* (2018), who reported higher inhibition at higher extract concentrations. The current study shows an increase in antimicrobial effects of the plant extracts on the test microbes, which corroborated the finding of Chomini *et al* (2021a), who attributed it to be a reflection of their sensitivity, partly measured as inhibition zones. It was observed that the zones of inhibition increase proportionally with extract concentrations. Sarjono *et al.* (2019), The zones of inhibition are categorized based on range of average inhibition (AIZ). An AIZ value less than 5.0 mm is described as weak antibacterial potential (WAP), while 5.0 – 10.0 mm, 10.0 – 20.0 mm and $\geq$ 20.0 mm are considered moderate antibacterial potential (MAP), strong antibacterial potential(SAP) and very strong antibacterial potential (VSAP) respectively. In this study, the antibacterial potentials varied with test concentrations of the leaf extracts. While the 250mg/ml and 500mg/ml of the ELEAT had MAP, against *E. coli*,, only 500mg/ml concentration showed MAP against *S. typhi* and all other test concentrations below 250mg/ml and 125mg/ml showed weak antibacterial potential against *S typhi* and *E coli*, respectively (Table 1). Chomini *et al* (2024), reported a strong antibacterial potential against *S.typhi* and *E. coli* at concentration ranging from 50mg/ml to 200mg/ml of ethanolic leaf extracts of *Pterocarpus erinaceus* with AIZs between 10 and 21mm. The antibacterial activities of plant extracts have been attributed to the presence of active secondary metabolites (Umar and Muhammad, 2015). Usman *et al* (2007), reported tannins and flavonoids as growth inhibitors to microorganisms. Tannins have the tendencies to tannins form protein complex, which are lethal to bacteria, consequent upon their ability to alter microbial biochemical process (Shaimaa, 2014). Flavonoids show proclivity for microbial cell interruption, inhibition of nucleic acid metabolism and cell wall synthesis (Mishra *et al.*, 2009). Apart from having antioxidant property, Phenols also show inhibitory tendency (Maria *et al*., 2013). Saponins have been reported to destabilize microbial cytoplasmic and plasma membranes, by disrupting bacterial cell permeability, structure, and functions, leading to cell damage (Arabski *et al*., 2012).

MIC and MBC: The ethanolic leaf extract of *Agave tequilana* (ELEAT) shows varying inhibitory tendencies against the test microbes, which increase with concentration of the extract. MIC of *Agave tequilana* leaf extracts against *Salmonella typhi* was 250mg/ml and 125mg/ml for *Escherchia coli* in the present study, contrasting the findings of MIC reported Ade-Ajayi (2011), using extract of *A sisalana*, against some selected microbes This Could Be As A Result Of Adequate Or Inadequate Presence Of Active Phytochemical Compounds Extracted By The Solvent (Umar And Muhammad, 2015). The inhibition of the organisms by these plant extracts indicated that the plant has potentials in the treatment of diseases caused by the test organisms. The ELEAT shows bactericidal effects at extract concentration of 250mg/ml for both *Salmonella typhi* and *Escherichia coli.* This was similar Ordanel *et al*. (2023), who reported an MBC value of 250mg/ml against gram negative bacterium, *Vibrio harveyi*, using ethanolic leaf extract of *Agave potatorum*. Achinto and Munirudin (2009), affirmed that lower minimum inhibitory concentration (MIC) value of plant extract indicates a better antimicrobial activity. The antibiotic power (AP) which is a ratio of MBC to MIC, revealed ELEAT gave bactericidal effects on the test organisms, *S. typhi* and *E. coli*. This corroborated the findings of Noumedem *et al.* (2013), who described a test sample as bactericidal when the ratio MBC/MIC is ≤ 4 and bacteriostatic when this ratio is >4. Chomini *et al* (2021c) obtained a bactericidal effect on *S. typhi* and *S. typhimorum*, using leaf extract of *Acanthospermum hispidum* **D.C.,** while combined methanolic seed extracts of *Aframomum melegueta* and *Garcinia kola* gave bacteriostatic effects on *S. typhi* (Chomini *et al*.,2021b).

Conclusion : This study showed that ethanolic leaf extracts of ***Agave tequilana*** (ELEAT) exhibit antibacterial activities against *Salmonella typhi and Escherichia coli*. The phytochemical screening of ELEAT revealed the presence of Antraquinones, tannins, steroids, saponins, flavonoids, phenols, Glycosides and Commarins. The control drug gave significant sensitivity effects relative to the leaf extract. However, ELEAT had a bactericidal effect on the test microbes. The extract indicated a weak, moderate and strong antibacterial potential on *E. coli*, and a moderate and strong antibacterial potentials on *S. typhi* across the test concentrations. This reveals its antimicrobial integrity for pharmaceutical industries as well as raising afforestation concern of this valuable botanical.

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Implications of Weeds and Weed Management on Food Security, Livelihood in Nigeria

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Abstract:

Weeds in Nigeria pose substantial difficulties to agricultural productivity and food security, hurting crop yields as well as farmer livelihoods. This study investigates how weed infestations and control tactics affect food production and economic stability in diverse agricultural systems across the country. We identify main weed species prevalent in Nigerian agriculture and estimate their impact on major staple crops based on a thorough study of literature and field research. The findings underscore the clear association between successful weed control tactics and better food security, showing that integrated approaches—combining mechanical, cultural, and chemical methods—can dramatically reduce crop losses and improve farmers' livelihoods.

Keywords: *Agricultural productivity, Food Security, Livelihood, Weed species, Weed control*

Introduction: Weeds and weed control have crucial consequences for food security and livelihood development in Nigeria, since they severely diminish agricultural production, affecting both food supply and farmer income. Effective weed control practices can boost agricultural yields, helping to promote food security and alleviate poverty [Christensen, 2009]. In Nigeria, where agriculture is a major source of income, tackling weed-related issues with contemporary, sustainable approaches is critical for increasing agricultural productivity, assuring food sustainability, and improving rural populations' livelihoods [Esposito *et al*., 2021].

Search Strategy : The primary motivation for doing this research is that integrated weed management is critical to agricultural productivity and sustainability. The literature review included a keyword-based search for conference and/or journal publications. This review used Science-direct research databases and Google Scholar web scientific search engine. We gathered information on the existing weed management approaches and summarized different methods for this agricultural practice. To reach the research goal, studies were gathered using the search phrases "weed management" and "food security" with no constraints for the years investigated. Other keywords were "integrated weed management".. **Socio – economic Status:** Socioeconomic level has a substantial impact on weed management techniques in Nigeria. Farmers with more financial resources have access to sophisticated weed control technology such as pesticides, automated tools, and enhanced agricultural processes, resulting in better weed management and higher crop yields. In contrast, low-income farmers frequently use conventional, labor-intensive methods such as hand weeding, which are inefficient and time-consuming. Poorer farmers' capacity to use new weed control measures is further limited due to a lack of access to financing, education, and extension services, hurting their production and overall livelihood.

Agriculture in Sub-Saharan Africa: Weeds are a severe challenge to agriculture in Sub-Saharan Africa, lowering crop yields by 25% to 100% and jeopardizing food security in an area already suffering from starvation. Traditional weed management methods, such as hand weeding, are labor-intensive, restricting farmers' production, particularly among women and children. Although chemical herbicides are more effective, their high cost, limited availability, and inaccurate usage endanger the environment and human health. Integrated weed management (IWM), which integrates a variety of control strategies, is emerging as a viable approach. Farmers, on the other hand, require greater access to training, resources, and government backing in order to adopt it more widely [Hartzler and Buhler. 2007]. Improving weed control is critical for increasing agricultural productivity and promoting rural lives in the region.

Challenges in Agriculture: Weed control poses several issues in agriculture, affecting crop yields, labor efficiency, and overall farm production. Key challenges include:Labor-intensive methods: Traditional hand weeding is time-consuming and physically demanding, particularly for smallholder farmers. It reduces the size of agriculture and diverts manpower away from other critical farming operations.;Chemical pesticides and mechanical weed control instruments can be helpful, but they are typically too expensive for many farmers, particularly those in poor countries.;Limited Knowledge and Training: Many farmers do not have access to knowledge about effective weed control strategies such as pesticide safety, integrated weed management (IWM),

and sustainable practices. Misuse of herbicides can result in environmental contamination, soil deterioration, and health risks for farmers and surrounding people.;Weed Resistance: Overreliance on chemical herbicides can result in herbicide-resistant weed species, making it more difficult to manage particular weeds and diminishing the efficacy of existing pesticides.; **Access to Resources**: Smallholder farmers, particularly in rural areas, often face limited access to weed management resources such as herbicides, machinery, and expert guidance.; **Climate Variability**: Changing weather patterns affect weed growth and the timing of weed control measures, making it more difficult to predict and manage weed infestations effectively.
Addressing these challenges requires a combination of improved access to affordable resources, training, sustainable practices like IWM, and supportive policies to ensure more effective weed control in agriculture.

Major Weeds Affecting Agriculture in Nigeria: Weed competition is a serious barrier for Agricultural crops, particularly during their early growth stages. These crops develop slowly for the first week after sowing, which allows weeds to establish fast and compete for resources. The important period for weed competition typically spans 2 to 6 weeks post-sowing, thus keeping fields weed-free during this time is essential [Woghiren *et al*., 2021[b]]. Failure to control weeds can result in substantial yield decreases of 50-70%, and in extreme situations, farm abandonment, especially if parasitic weeds like *Striga* spp. or aggressive perennial grasses like *Imperata cylindrica* are present. Weeds compete not just for light, nutrients, and space, but they can also produce allelopathic compounds that prevent crop growth [Woghiren *et al*., 2021[a]]. Furthermore, many weeds act as hosts for insect pests that attack crops. Weeds found in a particular cropping system frequently resemble those found in other crops grown in the same agroecological zone. Parasitic weeds such as *Striga hermonthica* and *S. gesnerioides*, for example, primarily impact crops in dry savanna locations, whereas *Imperata cylindrica* is a concern in moist savanna areas. Other frequent weeds include *Sporobolus pyramidalis*, *Rottboellia cochinchinensis*, *Ageratum conyzoides*, and many more.Effective weed management tactics in the early stages of growth can provide crops with a competitive advantage, allowing them to thrive despite later-emerging weeds.

Weed Management Approaches in Agriculture: Challenges, Opportunities and Implications of Weed Management for Sustainable Food Production: There are a number of drawbacks associated with the utilization of herbicides for weed management, primarily due to the limitations of traditional spraying technologies [Partel *et al*., 2019]. Continuous use of the same set of herbicides on the same area of land over time causes ecological imbalances such as weed shift, herbicide resistance in weeds, and environmental contamination [Gnanavel, 2015]. Indeed, overuse of herbicides with the same mode of action can result in the establishment of herbicide-resistant weed populations. Agricultural landscapes are often dominated by difficult-to-control weed species, resulting in little biodiversity [MacLaren *et al*. 2020]. Herbicides can also have detrimental side effects, including as contaminating surface and ground water and leaving herbicide residues in the food chain [Lancaster, 2021]. Furthermore, chemical herbicides can significantly reduce soil microbial communities and earthworm populations, and the persistent impacts of weed suppression can lead to a reduction in nutrient availability and soil biodiversity [Mia *et al*. 2020].

In a comparable manner excessive tillage has a significant negative impact on soil quality measures such as biological diversity, soil structure, and water storage capacity. Tillage limits the amount of carbon and nitrogen available to microorganisms [Mia *et al*. 2020]. Soil erosion and degradation, which are inherent in tillage-based systems, contribute to environmental pollution from agricultural chemical inputs such as fertilizers and pesticides, jeopardizing crop production sustainability and ecosystem services while also threatening global food security in the long run [Radicetti, and Mancinelli, 2021]. Furthermore, the operation may be limited due to severe weather conditions. There are also possible issues with limited tillage or no-tillage.

Increased bulk density and compaction of topsoil lead to worse phytosanitary conditions, with more fungal diseases and weed infestations. Farmers using reduced tillage often resort to herbicides, raising soil phytotoxicity. Ground cover methods like mulching and livestock grazing have limitations, including high costs, potential allelopathy, and weed seed propagation. Cover crops require extra equipment and management, potentially harming main crop yields and increasing pest risks. Soil solarization can stimulate weed seed emergence if not managed properly. Flaming for weed control is resource-intensive and restricted during summer. Livestock grazing can damage soil and spread weed seeds. However, integrating precision agriculture technologies like sensors and AI can enhance integrated weed management (IWM), marking a shift toward more sustainable farming practices.
Conclusion and Recommendation: As the world's population grows, there is an urgent need to expand agricultural production to provide food security, which necessitates better management of agricultural resources while minimizing environmental damage. Weeds are seen as a significant threat to agricultural efficiency since they contribute to output losses. They do, however, fulfill significant ecological tasks, such as being biodiversity indicators and delivering a variety of ecosystem services. Effective weed management requires various strategies; focusing on a single option can result in resistance and inefficient long-

term solutions. Thus, a comprehensive integration of various weed control tactics is required. Herbicide use can disturb ecosystem balance and promote resistance in particular weed species, causing major environmental dangers as well as threats to human and animal health. Consequently, sustainable weed management is critical for the future of agriculture. Furthermore, the advancement of precision technologies in weed control can significantly enhance sustainability and productivity, emphasizing the importance of collaboration between researchers and farmers in incorporating ecological and technological insights into weed management strategies.

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Rural Women Participation in Sustainable Forest Resources Management in Nigeria: Challenges and Prospects

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Abstract

Forest resources management guarantees ecological and economic sustenance critical for the livelihoods and well-being of rural populations in terms of services, products, and incomes. Rural women in Nigeria play a vital role in forest resources management contributing significantly to sustainable livelihood and biodiversity conservation. The review adopted integrative approach to identify patterns in rural women contributions to the formal and informal forestry sectors through their participation in sustainable forest resources management in Nigeria, their challenges and prospects. Hence, their active participation and huge contribution to the labour force in forest industries. Similarly, the review depicts how exploitation of forest products by rural women promotes the management of sustainable forest resources and socio-economic development which puts deforestation in check, preserves the climate, biodiversity, energy resources and livelihood provision for the general population. However, their participation is hindered by challenges like inequality in landownership rights, inadequate access to credit facilities, illiteracy and inadequate access to information, innovations and modern technology. In addition, poor government attention to forestry and forest stakeholders among others are deterrence to their efforts on sustainable forest management.The provision of legal frameworks that help reforms the landownership rights and prioritize rural women access to credit facilities are recommended to maximize the full potentials of rural women participation to forest resources management.

Keywords: *Forest resources, sustainable forest management, rural women participation.*

Introduction: Forest and trees play an important role in the landscapes and climate context, by serving as climate change mitigation function as carbon sinks and regulating water losses for sustainable agriculture, energy resources and livelihoods for women and men living in rural and urban settings (Food and Agriculture Organization [FAO], 2015a; World Bank 2009a;). According to FAO (2020), the report estimated that more than one billion people worldwide strongly depend on forests for food, medicine, fuel, and for their livelihood, particularly in low and middle-income countries (LMICs). This is because rural people have limited access to markets, poor infrastructures, very limited employment opportunities, no access to good roads and other facilities. More so, this situation is more prevalent among women whose 50% mean income largely depend on forests, and thus require secure access and use rights to these resources (Akinbamijo *et al*, 2017;World Bank 2016; Moss and Swan 2013). In addition, the use of forest resources is heavily linked to social rules and customs developed by each community over time, with gender norms being one of the most important determinants of access to, use of, and control and management of forests and their resources (Eguyom, 2020;Ingram *et al.,* 2016; Adedayo *et al.,* 2010; Quisumbing *et al.,* 2001).

In truth, women have always performed the role right from the beginning by managing the household economy and taking care of the livelihood of the family (Thapa and Singh, 2020).The level of inequalities and bias between women and men in terms of available opportunities, roles, and responsibilities in relation to forest resources remain one to ponder about (Kimanzu *et al.,* 2021). The argument that women and men have different roles and thus deserve different opportunities and responsibilities' is weak. Again, portraying women as operating separately from men reproduces ingrained stereotypes (Danielsen and Hinton, 2020; Sunderland *et al.,* 2014) such as ascribing authority and economic roles to men, while concealing or framing women's natural resource management as part of their domestic responsibilities (McDougall *et al.,* 2021). As such, failing to acknowledge disparities in women's and men's abilities to make decisions and benefit from forests and their products can also reinforce gender biases in forestry research (Elias *et al.,* 2017; Sunderland *et al.,* 2014). Furthermore, the lack of tenure rights also impacts women's access to financial resources and women's income-generating opportunities (Kiptot, 2015). Even though women contribute significantly to the forestry industry, their contributions are not completely acknowledged and documented. Transparency, accountability, and responsibility are also necessary for knowledgeable women to participate in sustainable forest management.(IFAD, 2015 and FRA, 2020).

This review adopted integrative approach to provide insights on rural women participation in forest resources management in Nigeria and enumerate the challenges and prospects in their participation. A comprehensive search was done to identify gaps and summarize empirical findings as well as patterns on the significance, prospects and challenges to rural women participation in sustainable forest resources management.

Significance of Rural Women Participation in Forest Resources Management: Rural women participation in forest resources management and usage in Nigeria has a positive influence on their livelihood. According to Fernande and Ghislaine, (2014) and Amusa *et al.*, (2012). Rural women in Nigeria engaged in the exploitation of Forest resources using their vast indigenous knowledge on the medicinal, nutritional, spiritual and economic uses to generate stream of income for their needs and families. In addition, Bamiwuye *et al.,* (2020) asserted that 71.6% of the rural women in South-west Nigeria exploit forest resources from the study to contribute to their livelihood and the region economy. Similarly, recent studies have also shown that in most settings' majority (about 90%) of women tends to use the resources and income at their disposal for improving the welfare of their families (AfDB, 2016).

According to the findings of Ilori *et al.,*(2022) access to forest resources increases the household's income of the locals by 85.4% and reduces households' hunger by 78.4%. Similarly, the study confirmed that forest resources management provided employment opportunity to about 42.3% of those living in the rural area.

In a study conducted by Oloruntoba and Adetokumbo, (2006) women were able to name forest resources such as Non-Timber Forest Products and their uses, animal species, hardwood species such as spices as well as mushrooms. This finding corroborates Eneji, *et al.,* (2009) conclusion that women are quite versatile in forest resources exploitation and management than their male counterpart.In addition, the study of Robert *et al.,* (2022) showed that forest resources such as edible leaves and fruits were mostly collected by rural women. This also corroborate the findings of Raufu *et al.,* (2012) who also identified leaves and seasonal fruits as non-timber forest activities frequently collected by rural wojmen in Osun State, Nigeria. It also agrees with the findings who posited that edible leaves and fruits including snails were habitually collected by rural women in Akwa Ibom State, Nigeria, Egbe *et al*.,(2022) concluded their their finding by stating that indigenous practices of rural women have positive and significant relationship with forest resources conservation. This implies that the use of indigenous practices encourages forest resource conservation.

Impacts of Forest Access and Ownership on Women's Employment and Livelihoods: Forest resources and land ownership are related to Socio-economic development and poverty alleviation. Studies have shown that land rights empower women by improving their control over household income and bargaining power over resource allocation; providing security in case of abandonment, divorce or death; and increasing their participation in the community and institutions (World Bank 2009b).According to the food and agricultural organization (FAO, 2015a),while women account for 70-80% of agricultural labour and output in Nigeria. Only 10 percent of land owners in Nigeria are women, despite the 45 years old land use act that gives women equal right to ownership. According to the report by (Africa Development Bank [AfDB], 2011), lack of access to land limit women economic alternatives. It equally limits their access to credit to purchase other essentials. Gender rights in land access, ownership, and the capacity to make genuine choices must be addressed in any serious effort to promote women's livelihood.

Legal and socio-cultural reforms could benefit women's rights to land tenure and inheritance via abolishment of reforms that discriminates against women inheritance due to their marriage illegality, ignoring traditionally married women and widows empowers women and support their household's livelihood (Bandiaky-Badji *et al.,* 2016).

Impact of Rural women's Access to Forest Resources as a means of Household welfare Improvement in Nigeria. Gathering of forest produce compared to timber harvesting is not a destructive activity according to an empirical study carried out by (Olawuyi, E.B.,2019 and Olaniyi *et al*., 2013) .Consequently, gathering and trading of forest produce potentially offers a means of concurrently achieving sustainable rural livelihood. Suleiman*et.al.,*(2017) also affirms that women involvement in forest and wildlife gathering therefore can be a panacea towards mitigating poverty in rural households towards sustainable livelihood.

According to International Food for Agricultural Development report (IFAD,2023) sociocultural factors do not sometimes favour women access and exploitation of productive resource such as land and forest material (Adedayo *et al.,* 2010) in his study affirm that, women's access to the exploitation of forest resources has direct impact on provision of income, food, energy and medicinal materials. From their findings, women have restricted access to firewood and forest fruits. However, over 60% of the rural women who participated in the study reported to obtain more than 50% of their income from forest resources. .The research showed that there was a positive association between women's access to the exploitation of firewood and forest fruits and the income they earn from exploiting those resources. Hence, an increase in women's total annual income increased the proportion of income women spent on food and the likelihood of spending more on their children's education.. Women's access to, use and ownership of forest resources improve household overall well-being (Ajala *et al*., 2023). Further more, indigenous practices of rural women have positive and significant relationship with forest resources conservation. This implies that the use of indigenous practices encourages forest resource conservation.(Egbe *et al.,* 2022).

Challenges to Women Participation in Forest Resources Management: Many efforts at forest resource management in Nigeria today failed because government and other forest management organization paid inadequate attention to the various stakeholders' interests particularly on gender/women participation in the exploitation and management of these forest resources even though today rural women and conservation agencies like World Wildlife Fund for Nature (WWF), Nigerian Conservation Foundation (NCF) and more (Eneji *et al.,* 2015). In addition, global bodies like the United Nation and Food and Agricultural Organization are actively involved in forest resource management and conservation, despite all these bodies, women are still under represented in the system. (Nwajuba, 2020).Other challenges faced by women in their participation in forest resources management includes.

- **Land ownership and tenure**: Nigeria, women lack independent rights to land. Land rights are usually allocated through men, either sons or husbands. FAO,(2009) agrees with the sentiment that women be allowed to access land either directly or indirectly, as the majority have limited or no access to or control over land.In addition, Abara (2012) noted there is no part of Nigeria where women and men have equal social, economic and legal rights.This is also in line with the research of Ajewole (2019) who revealed that women have been deprived ownwership of right to lands in Nigeria.Similarly, according to Gender in Nigeria 2012 reported by the British Council, women own 4% of land in the North-East, and just over 10% in the South-East and South-South, less than 10% of Nigerian women own land. (Sasa *et al.,* 2022).

- **Access to credit and financial resources**

As witnessed in some locals in Nigeria, women are encouraged only to rely on forest products to feed themselves and sustain their family. These difficulties arise from cultural practices and stereotypes such as women's role within the family and on interactions between persons of different sexes(Ogunsumila, 2018) as well as socio- economic factors in terms of access to credit. women's higher illiteracy rates, lack of information about available credit programme, lack of land titles to be offered as collateral, more limited access to formal employment, and exclusion from credit cooperatives (FAO, 2009).This collobrates with the work of (Adesina et al.,2019)which state that women are disadvantage when it comes to accessing credit due to alot cultural and socio barrier in Nigeria.

- **Lack of Education and training**

Education is one of the significant factors affecting women's participation in sustainable forest management. Education enhances active participation in innovation and the development of new knowledge. According to (Butt,*et al.,*2010), women are faced with difficulties in access to agricultural extension education services, and newest technical knowledge and information sources on forest resources management due to the high illiteracy in the rural areas which agree with the works of (Akinbamiyo *et al.,*2017 and Oyinlola *et al.*,2019). Other factors such as geneder-based violence and harrassement also deperive women from accessing quality education and training in this field of study was stated in the work of (Eguyomi, 2020).

Prospects for Improved Rural Women Participation in Forest Resources Management: Women role in forest resources management cannot be negotiated. There efforts through the harvesting and marketing of NTFPs as well as other forest products has great economic impact and can impprove forest governance and decision making Therefore, providing them with required skills, trainings and education(Adesina *et al*.,2019) forest security and financials that aids their efforts on sustainable forest resources management could spur their contributions to the socio-economic development of the Nigeria population particularly the locals.(Oyinlola *et al*.,2019) This is corroborated by the findings of (Ekwugha and Onyema, 2014) where evidence had shown that the exploitation of herbs from the forest by the rural women has contributed to treatment of sickness as malaria, typhoid fever, skin and eye infections among other ailments. More so, 24.0% of the extracted NTFPs in Imo State, Nigeria by women were transported and traded in other local as well as regional markets in their geopolitical zone. In addition, among these rural women are those who had become major merchants actively engaged and contributing to the sustainable development goals(Ajewole *et al*.,2019).

Conclusion: Sustainable forest management could help manage deforestation, biodiversity and also economic opportunities for women through reduction in their vulnerability and enhancement of their socio-economic empowerment. In Nigeria and across Africa, some women have created great impact in forestry by continuously advocating for sustainable forest practices and women involvement in forest mangement, such names like Dr (Mrs)Olumilaya Adeboye,Abeokuta, Ogun State Nigeria, Dr Hakima El Haissouni, from Morocco, just to mention but few are changing the narrative for women in forestry within and across the globe. Similarly, rural women vast wide knowledge in forest resources use and management has provided for them the opportunity to generate stream of income for their needs and families and a potential to fight poverty and households' hunger. However, limitations such as poor government attention and care for forest resources management, inadequate access to credit, poor education and literacy of the rural women as well as land ownership/ forest insecurity among other issues have bewildered the realization of their potentials in sustainable forest resources management. Understanding the significance role of women participation in sustainable forest management and the challenges they faced is key harness the potential of diverse forest resources and its management sustainably particularly in Nigeria rural settings.

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Water Quality Parameters of *Clarias gariepinus* (Burchell, 1822) Fingerlings Fed Graded Levels of Bambara Groundnut (*Vigna subterranea* L.) Meal as Replacement for Fishmeal

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Abstract

The water quality parameters of Clarias gariepinus (Burchell, 1822) fingerlings fed graded levels of Bambara groundnut meal as a replacement for fishmeal was evaluated. Five (5) isonitrogenous (40% crude protein) and isocaloric (1,732kcal kg^{-1} gross energy) diets were formulated*, where Bambara groundnut was included at 0.0g/100g, 5.00g/100g, 10.00g/100g, 15.00g/100g and 20.00g/100g feed graded levels, diets without the Bambara groundnut served as the control diet. Formulated diets were fed to Clarias gariepinus fingerlings (n = 300, 10.0±0.00g)* in *fifteen (15) rectangular white plastic tanks (n = 20) at a fixed feeding rate of 3% body weight twice daily between the hours of 8:00 - 9:00am and 4:00 - 5:00pm at regular interval and adjusted after every two (2) weeks of sampling for a period of twelve (12) weeks. Water temperature, pH, dissolved oxygen, and ammonia were measured at the beginning of the experiment after which they were measured weekly throughout the period of the experiment. Data obtained were analysed using one - way analysis of variance (ANOVA) at P = 0.05. Water temperature values range from; 27.76°C - 27.85°C, pH (7.22 - 7.78), dissolved oxygen (5.38 mg/L - 5.59 mg/L) and ammonia (0.03 mg/L - 0.05 mg/L) respectively. Findings from this study indicated that the inclusion of Bambara groundnut at 0.0g/100g, 5.00g/100g, 10.00g/100g, 15.00g/100g and 20.00g/100g feed graded levels as a replacement for fish meal does not have any negative effects on the water quality parameters evaluated.*

***Keywords**:* Water Quality, Parameters, Clarias gariepinus, *Bambara Groundnut, Fishmeal.*

Introduction: Nutrition experiments are mainly conducted in controlled environment to prevent interaction of environmental effects such as natural food organisms, temperature and other water quality parameters with the variable being studied (Ali, 2022). Such experiments are conducted in tanks placed indoor or outdoor to allow accurate collection of data (Elezuo, 2016). The effects of water quality on feeding fish in intensive system have received considerable attention in recent years particularly in Nigeria (Omitoyin, 2007; Ali, 2022). Water quality parameters such as temperature, pH, dissolved oxygen and ammonia affects all the phases of life of fish (Babale, 2016). Temperature is a fundamental parameter in all aquatic environments. It is the dominant regulator of nearly all physio-chemical cycles and consequently of metabolism and fish pond productivity, tropical fish require water with a temperature range of 25 - 32°C to grow and reproduce (Ali, 2022). pH is a measure of acidity or alkalinity of water, water with a pH less than 7 is acidic, above 7 is alkaline while 7 is neutral, water with a pH value of about 6.5 - 9 is the best for fish culture (Elezuo, 2016). The dissolved oxygen content of the pond water is one of the most critical factors in fish culture (Babale, 2016). Fish require adequate dissolved oxygen in the water. 5 - 6ppm (mg/L) of oxygen is considered to be an absolute minimum requirement for fish (Elezuo, 2016). Ammonia is a nitrogenous waste produced by either the pond organisms (including fish) or decomposition of organic matter (Babale, 2016). For catfish culture, unionized ammonia level in ponds should be maintained at less than 0.05 ppm (Elezuo, 2016). Both water quality and quantity have the potential to significantly affect fish metabolism, survival and growth (Ekundayo *et al.,* 2014; Babale, 2016). It is therefore pertinent to ensure good water quality for optimum fish growth, survival and yield. It is always needful to change 40-50% of the water in the culture receptacle bi - weekly; this is because fresh water replenishes trace minerals that are used up in the tanks by fish, flora and fauna (Ali, 2022). This study was carried out to evaluate the water quality parameters of *Clarias gariepinus* (Burchell, 1822) fingerlings fed graded levels of Bambara groundnut (*Vigna subterranea* L.) meal as a replacement for fishmeal.

Materials and Methods: Study Area: The study was conducted at the Aquaculture section of the National Biotechnology Research and Development Agency, Billiri local government area (LGA), Gombe State. Billiri LGA lies within latitude 9°50' and 11°09'´N and longitude 9.833°and 11.150°E. It covers an area of 737km² and is 50 km away from Gombe the state capital.

Experimental Fish: Three hundred (300) *Clarias gariepinus* fingerlings with mean initial weight (10.0±0.00g) were stocked at twenty (20) fingerlings per tank in triplicates per treatment after one (1) week of acclimatization, the study lasted for a duration of twelve (12) weeks.

Experimental Diets: The experimental diets contained fish meal (FM), Bambara groundnut meal (BGNM**)** soybean meal (SBM), yellow maize meal (YMM), groundnut cake meal (GNCM). All the ingredients were grounded into a fine powder using a hammer mill and sieved by a 0.25 mm sieve. fish meal, soybean meal, groundnut cake meal and yellow maize meal were obtained from commercial suppliers in Gombe, the vitamin/mineral premix, fish oil and chromic oxide (Cr_2O_3) were purchased from TTS Integrated Farms Nigeria Limited, Agege - Lagos. Five (5) isonitrogenous and isocaloric diets were prepared, each diet with crude protein (CP) content at 40% CP as calculated according to Pearson's square method and gross energy content at 1,732kcal kg^{-1} respectively for the feeding the experimental *Clarias gariepinus* as recommended by Ali (2022) was prepared (Table 1).

Experimental Design: The *Clarias gariepinus* fingerlings were cultured in fifteen (15) rectangular white plastic tanks (flow - through system) with a water holding capacity of one thousand litres (1,000L) each in a complete randomized design (CRD). Each tank was washed thoroughly with salt, filled to just a little over 1/3 (350 litre) capacity and stocked with twenty (20) fingerlings of *Clarias gariepinus* with mean initial weight (10.0±0.00g). The *Clarias gariepinus* fingerlings were fed the experimental diet at 3% body weight two (2) times daily between the hours of 8:00 - 9:00am and 4:00 - 5:00pm for a period of twelve (12) weeks. The quantity of feed was adjusted accordingly after every two (2) weeks of sampling for growth performance and survival rate (mean body weight and mortality). Water temperature, pH, dissolved oxygen, and ammonia were measured at the beginning of the experiment after which they were measured weekly throughout the period of the experiment. Water temperature, dissolved oxygen and pH were measured using Horiba U-22 XD multi - parameter water quality checker while ammonia was measured using freshwater aquaculture test kit (Model AQ-2, Code 3633-03, Lamotte U. S. A.

Statistical Analysis: The data obtained were subjected to one - way analysis of variance (ANOVA) using the GraphPad instant package for windows 2010 of statistical analysis system (SAS, 2010). Mean separation was done (at P = 0.05) using Fisher's least significance difference (LSD) to separate the means in cases of significant difference.

Table 1: Ingredient Percentage Composition (g/100g) of Experimental Diets with Different Levels of Bambara Groundnut

Ingredients (%)	TB_0	TB_1	TB_2	TB_3	TB_4
Fish meal	20.00	15.00	10.00	5.00	00.00
BGN meal	**0.00**	**5.00**	**10.00**	**15.00**	**20.00**
Soybean meal	20.00	20.00	20.00	20.00	20.00
GNC meal	24.00	24.00	24.00	24.00	24.00
Yellow maize	30.00	30.00	30.00	30.00	30.00
Fish oil	1.00	1.00	1.00	1.00	1.00
Vegetable oil	1.00	1.00	1.00	1.00	1.00
Starch	1.00	1.00	1.00	1.00	1.00
Lysine	0.50	0.50	0.50	0.50	0.50
Methionine	0.50	0.50	0.50	0.50	0.50
***Vitamin/premix**	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50
Cr_2O_3	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00

Keys: TB_0 - Bambara groundnut (0.0g/100g), TB_1 - Bambara groundnut (5.00g/100g), TB_2 - Bambara groundnut (10.00g/100g), TM_3 - Bambara groundnut (15.00g/100g), TM_4 - Bambara groundnut (20.00g/100g), BGN - Bambara groundnut and GNC - Groundnut cake.

Results

The results of the water quality parameters of the *Clarias gariepinus* fingerlings fed graded levels of Bambara groundnut meal as a replacement for fishmeal is presented in Table 2. Initial water temperature value was 27.74°C. This increased in all the diets with Bambara groundnut and the control diet (TB_0) final values at the end of the 12 week's period of the study to a narrow range of 27.76°C - 27.85°C. There were no significant differences (p>0.05) in the mean water temperature values of the experimental tanks during the feeding trial. Initial water pH value was 7.50. This increased only in the control diet (TB^0) and decreased in all the diets with Bambara groundnut final values to a narrow range of 7.22 - 7.78. There were no significant differences (p>0.05) in the mean water pH values of the experimental tanks during the feeding trial. Initial dissolved oxygen value was 5.69 mg/L. This decreased in all the diets with Bambara groundnut and the control diet (TB^0) final values to a narrow range of 5.38 mg/L - 5.59 mg/L. There were no significant differences (p>0.05) in the mean water dissolved oxygen values of the experimental tanks during the indoor feeding trial. Initial ammonia value was 0.02 mg/L. This increased in all the diets with Bambara groundnut and the control diet (TB^0) final values to a narrow range of 0.03 mg/L - 0.05 mg/L. There were no significant differences (p>0.05) in the mean water ammonia values of the experimental tanks during the feeding trial.

Table 2: Water Quality Parameters of *Clarias gariepinus* Fed Graded Levels of Bambara Groundnut Meal

Parameters	Initial	TB_0	TB_1	TB_2	TB_3	TB_4
Temperature (°C)	27.74	27.76	27.87	27.79	27.82	27.85
Ph	7.50	7.78	7.47	7.39	7.25	7.22
Dissolved oxygen (mg/L)	5.69	5.59	5.56	5.53	5.46	5.38

Ammonia (mg/L)	0.02	0.03	0.04	0.04	0.05	0.05

All Means values are not significantly different (p>0.05)

Keys: TB_0 - Bambara groundnut (0.0g/100g), TB_1 - Bambara groundnut (5.00g/100g), TB_2 - Bambara groundnut (10.00g/100g), TM_3 - Bambara groundnut (15.00g/100g), TM_4 - Bambara groundnut (20.00g/100g).

Discussion*:* The water temperature values, 27.76°C - 27.85°C recorded from this study were comparable with the values, 27.78°C - 27.88 °C reported by Ali (2022) for *Clarias gariepinus* reared in circular plastic tanks. All the water temperature values recorded from this study were within the acceptable recommended range. The water pH values, 7.22 - 7.78 recorded from this study were comparable with the values, 7.50 - 8.00 reported by Fakunle *et al*. (2014) for *Clarias gariepinus* reared in rectangular plastic tanks. All the water pH values recorded from this study were within the acceptable recommended range. The dissolved oxygen (DO) values, 5.38 mg/L - 5.59 mg/L recorded from this study were comparable with the values, 4.80 - 6.0 reported by Ogundele *et al.* (2014) for *Clarias gariepinus* reared in aquaria tanks. All the DO values recorded from this study were within the acceptable recommended range. The ammonia (NH_3) values, 0.03 mg/L - 0.05 mg/L recorded from this study were comparable with the values, 0.04 - 0.05 reported by Babale (2016) for *Clarias gariepinus* fingerlings reared in plastic tanks. All the NH_3 values recorded from this study were within the acceptable recommended range. The good water quality parameters recorded at the end of the 12 weeks' period of the study from all the diets with Bambara groundnut and the control diet (TB^0) indicated that the inclusion of graded levels of Bambara groundnut meal as a replacement for fishmeal used in this study does not have any negative effects on the water quality parameters.

Conclusion: Bambara groundnut at 0.0g/100g, 5.00g/100g), 10.00g/100g, 15.00g/100g and 20.00g/100g feed inclusion levels into the diet of Clarias *gariepinus* does not have any negative effects on the water quality parameters of the culture tanks as observed in this study.

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Analysis of Rice Farmers' Access to Agricultural Credit in Wase Local Government Area of Plateau State, Nigeria

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Abstract
This study examined rice farmers' access to agricultural credit in Wase Local Government Area of Plateau State, Nigeria, with the objective of analyzing the factors influencing credit access, the volume of credit obtained, and the constraints faced by farmers. A multi-stage sampling technique was employed to select 120 rice farmers from two districts in the study area. Data were collected through structured questionnaires and analyzed using both descriptive and inferential statistics. Descriptive statistics such as frequency distributions, means, and percentages were used to describe the socio-economic characteristics of the farmers and sources of credit, while a multiple regression model was employed to identify the determinants of access to credit. The findings revealed that the majority of farmers (43%) were aged 31-40 years, with 78% being male, and 92% married. Cooperative societies (70%) and microfinance banks (56%) were the most common sources of credit. Over half of the farmers (52%) accessed credit ranging between ₦50,000 and ₦100,000, while 17% did not receive any credit. Key determinants of credit access included education level (coefficient: 1.0333), farm size (0.432), annual income (0.9999), and membership in farmer associations (2.4974), all of which had significant positive impacts. However, gender was significant and negative implying that female farmers are less likely to access credit (coefficient: -0.581). The major constraints identified were bureaucratic delays in loan processing (73%), high interest rates (49%), and insufficient rural credit facilities (46%). The study recommends streamlining bureaucratic processes in financial institutions, lowering interest rates, and promoting inclusive credit access policies that cater to female farmers. Additionally, strengthening cooperative societies and expanding rural credit facilities would enhance farmers' access to financial resources, thereby improving productivity and contributing to food security.
Key words: *Analysis, rice farmers, access, agricultural credit, Wase local government area*

Introduction: Rice is one of the most valuable cereal crops cultivated and consumed all over the world. It is a staple food in several African nations and constitutes a large portion of the diet on a regular basis (Silong and Gadanakis, 2019; Sennuga, *et al.* 2021). According to Mrindoko (2022), due to its significant contribution to the agricultural sector and the activities that occur along the distribution chains from production to consumption, rice is one of the cereal crops that has achieved cash crop status in Nigeria. This is because it provides up to 80% of the jobs in the producing areas for the local population. Although rice consumption has risen steadily in recent years, local supply has not yet kept up with public demand. Factors including a rise in population, economic levels, and rural-urban movement are blamed for the rising demand for rice (Samson and Obademi, 2018). The trend in domestic production/supply and consumption in Nigeria is very high. Statistics reveal that rice is grown in practically all of Nigeria's ecological zones, but despite this, its contribution to human nourishment is still relatively minor due to the world's rising population. This is because the agricultural sector incidentally lies in the hands of small scale farmers, whose expansion in terms of provision of scale of production is low due to low inputs and low income. The decline in the Nigerian economy, particularly in the area of agricultural productivity, has often been blamed on lack of credit facilities, which prevented many farmers from adopting improved practices, since some of them lack the collateral for secure loan or credit from financial institutions (Asogwa *et at.,* 2014). Acquisition and utilization of credit for agricultural purposes promote productivity and consequently improve food security status of a community. Access to agricultural credit has the capacity to raise the level of the national income distribution of the country (Bahinipatim, 2020).

Agricultural credit is the amount of investment funds made available for agricultural production from resources outside the farm sector (Akintunde *et al*., 2020). They are loans extended to farmers for production, storage, processing and marketing of farm products. Such credit can be short, medium or long term depending on its duration. It is one of the fundamental ingredients of sustainable agricultural production, as such, its accessibility and demand is among the prerequisites for attaining the national goal of reducing poverty and ensuring self-food sufficiency goal in the country (Akudugu, 2012). According to Odoh *et al.* (2009) Agricultural credit is seen as an undertaking by individual farmers or farm operators to borrow capital from intermediaries for farm operations. Credit according to Jeiyol *et al*. (2013) involves all advances released for farmers' use, to satisfy farm needs at the appropriate time with a view to refunding it later. Thus, credit can be in the form of cash or kind, obtained either from formal or informal sources. In the formal credit, institutions provide intermediation between depositors and lenders, and charge farmers for relatively lower rates of loans interest that usually are government subsidized. In informal credit, markets money is lent by private individuals. The formal sources of credit include; Nigerian agricultural cooperative and rural development bank, microfinance banks and commercial banks while informal sources of credit to farmers include family or friends, money lenders, produce buyers and farmers' cooperatives. The need for credit can, therefore, not be overemphasized. Credit supply to farmers is widely perceived as an effective strategy in enhancing agricultural productivity (Philip *et al.,* 2008). It has been argued that if only sufficient agricultural finance was made available, the decline in the production and supply of poultry products in Nigeria, would improve (Oludimu *et al.,* 2004). It must be admitted that micro-credit has increased the financial choices of millions of rural smallholders who were perennially trapped by usurious loans from informal money lenders (Kiros and Meshesha, 2022). Smallholder farmers who have access to financing can buy new equipment, better seed, fertilizer and other essential inputs to increase the size of production (Masaood and Keshav, 2021). Access to credit gives rural households the chance to improve their social well-being, particularly in the areas of health and education, in addition to an increase in production and income (Abubakar, 2019; Alfa *et al.* 2022). Agricultural credit enhances productivity and promotes standard of living by breaking vicious cycle of poverty of small scale farmers. Credit is not only needed for farming purpose, but also for family and consumption expenses especially during the off season period. The decline in the Nigerian economy, particularly in the area of agricultural productivity, has often been blamed on lack of credit facilities, which prevented many farmers from adopting improved practices, since some of them lack the collateral for secure loan or credit from financial institutions (Asogwa *et at.,* 2014). This is because the agricultural sector predominantly lies in the hands of small scale farmers, whose expansion in terms of provision of scale of production is low due to low inputs and low income. According to Olagunju and Ajiboye (2010), one of the reasons for the decline in the contributions of agriculture to the economies of many developing countries is lack of a formal national credit policy and paucity of credit institutions which can assist farmers have access to agricultural credit. Smallholder farmers often require small loans which are difficult to administer while majority of them also lack the needed collateral to be able to borrow from formal sources. Where collateral requirements are met, the sheer size of potential borrowers always seems to exclude others from borrowing. Consequently, smallholder farmers have been marginal participants in the credit market in many developing countries (Vihi *et al*., 2018). The need for credit is more acute in the rural areas, because access to financial resources is lowered by low productivity and wide spread poverty of the rural farm sector.

Methodology: Study Area: The study was carried out in Wase Local Government Area of Plateau State, Nigeria. Situated some 216 km south east of Jos the Plateau State capital, Wase is a traditional state founded in the area in 1820; this became part of the British Royal Niger Company protectorate (later Northern Nigeria) in 1898. The Wase Emirate Council consists of four (4) districts, namely: Wase, Bashar, Lamba, and Kadorko. The projected population of Wase Local Government Area in 2023 from 2006 census figure of 159,861 is 271,871. The local government has an urban area of 1750 km2 and the land covers an area of 4,587 square kilometers. The annual rainfall is 1,083 mm and 27.4 °C average temperature. Major crops grown are food and cash crops as maize, sorghum, rice, groundnut, cotton, vegetables and beans. The major livestock are cattle, sheep, goat, poultry, and pigs.

Sampling Technique: Multi-stage sampling technique was adopted to select sample for this study. The first stage involved a purposive selection of only two out of the four districts in the Local Government Area for the study. The districts to be selected have high concentration of rice farming population. They include; Lamba, and Kadorko. The second stage involved a systematic random selection of four communities from each of the two districts giving a total of eighth (8) communities. A reconnaissance survey of the eight (8) selected villages gave a total of 1,201 registered rice farmers. The third step involved a random selection of 10% of the rice farmers from each of the selected communities bringing a total of one hundred and twenty (120) respondents for the study.

The data for this study was sourced primarily. The primary data will be generated through administration of well-structured questionnaire designed in line with the objectives of the study.

Method of Data analysis : Data for this study was subjected to both descriptive and inferential statistics. Objectives 1, 2 and 4 were achieved using descriptive statistics such as frequency, percentages and mean while Objective 3 was achieved with the use of multiple linear regression model.

Model Specification: Multiple regression: In order to understand the effect of the individual factors of age, sex, marital status, family size, level of education, farm size, loan security provided, farmers' income etc. on the agricultural loan access by farmers, an econometrics model (multiple regression using the least square estimation techniques) was adopted using these factors as independent variables and the amount of loan approved and granted the farmer applicant by the banks as the dependent variable.

The functional relationship of these variables is expressed thus:

$y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9)$…………………………… (1)

Where,

Y = Amount of credit accessed (naira)

X_1 = Age of the farmer (years)

X_2 = Sex (1 for male, 0 for female)

X_3 = Marital status (1 married, 0 for single)

X_4 = Level of education (Number of years in formal school)

X_5 = Farm size (Hectares)

X_6 =Annual income (₦)

X_7 =Membership (Yes 1, No 0)

X_8 =Land ownership (Yes 1, No 0)

X_9 =Extension visit (Yes 1, No 0)

It is assumed that there is an approximately linear relationship between the dependent variable Y and the independent variables: $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9$.

Therefore, equation 1 is specified as:

$Y = bo + b_1X_1, b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9$………………… (2)

Where,

bo = intercept term showing value of y when X_1, X_2, X_3, X_4, X_5 etc are zero. That is, the value y is predicted to have when all the independent variables are equal to zero.

b_1 to b_9 = the coefficients or multipliers that describe the size of the effect the independent variables (X_1 to X_9) are having on the dependent variable y.

To make the model more realistic, the disturbance term u is introduced to get equation 3 from equation 2, thus:

$Y = bo + b_1X_1, b_2X_2 + b_3X_3 + b_4X_4 + \ldots + Xn + u$………………………………………. (3)

Results and Discussion : Socio-Economic Characteristics of Rice Farmers : The age distribution of the farmers is presented in Table 1. The result reveals that 43% of the farmers are between the ages of 31-40 years, followed by 23% in the 21-30 age range. Farmers between 41-50 years constitute 17%, while 11% fall within 51-60 years, and only 6% are above 60 years. The mean age of the farmers is 39 years, indicating that the rice farming population in Wase Local Government Area is predominantly middle-aged, which may have implications for agricultural productivity and credit access. Younger farmers represent a significant portion, suggesting a potential for technology adoption and modernization in farming practices. Studies have shown that younger farmers are more likely to adopt innovative agricultural technologies and access credit for improved practices. For example, a study by Abdulsalam *et al.* (2019) found that younger farmers are more flexible and willing to take risks in adopting credit-based interventions compared to older farmers.

The data in Table 1 also reveals that male farmers (78%) dominate rice farming in Wase, while females represent only 22%. This gender disparity suggests a potential gap in access to agricultural resources, including credit. A similar gender disparity was found in the study by Odozi and Akinlade (2019), which noted that male farmers have better access to agricultural credit due to socio-cultural factors that limit women's involvement in formal financial transactions. Result in Table 1 further shows that the overwhelming majority of farmers (92%) are married, indicating that rice farming is often a family-based enterprise in Wase. Only

8% are single, reflecting the societal norm where marriage is common among farmers. This may influence credit access since married individuals may have larger responsibilities and a need for more credit to support both farming and household needs. Ali *et al*. (2018) noted that married farmers are more likely to seek credit as they tend to have more dependents and larger farm sizes, which demand greater financial resources.

The household size as presented in Table 1 is relatively large, with 65% of the respondents having 6-10 members, and 22% having 11-15 members. Only 8% have 1-5 members, while 5% have more than 15 members. The mean household size is 10, suggesting that many farmers have considerable family responsibilities. This large household size suggests a potential labor force for farming but also a greater financial burden. Farmers with larger households may seek more credit to meet the demands of their family and farm. According to Adebayo and Adeola (2020), household size significantly influences the need for credit in rural farming households, as larger households require more inputs and resources for farming activities.

Regarding educational attainment, 41% of the rice farmers have completed primary education, 25% have secondary education, and 22% have tertiary education. Additionally, 12% have no formal education, indicating varying levels of literacy among the farmers. Education plays a vital role in accessing agricultural credit, as more educated farmers may have better knowledge of credit institutions and financial management. Studies such as that by Eze *et al*. (2021) have established that higher educational attainment positively correlates with access to formal credit facilities due to better understanding and navigation of credit procedures.

Table 1 reveals that most farmers have moderate farming experience, with 54% having farmed for 6-10 years, followed by 20% with 1-5 years of experience. Seventeen percent of the farmers have been in the field for 11-15 years, while only 9% have more than 15 years of experience. The average farming experience is 7 years, suggesting that many farmers are relatively seasoned in rice farming. This level of experience is likely to enhance their creditworthiness and ability to utilize credit effectively. Olagunju (2019) found that farmers with more farming experience are more likely to secure loans, as lenders perceive them as being better able to manage farming risks and repay loans.

Table 1 also shows that a large proportion (66%) of the rice farmers operates on 2.1-4.0 hectares of land, and 29% have more than 4 hectares. Only 5% farm on 0.1-2.0 hectares. The mean farm size is 3.5 hectares, indicating that most farmers have moderately sized farms. Larger farm sizes generally require more inputs and, consequently, more credit to finance operations. Empirical findings by Adeoye *et al*. (2020) revealed that farmers with larger farm sizes are more inclined to access credit to scale their operations, as they require greater capital for inputs.

The annual income of rice farmers varies, with 35% earning N151, 000-N200, 000 and 29% earning N201, 000-N300, 000. About 23% earn between N301, 000-N350, 000, while 9% earn more than N350, 000. A smaller proportion, 4%, earn between N100, 000-N150, 000. The mean annual income is N247, 475. This relatively low income might limit farmers' ability to secure large amounts of credit or repay loans, thus affecting their access to financial services. A study by Umar *et al*. (2021) found that lower-income farmers face difficulties in accessing credit because lenders often require proof of sufficient income for loan repayment.

Most rice farmers (67%) cultivate on inherited land, while 27% use hired land. Only 6% have purchased their land, indicating a heavy reliance on traditional land ownership systems. The land tenure system affects the farmer's collateral for credit, as those without ownership of land might face difficulties in accessing loans. According to Oladele (2022), farmers who own their land are more likely to access formal credit since they can use their land as collateral, unlike those who hire or lease land.

Results in Table 1 shows that more than half of the farmers (57%) are members of a farmers' association, while 43% are non-members. This suggests that a significant proportion of farmers may not be benefiting from the advantages that come with association membership which can improve their chances of accessing credit through group lending schemes. Adeola *et al*. (2020) stated that membership in agricultural cooperatives is strongly linked with better access to credit, as cooperatives often have established relationships with financial institutions.

Table 1. Distribution of Rice Farmers According to Age

Variable	Frequency	Percentage	Mean
Age			
21-30	28	23.0	
31-40	52	43.0	
41-50	20	17.0	
51-60	13	11.0	
>60	7	6.0	39
Gender			
Male	94	78.0	
Female	26	22.0	
Marital status			
Married	110	92.0	
Single	10	8.0	
Household size			
1-5	10	8.0	
6-10	78	65.0	
11-15	26	22.0	
>15	6	5.0	10
Highest educational status			
Primary	49	41.0	
Secondary	30	25.0	
Tertiary	27	22.0	
Non formal	14	12.0	
Farming experience			
1-5	24	20.0	
6-10	65	54.0	
11-15	20	17.0	
>15	11	9.0	7
Farm size			
0.1-2.0	6	5.0	
2.1-4.0	79	66.0	
>4	35	29.0	3.5
Annual income (₦)			

100,000 - 150, 000	5	4.0	
151,000 - 200, 000	42	35.0	
201,000 - 300, 000	35	29.0	
301,000 – 350, 000	27	23.0	
>350, 000	11	9.0	247, 475
Land Tenure			
Hired	33	27.0	
Inheritance	80	67.0	
Purchased	7	6.0	
Membership of Association			
Yes	68	57.0	
No	52	43.0	

Awareness of Credit Facilities: As presented in Table 2, a high percentage (87.5%) of the farmers are aware of available credit sources, while 12.5% are not. This indicates a general awareness of financial opportunities among farmers. However, awareness does not always translate into access. In line with findings by Okeke *et al*. (2019), awareness of credit sources is often not the major obstacle; instead, factors like collateral and bureaucracy prevent access.

Table 2: Distribution of Respondents according to Awareness of Credit Sources

Aware	Frequency	Percentage
Yes	105	87.5
No	15	12.5
Total	**120**	**100**

Source: Field survey, 2024

Sources of Credit Obtained: The most common source of credit is through cooperative societies (70%), followed by microfinance banks (56%) and rotating credit (46%). Friends and relatives (37.5%) and private money lenders (29%) are also significant credit sources. Agricultural Development Banks (7.5%) and commercial banks (2.5%) are less utilized by farmers. This reliance on informal and semi-formal credit sources indicates that formal banking institutions are not meeting the credit needs of these farmers. Similarly, Balogun *et al*. (2020) found that informal credit sources dominate rural credit markets due to the more flexible terms and fewer collateral requirements compared to formal banks.

Table 3: Distribution of Rice Farmers according to Sources of Credit obtained

Source of credit	*Frequency	Percentage
Agricultural Development Bank	9	7.5
Commercial Bank	3	2.5
Microfinance Bank	67	56.0
Rotating Credit	55	46.0
Cooperative Societies	84	70.0
Friends/Relatives	45	37.5
Private money lenders	35	29.0

Source: Field survey, 2024

Volume /amount of credit received

The result on the volume/amount of credit accessed by the farmers is presented in Table 4. Over half of the farmers (52%) accessed credit within the range of N50, 000 - N100, 000, while 12% obtained N101, 000 - N200, 000. A smaller proportion, 10%, received between N201, 000 -N300, 000, and 9% obtained more than N300,000. However, 17% of the farmers did not receive any credit. This limited access to larger sums of credit could restrict farmers' ability to expand or invest in capital-intensive improvements. Adebayo *et al*. (2019) pointed out that smallholder farmers tend to access only minimal credit amounts, which is often insufficient to cover major investments in modern agricultural technologies.

Table 4: Distribution of Rice Farmers according to Amount of Credit Accessed

Credit Range	Frequency	Amount accessed	Percentage
50,000-100,000	62	4,100,000	52.0
101,000-200,000	14	2,800,000	12.0
201,000-300,000	12	3,000,000	10.0
>300,000	11	3,300,000	9.0
Not Received	21	-	17.0
Total	**120**	**13,200,000**	**100**

Source: Field survey, 2024

Determinants of Access to Credit by Rice Farmers

Multiple linear regression model was employed to assess the factors influencing rice farmers' access to agricultural credit. The result of regression analysis is presented in Table 15. The model's R-squared value of 51.96% indicates that 51.96% of the variability in rice farmers' access to credit is explained by the independent variables in the model, meaning the model has a relatively good fit. Additionally, the F-statistic of 767.886 is highly significant, indicating that the overall model is statistically significant and capable of explaining the variations in access to credit. The constant term has a positive coefficient of 16.8951 and is significant at the 1% level ($p = 0.011$). This suggests that when all independent variables are held constant, there is still a substantial baseline influence on access to credit, likely representing other unmeasured factors. The results indicate that education, farm size, annual income, and membership in farmers' associations are the most significant factors positively influencing rice farmers' access to agricultural credit. Gender negatively impacts access, with women facing more barriers compared to men.

Gender (X_2): Gender has a significant negative coefficient of -0.581 ($p = 0.001$). This suggests that being female reduces the likelihood of accessing agricultural credit compared to being male. The result reflects potential gender biases or inequalities in credit access, with women possibly facing greater barriers to obtaining credit in the agricultural sector.

Education (X_4): Education has a positive and significant coefficient of 1.0333 (p = 0.001), indicating that higher education levels significantly increase access to agricultural credit. Farmers with more education are likely better informed about credit opportunities, possess better financial literacy, and have a greater capacity to meet the requirements of credit institutions.
Farm Size (X_5): The coefficient for farm size is 0.432 and significant at the 5% level (p = 0.040), indicating that farmers with larger farm sizes have greater access to agricultural credit. Larger farm sizes may represent better collateral or greater farming productivity, which makes farmers more attractive to credit institutions.
Annual Income (X_6): Annual income has a significant positive coefficient of 0.9999 (p = 0.003), indicating that farmers with higher annual incomes are more likely to access credit. This is likely because credit institutions view higher income farmers as less risky, given their better ability to repay loans.
Membership in Farmers' Association (X_7): Membership in farmers' associations has a positive and significant effect, with a coefficient of 2.4974 (p = 0.026). This shows that being part of an agricultural cooperative or association significantly increases access to credit, as these groups often provide collective bargaining power and better access to credit facilities for their members.

Table 5. Factors Influencing Rice Farmers Access to Agricultural Credit

Variables	Coefficients	Standard Error	Z-values	P-values
Constant	16.8951	6.6256	2.55	0.011
Age (X_1)	1.02184	0.0186	1.18	0.238
Gender (X_2)	-0.581	0.168	-3.46***	0.001
Marital status (X_3)	-0.850	0.711	-1.19	0.234
Education (X_4)	.0333	0.1920	3.15***	0.001
Farm size (X_5)	0.432	0211	205**	0.040
Annual income (X_6)	0.9999	2.190	2.89**	0.003
Membership (X_7)	2.4974	1.0309	2.22**	0.026
Land ownership (X_8)	0.054	0.263	0.20	0.838
Extension visit (X_9)	-0.149	0.181	-0.82	0.411
R Square = 51.96				
F statistics = 767.886				
Observations = 120				

*** and ** indicates significance at 1%, 5% level of probability respectively.

Constraints to Credit Access by Rice Farmers

Farmers reported several challenges in accessing credit. Bureaucracy in loan processing was the most common constraint (73%), followed by delays in disbursement (51%) and high interest rates (49%). Other issues include short repayment periods (33%), lack of collateral security (18%), difficulty in getting a surety (8%), and the unavailability of credit facilities in rural areas (46%). This suggests that institutional inefficiencies and financial costs are limiting the ability of farmers to secure loans. Ogunleye *et al*. (2020) similarly identified bureaucratic delays and high interest rates as critical obstacles in rural farmers' credit access, advocating for more streamlined and farmer-friendly processes.

Table 6: Distribution of Respondents according to constraints faced in accessing credit

Constraint	Frequency	Percentage
Lack of collateral security	22	18.0
Difficulty in getting surety	10	8.0
Delay in disbursement	61	51.0
Short period of payment	39	33.0
High interest rate	59	49.0
Bureaucracy in loan processing	87	73.0
Lack of credit facilities in rural areas	55	46.0

Multiple Responses allowed

Conclusion: The study concludes that rice farmers in Wase Local Government Area face significant challenges in accessing agricultural credit, primarily due to bureaucratic processes, high-interest rates, and limited availability of formal credit facilities in rural areas. Factors such as education, farm size, annual income, and participation in farmers' associations positively influence credit access. However, gender inequality in credit distribution remains an issue, with women having lower chances of securing credit compared to men. Enhancing access to agricultural credit would improve farm productivity, contribute to food security, and alleviate poverty among rice farmers in the region.

Recommendations: Based on the findings from the study, the following recommendations were made:; **Simplify Bureaucratic Procedures:** Financial institutions should streamline the loan application and disbursement processes to reduce delays and make credit more accessible to farmers.; **Promote Women's Access to Credit:** There should be gender-sensitive credit policies that encourage the inclusion of women in formal credit systems to ensure equal opportunities.; **Strengthen Farmers' Cooperatives:** Cooperative societies should be supported and expanded to facilitate collective bargaining for better credit terms and conditions for farmers.; **Increase Awareness and Education:** Financial literacy programs should be introduced to educate farmers on available credit options and how to navigate formal credit systems.**Lower Interest Rates:** Government policies should encourage financial institutions to offer lower interest rates and flexible repayment schedules for agricultural loans, particularly for small-scale farmers.

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Use of Information and Communication Technology (ICT) and Social media Platforms in Accessing Agricultural Information among Arable Crop Farmers in Shendam Local Government Area, Plateau State, Nigeria

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Abstract

The study analyzed the use of Information and Communication Technology (ICT) and social media platforms among arable crop farmers in Shendam Local Government Area of Plateau State, Nigeria. A multi-stage sampling technique was employed to select 180 respondents, and data were collected using a structured questionnaire. The results revealed that most farmers were middle-aged, with a mean age of 43 years, predominantly male (59%), and had secondary education (44%). The average household size was nine, with a mean farming experience of seven years. Most respondents (37%) operated small farms ranging from 1.6 to 2.0 hectares, with rice, yam, and cassava being the major crops cultivated. The mean annual farm income was ₦215,789. Radio (mean = 3.3) and mobile phones (mean = 3.0) were the most frequently used ICT tools, while social media platforms like WhatsApp (mean = 2.0) and Facebook (mean = 2.3) were less frequently used. Factors influencing the use of ICT and social media included age, education, household size, farm size, and annual income. The study concluded that integrating ICT into farming practices has the potential to improve agricultural productivity and income. However, access to digital tools and platforms remains limited, suggesting a need for targeted interventions to enhance digital literacy and connectivity in rural farming communities..
***Keywords**: Evaluating, arable crop farmers, ICT, social media, Shendam, Plateau State.*

Introduction: Sustainable agricultural development cannot be achieved successfully without accurate and up-to-date information and technologies to cope with globalization and its simultaneous rapid technological changes. This is because information is important for the development of any society and success for human endeavor (Sokoya *et al*., 2014). According to Tiwari and Sharma (2015), information is considered the fifth human need after air, water, food and shelter. Agricultural information refers to data, knowledge, and advice that is relevant to farming activities and agricultural practices. This information is essential for farmers to make informed decisions about crop production, livestock management, pest and disease control, market trends, and other aspects of agriculture. Access to timely and accurate agricultural information helps farmers improve their productivity, adapt to changing conditions, and make better economic decisions. Therefore, the concept of agricultural information in general and in particular, as a source of development, is of great importance in the contemporary world and cannot be overemphasized (Ogbonna and Aguvu, 2013).

In recent years, Information and Communication Technology (ICT) and social media platforms have emerged as key tools for bridging agricultural information search gap. There is hardly an area of human activity today that has not been touched by dramatic changes in information and communication technologies (ICT). The rapid advancements in Information and Communication Technology (ICT) have revolutionized various sectors globally, including agriculture. Ozor and Madukwe (2009) conceived ICT as a set of technologies that facilitate the processing, storage, retrieval and transmission of information. Information and communication technologies can be broadly defined as technologies that simplify communication, through the process and transmission of information through electronic media (Suleiman *et al*., 2015).

Social media on the other hand refer to a website or internet service that allows users to interact with each other and create content instantaneously. They are wide range of internet-based and mobile services that allow users participate in online exchanges, contribute user-created content or join online communities (Michael, 2012). The evolution of social media provided a visible solution to the challenge of information gap that hinders improvement of standard of living of people and achievement of development (Ministry of Agriculture (MOA), 2013). This is premised on the fact that social media enable blogging, tagging, discussion, networking, and so on and help to transfer information to large audiences at the same time and at a cheaper rate (Sokoya *et al.*, 2012). Social media have long been used in agriculture for facilitating communication among stakeholders, especially extension personnel (Sophie, 2013). According to Italie (2015) social media is the most recent form of digital communication and on a global scale accessing news through it by using mobile devices is gaining popularity. Within a few years, it has completely changed communication globally (Suchiradipta and Saravanan, 2016) and has become extremely popular because it allows people to connect in the online world to form a group, a forum and a community where ideas and information can be exchanged without any geographical barrier (Chui, *et.al,* 2012). They have impacted global development making people more informed and aware. A study conducted by Balkrishna and Deshmukh, (2017) revealed some benefits of social media in agriculture such as prompt response to questions relating to the field, saves time and cost of communication, provision of right information and at the right time like weather report, disease control, etc. Unfortunately, farmers, extension agents and other stake holders in agriculture may not be familiar with these benefits of social media.

Arable farming entails the production of wide range of food crops or annual crops. This entails crops in which the life cycle is within one year; from germination to seed production and maturity. Arable crops included; yam, maize, cocoyam, cassava, among others. Within the agricultural sector, the crops sub-sector is the largest, with arable crop production dominating about 30 percent of overall GDP (CBN, 2016). Dissemination of useful agricultural information to the farmers will enhance arable crop production. New approach for improving access to relevant agricultural information could be achieved through the use of information and communication technologies (Olaniyi and Ismaila, 2016). ICT provide recent knowledge and information on agricultural technologies, best practices, markets, price trends, and weather conditions (Yimer, 2015). Farmers need information on improved farm inputs, modern farming technologies, and climate change to enhance food production for ever increasing population. Important agricultural information such as sowing, improving soils, profit maximization and control pests and diseases will empower the farmer and their decision making capabilities (Lokeswari, 2016). ICT is an effective solution to problems that militate against the development of agricultural industry, such as weak marketing linkages, poor information management, low productivity, low income and lack of diversity (Ramli et al., 2015). The ICT devices which are of potential dissemination of agricultural information in farming activities include like radio, television, cellular phones, computers, and networks among others (Pande and Deshmukh, 2015). Shendam Local Government Area in Plateau State is predominantly an agricultural zone where arable crop farming forms the backbone of the economy. However, the extent to which farmers in this region utilize ICT and social media platforms for accessing agricultural information remains underexplored. Despite the growing importance of ICT and social media platforms in agricultural information dissemination, there is limited empirical data on their usage among arable crop farmers in Shendam Local Government Area. Many rural farmers continue to rely on traditional sources of information, such as interpersonal communication or extension services, which may not be timely or comprehensive enough to meet their needs. This creates a knowledge gap that can hinder productivity and limit farmers' ability to adapt to changing agricultural conditions. This study seeks to address these gaps by evaluating the current use of ICT and social media platforms among arable crop farmers in Shendam LGA, examine the factors driving adoption, assess the constraints faced by farmers, and provide insights into how these digital tools can be better leveraged to improve access to agricultural information.

Materials and Methods: Shendam Local Government is one of the seventeen local government areas of Plateau State. It has four districts namely: Dorok, Derteng, Dokan Tofa and Shendam. The LGA occupies a total land area of 2,477km2 with a population of 208,017 people consisting of 109,519 males and 98,498 females (NPC, 2006). It lies on latitude 8053´N and longitude 9032´E with mean annual rainfall of 57in and annual average temperature of 220C. Shendam LGA is bounded in the north by Mikang LGA, Quan Pan LGA in the west, Langtang South in the east and Taraba State in the south. The hottest months are normally March and September while the coldest months occur between December and January with a lot of harmattan haze. The rainy season is normally between the months of May to October while the other months remain dry. The population within the LGA is majorly agrarian. Rice and yam form the major food crops produced within this lower Benue basin having soils ranging from rich silt deposits to a sandy-loamy texture.

Sampling Technique: Multi-stage sampling technique was used to select the sample size for this study. The first stage involved the selection of the three districts in the Local Government for the study. They are Shendam, Dakan Tofa and Dorok districts. The second stage involved a purposive selection of three communities from each of the districts giving a total of nine communities for the study. The communities in Shendam districts are Derlit, Guras and Dungba. In Dakan Tofa district, the communities selected are Katai, Kirgangan and Tok Doka while in Dorok district, the communities selected are Gonvel, Kuka and Makera. The purposive selection is based on high volume of agricultural production in the areas. The third stage will involve random selection of twenty (20) youths from each of the communities selected. This will give a total of one hundred and eighty (180) respondents for the study. Data for this study was obtained through primary source. The primary data was generated through the administration of structured questionnaire designed in line with the objectives of the study.

Method of Data Analysis: Both descriptive and inferential statistics were used to analyze the data. Descriptive statistics (i.e. frequency counts, percentages, mean, Likert scale) and Logit regression were used to achieve objectives of the study.

Four poin Likert scale: The level of ICT use was measured using four-point Likert-type scale with the following options frequently used = 4, occasionally used = 3, rarely used = 2 and never Used = 1. The mean score was calculated by dividing the total score by the number of scale points: i.e.4+3+2+14/2 = 2.5. ICTs with a mean score of 2.5 or above were considered to be used by the farmers, while those below 2.5 were considered not used.

Logit Regression: Use of ICT in accessing agricultural information among farmers was measured using a binary, categorical variable taking up the value of1 for ICT use, and 0 for non-use of ICT. Since the dependent variable (use of ICT) is dichotomous, its relationship with the independent variables (factors) was estimated using a binary logistic regression model. The logit model is specified as:

Lny = Ln (p/1 - p)

Ln (p/1 - p) = f (βiXi) + ei

Where;

Y = Level of use of ICT (1= use, 0 = otherwise)

P = Probability of ICT use in arable crop production

1 – P = probability of non-use of ICT in arable crop production

Ln = Natural logarithm function.

β_i = vector of logistic regression coefficients.

X_1 = Age of respondent (Years)

X_2 = Gender (1 if male, 2 female)

X_3 = Marital status (Yes= 1, No= 0)

X_4 = Educational level (Years of formal education)

X_5 = Household size (number of persons)

X_6 = Farming experience (years)

X_7 = Farm size (hectares)

X_8 = Annual income (Naira)

Results and Discussion: Socio-economic Characteristics of Farmers: The age distribution of the farmers shows a mean of 43 years, placing the majority of farmers in the middle-aged category. The relatively low representation of younger farmers (12%) poses a challenge since younger individuals tend to be more tech-savvy and adaptable to new technologies. Efforts to attract youth to agriculture through incentives, access to modern technology, and entrepreneurship opportunities are crucial. The gender breakdown reveals that the sector is male-dominated, with 59% of the farmers being male and 41% female. This aligns with the traditional gender roles in many rural settings, where men are often more engaged in agricultural production, particularly in tasks that require more physical strength. Chikezie *et al*. (2012) stated that gender should not be a barrier to active participation in agricultural production activities. The majority of farmers (80%) are married, which is typical in rural farming communities where family labor is often relied upon. Marital status can have mixed implications for ICT use. On the one hand, large households may provide opportunities for family members, particularly the younger generation, to assist in using ICT tools for accessing agricultural information. On the other hand, larger households also create pressure on financial resources, making it more difficult to invest in ICT infrastructure like smartphones, computers, or internet subscriptions. Families with limited financial resources may prioritize basic needs over technological investments. Education is a critical determinant of a farmer's ability to access, comprehend, and adopt new technologies and farming practices. The data shows that 44% of the farmers have secondary education, followed by 27% with primary education, and 18% with tertiary education. Only 11% have no formal education. This moderate level of education among the farmers suggests that a significant number of them are literate and able to engage with agricultural extension services, access information through ICT platforms, and potentially adopt modern farming practices. The mean household size is 9 members, which is considerably large. Larger household sizes often imply a greater availability of family labor for farming activities, which is advantageous for smallholder farmers who may not afford hired labor. However, larger households also increase the pressure on farm resources and income, as more mouths need to be fed. The mean farming experience is 7 years, with over half of the farmers (53%) having 6-10 years of farming experience. This suggests that most of the farmers are well-versed in arable farming practices, although there is room for further learning and improvement. Experienced farmers often have better knowledge of local conditions, crop varieties, and market trends, but they may also be resistant to change or new innovations if they have relied on traditional practices for extended periods. The results of Bamire *et al*. (2010) and Mignouna *et al*. (2011), who claimed that farmers should be able to assess the benefits of new technology and enhance their production skills given sufficient experience, are consistent with this finding. Majority of farmers operate on small-scale farms, with a mean farm size of 1.3 hectares, and face financial limitations, as reflected in their low annual income. Small farm sizes and low incomes limit farmers' capacity to invest in ICT infrastructure, such as smartphones, computers, and internet access. With 34% of the farmers earning between ₦201,000-₦250,000 and only 9% earning above ₦300,000, many farmers operate at a subsistence level. This financial constraint poses a significant barrier to adopting ICT, as farmers may prioritize immediate needs over long-term technological investments. The most common crops grown by the farmers are rice (32%), yam (26%), and cassava (17%), reflecting a focus on staple food production. These crops are essential for food security and are likely grown for both subsistence and market purposes. Less common crops include millet (10%), maize (8%), sorghum (4%), and potato (3%). The crop mix suggests that farmers are primarily engaged in subsistence farming, with limited crop diversification. This lack of diversification may expose farmers to risks such as crop failure or market price fluctuations. ICT platforms can play a crucial role in providing farmers with timely market information, crop management tips, and weather updates, which are critical for optimizing the production and marketing of staple crops. Social media platforms, WhatsApp groups, and mobile-based apps can enable farmers to share information about prices, input availability, and best practices. The mean annual farm income is ₦215,789, reflecting low-income levels among the farmers, making it difficult for them to afford ICT devices and internet services. Low-cost ICT solutions, affordable data plans, and public internet access points could help mitigate the impact of these financial barriers.

Table 1: Socio-economic Characteristics of Arable Crop Farmers.

Variable	Frequency	Percentage	Mean
Age			
20-30	21	12.0	
31-40	40	22.0	
41-50	83	46.0	
>50	36	20.0	43
Gender			
Male	107	59.0	
Female	73	41.0	
Marital status			
Married	144	80.0	
Single	36	20.0	
Educational status			
Primary	44	27.0	
Secondary	70	44.0	
Tertiary	29	18.0	
Non formal	17	11.0	
Household size			
1-5	39	22.0	
6-10	77	43.0	
11-15	42	23.0	
>15	22	12.0	9
Farming experience			
1-5	56	31.0	
6-10	96	53.0	
11-15	28	16.0	7
Farm size			
0.5-1.0	37	20.5	
1.1-1.5	46	25.5	
1.6-2.0	66	37.0	
2.1-2.50	23	13.0	

>2.50	8	4.0	1.3
Major arable crops produced			
Rice	58	32.0	
Yam	46	26.0	
Cassava	31	17.0	
Maize	14	8.0	
Millet	18	10.0	
Potato	6	3.0	
Sorghum	7	4.0	
Annual farm income (Naira)			
100,000- 150,000	29	16.0	
151,000-200,000	37	20.5	
201,000-250,000	62	34.0	
251,000-300,000	35	19.0	
>300,000	17	9.0	215,789

Source: Field survey, 2024

Level of Use of ICT and Social media Platforms by Crop Farmers: Radio with a mean score of 3.3 is the most frequently used ICT tool by farmers. This high level of usage suggests that radio is a trusted and accessible source of agricultural information for farmers. It is a widely available medium in rural areas, where internet connectivity may be limited, making it a crucial channel for disseminating agricultural information. Mobile Phone having a mean score of 3.0 indicates that mobile phones are also regularly used by farmers. Mobile phones, especially for calls and SMS, are effective tools for communication and accessing information, including market prices, weather updates, and advisory services. The high usage reflects the growing penetration of mobile technology even in rural areas. Television with a mean score of 2.3 shows that television is not frequently used by the farmers, falling below the threshold of 2.5. This suggests that, while some farmers occasionally access agricultural information through TV, it is not as widely used as radio or mobile phones, possibly due to higher costs or lower accessibility in rural areas. Print Media with a mean score of 2.0, print media (newspapers, magazines) are even less frequently used by farmers. This could be due to low literacy levels, limited circulation in rural areas, or farmers' preference for more accessible and immediate forms of communication like radio and mobile phones. This finding aligns with those of Akinnagbe & Oladipupo (2018), who reported that arable crop farmers primarily used the following ICTs: radio (81.7%), mobile phones (79.2%), and television (73.3%). Facebook with a mean score of 2.3 indicates that it is occasionally used, but it is not a dominant platform for farmers. While some farmers use it to access agricultural information, it hasn't reached a level of widespread adoption, likely due to internet connectivity issues or lack of familiarity with the platform. WhatsApp with a mean score of 2.0 indicates that it is not frequently used by farmers. Although WhatsApp can be a useful tool for group communication and information sharing, its lower usage suggests that many farmers may not have consistent access to smartphones or reliable internet.

Table 3: Mean Rating of Level of Use of ICT and Social media Platforms by Farmers (N=180)

ICT facilities	FU(4)	OU(3)	RU(2)	NU (1)	Sum	Mean($\bar{x}$)
Radio	388	168	42	6	604	3.3*
Mobile Phone	244	219	62	15	540	3.0*
Television	96	168	118	41	423	2.3

Print media	44	153	128	54	379	2.0
Facebook	124	147	114	43	428	2.3
WhatsApp	84	75	126	71	356	2.0

FU= frequently used, OU= occasionally used, RU= rarely used, NU = never used

Factors Influencing ICT and Social Media Use among the Farmers: This table presents the results of a **binary logit regression analysis** to identify the factors influencing farmers' use of ICT and social media platforms for accessing agricultural information. The constant (16.8951, P = 0.011) is statistically significant at 5% level**,** meaning that, when all other factors are held constant, the model predicts a baseline positive likelihood of ICT and social media usage for agricultural information access. The large coefficient suggests that even without considering the specific characteristics of the farmers, there is a strong underlying propensity for ICT use in this context. The pseudo R-squared indicates that about 16.54% of the variation in the use of ICT and social media platforms is explained by the independent variables in the model. While not a high value, it suggests the model has a moderate explanatory power. The results indicate that age**,** educational status, household size, farm size and annual income are significant factors influencing the use of ICT and social media for accessing agricultural information.

Age (X_1): Age has a negative **(**-1.2068) and statistically significant at 5% level. This implies that for every additional year in age, the likelihood of using ICT decreases. It suggests that younger individuals are more likely to use ICT and social media, possibly due to greater familiarity and ease of technology adoption. It is opten thought that younger people are often more tech-savvy. This confirms the findings of Asadu *et al.* (2013) in a study on communication techniques used by extension workers. They observed that extension workers in their active age are able to respond and meet the needs of farmers using variety of communication strategies.

Educational status (X_4): The Coefficient of educational status is positive (0.0958) at 10% level suggesting that more educated individuals are more likely to use ICT and social media for agricultural information. This is in line with the expectation that higher education levels increase digital literacy, which facilitates the adoption of ICT.

Household size (X_5): Household size has a negative **(**-0.0538) with marginally significant (10%) effect. Larger households are slightly less likely to use ICT and social media for agricultural purposes. This could be because larger families might have less time or resources to invest in technology, or they may rely on traditional methods of accessing agricultural information.

Farm size (X_7): Farm size has a positive (8.6964) effect on ICT and social media use, and is statistically significant at 5%. This suggests that farmers with larger farms are much more likely to use ICT and social media, likely because larger-scale operations demand more advanced tools for accessing agricultural information to manage their farms efficiently.

Annual income (X_8): Annual income has a positive coefficient **(**1.20860) and is significant at 5%. Higher annual income is positively and significantly associated with the likelihood of using ICT and social media. This result supports the idea that wealthier individuals have better access to the necessary resources (such as smartphones, computers, and internet access) to engage with ICT and social media platforms.

Table 3: Factors Influencing Use of ICT and Social Media Platform for accessing Agricultural Information

Variable	**Coefficient**	**Std Error**	**Z**	**P value**
Constant	16.8951	6.6256	2.55	0.011
Age	-1.2068	.4904	-2.46**	0.014
Gender (X_2)	-.3138	.2302	-1.36	0.173
Marital status (X_3)	.4421	.4351	1.02	0.310
Educational status (X_4)	.0958	.0562	1.70*	0.088
Household size (X_5)	-.0538	.02831	-1.90*	0.057
Farming experience (X_6) 2.5581	1.6822	1.52	0.128	
Farm size (X_7)	8.6964	3.4680	2.51**	0.012
Annual income (X_8)	1.2086	.5732	2.11**	0.035
No. of observations =	180			
LR Chi2 (7) =	30.17			
Log likelihood =	-76.0870			

Pseudo R^2 = 0.1654.

Note: ***, ** and * Significant at 1%, 5% and 10%

Constraints to Use of ICT and Social Media Platforms among Farmers

The results in Table 4 highlight the key challenges farmers face in using ICT and social media platforms to access agricultural information. These constraints are ranked based on their frequency of occurrence, reflecting the most pressing issues as identified by the respondents.

1. **Inadequate Extension Support (66.0%, Ranked 1st):** The most commonly reported constraint is the lack of adequate extension support. Farmers often depend on agricultural extension officers to guide them in accessing and using ICT tools and social media platforms. When this support is insufficient, farmers struggle to adopt new technologies. This underscores the crucial role of extension services in facilitating the effective use of ICT, showing that integrating digital tools with traditional extension methods can significantly enhance farmers' access to agricultural information.
2. **Poor Electricity and Internet Connectivity (64.0%, Ranked 2nd):** The second-highest constraint is the unreliable or non-existent infrastructure in rural areas, particularly concerning electricity and internet access. Farmers in these regions face difficulties in charging their devices and maintaining consistent online connectivity. This lack of infrastructure severely limits their ability to use ICT tools, emphasizing the urgent need for better rural infrastructure to support technological adoption.
3. **Limited Awareness of Available Platforms (56.0%, Ranked 3rd):** Over half of the farmers reported that they are not aware of the various ICT platforms and social media tools available to access agricultural information. This lack of awareness prevents them from taking advantage of useful technologies. The findings suggest that more comprehensive outreach and education programs are needed to ensure that farmers are informed about the platforms they can use and the benefits these tools offer.
4. **Language and Literacy Barriers (54.0%, Ranked 4th):** Language and literacy challenges are another significant constraint, affecting over half of the respondents. Many farmers, particularly in rural areas, may struggle to understand the content on ICT platforms due to language differences or low literacy levels. This highlights the need for digital tools to offer local language options and user-friendly interfaces that cater to farmers with varying literacy levels, making the information more accessible.
5. **High Cost of Technology (43.0%, Ranked 5th):** The high cost of purchasing and maintaining technology, such as smartphones, computers, and internet services, remains a barrier for many farmers. While there are more affordable options available today, the costs are still prohibitive for many small-scale farmers. This finding suggests that providing financial support or subsidies for technology could increase the adoption of ICT tools among farmers with limited resources.
6. **Low Digital Literacy (42.0%, Ranked 6th):** A significant number of farmers cited low digital literacy as a challenge. Even when they have access to technology, many farmers lack the skills needed to effectively use ICT platforms and social media for agricultural purposes. This indicates the need for targeted digital literacy training programs, particularly for older or less-educated farmers, to help them become more comfortable with technology.
7. **Economic Constraints (34.4%, Ranked 7th):** Although ranked lower, economic constraints still present a barrier. Farmers with limited financial resources may prioritize immediate needs like food and household essentials, leaving little room for investing in technology or internet services. This underscores the importance of improving the overall economic conditions of rural farmers, as better financial stability could encourage more investment in ICT tools.

Table 4: Constraints to Use of ICT and Social media by Farmers

Constraints	***Frequency**	**Percentage**	**Rank**
Lack of electricity and internet connectivity	115	64.0	2nd
High cost of technology	78	43.0	5th
Low digital literacy	76	42.0	6th
Limited awareness of available platforms	101	56.0	3rd
Limited extension support	119	66.0	1st
Language and literacy levels	97	54.0	4th
Economic constraint	62	34.4	7th

***Multiple responses**

Conclusion: This study assessed the use of Information and Communication Technology (ICT) and social media platforms among arable crop farmers in Shendam Local Government Area of Plateau State, Nigeria. The findings highlighted that although the farmers had access to various ICT tools such as mobile phones and radios, the utilization of social media platforms like WhatsApp and Facebook was limited. Socio-economic factors such as age, education, farm size, and income significantly influenced the adoption of ICT. While the potential for ICT to enhance agricultural practices and improve farmers' livelihoods is evident, barriers such as inadequate access to digital infrastructure and limited digital literacy remain challenges in rural communities.

Recommendations: Base on the findings of this study, the following recommendations were made;**;** **Improved ICT Infrastructure**: Government and private sector partnerships should prioritize the expansion of digital infrastructure, particularly in rural areas, to enhance farmers' access to ICT tools and internet connectivity.**;** **Capacity Building Programs**: Extension services and agricultural organizations should conduct training sessions aimed at improving farmers' digital literacy and skills in using social media platforms for agricultural purposes. This would enable farmers to access timely information and market opportunities.**;** **Subsidized ICT Tools**: Governments and non-governmental organizations should consider providing subsidized ICT tools, such as smartphones and internet data, to low-income farmers to enhance their ability to adopt modern farming practices.**; Strengthening Extension Services**: Agricultural extension officers should be equipped with ICT tools and trained to use social media platforms for disseminating agricultural information. This would facilitate more efficient communication between farmers and extension personnel.**; Promotion of Local Content**: Content developed for ICT platforms should be localized to suit the cultural and educational background of the farmers. This will make it easier for farmers to relate to and apply the information they receive.**; Further Research**: Additional studies should focus on understanding the specific barriers hindering the use of advanced ICT tools, including social media platforms, and developing tailored interventions to address these challenges.

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Systematic Review of Literature on Teacher and Student Related Variables Affecting Performance of Students in Mathematics Examination in Secondary Schools In Nigeria

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Abstract

Although the current education is moving away from examination oriented education examination still holds an important place as a summative method to determine students' achievement in the subject against their peers. Across many countries in the there is a growing concern among educators on the factors that predict students' performance, especially in external examinations in mathematics. The critical issues for educators and relevant stakeholders in education are therefore to understand the factors which predict student's performance to optimize students' overall success. The reviews of the literature will be presented to reveal the predicting factors responsible for students' poor performance in mathematics that affect students' performance in mathematics which include teacher and student-related variables. This study will include empirical studies on teacher and student -related variables in relation to students' performance within and outside Nigeria. The teacher related variables are; Teachers' Teaching Qualification, Teachers' Teaching Experience, Selection and Use of Instructional Materials. The student- related variables considered in this study are; Motivation in Learning Mathematics and Students' Study Habit which are variables that relate to mathematics education, teaching and learning process in relation to students' performance in mathematics in secondary schools.

Key words: Teacher-Related Variables, Student-Related Variables, Performance and Mathematics.

Methods: We used the ERIC database as the main source of articles. ERIC (Education Resources Information Center) is an authoritative database of indexed and full-text education literature and resources. It is an online digital library of education research and information. ERIC is sponsored by the Institute of Education Sciences of the United States Department of Education. The database as the main source of articles is an authoritative database of indexed and full-text in education other literature and resources. It is an online digital library of education research and information. We supplemented with published in peer reviewed journals were included in online data bases in the Universiti Teknologi Malaysia (UTM) library available to all current UTM students. E- journals from google scholars, science direct and random google search were extracted from studies conducted in the North-America, Europe, Asia, Africa and other parts of the world. The initial search generated 20,854 articles related to our study conducted between the year 2010 and 2023. We further refined the subject by themes and generated 2,025 articles on mathematics performance, 1,705 articles on mathematics education, and 2,581 articles on mathematics teaching methods, 1,719 on students' attitude. We further filtered the articles and generated 1,056 articles. Finally forty (40) articles met the criteria and were reviewed. Review was based on topics of academic performance in mathematics including; students' attitude, students' anxiety, meta-cognition in problem solving and other students' and teachers' factors.

Inclusion and Exclusion procedures: The procedures were followed in articles inclusion. That is only;

1. peer- reviewed scholarly articles
2. Peer- reviewed articles on the factors that affect students' performance in mathematics.
3. Peer-reviewed scholarly articles published from 2010 to 2023.
4. Articles international perspective on factors that affect students' performance in mathematics in senior secondary schools.
5. Factors that are either teacher related or student- related factors.

To exclude some articles from the review the criteria below were applied. That is

1. Non-peer reviewed articles.
2. Articles published before 2010 unless it is critical and impactful.
3. Media generated articles and news-paper.
4. Articles not published in English language.
5. Quantitative articles were used only.

Results: Predicting factors affecting students' performance in Mathematics: Teachers and students themselves and many other stake holders have raised many questions on why students perform so poorly in mathematics. The state government through the ministry of education has shown some concern over this in recent times by introducing low costs books for secondary schools in three zonal offices in the state. Although this was meant to create the desire for students to study, but has not helped the situation much because students do not read these books. Students prefer visiting the internet to browse for information easily. Studies indicated that, the performance of students on internal and external mathematics examinations is not encouraging (Osa-Edoh & Alutu, 2012; Umar, Adamu & Abdullahi, 2014). This study categorized the predicting variables in to teacher-related and student-related variables as follows.

Teacher-Related Variables and Students' Performance in Mathematics: The teacher-related factors affecting students' performance in mathematics are teachers' teaching qualification, teaching experience, selection and use of instructional materials would be explained in relation to mathematics education.

Teachers' Teaching Qualification: Collins Co-Build Dictionary in Omaliko & Okpala (2021) defines teaching as the work done by a teacher in helping students to learn, while qualification is the number of examinations the teacher passed to become a professional teacher. Therefore, teaching qualification refers to academic and professional qualifications that enable a person to become a registered teacher at all levels of education. Omaliko & Okpala (2021) further reiterated that teaching qualification is an important factor in improving students' performance in science and mathematics. Udofot (2010); Achile (2011) posited that a qualified teacher is one who is fully certified in the field being taught. (Musau & Abere, 2015; Obeka, 2024) added that teacher education program at present is categorized in to three levels on the basis of their training and certificate; Nigeria Certificate in Education (NCE) which is minimum teaching qualification in Nigeria is run for a minimum of three years and a maximum of five years obtainable from colleges of Education and comparative institutions. Bachelor degrees in Education (B.Ed), (B.A.Ed), (B.Sc.Ed.) which is run for a minimum of three and a maximum of five years and Post Graduate Diploma in Education (PGDE) in one year as an auxiliary teacher in universities for those who have bachelor degrees or Higher National Diploma (HND) without education background M. (Ed.) M.A. (Ed.) or M.Sc (Ed.) Master Degree for two years and Doctor of Philosophy (PhD.) for minimum of three years in the University. Another requirement is that a teacher must be a registered and certified member as a- professional teacher by the Teachers Registration Council of Nigeria (TRCN) for basic requisite professional status.

In Nigeria, there are several states whose school teachers at the secondary level are so unqualified that the percentage could be as high as eighty (Oluwakemi, Tomitope & Olukayode, 2015). Thus, that the high percentage of unqualified teachers in public secondary schools is a major cause responsible for the poor students' academic performance in mathematics. A major feature of this poor academic performance is the dismal performance in Mathematics in the Senior School Certificate Examination (SSCE) in Nigeria in the recent years which has been linked to decline in the quality of teaching and learning (Daso, 2013; Chhinh and Tabata, 2013; Akinsolu, 2010; Ewetan, 2010). The study conducted by Bamidele & Adekola, (2017) revealed significant difference in the performances of students taught by professional teachers and non-professional teachers which was in favor of students taught by professional teachers. Similarly, Awogbemi (2013) and Abe (2014) concurred that there was significant difference in the academic achievement of students taught by teachers with high qualification and those students taught by teachers with low qualification. Umar, Ahmad, and Awogbemi (2013) reported that better students' results are the main indicator of quality teachers in our schools and that positive correlation between teachers' qualification and students' academic performance. On the contrary, Maphoso and Mahlo, (2015); Musau and Abere, (2015); confirmed that teacher's qualifications did not have a significant influence on students' academic performance in Mathematics.

These studies appear to indicate that teacher qualification have a significant influence over students' results. Taking this into consideration, this study would like to determine if the qualification of teachers in Nigeria and other African sub Saharan countries has a significant effect on students' performance in mathematics and how it inter- plays and relates to other variables of this study. This is because, the results in Nigeria have shown a worrying trend of poor performance and being able to identify the effects of teacher qualification and results may help to assist in future direction of teacher employment in the country.

3.2.2 Teachers' Teaching Experience

Teaching experience is the attainment of skills, exposure or training acquired over time that enables you to perform your job better or prepare you for a teaching position. Kini, and Podolsky, (2016) in their studies which was based on the effect of teachers' teaching experience on students' outcomes found that teacher's teaching experience is positively associated with students' achievement throughout a teacher's career. The gains in teacher effectiveness is associated with experience and are most steep in teachers' initial years, but continue to be significant as teachers reach the second and even third decades of their careers. Also, as teachers gain experience, the students not only learn more but they are measured by standardized tests where they are also more likely to do better on other measures of success, Yusuf, and Dada, (2016) in their studies opined that, there was a significant difference in the academic performance of students based on the teachers' teaching experiences such that students taught by teachers with teaching experience between six - fifteen (6-15) years performed better than those taught by teachers with teaching experience between one - five (1-5) years. Similarly, Agbo-Egwu, Adadu, Nwokolo-Ojo, and Enaboifo, (2017) confirmed that, schools having more teachers with more than ten (10) years teaching experience achieved better results than schools having more teachers with less than ten (10) years teaching experience. Findings established by some scholars such as (Yusuf, and Dada, 2016; Agbo-Egwu, Adadu, Nwokolo-Ojo, and Enaboifo, 2017) indicated that teaching experience and qualification (degree level) had interactive effect on students' performance in Mathematics. Ewetan and Ewetan (2015) also argued that teachers' length of training and teaching experience are significant determinants of students' academic achievement. Bamidele and Adekola (2017) posited that long years of teaching experience improves teaching skills and students learn better at the hands of teachers who have taught them continuously over a period of time which means that long years of teaching experience is a strong determinant of quality mathematics education.

On the contrary, the study by Kadri, Alwi, and Hashim (2018) revealed that there was no significant difference in students' achievement between students taught by teachers with ten (10) years and more teaching experience and teachers with less than ten (10) years teaching experience. The previous studies indicate that teacher experience has a significant effect on student' results in examinations. Taking this into consideration, this study will determine the sample teachers of this study teaching experience and its relationship to students' results and other variables of this study such as teachers' teaching qualifications, teachers' self - concept, methods of teaching mathematics and selection and use of instructional materials. The worrying results of students' performance in mathematics in developing countries could be partly due to having a large amount of inexperienced teachers. The results from this study could mean that efforts need to be made to ensure appointment of more experienced teachers, or mobilizing experienced teachers to mentor inexperienced teachers in schools.

Selection and use of instructional materials: (Adebule & Ayoola, 2016) described instructional materials as resources that may be used as part of instructional process which disseminate information and ideas which makes possible and easy communication to learners in the teaching-learning process. Experience shows that teachers in those days have been depending on excessive use of words termed 'chalk-talk' method to convey ideas or facts in the teaching-learning process. Today advancement in technology have made it possible to produce materials and devices that could be used to minimize the teachers' talking and at the same time make the message clearer, more interesting and easier for the learner to assimilate (Afolabi & Adeleke , 2010). Ayoola (2015) & Aina, (2012) opined that instructional materials influences teaching and learning. These are, the ICT, classrooms, libraries, laboratories, school management, and peers are related to the expectation of students' influences teaching and learning which form the determining variables that affect students' academic achievements.(Ayoola, 2015) suggested that the abstract nature of some mathematical concepts could be addressed by the use of relevant instructional materials and need to diversify the strategy for teaching mathematics. The application of relevant media materials in teaching can help solve the problems faced in the teaching of mathematics. Findings from Adebule & Ayoola, (2016); Umar, Adamu, & Abdullahi,(2014), Asamoah, Sundeme, Atta, Adom-Fynn, Ebow, & Afrane (2020) revealed that, students who were taught Mathematics with the aid of instructional materials achieved significantly higher scores compared to those that were not taught with instructional materials. This was in line with the findings of Umameh (2011), Fakomogbon (2012) and Ayoola (2015) who observed that the use of improvised instructional materials make students to achieve better in their studies. Lack of instructional materials to facilitate teaching-learning in mathematics are noticeable particularly in senior secondary schools in the developing countries. The research shows that the application of appropriate media materials, Information and Communication Technology (ICT) may help solve the problems faced in the teaching of mathematics in senior secondary schools. The use of instructional material can help significantly in making mathematics very interesting to students as the global world is going digital. The researchers Umar, Ismail & Mahmood (2018) asserted that where information is difficult to explain verbally, exact interpretation is needed by the use of instructional materials by illustrating the concept to the learner by adding emphasis to the essential points to raise students' academic performance, emphasis will be placed on the choice and application of mathematics educational resources. This suggests that if mathematics is taught without the use of instructional resources, poor academic performance may result and it will be less common to teach mathematics in an abstract way if students are actively engaged in the learning and teaching processes.

Student-Related Variables and Performance in Mathematics: The student-related factors which also affect students' performance includes motivation in learning mathematics and students' study habits which are also related to mathematics education.

Motivation in Learning Mathematics: McGrew (2008) defined academic motivation as a student's desire (approach, persistence and interest) regarding academic subjects when the students' competence is judged against a standard of performance or excellence. (Yazici, 2009) described motivation as a learning process which does not necessarily have the input or output of it, but a pushing factor that influences learning behavior which can be categorized into intrinsic and extrinsic motivation. Yazici also added that intrinsic motivation is based on the individual factor or willingness of a person while extrinsic motivation is based on organization level. (Schreglmann, 2018) described motivation as one of the most important factors that affect learning process and success and that motivation can also be the power that stimulates a person to act in order to do something. Motivation is a fundamental recipe for academic success and plays an important role in learning because it greatly explains academic performance Gasco, Goni, & Villarroel (2014). The scholars explained that, motivation is what gets you going, keeps you going, and determines where you are trying to go.

A good number of studies have examined factors of students' motivation and their relationship with efficacy and mathematical thinking (Umar, 2011; Karadaq, 2017; Lee & Stankov, 2018). The researchers found that motivation affects students' performance in mathematics examinations. Based on their investigations and evaluations, the researchers discovered a positive relationship between students' motivation and academic performance. Studies on influence of motivation on students' academic performance revealed that students' motivation actually influences students' performance as it is paramount for students' success if the students' motivational level is increased by stimulating their positive emotions by spurring them with an inspirational event accompanied by music and lyrics that are inspiring as opined by Karadag, (2017). Looking at motivation as an important factor combined with other factors that influences students' performance in mathematics, the need therefore to investigate the effects of motivation in learning mathematics in secondary schools.

Study Habit: Dikko (2008) defined study habit as an activity that leads students to mastery of their studies which plays an important role in students' academic achievement. Some scholars identified certain constructs of study habits and reading skills deficiencies our students should learn to achieve competence in their studies in mathematics. Some scholars identified study techniques most students do not know how to study probably because they are not aware of what techniques to apply in the study situation or they study at odd times or places. The environment to study mathematics should be well -ventilated, noise free and well lighted room or open place with a desk and a chair, the need to consider the type of chair and desk be used for study. These should be such that students maintain an erect and comfortable sitting posture. The study desk should be spacious enough for the books and materials but should contain only what one need at a time. Time planning is a technique students utilize on study by organizing and planning time to avoid distraction from regular studies. Effective and fast reading is a study technique where Students has much to read because of the great demand inherent in mathematics in secondary school core curriculum. (Osa-Edoh, & Alutu, 2012) in their study on factors responsible for effective study habits in secondary schools found out that some students perform woefully in examination not because they are not intelligent, but because they lacked techniques for effective study habits. The scholars recommended the development of study habits right from primary schools as this will give a lasting effect on their future performances. (Umar, 2011) in his study on an analysis of different study habits and their effects on students' academic performance in schools discovered that, there is significant relationship between students' study habit and their academic performance. Similarly, Osa-Edoh & Alutu (2012) in their studies found that poor study habits ranked high when compared with other factors responsible for poor academic performance in mathematics among students.

Findings: The results showed that the academic performance of students taught by highly qualified teachers varies significantly from that of students taught by less qualified teachers. Results were shown to be better for schools with more teachers with over ten (10) years of teaching experience and better teaching qualifications than for those with more instructors with less than ten (10) years of teaching experience. The results showed that children do better academically when teaching materials are chosen and used appropriately. It is evident that there are insufficient teaching resources to support mathematics instruction, especially in senior secondary schools in developing nations. According to the research, the use of suitable media resources and information and communication technology (ICT) could aid in resolving issues related to mathematics instruction in senior secondary schools. As the world becomes more digitally connected, the utilization of educational resources can greatly aid in making mathematics engaging for students. Effective study habits in senior secondary schools were shown to be influenced by the fact that some students perform poorly on exams not because they lack intelligence but rather because they lack study habits.The researchers found a positive correlation between students' academic achievement and motivation based on their investigations and ratings. According to the study, students' performance in mathematics is influenced by their motivation to master the subject. It is crucial for students to succeed if their motivation is raised by encouraging them to feel good.

Conclusion: The study was carried out to provide a systematic review of the factors affecting students' performance in mathematics in secondary schools. Findings from this study reveals that the teacher- related variables which are; Teachers' Teaching Qualification, Methods of Teaching Mathematics, Teachers' Self- Concept, Teachers' Teaching Experience, Selection and Use of Instructional Materials.
The student- related variables considered in this study are; Students' Attitude Toward learning of mathematics, Students' Mathematics Anxiety, Academic Motivation in Learning Mathematics, Students' Study Habit, Students' Meta-cognition in Problem Solving which are variables that relate to mathematics education, teaching and learning process in relation to students' performance in mathematics in secondary schools. Results from this review shows it is important that these factors be tackled earlier at primary through their secondary levels to inculcate good values towards their liking of mathematics.

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Impact of Poverty and Food Insecurity on Students' Metacognition in Problem Solving Variable on Students' Performance in Mathematics Examination in Senior Secondary Schools in Bauchi State, Nigeria

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Abstract:
This paper discusses the impact of poverty and food insecurity on students' meta-cognition in problem solving and students' performance in mathematics in Bauchi state. In this study, two research questions were answered at 0.05 level of significance. The causal comparative (ex-post facto) and correlational research designs were adopted for the study. The population of the study consisted of all the 615 mathematics teachers and 47,187 mathematics students in public senior secondary schools that participated in the 2023/2024 mathematics trial examination in Bauchi metropolis in Bauchi State. A sample of 133 mathematics teachers and 381 mathematics students who participated in the study and were drawn using sample size table for calculating sample size for population in sampling techniques by Kredjie & Morgan (1970). Two research questions were answered in the course of the study.The instrument used for data collection was the Meta-cognitive Awareness in Problem-solving Questionnaire (MAPQ) and Mathematics Trial Examination Records (MTER). Finding shows that the metacognition in problem solving affects performance of students in mathematics in Bauchi State. The study also shows that meta-cognition has a high influence on success in problem solving and thus, good results in mathematics examination. The Bauchi state government should run the free school feeding program where students receive food. It should also carry up a comprehensive implementation of this program by closely monitoring its overall execution. The Bauchi state government should offer free buses and other forms of student transportation to reduce the expenses of transportation a key reason why students skip lessons.
Key words: Poverty, Food security, Metacognition, Trial examination, Problem –Solving.

Introduction Food insecurity amongst secondary school students is a critical problem in Nigeria that is increasing at alarming rate. It is critical that there is a clear understanding of the potential relationships that pose between food insecurity and academic determination as well as understanding and identifying potential relationships between secondary factors in order to identify practical solutions to the social problems (Akinfolarin, Akinola, Ismail & Owoicho, 2024). This research study attempts to explore the relationship between food insecurity and metacognition in problem solving) in secondary school students in Bauchi state, Nigeria. Meta-cognition is a phrase often talked about in our schools, though many among the teachers did not know exactly the clear meaning about it. The word Meta-cognition is a combination of two Greek words "meta" and "cognition". 'Meta' means going beyond and 'cognition' means thinking. Therefore, meta-cognition means going beyond ordinary thinking. It may also be defined as thinking about thinking that is cognitive that goes beyond conventional thinking. The Greek word meta means going beyond. The term 'meta' according to Flavell (1979), relates to second level knowledge. Several tangible and significant benefits of meta-cognition on mathematical learning have been identified. According to Flavell (1979), the major concerns for education are oral comprehension, reading comprehension, problem solving, attention, memory, social cognition, personality development, communication, and various forms of self-control and self-instruction.

Many experts think that meta-cognition has a lot of potential to improve student performance. Numerous beneficial academic outcomes for students, including improved grades and performance on tests for intelligence, have been related to meta-cognition. Maqsud (1997) looked into how nonverbal aptitude and meta-cognitive abilities affected high school students' academic performance. He discovered that a high school student's meta-cognitive capacity tended to correlate well with their academic performance. Desoete (2007) recommended that teachers emphasize meta-cognition in order to help students improve their problem-solving abilities. Meta-cognitive skills have been emphasized as an important part of mathematics education in a number of nations, including the US (National Council of Teachers of Mathematics [NCTM], 2000] and Turkey (Ministry of National Education (MoNE, 2018]), and teachers should provide experiences for reasoning and problem-solving (Ader, 2019). Meta-cognition was suggested as a very strong variable that could examine the correlation between measures of meta-cognitive knowledge, learning, and study strategies to improve students' academic achievement across the domains of verbal ability and mathematics, based on the ongoing changes in Nigerian mathematics curricula.

However, because of the difficulty in analyzing and observing meta-cognitive abilities in problem solving, mathematics educators in Nigeria have not thoroughly looked into this topic. Determining how meta-cognition in problem solving affects students' performance in mathematics in Bauchi state to also see how it relates to other variables is the goal of the current study.

Research question: Two research question were answered in the course of the study.**: 1.** What are the estimates of strength of Metacognition in problem solving variable affecting students' performance in mathematics trial examinations in Senior Secondary schools in Bauchi State?**. 2.** What is the total effect of poverty on metacognition variable affecting senior secondary school Students' performance in mathematics trial examination in Bauchi State?

One of the complex procedures that call on meta-cognitive abilities in addition to cognitive resources is problem-solving. These abilities are essential for problem-solving because they support problem identification, choice of appropriate method, monitoring of method efficacy, control of solution accuracy, and process control (Sternberg & Hedlund, 2002). According to study findings, students who struggle in mathematics do not effectively use cognitive and meta-cognitive strategies to solve problems (Wilson & Clarke, 2004). High meta-cognitive ability students are better at solving problems (Desoete, 2008. To enhance the teaching of mathematics, it is crucial to look into students' meta-cognitive abilities (Livingston, 2006). There is a lack of information regarding the type of students' meta-cognitive skills and the use of these skills in problem-solving, despite the growing attention being paid to the importance of meta-cognition in problem-solving (Suriyon, Inprasitha & Sangaroon, 2013). The current study sought to investigate students' use of meta-cognitive abilities in problem-solving, the differences between those who do so and those who do not, and how successful problem-solving is impacted by these skills. In this vein, this study is directed towards how students' meta-cognitive abilities relate to problem-solving in secondary school.**.** Many researchers in mathematics education opined that Meta-cognition holds a great deal of promise by helping students do better in schools. Meta-cognition has helped a lot in linking positive academic performances of student's grades in tests of intelligence. The researchers revealed that there is a close relationship between Meta-cognition and performance of students. Mason & Nadalon (2005) discovered that the overall students' meta-cognitive competence correlated significantly with their achievement in mathematics, while students with a poor meta-cognition perform poorly in Mathematics test. A study was conducted by Sherry and Jessey (2005) cited in Eme & Inuibong (2011)) where path analysis was employed to investigate the relationship between instructional technology and students' achievement. Meta-cognition was used as the independent variables, with student achievement as the dependent reliable results from the analysis indicated that meta-cognition significantly predicted performance of students.

Nzewi, 2011; Nbina, 2012; Karaali, 2015; Arum 2017 and Alshabibi & Alkharusi, 2018 examined the correlation among measures of meta-cognitive knowledge, learning and study strategies, and academic achievement across the domains of verbal ability and mathematics. They found that meta-cognitive knowledge can be generalized across verbal and mathematical domains. There was also significant correlation between meta-cognitive awareness and performances of students on the test. According to Adamu, Abdullahi & Abani, (2021), students should be taught how to learn mathematics independently, have a deeper awareness of how they process information, evaluate their thinking, and think of ways to make their learning process more effective. These previous research support the notion that meta-cognition has a high influence on success in problem solving and thus, good results in mathematics examination. Previous studies on meta-cognition among Nigerian students appear to show that meta-cognitive skills have a significant effect on students' problem solving success. Regarding these claims, this study would like to determine the relationship between meta-cognition and results of teaching through problem-solving will develop students' higher order thinking skills and how they may also be related to other variables of this study such as mathematics anxiety, students' attitude towards mathematics, and so on.

Findings from this study can help teachers to design class room tasks together with other determining factors other than meta-cognition that can have an effect on students' performance in exam. The worrying performance of students in Bauchi state means that students should know how to incorporate problem-solving meaningfully into the mathematics classroom which remains a challenging task to mathematics educators nowadays.According to Adamu, Abdullahi & Abani, (2021), students should be taught how to learn mathematics independently, have a deeper awareness of how they process information, evaluate their thinking, and think of ways to make their learning process more effective. These factors might contribute to students' poor performance in Trial and national exams in Bauchi state.

Design: This research adopted the causal comparative (ex-post facto) and correlational research designs. The choice of causal comparative research design, specifically, was to study how the independent variables have affected the dependent variables, meaning that, already there is Trial mathematics- examinations, as well as the SSCE which are externally developed and administered to students.

Population: The population of this study consisted of all the mathematics teachers and SS3 mathematics students in the 153 Public Senior Secondary Schools in the 20 Local Government Areas (LGAs) of Bauchi state in the 2023/2024 academic session. The 20 LGAs were divided into three educational zones. The researcher chooses mathematics teachers and SS3 students in public senior secondary schools in 3 zonal education offices in Bauchi state to administer questionnaire.

Sample: The sample of the study consisted of 25 public Senior Secondary Schools that participated in the annual Trial mathematics examinations in Bauchi State for 2023/2024 session. A sample of 381 SS3 mathematics students were selected from public senior secondary schools in the three educational zones in Bauchi state.

Quantitative instrumentation: These involved preparing open and close ended questions which were sent to Mathematics teachers. The researcher designed both open and close ended; open ended questions and gave the respondents the opportunity to provide their own answers to the questions while close ended, the answers were provided for the respondents to choose from. The scoring schedule of Section A was measured discretely. The soring schedule of Section B, C, D and E of the students' related variables questionnaire items were measured on the five-point Likert scale: Strongly Agree (SA) = 5, Agree (A) = 4, Undecided (U) =3, Disagree (D) = 2, and Strongly Disagree (SD) = 1. The scoring of the trial mathematics examination scores are already document kept at the examination unit of the Bauchi state ministry of education. The researcher simply extracted scores of students from the sampled schools. The scores were used for data analysis using PLS-SEM.

The questionnaire consisted of ten (10) items and was based on five points Likert scale ranging from "always" to" not at all" in which the participants were asked to tick the appropriate box. To establish the reliability of internal consistency of the Mathematics students' related variables Questionnaire, the Cronbach Alpha of 0.75 was used to determine the internal consistency of the items of the mathematics student-related variables questionnaire using the Partial Least Square – Structural Equation Modeling (PLS-SEM).

Research Question 1: What are the estimates of strength of metacognition in problem solving variables affecting performance of students in mathematics trial examinations in Senior Secondary schools in Bauchi State?

Table 1: M**etacognition in problem solving**

Path	Estimate (Beta Coefficient)	Sample Mean (M)	Standard Error	T- Critical	P- Values	Label
Metacognition in Problem-solving -> Mathematics trial Performance	0.051	-0.350	0.358	1.443	0.000	MS

The path from metacognition in problem solving to mathematics performance with path coefficient of 0.051 is significant based on its p.value (0.000) that is less than 0.05.

From Table 1 The following paths were meaningful and significant:

1. The path from mathematics anxiety to mathematics performance with path coefficient of 0.008 is meaningful and significant based on its p.value (***) that is less than 0.05.
2. Similarly, the path from metacognition in problem solving to mathematics performance with path coefficient of 0.051 is significant based on its p.value (0.000) that is less than 0.05.

Research Question 2: What is the total effect of metacognition in problem solving variable affecting senior secondary school students' performance in mathematics Trial examination in Bauchi State?

Table 2: Total effects of metacognition in problem solving on the performance of students

Metacognition in problem solving	**Direct**	**Indirect**	**Total**
Path	0.051	0.013	0.064

Research question two was answered by interpreting the total effects of the variables on the performance of students. This was derived from the total path estimates based on the output of the path model using the Partial Least Square- Structural Equation Modeling (PLS-SEM).
Total effects of the variables on performance was 0.064 (the sum of total direct and total indirect effects). The findings from research question two indicated the total effect of metacognition in problem solving variable on students' performance in mathematics trial examination in senior secondary schools in Bauchi State I greatly influenced by the value of its direct effect (0.051). The results showed that the total effects of the variables (0.064) were found to be significant because their p-values were less than 0.05. This means that there is a significant relationship between all the variables and students' performance in mathematics trial examination in senior secondary schools in Bauchi State. This also means that the total effects of these variables do not significantly affect the performance of students in mathematics trial examination in senior secondary schools in Bauchi State.

Findings: Findings from this study on impact of poverty and food security on students' meta-cognition among students appear to show that meta-cognitive skills have a significant effect on students' problem solving success. This study determined a positive relationship between food security and students' meta-cognition in problem solving. The Bauchi state government should run the free school feeding program where students receive food. It should also carry up a comprehensive implementation of this program by closely monitoring its overall execution. The Bauchi state government should offer free buses and other forms of student transportation to reduce the expenses of transportation which has become a key reason why students skip lessons.

Conclusion: This study can help teachers to design class room tasks together with other determining factors other than meta-cognition that can have an effect on students' performance in examination. The worrying performance of students in Bauchi state means that students should know how to incorporate problem-solving meaningfully into the mathematics classroom which remains a challenging task to mathematics educators nowadays.

Recommendations: The removal of petroleum subsidy in mid - 2023 was a positive step but faced implementation challenges with a public backlash on food security and education driven by high food prices and currency devaluation.. It is therefore recommended that the Bauchi state government should invest on non -oil sectors to enhance revenue generation in the state to create conducive environment for learning.

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Effects of Fuel Subsidy Removal on Students' Anxiety and Study Habits Factors and Students' Performance in Mathematics in Senior Secondary Schools in Bauchi State, Nigeria

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Abstract

This study examines the effect of fuel subsidy removal on students' anxiety and study habits on academic performance of senior secondary school students. 47,187 senior secondary three (SS3) students and 615 mathematics teachers in senior secondary schools from three education zones (Bauchi zone, Central zone and Katagum zone) of Bauchi state, Nigeria was used for the study. The study adopted Expost- facto and correlational research designs. The sample of 133 mathematics teachers and 381 Senior Secondary three (SS3) students in senior secondary schools using stratified sampling techniques. The sample of the study consists of 25 public Senior Secondary Schools that participated in the annual Trial mathematics examinations in Bauchi State for 2023/2024 session. The samples were selected from public senior secondary schools in the three educational zones in Bauchi state. The Krejcie and Morgan table for determining sample size were used for selection. The instruments used for data collection are; Mathematics Anxiety Questionnaire (MAQ) Study Habit Questionnaire (SHQ) and Mathematics Trial Examination Records (MTER) used as a document for 2023/2024 academic session. The method of data analysis employed was the statistical techniques Partial Least Square- Structural Equation Modeling (PLS-SEM) using PLS Smart 4 software. Findings from the study identified that mathematics anxiety and poor study habits affect the performance of students in mathematics negatively. Therefore, it is dangerous to neglect the importance of mathematics anxiety and students' study habit and its adverse effect on students' academic performance as over anxiousness and poor study habit increases academic failure in mathematics

Keywords: *Mathematics Anxiety, Study Habit, Mathematics Trial Examination, Performance.*

Introduction: The process of removing fuel subsidies involves bringing prices up to market levels, which typically results in an increase in the price of fuel at the pump with major economic and social repercussions (Akinnibi, 2023). The withdrawal of the nation's fuel subsidy has affected mostly the students because it is being maintained for the first time since democracy was restored (Felix, 2023). According to Ogunnode and Aregbesola (2023), the cost of food, transportation, and other essential goods has skyrocketed, as has the price of fuel since the new Nigerian president promised complete deregulation of the downstream sector. The student performance in senior secondary school over the years when taking both internal and external examinations has been low. Despite the importance of mathematics as a mandatory course in secondary education in Nigeria; it does not seem to be friendly with students to the extent that there is mathematics phobia at both senior secondary school and tertiary school level with a wide scope (Omirim & Ale, 2008). The perception has resulted to a noticeable decline in the number of students who perform better in mathematics at the senior secondary school level right from inception when the federal government of Nigeria declared fuel subsidy removal on petroleum products. Again, Amuche, Bello, Amuche-B, and Marwan (2014) observed that since then there is a steep decline in the performance of candidates in mathematics in the West African Senior Secondary Examination in Nigeria every year.

Research Questions: The following research questions were answered in the course of the study.; What are the estimates of strength of the causal model of students-related variables affecting performance of students in mathematics trial examinations in Senior Secondary schools in Bauchi State?; How do the teacher-related and students-related variables directly and indirectly affect performance of students in Mathematics Trial Examinations in Senior Secondary schools in Bauchi State?; What are the proportions of causal effects of the variables that influence the performance of students in mathematics Trial examination in senior secondary schools in Bauchi State?

Methodology: Research Design: A quantitative technique was used for this study. This research adopted the causal comparative (ex-post facto) and correlational research designs. The choice of causal comparative research design, specifically, was to study how the independent variables have affected the dependent variables.

Research Location: The study was conducted in all sampled public senior secondary schools in three educational zones in Bauchi state, namely; Bauchi education zone, Central education zone and Katagum education zone that have been chosen in order to have a representative sample size in the study. Some schools have their students operate from their homes on daily basis while some are boarding schools to have distinct data from students from diverse learning conditions.

Population: The population of this study consisted of all the mathematics teachers and SS3 mathematics students in the 153 Public Senior Secondary Schools in the 20 Local Government Areas (LGAs) of Bauchi state in the 2023/2024 academic session. The 20 LGAs were divided into three educational zones. The researcher chooses mathematics teachers and SS3 students in public senior secondary schools in 3 zonal education offices in Bauchi state to administer questionnaire and personal interview respectively. The public senior secondary schools with a total number of 612 Mathematics-teachers and 47,178 students who sat for the mathematics-Trial examination in senior secondary schools in Bauchi State for the 2023/2024 session would be presented.

Population Sample: The sample of the study consists of 25 public Senior Secondary Schools that participated in the annual Trial mathematics examinations in Bauchi State for 2023/2024 session. The sample of the study consists of research participants; 133 mathematics teachers (Male and Female) and 381 SS3 mathematics students were selected from public senior secondary schools in the three educational zones in Bauchi state. The Krejcie and Morgan Table (KMT) was use for determining sample size (Krejcie & Morgan, 1970). This table can be used for any defined population and does not require any calculations.

Research Instrument: The researchers designed a closed-ended question and gave the respondents the opportunity to provide their answers were provided for the respondents to choose from. Instruments used for data collection are; Mathematics Anxiety Questionnaire (MAQ) Study Habit Questionnaire (SHQ) and Mathematics Examination Records (MTER) used as a document for 2023/2024 academic session.

Validation of instruments: Experts from mathematics education from the Universiti Teknologi Malaysia, Abubakar Tafawa -Balewa University, Bauchi were given the instruments to judge the adequacy of each item on measuring the construct it claimed to measure. The comments, corrections and suggestion of the experts were strictly adhered to in producing the final copy of the instruments used for the study.

Analysis and Findings: Research Question 1: What are the estimates of strength of the causal modeling of teacher-related and students-related variables affecting performance of students in mathematics trial examinations in Senior Secondary schools in Bauchi State?

Table 1: The path coefficients (regression weights) of the variables from the saturated model

Path	**Estimate (Beta –Coefficient)**	**Sample mean (M)**	**Standard Error**	**t- Critical**	**p-values**	**Label**
Anxiety -> Performance	0.008	-0.015	0.066	0.456	***	MS
Study Habit ->Performance	0.308	0.042	0.108	2.843	0.005	MS

Note: *** is highly meaningful and significant, MS = Meaningful and Significant at 0.05 level of significance.

From Table1 above, according to Ringle, Wende, and Becker (2024) on the use of PLS-SEM. the following paths were meaningful and significant: The path from mathematics anxiety to mathematics performance with path coefficient of 0.008 is meaningful and significant based on its p.value (***) that is less than 0.05.

The path from study habits to mathematics performance with path coefficient of 0.308 is significant based on its *p.*value (0.005) that is less than 0.05. Likewise, the findings from research question one as presented in Table 1 shows the paths with their corresponding path coefficients that determines the test for significant path coefficients or otherwise. The result indicated that all the paths were significant (P <0.05). These included the paths between mathematics Anxiety to mathematics trial examination performance. The paths from study habit to Mathematics trial examination performance are also meaningful and significant. The significant path coefficient implies that there was a significant relationship between the variables. In other word; it means that the variable affects students' performance in mathematics trial examination in senior secondary schools in Bauchi State. This means that the paths had significant relationship with the students' performance in mathematics trial examination and that the variables were significantly connected to one another using connecting nodes. This conformed to the theory of connectivity by Sieman (2016) that construct variables are connected to one another by connecting nodes. In case of the present study, the arrows and the p-values indicated the connecting nodes. The implication of the findings to the principles and practice of education is that teachers need to be motivated so as to be effective in teaching learning process of mathematics in senior secondary schools. This was in line with the findings of Musau & Abere (2015); Oluwakemi & Olukayode (2015); Bamidele & Adekola, (2017); Omaliko & Okpala (2021); Kadri, Alwi & Hashim (2018) that there was a significant relationship between students' , study habit and academic performance in mathematics. This implies that effective mathematics teacher will produce highly motivated students with low anxiety in trial mathematics examination in order to prepare them for external SSCE examination in secondary schools in Bauchi state.

Research Question 2: How do the teacher-related and students-related variables directly and indirectly affect performance of students in Mathematics Trial Examinations in Senior Secondary schools in Bauchi State?

Table 2: Direct and Indirect Effects of the students-related Variables on Performance

S/N	Path	Direct Effect	P. Value	Interpre	Indirect Effect	P. Value	Interpre
1.	Mathematics Anxiety to performance	0.008	***	MS	0.067	0.000	MS
2.	Study habit to performance	0.308	0.005	MS	0.0463	0.000	MS

The findings from research question two indicated the total effect (0.3623) of variables on students' performance in mathematics trial examination in senior secondary schools in Bauchi State. The results showed that the total effects of the variables students' anxiety (0.008) and Study Habit (0.3543) were found to be significant because their p-values were less than 0.05. This means that there is a significant relationship between all the variables and students' performance in mathematics trial examination in senior secondary schools in Bauchi State.

Research Question 3: What are the proportions of causal effects of the fuel subsidy on variables that influence the performance of students in mathematics Trial examination in senior secondary schools in Bauchi State?

Table 3: Proportion (Percentage) of Direct and Indirect Effect of Variables on Performance

S/N	Path	Direct Effect	%	Indirect Effect	%
1.	Anxiety	0.008	16	0.064	58
2.	Study Habit	0.042	84	0.046	42
	Total	0.500	100	0.11	100

Results in table 3 showed the proportion (percentage) of the direct and indirect effects the variables on performance. The findings from research question three presented in Table 3 revealed the total proportion (percentage) of the direct and indirect effects of the students' mathematics anxiety and students' study habit variables on performance of students in mathematics trial examination. The proportion (percentage) of total direct effect was 82% with a corresponding total path coefficient of 0.61. The total proportion (percentage) of the indirect effects of the variables on mathematics trial examination was 18% with a corresponding total path coefficient of 0.61. This result implies that significant proportion (82%) of the students' mathematics anxiety and study habit variables have direct links or direct relationship with students' performance in the mathematics trial examination. In another words, significant proportion of the variables have direct causal links with students' performance in the mathematics trial examination. This means that if students with high mathematics anxiety coupled with a good study habit in senior secondary schools in Bauchi State can improve on the performance of students in mathematics trial examination in senior secondary schools in Bauchi State. The proportion of variables that had indirect links or indirect relationships with students' performance in mathematics trial examination was 18%. The proportion of direct and indirect links had a significant difference. This implies that the performance of students in mathematics trial examination does not only depend directly on anxiety and study habit variables, but indirectly depend on multiple variables since both variables had significant effects on students' performance in the mathematics trial examination. Concordantly, researchers Asikhia (2010) in Ogun state, Apata (2019) in Jigawa state and Asamoah, Sundeme, Atta, Adom-Fynn, Ebow and Afrane (2020) in Ghana have revealed that the variables that influence performance of senior secondary school students in mathematics were multifaceted and these variables were interrelated with one another using connecting nodes.

Discussion: This proved that anxiety and study habit were potent attributes that significantly affect students' performance in mathematics trial examination in senior secondary schools in Bauchi State. The finding agreed with Owonwami (2017) and Ibrahim (2018) who found that students' anxiety had a great impact on students' performance in mathematics. The findings also agrees with that of Aremu & Sokan (2003); Oladeni & Bimbo (2017) that students' attribute such as anxiety combined with a good study habit correlate with students' performance in senior secondary schools in Nigeria. The implication to the principle and practice of education is that the role of a student and learning of mathematics for trial examination cannot be over-stated. It also implies that when effective mathematics teachers are effective students developed in all aspect of mathematics and eventually influences students' performance in mathematics trial examination.

This implies that mathematics performance did not depend on students' anxiety and study habit alone but depended also on other variables due to the connectivity of both dependent and independent variables. This agrees with the theory of connectivity by Sieman (2004) that learning occurs in stages multiple variables as presage-product, process-product, mediation and contextual paradigm that are interconnected to produce an outcome of learning. The implication to present education practice is that teacher-related and student-related variables relationships will produce better performance in trial mathematics examination in Bauchi state.

Findings: Findings from the study revealed that mathematics anxiety and study habit positively affects and influences students' performance which confirmed the findings of Chapell, Blanding, Siverstein, Takashi, Newman, Gubi, McCain (2005) that anxiety affects the performance of students in mathematics.The data collected for this study were analyzed and interpreted, and the following findings were made: Fuel Subsidy removal has a very negative effect on secondary school students and such negative effects include lack of adequate funds to manage the schools this findings shows that there was a noticeable drop in number of students who are attending classes, participating in general school activities and as well the teachers whose salary have not been increased could not go to school in good time. All these reduced the academic performance of secondary school students. Study of Ogunode et al (2023) supports this finding were they found that fuel subsidy removal increase the cost of running schools, affected teaching program, learning program and reduce school supervision activities in Nigerian educational institutions. Poor academic results from students, lack of interest by teaching staff. A study by Okpe et al (2023) supports this finding as their own study found that secondary school students are facing financial difficulties after the removal of fuel subsidies. More so, the study also revealed that the students did not receive any financial incentives such as students' loan from as promised by the federal government of Nigeria. The students therefore exhibits high anxiety coupled with poor study habit that students worry increased with decrease in students' performance which is in consonance to the findings of (Maloney & Beilock, 2015).

Evidence from this study indicated that anxiety in mathematics is associated with poor test preparation which always resulted to cramming over- night before the examination, poor time management, a failure to organize text information combined with a poor study habit, and worry about past performance on the examination as a result of how friends and other students are doing and the consequences of failing it which confirmed the findings of Penberthy (2007).

Recommendations: Based on the findings above, the authors of this research recommended that;**;** Low self-esteem and a fear of failure are the root causes of mathematics anxiety, which makes it difficult to process new information as it comes in and to use knowledge that has already been taught to solve problems. In such case when given chance such students tend to avoid mathematics in its entirety; In order to support students during this period of severe economic realities, the ; Bauchi state government is here by urged to plan for financial and food palliatives for them. These palliatives will help to mitigate the effects of the removal of fuel subsidy on secondary school students nationwide.;The government runs the school feeding program, just as in other nations where students receive subsidies for food using vendors. It is anticipated that the government will carry on the previous administration's comprehensive implementation of this program by closely monitoring its overall execution.;To reduce the expenses of transportation, which has become a key reason why students skip lessons, the Bauchi state government offers free buses and other forms of student transportation. This might be accomplished by sending busses to schools so that students can go to and from classes.

Conclusion: It is therefore, very dangerous to neglect the importance of mathematics anxiety and students' study habit and its adverse effect on students' academic performance in mathematics as over anxiousness and poor study habit increases academic failure in mathematics. According to the study's findings, secondary school students found it extremely difficult to deal with the negative effects of the removal of the fuel subsidy. The majority of those affected are secondary school students, as many have been forced to engage in morally repugnant behavior and socially risky lifestyles in order to continue attending their schools. Even though the aforementioned is the current situation, it can be said that if the government does not adequately regulate it, there will be severe socioeconomic and political repercussions that could impede the country's progress. The education culture will suffer, and the next generation of leaders will not be able to emerge.

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Repellent Property of *Lantana Camara Lin* Extract on Some Insect Pests.

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Abstract

The repellent property of Lantana camara aqueous extract was investigated against two insect pests of cowpea C. maculatus and A. obtectus and one insect pest of maize S. zeamais. Preliminary phytochemical screening of the aqueous extract revealed the presence of carbohydrates, alkaloids, phenolic compounds, saponins, flavonoids and tannins. Proteins and fats and oils were absent. The results also showed that the extract displayed a mild repellency on C. maculatuswith mean repellency of 39.9%. S.zeamais had mean repellency of 33.3% and A. obtectus 24.4%. The extract did not show excellent repellent activities against any of the three test insects as all of them have class repellency of 2 each. Further investigation of the extract should be carried out using other organic solvents on the test insects.

Keywords: *Repellency, Extract, L. camara, C. maculatus, A. obtectus, S. zeamais*.

Introduction: *Lantana camara* is a widely growing shrub which belongs to the family *Verbanaceae*. The family consists of more than 100 genera and nearly 2600 species. It is a fast growing, low-maintenance plant with wide ecological tolerance. *It* is a wild plant that produces essential oils. It is extensively studied for its bioactive properties and reported as having insecticidal (Javier *et al.,* 2017), acaricidal (Adehan *et al.,* 2016), larvicidal (Costa *et al.,* 2010, Zandi-Sohani *et al.,* 2012), fumigant (Gotyal *et al.,* 2016) and repellent (Yuan and Hu, 2012) actions among other features against a wide range of pests.*Lantana camara* and *Clerodendrum inerme* powders have shown biopesticidal property and interference with normal metabolic activities in rice moth (Kiran *et al.,* 2010). Direct insecticidal action of the crude aqueous extract of the plant was indicated when maximum mean mortality of 96.66% was observed in tobacco caterpillar (Pratibha *et al.,* 2011). Bioactive compounds from pesticidal plants used as pesticides play a crucial role in controlling pests sustainably (Campolo *et al.,* 2017) by reducing the pest population while minimizing the environmental effect.

Extracts of *L. camara* and *A. indica* have been reported to be effective in the management of *plutella xylostella*, *Brevicoryne brasscae* and *Hellula undalis* on cabbage (Baidoo *et al.,* 2012). *L. camara* displayed a strong repellent activity foroviposition and a significant larvicidal activity against *Musca domestica* (House fly) (Sohail *et al.,* 2013). Biological studies by (Zhonglin *et al.,* 2012) showed that the chloroform leaf extract of the plant possessed excellent repellent and moderate toxic and antifeedant activities against eastern subterranean termites.
This study tests and compares the repellent potentials of aqueous extract of *Lantana camara* on three insect pests *Callosobruchus maculatus*, *Acanthoscelides obtectus* and *Sitophilus zeamais.*

Materials and Methods: **Plant Processing:** Fresh leaves of *lantana camara* were collected in the month of June 2014. There was no history of chemical applications in that area. The leaves were washed thoroughly with distilled water and shade-dried at room temperature for 4 days. The dried leaves were transformed into fine powder with the aid of wooden pestle and mortar.

Extraction: 100g of the leave powder was macerated in 500ml distilled water, left for 24 hours at room temperature with 6 hours stirring intervals. The mixture was filtered using Whatman number 1 filter paper. The filtrate was concentrated at 40˚C under reduced pressure (72 mbar) with a Rotary evaporator and dried. Dried extract was stored in an air tight container at about 4°C up for further use (Kalita *et al.,* 2011).

Phytochemical Screening: Phytochemical screening of the aqueous leaves extract was carried out using the standard methods of analysis (Sofowora 1993). The extract was screened qualitatively for carbohydrates, alkaloids, phenolic compounds, saponins, proteins, fats and oils, flavonoids, glycosides and tannins.

The Test Insects: A small population of *C. Maculatus,A. obtectus*and *S. zeamais* weevils of both sexes were obtained from an entomology laboratory stock. They were bred under laboratory conditions on diet of the seeds of black-eyed peas*Vignaunguiculata*(obtained directly from their pods) except *S. Zeamais* which were bred on the diet of maize seeds obtained directly from their cobs. They were all reared inside a growth chamber at 27 ± 2° C, with L: D 12: 12 and 70 ± 5% relative humidity. Initially, 50 pairs of the three test insects of 1-2 day-old adults were placed in three separate jars in which two contained black-eyed peas while one contained maize seeds. The jars were sealed and a maximum of 7 days were allowed for mating and oviposition. The parent stocks were removed and black-eyed peas and maize seeds containing eggs were transferred to fresh black-eyed peas and maize seeds in the breeding jars that were covered with pieces of cloth fastened with rubber bands to prevent the contamination and escape of insects. The progenies of the weevils in the three separate jars were immediately used for the experiment (Rahman and Talukder 2006).

Repellent Activity (Bioassay): The method of Talukder and Howse (1993, 1994) for repellency test was employed in this work. Filter papers of 9cm diameter were cut in halves. To one halves were applied plant extracts at 10mg/ml concentration. One millilitre (1ml) of the solution was uniformly applied with a pipette in such a way as to have a treated substrate of 0.31mg/cm^2 (Andriana *et al.,* 2008). The treated half-cycles were shed-dried allowing the solvent to evaporate. The treated and untreated half-cycles were placed tangentially to each other using a cellulose strip on Petri dishes. Ten (10) adult insects were released into each dish at the centre of the cycle and the surfaces were covered with a muslin cloth in order to enhance adequate aeration and forestall entry of other insects. Three replicates were made for each treatment. The test insects in each half of the filter paper were counted after 0.5, 1, 2, 3, 5 and 24 hours. The data obtained were converted to express percentage repulsion (PR) using the formula of McDonald 1970.

$$PR(\%) = (Nc - 50) \times 2$$

Where PR = percentage repulsion

Nc = percentage of insects present in the untreated half

Positive values indicate repellency and negative values indicates attractancy. The averages were assigned to different classes below;

Class	Repulsion R (%)
0	>0.01 to <0.1
1	0.1 to 20
2	20.1 to 40
3	40.1 to 60
4	60.1 to 80
5	80.1 to 100

Data obtained were subjected to one way analysis of variance (ANOVA).

Results and Discussion: Phytochemical Screening: Qualitative phytochemical screening of the extract revealed the presence of carbohydrates, alkaloids, phenolic compounds, saponins, flavonoids and tannins. Alkaloids, phenolic compounds and flavonoids appeared in large quantities followed by saponins and tannins. Proteins, glycosides, fats and oils are absent (Table 1).

Table 1: Phytochemical Screening of Aqueous Extract of *Lantana camara*

Phytochemical	*Lantana camara*
Carbohydrates	+
Alkaloids	+
Phenolic compounds	+
Saponins	+
Proteins	−
Fats & Oils	−
Flavonoids	+
Glycosides	−
Tannins	+

+ = present, − = absent.

Repellent Activity: The repellent activity of the extract was a bit pronounced on *C. Maculatus* with mean repellency of 39.9%. *A. obtectus* and *S. Zeamais* displayed mean repellencies of 24.4% and 33.3% respectively (Table 2). But all the three test insects have the same class repellencies of 2 which are in contrast with the result obtained by (Pratibha *et al.,* 2011). This could be attributed to some climatic factors like temperature and relative humidity. Despite the fact that analysis of variance (ANOVA) did not show significant difference between the three treatments, however, the repellent activity of the extract on *C. maculatus* can be said to be effective with the highest percentage repulsion of 73.3 at 24hours.The abundance of alkaloids and other phenolic compounds in the extract might have influenced it to sluggishly repel the insect *C. maculatus*.

The extract showed moderate repellent effect on *S. Zeamais* though not too appreciable even after 24hours.The highest attractancy of the extract was recorded in *A. abtectus* which displayed attractancy of −46.6% at 5hours. The inability of some plant extracts to repel *A. Obtectus* was also reported by (Catherine *et al.,* 1994). A combined negative effect was produced when most of the plants from *T. vulgaris* and *T. serpyllum, M. piperata, R. officinalis, S. hortensis, E. globulus, L. nobilis, O. vulgare*, and *C. nardus*were tested on *A. obtectus*. Results from this research indicated that *L. camara* aqueous extract could be used as a replacement for hazardous synthetic chemicals against grain damaging insects' especially *C. maculatus*. The effects of the plant extract on the specie *A. obtectus* and *S. zeamais* should be further investigated using other solvents.

Table 2: Repellency of *L. camara* Aqueous Extract on Insect Pests

Test Insect	Repellency (%)						Mean Repellency (%)	Class Repellency
	½h	1h	2h	3h	5h	24h		
C.maculatus	13.3	33.3	33.3	46.6	40	73.3	39.9±0.32a	2
A. obtectus	13.3	20	26.6	20	46.6	20	24.4±0.15a	2
S. zeamais	20	33.3	33.3	33.3	33.3	46.6	33.3±0.42a	2

Values having the same letters within same column are not significantly different ($P \leq 0.05$).

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Impact of Costs and Demands on Sales of Matured Birds in Plateau State, Nigeria

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Abstract

In this research, impact of costs and demands on sales of matured birds was investigated in selected markets of Plateau State, Nigeria. While purposive sampling technique was employed in the choice of markets, simple random sampling technique was used in administration of questionnaires to respondents. Analyses of data obtained from 162 sellers of matured birds in Yan Kaji, Terminus and Chobe markets were carried out. Results obtained from descriptive statistics indicated that broilers were the mostly demanded birds in the study areas. It was further shown that most bird sellers sold their birds in price range of N9,500 - N 11,499 which is equivalent to a range of $5.94 - $7.19 US dollar per bird at exchange rate of a dollar to N1,600.00 Nigerian Naira. Positive correlation was indicated when pair-wise use of Pearson Product Moment Correlation (PPMC) was employed to investigate strength of relationship between the sales, costs and demand for matured birds in the study area. Further analysis using F-test statistics showed that costs and demand for birds induced statistically significant difference on sales of matured birds ($p<0.05$). However, t-test statistics indicated how demands induced more effects than costs on sales of matured birds in the study area. Finally, models for sales prediction of matured birds were derived using multiple linear regression and simple regression analyses. Since effect of demand outweighs effect of costs on sales of matured birds, sellers stand to gain which could also encourage establishment of more farms in Plateau State, Nigeria. Furthermore, this study recommends creation of more organised market structures and buildings in sections where matured birds are sold in Plateau State, Nigeria.

***Keywords**: broiler, layer, noiler, cockerel*

Introduction

Matured birds are fully developed or grown-up warm blooded animals; they have feathers and are in the class of Aves and in phylum Chordata. While some birds are raised for egg and meat production, others are raised mainly for meat production to serve as source of protein for human consumption in livestock markets of Plateau State, Nigeria. Osinowo and Tolorunju (2019) discussed high costs of feed, poor power supply, inadequate method of disease control and lack of adequate fund as factors which contributed to retarded growth in rearing birds for egg production in Ogun State, Nigeria. However, they did not focus on middlemen who were directly involved in sales relative to costs and demand for matured birds in their study location. Other researchers (Ingweye and Meinderts, 2021; Mukhtar et al., 2014; Oladeebo and Ojo , 2011) also focused on egg production relative to demand, supply and profitability in the southern and northern parts of Nigeria. Though a profitable venture, it was found that egg production do not have significant effect on Nigeria's national gross domestic product (Ewubare and Ozar, 2018; Osinowo and Tolorunju, 2019). The researches (Umeh and Odo, 2002; Sanni and Ogundipe, 2005; Chukwuji et al.,2006; Yusuf et al., 2016; Fajemisin and Ogunribido, 2018; Bamiro, 2008; Mengesha, 2013) also focused on poultry production relative to farmers in other aspects of limestock industry.

Investigation of Olorunwa (2018) revealed that broiler production in Lagos State, Nigeria had similar problems as highlighted in poultry egg production (Osinowo and Tolorunju, 2019) which include high cost of feed, disease outbreak and poor finance structure. While studying production and constraints of broilers, cockerels and layers in five out of six South-Western states of Nigeria, Adesehinwa et al. (2016) identified marketing challenge in sales of chicken products at farm gates which indicated that farmers were not able to fully access market opportunities. Some other main constraints identified in their study were high cost of feed and inadequate capital. However, their focus was on southern part of Nigeria.. Panwal and Shuaibu (2020) studied effects of some factors on production weight of broilers at point-of-sale and showed that flock size, drugs, water, litter material, feed, growth cycle and farming experience have positive relation with output production weight of broilers at point–of–sales. Though their study considered some areas in the northern part of Nigeria, it focused only on production weight of broilers and factors affecting it.

Dafwan et al. (2010) studied two agro-ecological zones in Plateau State but their focus was on rural poultry production. They however did not consider commercial birds but emphasized on local domesticated breeds of birds which included chickens, ducks, turkeys, pigeons and guinea fowls. Onuwa et al. (2020) investigated demand for poultry products among households in Jos-North area of Plateau State. Their results showed that most households consumed more poultry products than other livestock proteins. However, the study was restricted to consumers not the sellers. Another study from Onuwa et al. (2022) mainly discussed poultry egg traders in Plateau State; they also did not include sellers of poultry meat who are actively involved in storage of live birds for meat during the period of sales.

Chicken production was also studied by Maduka et al. (2016) in one of the northern cities of Nigeria. Their research was on assessment of biosecurity practices - principles of preventing spread of pathogens - among commercial and semi-commercial farms. They did not consider sales, demand and costs of matured birds in their study area.. Though Bamiro (2008) indicated that broiler production was not as profitable as egg production, it was however found out that broiler production is profitable in Nigeria and have significant effect on Nigeria's agricultural GDP (Ewubare and Ozar, 2018).

From researches in literature, there has not been investigation on sales of matured birds relative to costs, demand and sales in Yan Kaji, Terminus and Chobe markets in Plateau State, Nigeria. Only a few of them such as Onuwa et al. (2022) have shifted focus from chicken production to sales but aspects involving sellers as middlemen were not considered. They only focused on poultry egg traders without considering activities in sales of birds with reference to demand, costs and sales of matured live birds for meat consumption.Motivation to involve in this research is based on solving problems associated with sales of matured birds in Yan Kaji, Terminus and Chobe markets. There are two main advantages to this: the first advantage is that sellers - who might not necessarily be farmers- would be able to plan effectively to optimize their profit based on sales, demands and costs of matured poultry live birds; the second advantage is that farmers would be able to get more middlemen who would buy more live birds. The implication of this investigation would be beneficial to both farmers and middlemen whose profits are expected to rise when knowledge of influence of demand, costs and sales of matured live birds are fully comprehended in the study area. It could also be a basis for consideration when farmers and middlemen intend to involve in sales of matured live birds in other climes.. In this study, we aim to determine impact of costs and demands on sales of matured birds in Plateau State, Nigeria. The specific objectives of this study are to determine: average cost per matured bird, type of birds mostly sold, average number of sales of matured birds on a daily basis and quantity of matured birds demanded daily in selected markets of Plateau State, Nigeria. The remaining sections of this study are arranged as follows: materials and methods, results, discussion and conclusion.

Materials and Methods: Study Area: Terminus market is one of the main markets in Plateau State which is one of the states situated in north-central geopolitical zone of Nigeria on coordinate 9º 34' N and 9º 04' E. There are many sections in the Terminus market for some specified goods and services. The section for poultry live birds of the market is situated close to old site of Jos University Teaching Hospital in the neighbourhood of Nigeria Railway Corporations. Traders and other middlemen in poultry live birds would be seen selling to buyers at different prices depending on the bargaining power of the buyers. Large number of birds of different types can be bought in the market when supplied from poultry farms. It was discovered through oral interview that poultry live birds could be obtained all-year round at different prices from the Terminus market.

Yan Kaji market is another market where matured birds can be bought in Plateau State, Nigeria. Many traders from other local government areas of Plateau State and other states of Nigerian federation usually come to Yan Kaji for poultry live birds and other poultry products. Through oral interview, many sellers of matured birds stated that bird-flu epidemic affected availability and prices in the market. Types of birds available in the market for sale in include: native live birds, layers, cockerels and broilers. The matured native live birds also known as local birds or chickens are those raised around homes without specific confinement to a farmhouse. Such birds roam about their compounds during the day and at night would migrate to a location to roost in anticipation for another day to begin. The broilers, layers and noilers on the other hand are birds also referred to as agric chickens in the market. They are usually kept in cages and other farmhouses where they are cared for with feed and water. Chobe marketis situated in Plateau State, Nigeria. It is one of the main markets popularly known as a place where food stuffs could be purchased at affordable prices. Therefore, buyers from different parts of Plateau State usually prefer to make bulk purchase of different food materials such as onions, tomatoes, palm oil, vegetables, fish, groundnut oil and matured poultry live birds from the market.

Data Collection and Sampling Techniques: Data for this study were obtained from 163 sellers of matured poultry live birds in Yan Kaji, Terminus and Chobe markets using structured questionnaires. While the questionnaires were administered to the respondents using simple random sampling technique, purposive sampling technique was used when choices of markets were made.

Design Framework and Data Analysis: The design of this study is centred on measuring impact of costs and demand on sales of matured chicken in selected markets of Plateau State, Nigeria. The effect of costs and demands for matured birds is shown in Figure 1.,

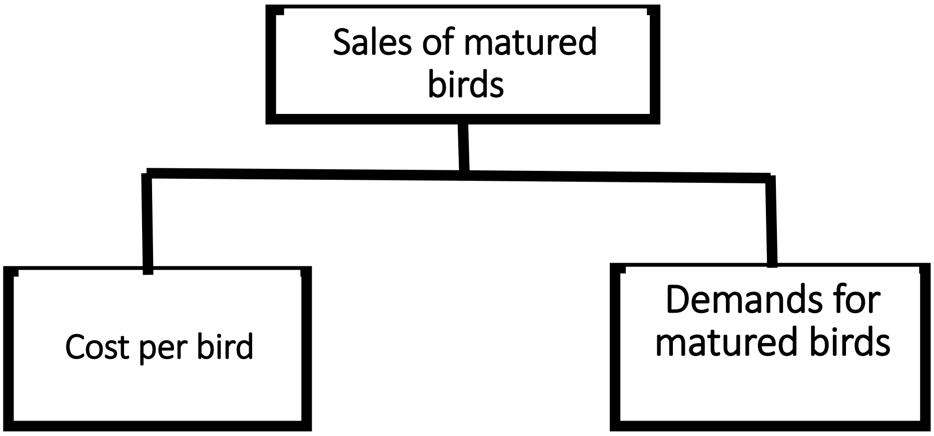

Figure 1: Design framework representing impact of cost and demand on sales of matured birds.

The design framework shown in Figure 1 aimed at investigating impact of factors affecting sales of matured birds in Yan Kaji, Terminus and Chobe markets of Plateau State,Nigeria.

Data for this study were analysed using descriptive statistics, F-test, t-test statistics and multiple linear regression analysis with application of Statistical Package for Social Sciences (SPSS) version 23.

Model Specification: Using the design framework, let functional relationship among sales, costs and demands for matured birds in Yan Kaji, Terminus and Chobe markets be defined by

$$S = F\ (V_i\ ,\ b_i) + \epsilon \qquad (1)$$

where S represents sales, F represents a function of variables $V_i\ (i = 1, 2)$for costs per bird and demand for birds such that $b_i\ (i = 0,1,2)$ and ϵ are associated constants of independent variables and errors of the relationship respectively.

For the two independent variables, equation (1) for multiple linear regression analysis gives

$$S = b_2V_2 + b_1V_1 + b_0 \qquad (2)$$

where $F\ (V_i\ ,\ b_i) + \epsilon = b_2V_2 + b_1V_1 + b_0$ and pairwise Pearson Product Moment Correlation (PPMC) is defined by

$$r = \frac{N\sum V_iS - (\sum V_i)(\sum S)}{\sqrt{[N\sum {V_i}^2 - (\sum V_i)^2][N\sum S^2 - (\sum S)^2]}} \qquad (3)$$

where r is the correlation coefficient such that $-1 \leq r \leq 1$.

Results and Discussion: Types and number of live birds demanded by consumers from 162 sampled sellers of matured live birds in selected markets of Plateau State, Nigeria are shown in Table 1.

Table 1: Types and number of matured live birds demanded daily in selected markets of Plateau State, Nigeria.

Types of birds	*1-10 birds*	*11-20 birds*	*21-30 birds*	*31-40 birds*	*41-50 birds*	*Above 50 birds*	*Total*	*% Demand*
Layers	7	4	7	2	0	9	29	17.9
Broilers	32	18	15	9	4	0	78	48.1
Noilers	5	2	1	5	0	0	13	8.0
Cockerels	9	7	3	0	3	0	22	6.0
Others	7	0	2	2	1	8	20	25.5
Total	60	31	28	18	8	17	162	100

From the descriptive statistics shown in Table 1, about 48.1% sellers of poultry live birds have broilers as the mostly demanded type of birds in Yan Kaji, Terminus and Chobe markets of Plateau State, Nigeria. It can be observed that about 12.3% of the demands for other types of birds is also known. However, types of birds classified as others include: local birds, ducks and geese. While the second mostly demanded birds in the surveyed markets of Plateau State are layers, it can be seen in Table 1 that noilersare the least demanded type of birds. It can be further observed that while some sellers have demands for more than 50 birds per day, the number of birds mostly demanded is in the range of 1-10 birds per day which constitutes about 37% of the demand for matured live birds in the study area.

Results in Figure 2 show average range of costs per bird in the selected markets of Plateau State, Nigeria.

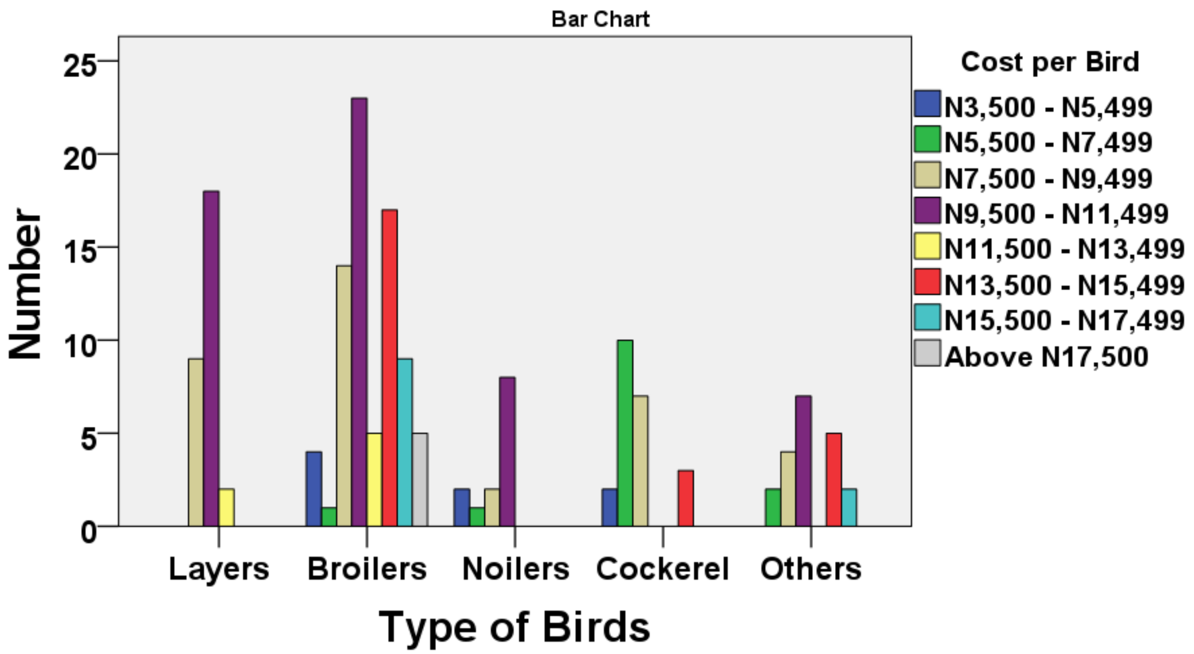

Figure 2: Cost per live bird in surveyed markets of Plateau State, Nigeria.

From Figure 2, it can be seen thatcost per bird in the range of N9500 – N11,499 ($5.94 - $7.19 US dollar) at exchange rate of a dollar to N1,600.00 Nigerian Nairaconstituted highest range at which layers, broilers, noilers and those in the category of others are sold out to buyers. It can be observed further that highest range at which cockerels are sold to the consumers per bird is N 5500 – N 7,499 ($3.44- $4.69 US dollar) at exchange rate of a dollar to N1,600.00Nigerian Naira. Figure 2 further indicated that a class of boilers are sold at prices above N 17,500 ($10.94US dollar) at exchange rate of a dollar toN1,600.00 Nigerian Naira.

Pairwise use of Pearson Product Moment Correlation (PPMC) for comparison of sales of birds with cost per bird and demand for birds is presented in Table 2.

Table 2: Pairwise PPMC of costsand demands with sales of matured birds in selected markets of Plateau State, Nigeria.

	Costperbird	**Demand for bird**
Sales of matured birds	0.253	0.625

From results presented in Table 2, there is positive correlation of sales with cost and demand for birds. This suggests some degree of relationship between sales of birds and the two factors of cost and demand for poultry live birds in selected markets of Plateau State, Nigeria.

Variations of about 69.1% occurred in sales of matured birds when associated with factors affecting sales of matured birds as shown in Table 3.

Table 3: Variations in sales relative to costs and demands for matured birds in selected markets of Plateau State.

Model[b]	***R***	***R-Square***	***Adjusted R-Squared***	***Std Error of the Estimate***
1	0.925[a]	0. 691	0.683	1.338

a. Predictor: (constant), demands for birds (daily quantity), cost per bird..
b. Dependent variable: Sales of birds (daily quantity) .

F-test statistics is shown in Table 4 in order to investigate the possibility of whether R= 0.925 in Table 3 occurred by chance or otherwise

Table 4: F-test statistics for sales, costs and demands for birds at α = 5% level of significance.

Model[d]	Sum of squares	Df	Mean square	F	p-value
Regression	182.566	2	91.283	50.976	0.000 [(c)++]
Residual	284.724	159	1.791		
Total	467.290	397			

c. Predictor: (constant),(constant), demands for birds (daily quantity), cost per bird..
d. Dependent variable: Sales of birds (daily quantity).
++ Significant at α = 5% level of significance

From Table 4, it can be seen that p-value is less than 0.05 ($p<0.05$) . This indicates that both costs and demand for birds induced significant difference on sales of birds in the three selected markets of Plateau State, Nigeria of 95% confidence limit. This means that sales of matured birds are significantly affected by costs and demands for birds in the study area. However, the F-test statistics is not sufficient to determine which of the two independent variables (costs and demands) or whether both of them are mainly influencing the sales of natured birds in the selected markets. To determine how the predictor variables are affecting the sales of birds, t-test statistics is presented in Table 5.

Table 5: The t-test statistics of sales of birds with two independent variables.

Model[e]	*B*	*Std Error*	*Beta*	*t*	*p-value*	*LBound*	*UBound*
(constant)	0.937	0.316		2.967	0.003[++]	0.313	1.560
Cost per bird	-0.002	0.064	-0.002	-0.028	0.977 [++]	-0.127	0.124
Demands for birds	0.639	0.064	0.625	10.061	0.000[++]	0.514	0.765

e. Dependent variable: Sales ofbirds (daily).
++ Significant at α = 5% level of significance

From Table 5, the multiple linear regression eqn(1) becomes

$$S = 0.639\, V_2 - 0.002\, V_1 + 0937 \qquad (4)$$

where $V_1$is the variable representing costs and V_2 is the variable representing demand for predicting sales S of matured live birds in the selected markets of Plateau State, Nigeria. It can be observed from eqn(4) that the coefficient of independent variable V_1representing costs per bird is negative. This means that if sellers increase the price of matured live birds, there would be reduction in the quantity of matured live birds that would be sold. However, the positive value of variable representing demands for live birds means that increase in the demand for matured live birds have direct impact on daily sales in the selected markets of Plateau State, Nigeria. Furthermore, it can be seen from Table 5 that after checking the effect of demands for birds in the study area, costs per bird do not indicate significant contributions ($P>0.05$). This suggests possibility of re-fitting the model using backward elimination procedure with the aid of SPSS which gives the results in Table 6.

Table 6: The t-test statistics of sales of birds with one independent variable.

Model[f]	B	Std Error	Beta	t	p-value	LBound	UBound
(constant)	0.930	0.194		4.786	0.000[++]	0.546	1.313
Demands for birds	0.639	0.063	0.625	10.129	0.000[++]	0.514	0.764

f. Dependent variable: Sales ofbirds (daily).
++ Significant at α = 5% level of significance

Results from Table 6 gives association of sales with demand for matured live birds which gives simple linear regression equation

$$S = 0.639\, V_2 + 0930 \qquad (5)$$

where the variables in eq.(5) are as defined in eq.(4).

Conclusion: Impact of costs and demands on sales of matured birds in selected marketsof Plateau State, Nigeria was carried out. From the use of descriptive statistics, results from Yan Kaji, Terminus and Chobe markets indicated that broilers were the mostly demanded matured birds. It was found that noilers were the least demanded birds in the study area. Results from costs analyses showed that more birds were sold at highest frequency range of N9500 – N11,499 ($5.94 - $7.19 US dollar) per bird at exchange rate of a dollar to N1,600.00 Nigeria naira. Also, there was positive correlation when sales of matured birds were compared with costs and demand for matured birds. Further analysis using F-test statistics showed that costs and demand have significant effect on sales of matured birds. However, t-test statistics indicated that demand for birds exerted more significant effect than costs on sales of matured birds. Finally two models were presented for prediction of sales in the selected markets. While the first model equation combined both effects of costs and demands on sales of matured birds, the model obtained through backward elimination procedure showed effect of demands on sales of matured birds. Therefore, the model equations are recommended for prediction of sales of matured birds in the selected markets of Plateau State, Nigeria.

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An Extensive Examination of Poultry Production and Marketing Systems in Kaduna State, Nigeria

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Abstract

This paper provides a comprehensive analysis of the poultry production and marketing dynamics in Kaduna State, Nigeria. The study employs a robust methodological approach to gather data from 120 poultry farmers through structured interviews, questionnaires, and farm records. Analytical tools include Frequency Distribution, Percentages, Likert Scale, and Gross Margin Analysis. Findings reveal that 72% of poultry farmers are male, while 60% of respondents lack formal education. Key constraints, including inadequate capital, substandard feed quality, high labor costs, and insufficient veterinary services, contribute to low productivity. To mitigate these challenges, the study recommends interventions such as capital access through interest-free loans, the provision of training on improved management practices, and a strategic marketing network for poultry products. The study further underscores the potential for Kaduna State to become a leading hub for poultry farming if these constraints are adequately addressed.

Keywords*: Poultry Production, Marketing, Kaduna State, Poverty Alleviation, Agricultural Economics, Nigeria*

Introduction: Agriculture is an indispensable sector of Nigeria's economy, accounting for a significant proportion of the nation's GDP and providing employment for a majority of the rural population. The poultry sector, a critical component of agriculture, plays a substantial role in the supply of animal protein and economic sustenance for millions of Nigerians (Burgos, 2009). In Kaduna State, the poultry industry is a potential driver of economic transformation, yet several systemic challenges continue to stifle its growth. This study aims to delve deeply into the factors influencing poultry production and marketing in Kaduna State, offering evidence-based solutions to enhance both productivity and economic returns for farmers. Kaduna State, situated in northern Nigeria, offers a diverse agro-climatic zone ideal for both livestock and crop production. However, the poultry industry faces constraints ranging from the high cost of inputs to insufficient infrastructure and poor market access. By focusing on these key issues, this paper will offer strategies for revitalizing the poultry sector in Kaduna and propose a model for sustainable agricultural development (Kajura, 2008).

Study Area: Kaduna State: Kaduna State is located in north-central Nigeria, with a land area of approximately 46,053 square kilometers, making it one of the largest states in the country. The state has a population of over 8 million people (NPC, 2006) and comprises 23 Local Government Areas (LGAs). Its capital, Kaduna City, is a hub for both economic activities and agricultural production. The climate of Kaduna is tropical, characterized by a wet season (April-October) and a dry season (November-March), making it suitable for both poultry and crop farming (FAO, 2007). Agriculture in Kaduna is dominated by smallholder farmers who produce both crops and livestock. Poultry farming, in particular, is concentrated in the southern part of the state, where the climate is more favorable for poultry rearing. The primary breeds reared include broilers, layers, and local breeds, and the scale of production varies from small backyard operations to more commercially oriented farms(Morgan, 2007).

Map of Kaduna State and Poultry Production Areas
Figure 1 shows a map highlighting poultry-producing areas in Kaduna State, focusing on regions with high concentrations of poultry farms such as Zaria, Kafanchan, and Kaduna South.

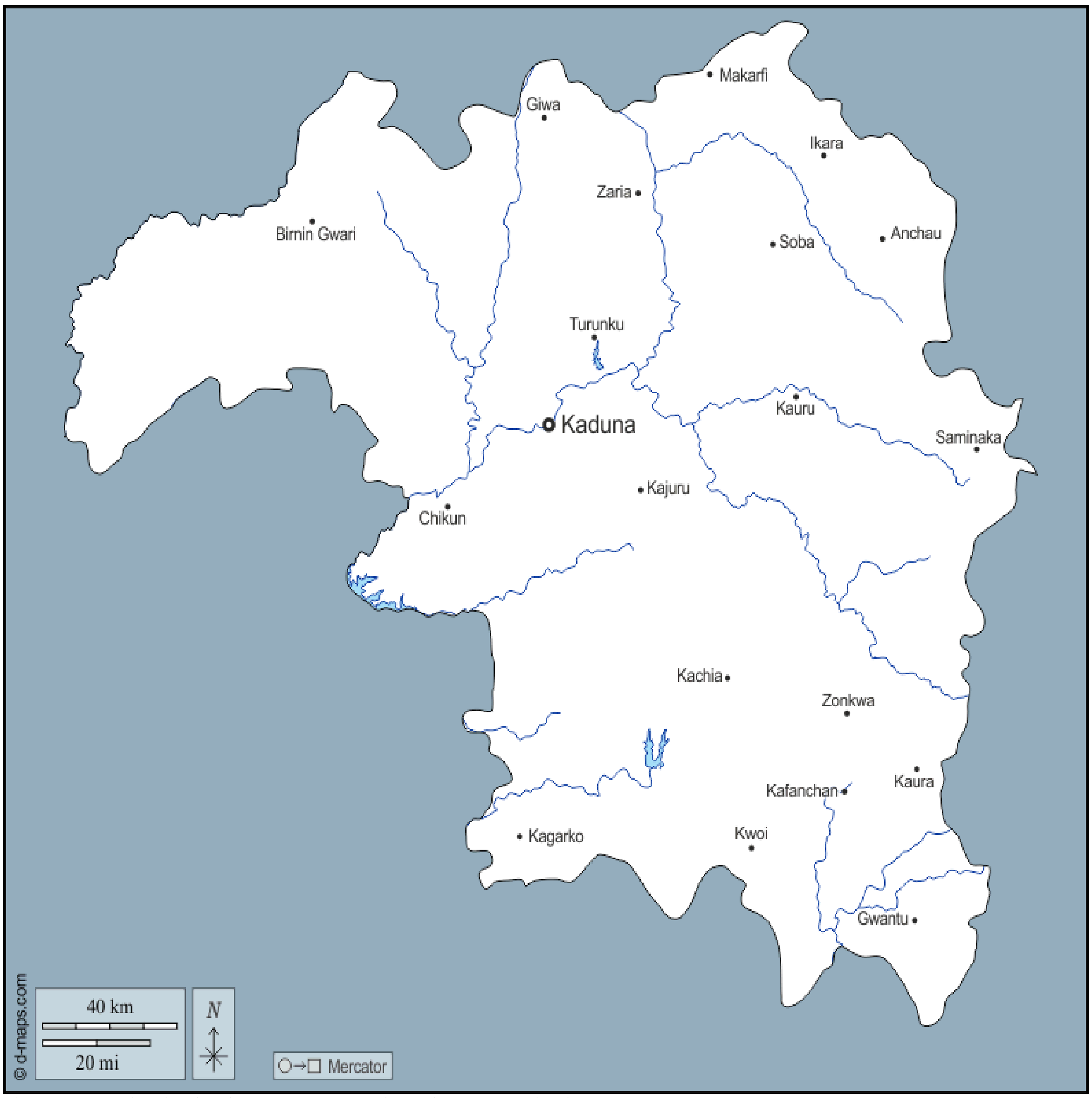

Figure 1. Map showing local government areas in Kaduna State, Nigeria

Methodology: The research adopts a multi-stage random sampling technique to select poultry farmers from across the three agricultural zones of Kaduna State—Northern, Central, and Southern. A total of 120 poultry farmers were selected for detailed interviews, representing a cross-section of smallholder farmers. Data were collected using a structured questionnaire that captured socio-economic data, farm management practices, and marketing challenges. Secondary data were gathered from farm records and government reports.

Table 1 Distribution of respondents across the three zones.

LGA Zones	Number of Communities	Number of Respondents
Northern Zone	5	40
Central Zone	5	40
Southern Zone	5	40

Table 1 shows the distribution of respondents across the three zones. This stratified sampling ensures that all poultry-producing areas are adequately represented, providing a comprehensive understanding of poultry farming in the state.

Analytical Tools: Data were analyzed using various statistical techniques. Descriptive statistics such as mean, frequency distribution, and percentages were used to summarize socio-economic data. Likert Scale was employed to evaluate the extent of marketing challenges faced by farmers, and Gross Margin Analysis was conducted to assess the profitability of poultry farming in Kaduna State.

Results and Discussion: Socio-Economic Characteristics of Poultry Farmers The socio-economic profile of poultry farmers in Kaduna State reveals that poultry farming is predominantly a male-dominated activity, with men constituting 72% of the respondents. Women, who make up 28%, are largely involved in supporting roles such as feeding and management of smaller poultry operations.

Table 2: Gender Distribution of Poultry Farmers

Gender	Frequency	Percentage
Male	86	72%
Female	34	28%

Table 2 indicates that men are more involved in poultry farming than women, suggesting that there may be socio-cultural barriers limiting women's participation in larger-scale poultry ventures.

Age Distribution of Poultry Farmers: The majority of poultry farmers in Kaduna are aged between 41 and 60 years (45%), followed by those in the 31-40 age group (35%). Farmers aged below 30 years constitute only 8%, indicating a concerning trend of low youth engagement in poultry farming.

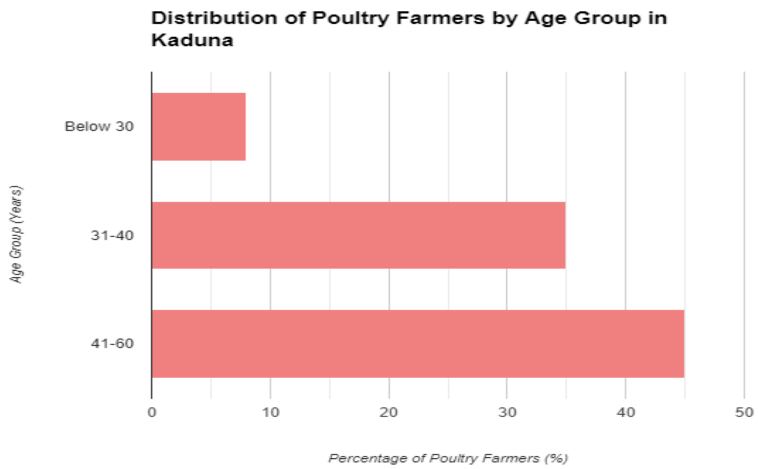

Figure 1: Age distribution of poultry farmers.

Graph 1 would show the distribution of farmers by age, highlighting the relatively low participation of younger generations in poultry farming, which could affect the sector's long-term sustainability.

Education Levels of Poultry Farmers: Education plays a crucial role in the adoption of modern farming techniques. Unfortunately, 60% of the farmers surveyed have no formal education, while only 5% have tertiary education. This lack of educational background hinders the ability of farmers to implement innovative farming practices, further reducing productivity (Gleeson, 2010).

Table 3: Education Levels of Respondents

Education Level	Frequency	Percentage
No formal education	72	60%
Primary education	25	20%
Secondary education	17	15%
Tertiary education	6	5%

Table 3 illustrates the low level of formal education among poultry farmers, which poses a significant challenge to their ability to manage farms effectively and access financial or technical resources.

Income and Farm Size: Poultry farming in Kaduna State is mostly carried out on a small scale, with 50% of the respondents earning less than N70,000 annually. Farm sizes range from less than one hectare to 3 hectares, with most farms being under one hectare. These information emphasizes the subsistence-level nature of most poultry farms, showing the limited income potential for many farmers.

Marketing Challenges in Kaduna State Poultry Sector: Poultry marketing in Kaduna State is plagued by several challenges, including poor access to markets, price fluctuations, and a lack of transportation infrastructure. Farmers reported difficulty in controlling prices due to market oversaturation, especially during festive periods when there is a glut of poultry products(Henning, 2007).

Table 4: Marketing Constraints Faced by Farmers

CONSTRAINTS	VERY GREAT EXTENT	GREAT EXTENT	SOME EXTENT	NOT AT ALL

POOR ACCESS TO MARKETS	75%	15%	7%	3%
HIGH TRANSPORTATION COSTS	60%	25%	10%	5%
PRICE FLUCTUATIONS	80%	10%	5%	5%
MARKET GLUT DURING FESTIVITIES	70%	20%	8%	2%

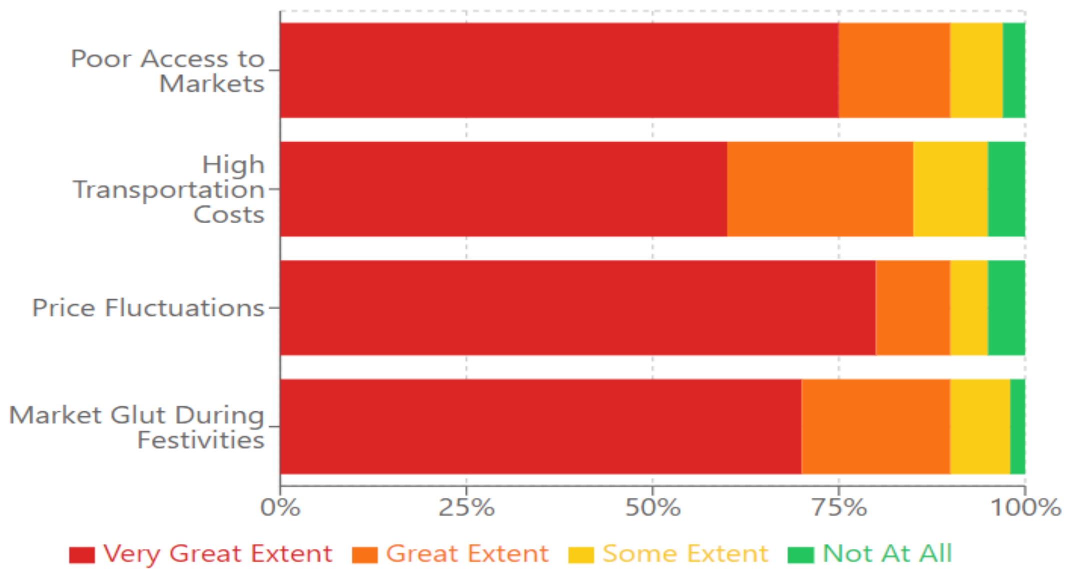

Figure 2. Market constraints by percentage for poultry farmers in Kaduna state

Table 4 and figure 2 highlights the severity of marketing challenges, with 75% of respondents indicating poor market access as their primary challenge. These constraints reduce farmers' ability to maximize profits and grow their businesses.

Profitability Analysis: Gross Margin of Poultry Farming: Gross Margin Analysis offers insights into the financial viability of poultry farming in Kaduna State. The study found that the average gross margin for small-scale operations is approximately N105,500 per production cycle (four months). Medium-sized farms, with better management practices, reported higher profitability.

Table 5: Gross Margin Analysis of Poultry Farms in Kaduna State

Variable Cost Components	Amount (Naira)
Feed	5,000
Medication	2,500
Sanitation	4,000
Water	1,500
Electricity	2,000
Day-old chicks	25,000
Labor	15,000
Total Variable Cost	62,500

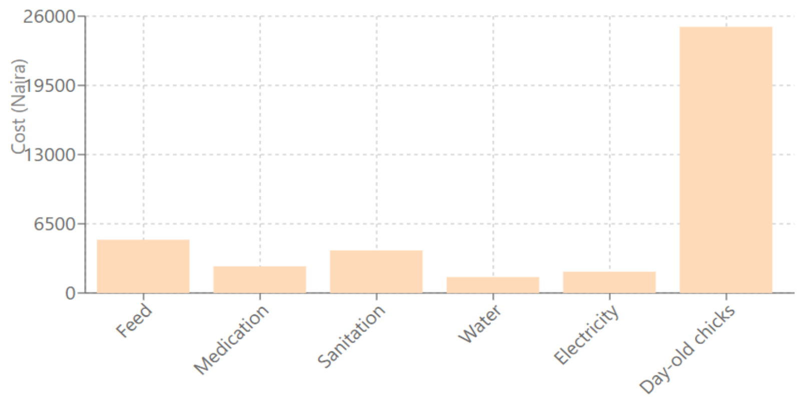

Figure 5. Variable cost for important poultry farm activities

Table 6: Fixed cost in poultry production

Fixed Cost Components	Amount (Naira)
Land	15,000
Pen (Infrastructure)	30,000
Equipment (Feeding/Watering tools)	7,000
Total Fixed Cost	52,000

Table 5 and 6 outlines the breakdown of both variable and fixed costs, which contribute to total expenses in poultry production. The table shows that feed represents the largest share of variable costs, consistent with findings from previous studies. Factors Affecting Poultry Productivity in Kaduna State: This section delves into the various factors influencing poultry production in the study area, categorized into internal (farm management, input quality) and external factors (market conditions, government policies).

*Internal Factors: **Feed Quality**: Poor quality of feed emerged as one of the leading causes of low productivity, with many farmers unable to afford high-quality, nutrient-dense feed for their birds.; **Veterinary Services**: The absence of accessible veterinary care leads to high mortality rates during disease outbreaks; **Labor Costs**: Skilled labor is difficult to come by, resulting in high costs for poultry management.; **Water Supply**: Poultry farms in more arid parts of Kaduna State struggle with regular access to clean water, impacting bird health.*

*External Factors: **Price Volatility**: As seen in the gross margin analysis, price fluctuations, especially during festive periods, negatively impact profitability. Farmers face lower prices when supply exceeds demand.; **Market Infrastructure**: Poor infrastructure, particularly in rural areas, limits farmers' access to more lucrative urban markets.*

Marketing Systems for Poultry Products in Kaduna State; The poultry market in Kaduna State operates on a multi-tier system involving farmers, middlemen, retailers, and consumers. The structure of the market influences how products are priced and sold.

Market Channels: Direct-to-Consumer Sales: These occur mostly in local markets or through direct farmgate sales. Small-scale farmers rely on this method for immediate revenue.; Middlemen: Middlemen dominate the distribution process, often buying in bulk from farmers at relatively low prices and reselling at a significant markup.; Retailers: Poultry products, especially eggs, are sold by retailers in open markets and shops.

Strategic Recommendations for Enhancing Poultry Productivity and Marketing: Based on the findings, several strategic interventions can help revitalize poultry production in Kaduna State:

Access to Capital: Many farmers cited the lack of capital as a major constraint. Introducing interest-free loans through government schemes or microfinance institutions could empower small-scale farmers to expand their operations.

Improved Veterinary Services: The establishment of veterinary outreach programs would address the high mortality rates currently affecting farms. Regular farm visits and the establishment of mobile clinics in rural areas could help prevent the spread of diseases.

Feed Subsidies:Subsidizing feed would lower the cost of production, allowing farmers to purchase higher-quality inputs. A government initiative to support local feed production industries could help stabilize feed prices.

Infrastructure Development: Improving road networks between rural poultry farms and urban markets will lower transportation costs and enable farmers to access better markets. Government investment in these areas would be key to reducing market barriers.

Conclusion: The poultry industry in Kaduna State presents substantial potential for contributing to both food security and rural economic development. However, the sector is impeded by several challenges, including inadequate capital, low productivity due to poor feed and lack of veterinary services, and market inefficiencies. Addressing these challenges through strategic interventions such as improved market access, subsidized feed costs, and better veterinary care will lead to higher productivity and profitability.By adopting these recommendations, Kaduna State could enhance its poultry production capacity, contributing significantly to the Nigerian agricultural sector and alleviating rural poverty. Further research is required to assess the impact of these interventions over time.

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Evaluation of Land Tenure System And Coping Strategies Adopted by Soybean Farmer's in Response to Climate Change in the North East Nigeria

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Abstract

The study was conducted to analyze land tenure system and coping strategies adopted by soybean farmers in response to climate change in the North East Nigeria. Multi-stage random sampling technique was used to sample respondents while primary and secondary data were used for the study. A well-structured questionnaire was used to collect data from 450 soybean farmers. Pearson's Chi Square (X^2) test of association was used to test the association. The result revealed that the Pearson Chi Square value for the relationship was 7.644 while the p-value was 0.177. This was used to test the hypothesis which states that there is no significant relationship between land tenure system and coping strategies adopted by soybean farmers in the study area. This was tested at 5% level of significance. The result shows that there was a significant relationship between Land tenure system and increase use of organic manure on soybean farm land. Therefore, we reject the null hypothesis and accept the alternative hypothesis. Conclusion, when the farmers have access to land it will positively influence the cultivation of soybean. Recommendation, the government should collaborate with traditional rulers, youths and other stakeholders in the community to provide adequate security of life and properties. Farmers should be adequately protected both they farm land, family and communities, in that ways production of agricultural products and food security can be guarantee.

Key words: Evaluation, Education, Coping, Strategies, Response, Climate, Change

Introduction: Soybean (*Glycine max*) is an important leguminous crop widely cultivated in Nigeria for food, oil, and feed purposes. It is cultivated because it naturally increases soil fertility, which raises agricultural yields. In Nigeria, soybean is an important source of protein that is consumed to address nutritional issues (Idrisa *et al.,* 2019). We need to change this tendency by include soybeans in our meals because Nigerians tend to eat more starchy staples food, which leads to malnutrition and a high prevalence of chronic illnesses like diabetes (Akah *et al*., 2021). Nigerians who consume vegetable oils high in omega-6 fat have health problems like cardiac difficulties (Falade *et al*., 2017). However, because soybean oil lowers cholesterol levels in the gastrointestinal tract by reducing cholesterol absorption, it is believed to reduce the risk of cardiac issues (Messina *et al*., 2021). To make soy-lafun, soy-gari, dadawa, soymilk, tom brown, and soy-ogi, soybeans are processed nowadays in Nigeria. Soybean meal is an important component of formulated feed used in livestock production. In order to boost output, soybeans are typically inter splanted with other crops like maize, wheat, and sorghum and control weeds that are parasitic, like striga (Smith, 2017). Climate change directly affects soil and water supplies, it has a severe impact on agriculture. Nigerian agriculture is experiencing a reduction in the productive potential of its soil resources as a result of declining soil fertility and increased fertilizer costs as a result of the elimination of subsidies. Crop productivity fell as a result of this continuous soil deterioration and loss of fertility (Al-Tayar, *et al.,* 2020).

Methodology: The North East (often hyphenated to the North-East) is the one of the six geopolitical zones of Nigeria representing both a geographic and political region of the country's northeast. It comprises six State-Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. The wet season lasts from April to October, whereas the dry season lasts for at least five months (November to March) yearly. An upsurge in rainfall in September in recent years is usually accompanied by floods with many people losing their life and properties due to both discharge of water from the Lagoo Dam in Cameroon and severe rainfall. They cultivate cash crops like Cotton and Groundnuts, alongside food staples such as Maize, Yam, Cassava, Guinea Corn, Soybean, Millet, and Rice. Communities residing along riverbanks are involved in fishing, and the Fulani people are known for cattle herding (National Population Commission and National Bureau of Statistics Estimates 2016)

Multi-stage sampling technique was used to select the respondents for the study. In the first stage: from all six states of north east, three state were randomly selected. The research work will make use of Agricultural Development Project (ADP) structure in the selected states. In the second stage: three ADP zones were purposefully selected from each state. The third stage: one block was randomly selected from each zone. The fourth stage: two cells were randomly selected from each of the blocks. From the cells 150 soybean farmers were randomly selected from each state to make a total of 450 respondents from the three states

Pearson's Chi-squared (X^2): The Pearson's Chi Square (X^2) test of association will be used to test the relationship between the socioeconomics characteristics of the respondents and coping strategies adopted by soybean farmers. This will be done to establish if there is a significant relationship between land tenure system and the respondent's adoption of coping strategies. The Chi-square (X^2) test is given as:

$$X^2=\sum \frac{(O-E)^2}{E} \quad \text{..........Equation 3}$$

Where;

O=the observed value or distribution

E=the expected value or distribution

Results and discussion: Land tenure system and increase in use of organic manure: Table 1.1 shows the result of the Pearson Chi Square test for the association between Land tenure system and increase in use of organic manure. The result revealed that the Pearson Chi Square value for the relationship was 7.644 while the p-value was 0.177. This was used to test the hypothesis which states that there is no significant relationship between land tenure system and coping strategies adopted by soybean farmers in the study area. This was tested at 5% level of significance. The observed frequency in table 1.1 shows that 33 respondents purchased land for soybean production and increase the use of organic manure on their farm land out of 39 respondents, with 34.8 expected frequency. Similarly, observed frequency in table 1.1 shows that 206 respondents inherited their soybean farm land and increase the use of organic manure on their farm land out of 225 respondents with an expected frequency of 200.5. In Addition, observed frequency in table 1.1 shows that 20 respondents use communal land and increase the use of organic manure on their farm land out of 26 respondents with 23.2 expected frequency. Moreso, observed frequency in table 1.1 shows that 39 respondents leased land for soybean production and increase the use of organic manure on their farm land out of 42 respondents with 37.4 expected frequency. Furthermore, observed frequency in table 1.1 shows that 46 respondents use government land allocation for soybean production and increase the use of organic manure on their farm land out of 54 respondents with 48.1 expected frequency. Likewise, observed frequency in table 1.1 shows that 57 respondents use family land for soybean production and increase the use of organic manure on their farm land out of 64 respondents with 57.0 expected frequency. The result shows that there was a significant relationship between Land tenure system and increase use of organic manure on soybean farm land. Therefore, we reject the null hypothesis and accept the alternative hypothesis.

Table 1.1: Land tenure system and Increase in Use of organic manure

	Response		Increase in use of organic manure		Row Total
			NO	**YES**	
Land tenure and increase in use of organic manure	**Purchased land**	Observed Frequency	6(12.2%)	33(8.2%)	39
		Expected Frequency	4.2	34.8	
	Inherited land	Observed frequency	19(38.8%)	206(51.4%)	225
		Expected Frequency	24.5	200.5	
	Communal land	Observed frequency	6(12.2%)	20(5.0%)	26
		Expected Frequency	2.8	23.2	
	Leased land	Observed frequency	3(6.1%)	39(9.7%)	42
		Expected Frequency	4.6	37.4	
	Govt. allocation	Observed frequency	8(16.3%)	46(11.5%)	54
		Expected Frequency	5.9	48.1	
	Family land	Observed frequency	7(14.3%)	57(14.2%)	64
		Expected frequency	7.0	57.0	
Column Total			**49**	**401**	**450**
Pearson Chi-Square =7.644; DF =5; P-value = 0.177					

Conclusion: It is concluded that the relationship between land tenure system in operation and farmers coping strategies were positively significant at five level. When the farmers have access to land it will positively influence the cultivation of soybean, the adoption of coping strategies in the face of climate change will not be difficult.

The major challenges faced by the soybean farmers in the study area are: inadequate government policies to empower soybean farmers in the area, insecurity in the society, poor agricultural extension delivery, poor access to land for soybean production in the area, high cost of fertilizer and other farm inputs.

Recommendations: The government should collaborate with traditional rulers, youths and other stakeholders in the community to provide adequate security of life and properties. Farmers should be adequately protected both they farm land, family and communities, in that ways production of agricultural products and food security can be guarantee.**;** Irrigation facilities and other farm inputs like fertilizers should be subsidize by the government so that the rural farmers can afford it and cultivate soybean all year round.

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Antagonistic effect of *Penicillium Pinophilum* on *Colletotrichum* Spp. Isolated from Anthracnose-Diseased Eggplant

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Abstract

Anthracnose disease, caused by Colletotrichum spp., is an important disease-complex affecting a wide variety of crops globally and in Nigeria. The in-vitro inhibitory effect of Penicillium pinophilum on Colletotrichum spp. isolated from anthracnose-diseased eggplant (Solanum melongena L.) was investigated. Diseased eggplant leaf samples were collected from a garden in Adim, Biase LGA of Cross River State, from which pathogen colonies were obtained and pure cultures of three Colletotrichum isolates (I, II, and III) derived by repeated subculturing on PDA media. A dual culture of Colletotrichum isolates and Penicillium pinophilum, separated 2 cm and 4 cm apart, was also maintained on PDA media (with three replicates) for a maximum of 4 weeks, during which their cultural and morphological characteristics were examined. In single cultures, Colletotrichum Isolates I and III were comparatively fast-growing, reaching the periphery of the petri dish in 9 and 7 days, respectively, while isolate II was slow-growing and required 14 days. The growth in dual culture plates revealed that P. pinophilum induced a stress response in Colletotrichum isolates, which led to hyphal discoloration, inhibition zone, and mycelial degradation at the boundary between both organisms wherever contact occurred. These indicate the production of compounds that are antagonistic to the Colletotrichum spp. isolates and points to the possibility of their biocontrol by Penicillium for the management of anthracnose disease in eggplants.

Keywords: *Anthracnose, Penicillium, antibiosis, biocontrol, Colletotrichum.*

Introduction: Eggplants are tender perennials cultivated in various climates and rich in vitamins and minerals. They are very popular in Nigerian cuisine. However, diseases pose significant challenges to their cultivation, yield and post-harvest quality, necessitating effective pathogen control measures for their sustainable production. Chemical fumigation, while effective, raises environmental and human health concerns due to the harmful effects of pesticides (Ibiang *et al*., 2014). This has led to interest in biocontrol agents, specifically plant growth-promoting microorganisms (PGPM), which are cost-effective and environmentally friendly. One such agent is *Penicillium pinophilum*, an endophytic fungus identified through morphological and genetic analysis (Teshima & Sakamoto, 2006) with biocontrol, phosphate solubilization, and siderophore production capabilities. *P. pinophilum* has been used to mitigate diseases and promote the growth of vegetable plants such as cabbage, tomato, and lettuce (Alam *et al*., 2011, Ibiang *et al*., 2020; 2021; 2023), making it a candidate for further development and more widespread use. However, it has not been tested against anthracnose disease-causing microorganisms. Anthracnose disease, which is caused by fungi in the Genus *Colletotrichum*, is one of the major economic constraints to vegetable production worldwide. It is a disease of the foliage, stems, fruits and causes pre-harvest and post-harvest losses in fruit crops (Abang *et al*., 2002). The study focused on isolating *Colletotrichum* spp. from anthracnose-infected eggplant, evaluating their cultural and morphological characteristics, and assessing the inhibitory effects of *P. pinophilum* on their growth and in vitro characteristics.

Materials and methods: **Experimental location**: The research work was carried out at the Pathology Laboratory of the Department of Genetics and Biotechnology, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria.

Isolation and subculturing of *Colletotrichum* spp. and *Penicillium pinophilum* : The diseased leaf samples were collected from several plants in an eggplant garden in Adim, Biase LGA of Cross River State. Excised leaves were immediately kept in a Ziplock bag containing silica gel then stored in a refrigerator (4°C) until the next day before use. Surface sterilization of the leaf was performed using a cotton swab soaked in 0.01% sodium hypochlorite for 30 seconds, followed by rinsing with sterilized distilled water. Infected leaf fragments (2-3 mm) were then cut from the junction of diseased and healthy tissue using disinfected scissors and placed in petri dishes. Four leaf pieces from each plant were aseptically transferred to petri dishes containing sterile potato dextrose agar (PDA) with chloramphenicol as general antibiotic. 39 g of PDA were suspended in 1000 mL of sterilized distilled water and autoclaved for 15 mins at 121 °C the two 500 mg capsules of chloramphenicol were added to suppress bacterial growth before pouring into the petri dishes and allowed to solidify for 5-7 minutes in a lamina air flow. The inoculated plates were incubated at 25 ± 2°C for four to five days, with regular monitoring to observe fungal growth. From the colonies obtained, pure cultures of three *Colletotrichum* isolates were derived by repeated subculturing on PDA. The *P. pinophilum*, available from the National Institute of Technology and

Evaluation, accession number 100411, was also sub-cultured and maintained on PDA, for one month before use in dual cultures. All waste materials and tools were autoclaved before and after use or final disposal.

Detached leaf assay and macromorphological characterization of *Colletotrichum* spp.: Young detached leaves of eggplant in sterile petri dishes were sprayed with a suspension of each isolate and kept at room temperature for one week then checked for disease incidence on leaf to confirm pathogenicity. Fresh cultures of each isolate were examined and characterized based on their mycelia colour, growth pattern, margin, elevation, texture and growth rate, for identification based on descriptions of *Colletotrichum* species by Abang *et al.* (2002).

In-vitro dual culture of *Colletotrichum* and *P. pinophilum*: To study its inhibitory effect on *Colletotrichum*, a dual culture with *P. pinophilum* was set up using PDA media. The *Colletotrichum* mycelial plug was placed 2 cm from the centre of the agar plate, and *P. pinophilum* was placed 2 cm and 4 cm away at the opposite end. The treatment groups were *Colletotrichum* isolate alone, *Colletotrichum* isolate + Penicillium 2cm apart, and *Colletotrichum* isolate + Penicillium 4cm apart, with three replicates. The plates were incubated in a sterile laminar airflow chamber for one month to observe the interactions between the two fungi. The colony diameter of *Colletotrichum* isolates were measured daily using a ruler for 7 days after dual culture, while other cultural characteristics were assessed until end.

Results: Three isolates of *Colletotrichum* spp. were obtained from the diseased leaf of eggplant (Plates 1 & 2) and their characteristics are shown in Table 1.

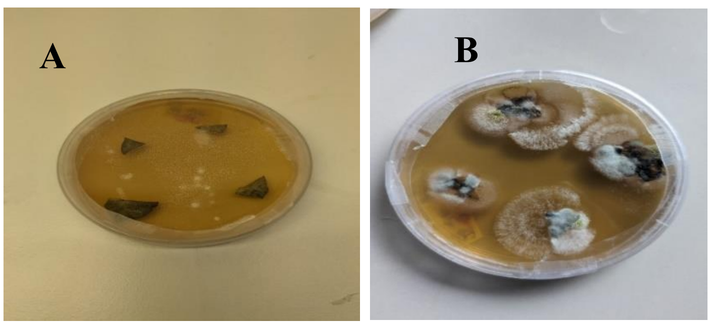

Plate 1: Samples of cultured infected *Solanum melongena* leaf fragments on PDA (A). Leaf fragments of *Solanum melongena* developing fungal growth after 5 days (B).

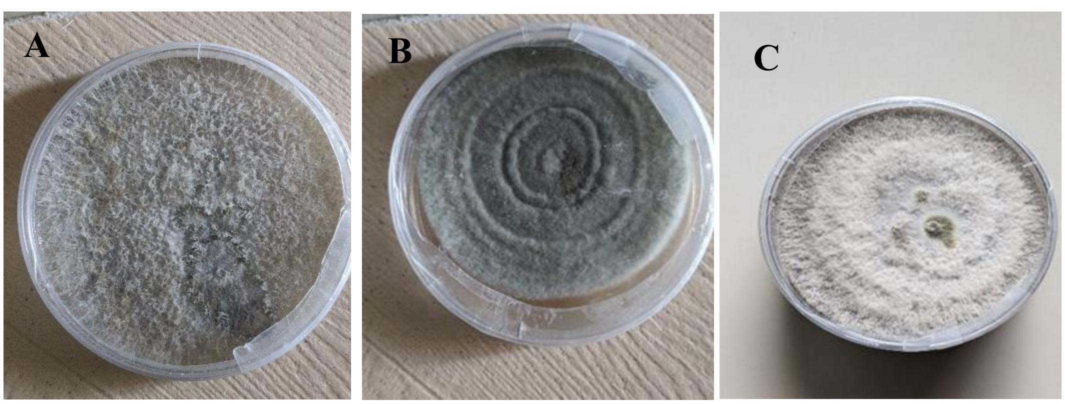

Plate 2: Pure cultures of three isolates of *Colletotrichum* spp. obtained from leaf of *Solanum melongena* showing anthracnose disease symptoms. Isolate I (A), Isolate II (B), Isolate III (C).

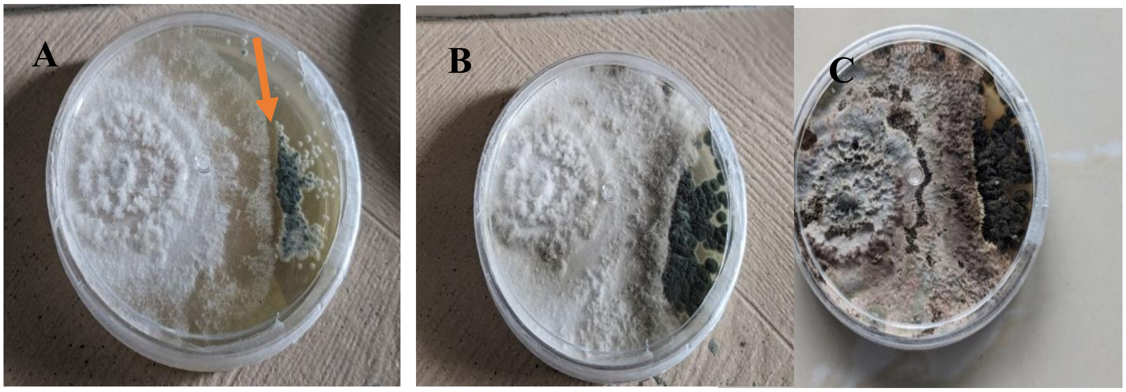

Plate 3: Dual culture of *Colletotrichum* isolate III and *P. pinophilum* (Pp) after 7 (A), 12 (B) and 30 (C) days, showing inhibition zone and hyphal discolouration of *Colletotrichum* at the boundary with Pp.

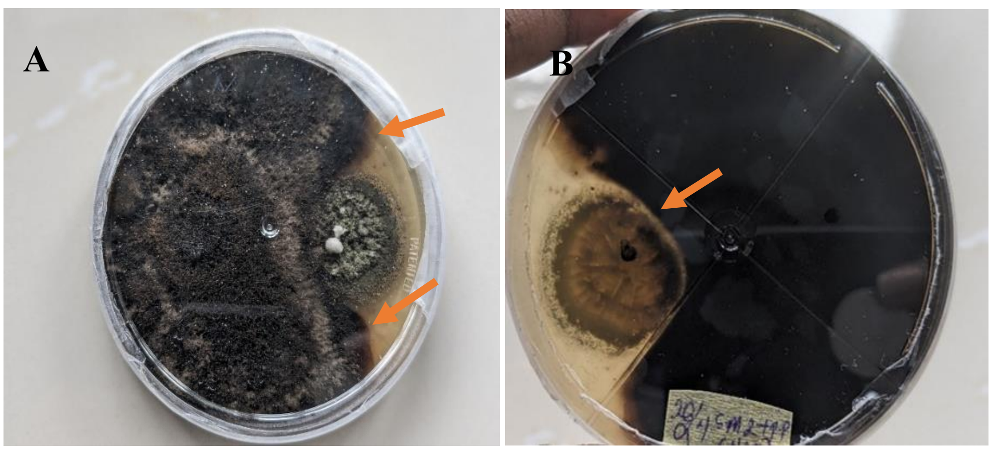

Plate 4: Dual culture of *Colletotrichum* isolate II and *P. pinophilum* at 2 cm apart after 30 days. Front (A) and reverse (B). Hyphal degradation (A) and a clear inhibition (B) zone seen after 30 days.

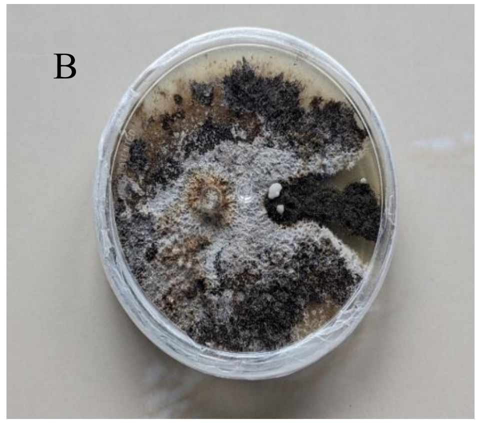

Plate 5: Culture of *Colletotrichum* isolate I alone and with *P. pinophilum* 2 cm apart, after 12 days (A). (B) Dual culture after 30 days.

Table 1

Macroscopic characteristics of *Colletotrichum* spp. isolates obtained from anthracnose-diseased eggplant

	I	II	III
Mycelial colour	White	White	White
Growth pattern	Ring	Ring	Ring
Margin	Entire	Entire	Entire
Ornamentation	Flat	Raised	Flat
Texture	Cottony	Woolly	Cottony
Time to cover Petri dish	9 days	14 days	7 days

Discussion: The macroscopic characteristics of *Colletotrichum* spp. isolates are shown in Table 1. All isolates were initially white, but the colour showed notable changes over time (plate 1b and plate 2). Colour variation of isolates have been reported from normal white to light grey, greyish brown, greyish white, greenish grey, pinkish and pinkish brown (Udhayakumar *et al*., 2019). The whitish mycelia of the *Colletotrichum* spp. isolates transitioned to a grey coloration over 21 days. This change in coloration showed the aging of the fungal mycelium. The isolates in this study bear similar morphological characteristics and exhibited comparable growth rates to two morphological forms described by Abang *et al*., (2002). Isolates I and III were comparable with the Fast-growing grey (FGG) and isolate II similar to Slow-growing grey (SGG). Isolate III reached the periphery of the petri dish in just 7 days, compared to Isolates I and II, which took 9 and 14 days, respectively. The growth in dual culture plates suggest that *P. pinophilum* induced a stress response in *Colletotrichum* spp., and eventually led to morphological changes such as hyphal discoloration and degradation at the boundary between both organisms. Isolate II grew evenly on the surface of the medium and extended into *P. pinophilum* at some point in the dual culture separated 2 cm apart. Eventually, however, its mycelia started decaying, leading to a clear margin between it and *P. pinophilum* (plate 4). This mycelial degradation confirms the antibiosis by *P. pinophilum* against the pathogen isolate (Ibiang *et al*., 2021). The observed inhibition zone, grey colour change and decay of the mycelia upon contact with *P. pinophilum* (plates 3, 4 & 5) indicate that the endophytic fungus (*P. pinophilum*) produces compounds or enzymes that are antagonistic to *Colletotrichum* spp. and cause damage to its mycelium.

Conclusion:The study demonstrates that *Colletotrichum* spp. isolates infecting anthracnose-diseased eggplant are susceptible to antagonism by *P. pinophilum*. Further screenhouse studies in inoculated plants exposed to the pathogens could shed light on the suitability or otherwise of *Penicillium* as a biocontrol agent for managing anthracnose disease in eggplants.

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The effect of Fuel Subsidy Removal on Agriculturaral Production and Agro-Allied Industry.

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Abstract

Fuel subsidy is government discount on the market price of fossil fuel to make consumer pay less than the prevailing market price of fuel. Fuel subsidy removal is a significant policy change that often spark debate and discussion due to its potential impacts on various sectors of economy. One of such sector that particularly sensitive to change in fuel price is agriculture and agro- allied industries. This study is aimed to explore the effects of fuel subsidy removal on agricultural production and agro- allied industry, focusing on short –term and long –term effects or consequences. The short –term or negative effects or implications includes; increase in inflation, poverty, skyrocketing of price of commodities, loss of job in company sector, crime and high cost of living, increase in production cost. While the positive or long- term effects or implications are, Fuel subsidy removal would free up financial resources for other sectors of the economy like agriculture and agro-allied industries, increase employment, channel funds for the development of critical public infrastructure, curb corruption associated with fuel subsidy payment and increase the budget surplus in the near future. Conclusion, this study provides a comprehensive analysis of the impact of fuel subsidy removal on agricultural production and agro- allied industries, drawn upon a rich body of literature review. The findings underscore the multifaceted nature of these effects and highlight the important of considering local context and dynamics in accessing the implications of fuel reform. The research aims to contribute and informed decision –makers to foster sustainable agricultural development in face of energy policy change. Recommendation, the recommendation base on the findings of this study, these include; targeted support measures to mitigate the hardship of farmers, Government should investments on alternative energy source, transportation and strategies to enhance the resilience and adaptability of agricultural production in the absence of fuel subsidy, policy makers can help to ensure the positive or long –term sustainability and viability of agricultural system in a changing energy land scape.

***KEYNOTE**: Effect, Fuel Subsidy Removal, Agricultural Production, Agro-Allied Industry.*

Introduction: This paper is interested in the effects of fuel subsidy removal on agricultural production and Agro-allied industry in Kogi state. Fuel subsidy is a Government discount on the market price of fuel to make consumer to pay less than the prevailing market price Ovaga and Okechukwu (2022). When subsidies are in place consumers will pay less below the market price per liter of the petroleum product. Globally, there are debates about fuel subsidy because of its huge amount and its effects on citizen welfare and Agricultural production. According to Couharde and Mouhoud (2020) the removal of fuel subsidy has generated a lot of argument because fuel subsidy is inform of aids given to the citizens in the society to buy fuel at affordable rate to help farmers and other sector of economy find it easy in their production activities. (Ozili and Ozen 2021) stressed that despite the favorable argument concerning the fuel subsidy removal, there are great negative consequence of fuel subsidy removal on agricultural production and other sectors of economy these include; increase in food price and other commodities, high inflation rate, high cost of transportation and increase in price of raw materials and other agricultural inputs like fertilizers, chemicals and seeds for planting. (Miculloh, Mevenhout, and Yang 2021) Stressed that policy makers are reluctant to remove fuel subsidy and to implement the reforms because, such reforms may result in significant increase in fuel price which could lead to economic hardship and suffering in the society. (Abong K.O 2000) Supported that a little change in fuel price will affect agricultural production and industries either negative or positive.

Agriculture according to (Iwena 2020) involves the production of plants and animals for man and industrial use. : Production according to Ebong (2000) is the utilization of technical transformation of resources into output. Production in the context of the study according to (Arene 2006) is the use of inputs such as land, labour, capital, and other resources to produce the farm products like crops and animals. Agro- Allied industries are industries that depend and use the agricultural products as their raw materials for their production (Iwena 2020). Such raw materials are skin, leather, bones, egg, maize, ground nut, cocoa, cotton etc. (Abundant 2018) stressed that, the relationship between fuel subsidy and agricultural production is vast which the scholars have long recognized the intricate mechanisms through which changes in fuel prices can affect agricultural supply chain, influencing everything from input cost, to production levels to market dynamics and consumers behaviors. The study focus to explore the effects of fuel subsidy removal on agricultural production and Agro-Allied industry, focusing both short- term and long –term effects or consequences. (World Bank 2019) outline the short –term effects of fuel subsidy removal which includes; ; Increase in production cost which directly translate to higher production cost for farmers, thus increase affects the stages of agricultural production like land preparation, planting, irrigation, transportation of goods to the market, as well as processing of agricultural products.; Decrease in profit margin; With higher production cost and relationship stable price for agricultural products in short-term, farmers often experience decrease profits margin, this may discourage the farmers from investing in new technology or expanding their operations.; Shifting in crop choices; In response to higher production cost, some farmers may opt to switch to crops that require less fuel-intensive input, or less reliant on mechanization. This shift could lead to changes in crop patterns and potentially impact food security and market stability. (World Bank 2019) further stressed that, the long-term consequences or effects of fuel subsidy removal includes; ; Technological innovation; The higher the fuel price incentivizes the development and adoption of more fuel –efficient, technology and practice in agriculture. This could lead to long- term improvement in productivity and sustainability in agricultural production and agro- allied industry.; Investment in infrastructure; Government may redirect savings from fuel subsidy removal towards investment system, storage facilities and machinaries. (Olugbenga 2023) supported that, savings from fuel subsidy removal could be channeled for the development of other sectors like agriculture and industries. (Gidigbi and Bello 2020) agreed with Olugbenga (2023) that, the removal of fuel subsidy can free up financial resources for the development of other sectors that require significant Government interventions and funds.

Statement of Problem: Fuel subsidy removal has generated a lot of global argument for years whether to remove fuel subsidy or not. Ozili and Ozen (2021) Sstressed that despite the favourable argument, there is great negative consequence of fuel subsidy removal on agricultural production. Therefore, there is need for Government to redirect the money from fuel subsidy removal to agricultural production and other important sector of economy. The problem of this study is, what are the effects of fuel subsidy removal on agricultural production and agro- allied I industry.

Purpose of The Study: The purpose of this study is specifically sought to determine;**;** The negative or the short – term effects of fuel subsidy removal on agricultural production and agro-allied industry.**;** The positive or long-term effects of fuel subsidy removal on agricultural production and agro- allied industry.

Research Question: The following research questions are formulated to guide the study.; What are the negative or short-term effects of fuel subsidy on agricultural production and agro-allied industry?; What are the positive or long –term effects of fuel subsidy removal on agricultural production and agro- allied industry?

Methodolog: Design of the Study; The study adopted a survey research design. The survey research design according to Nworgu (2006) is the process on which the entire population or sample is studied by collecting and analyzing data from the group through questionnaire. the design is suitable for stake holders and farmers on the effects of fuel subsidy removal on agricultural production and agro- allied industry in Kogi State.

Area of study: The study was carried out in Kogi East , which comprises Nine (9) Local Government Areas .

Population of The Study: The population of study was (150) one hundred and fifty farmers and fifty (50) stake holders in Kogi East Senatorial district.

Sample and Sampling Techniques: As a result of logistic problem that hinder the researcher to reach every farmers and stake holder in the study area, a representative of one hundred and fifty (150) farmers and fifty (50) stake holders were randomly selected.

Instrument for Data Collection: The instrument for data collection was structured questionnaire developed from the literature reviewed. The items were divided into two sections, that will give information to provide answers to the research questions. The section was divided into two parts A and B.

Section A is designed to find out the negative or short- term effects of fuel subsidy removal on agricultural production and agro- allied industry.

Section B is designed to find out the positive or long –term effects of fuel subsidy removal on agricultural production and agro –allied industry.

Each questionnaire item had a four (4) respond options with real limit as follows;

Strongly agreed	(SA)	3.50-------- 5.00
Agreed	(A)	2.50 ------- 3. 49
Disagreed	(D A)	1.50 --------2.49
Strongly disagreed	(SD)	0.50 -------- 1.49

The reliability of the instrument: To determine the internal consistency of the questionnaire items, the researcher gave out ten (10) copies of the questionnaire to the farmers and stake holders in Lokoja Local Government Area, which is aside the study area. The copies of questionnaire were collected and analyzed using Cronbach Alpha method and a reliability coefficient of 0.87 were obtained.

Method of Data Analysis: The data collected were analyzed using mean to answer the data research questions. Any items with a mean value of 1.50 and above was considered as agreed to the itemsS. While the value below 1.50 was regarded as disagreed to the items.

Discussion of the findings: The findings were discussed based on the finding from the study and organized on the bases of the two purpose of the study. The findings revealed that Nine (9) items were negative or short- term effects of fuel subsidy removal on agricultural productions and agro-allied industry. These nine negative or short - term effects include; hinder the massive production of agricultural product, excessive increase in food price, high inflation rate, increase in transportation and taxation, economic hardship and suffering, affects input cost, decrease in profit margin, shifting in crop choice and affects all stages of agricultural production. The findings of the study were in agreement with (Ozili and Ozen 2021) who stated that there is great negative effects of fuel subsidy removal on agricultural production, these includes; increase in food price, increase in inflation, and transportation.(Abang K.O 2000) Supported that a little change in price of fuel will affects all stages of agricultural productions. (World Bank 2019) supported that removal of fuel subsidy will increase production cost, decrease profit margin, and shifting of crop choice.

Positive or long-term effects of fuel subsidy removal on agricultural production. The findings of the study showed that SEVEN (7) items were identified as positive or long- term effects of fuel subsidy on agricultural production these include; technology innovation, redirect saving towards investment system, storage facilities and machineries, improvement in productivity and sustainability, free up financial resources for the development of other sectors, allow government to have sufficient money to fund agricultural production and enhancing investment in infrastructure that aids in agricultural production. The findings of the study were in consonant with World Bank (2019) that outline the positive effects of fuel subsidy removal on agricultural production these include; technology innovation, investment in infrastructure, the findings were in conformity with opinion of Olugbenga (2023) that saving from fuel subsidy removal could channeled for the development of other sectors like agriculture, industries and infrastructure. Gidigbi and Bello (2020) agreed with Olugbenga that removal of fuel subsidy free up financial resources for the development of other sectors.

Conclusion: The effects of fuel subsidy removal on agricultural production and agro- allied industry are multifaceted encompassing both short-term challenges and long –term opportunities. While immediate cost increase may pose difficulties for farmers, there also stimulates innovation and investment that enhance productivity and resilience in the agricultural sector. Policy makers must carefully consider, these dynamics when implementing fuel subsidy reforms to mitigate negative effects and maximize long- term benefits for agricultural production

Recommendation: It is recommended that; Targeted support measures to mitigate the adverse effects on farmers.**;** Government should strategies to enhance the resilience and adaptability of agricultural production system in the absence of fuel subsidy.**;**Government should invest on alternative energy sources, transportation and infrastructure; Policy makers can help to ensure the positive or long-effects sustainability and viability of agricultural system in a changing energy landscape.

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Portfolio Features of Contract Farming Model in Northwest Nigeria: *Smallholder Maize Farmer's Perspective from Kano and Kaduna State.*

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Abstract

Models of contract farming play a major role on welfare of smallholder farmers through increasing crop productivity and income. This study described portfolio features of contract farming model among smallholder maize farmers in Northwest, Nigeria. The data for the study was collected from a multistage randomly sampled 233 maize contract farmers. The data collected was analyzed using descriptive statistics (such as mean, frequency and percentages). Findings of the study revealed that Maize contract farming is dominated by a single firm in the study area (Above 90%). Meanwhile portfolio features of maize contract farming involves informal arrangement during raining season between farmers groups and the contracting firm(100%), All the participating farmers(100%) paid commitment fee at the beginning of the arrangement. Major services offers by the contracting firms were training on innovative practices, supervision, and access to improve inputs and market for their products. The most critical challenges faced by farmers participating in the contract were; excessive control on pricing by firm (79.83%), inadequate insurance provision (78.11%), lower pricing of harvested maize (75.54%), and delay in payment of farmers benefit (73.82%)**.** Therefore it is recommended that efforts shall be made by the government to facilitate bargaining power of the farmers; regulate contract farming operation towards improved pricing of maize produced by farmers and ensuring prompt payment of the farmers at the end of the season.

Key words: Contract, typology, farming, Maize, and Model.

Introduction: Nigerian agriculture is known to be dominated by small scale farmers who produce the bulk of food requirements in the country (Food and Agriculture Organization, FAO, 2021). The Smallholder farmers make up to 80% of farmers in Nigeria and produce substantial percentage of food consumed by Nigerians (Nazifi and Yusuf, 2022) these farmers are producing maize below the potential capacity because of various challenges they have, that includes limited access to modern agricultural practices; poor access to agricultural credit; poor access to extension service; small land holding and poor access to market (Mgbenka *et al*., 2015). Maize and other Staple food crops like cassava, and rice are over the years been produce through contract farming in Nigeria and other developing countries (Prowse, 2012). Contract farming is an agricultural production system where farmers produce specified agricultural commodities according to buyer's specifications for a guaranteed market and price (Ton *et al*., 2018). The contracting firm buys farm produce in advance in exchange for pre-financing agro-inputs and non-financial services like an extension on pre-agreed terms and conditions (Meemken *et al*., 2020).

Models of contract farming play major role on welfare of smallholder farmers through increasing crop productivity and output growth in agricultural sector by delivering better technology, coordinating producer's and consumer's market along with strong grass-root linkages (Iro, 2016, Nazifi et al, 2021). The most notable out-grower schemes for maize in Nigeria; especially, in northwest-axis were Bunkasa manoma (ThriveAgric), Manomalinks, Olam, West African Cotton Company Limited (WACOT), Babbagona and Afex-Agra among others. These firms operate using various contract farming models that are usually in the form of centralized, nuclear estate, multipartite, informal and intermediary models. Each of these models provide services that are paramount to increasing productivity and income of the farmers, that includes access to credit; extension service, agricultural production inputs; training on good agronomic practices, farm supervision, storage facilities, and ready markets for harvested crop (Nazifi et al, 2021). These contract model have different form of arrangement and services offered depending on the crop type and location of the contract. This study therefore evaluates Portfolio Features of Contract Farming Model among smallholder maize farmers in Kano and Kaduna State, Nigeria by achieving the following specific objectives; identifying firms operating maize contract farming in the study area; describing portfolio features of contract farming; identifying services offered to the farmers; and examining challenges faced by contract participating farmers in the study area.

Methodology: The Study Area: The study was conducted in Kano and Kaduna States Nigeria where maize is largely produced and there exists evidence of contract farming operation. The Local Government Areas (LGAs) where there are evidences of maize contract farming in Kaduna State include Soba, Kubau, Furu, Lere and Igabi and in Kano State they includes Rano, Bunkure , Garunmalam, Warawa, kura Karaye Rogo and Shanono LGAs.

Kaduna State: The State is located between latitudes $11^0 32''$ and $09^0 02''$north of the equator and longitudes $80^0\ 50''$ and $06^0\ 15''$ east of the Prime Meridian (Kaduna State Statistical Year Book, 1996). The State occupies an area of approximately 48,473.2 square kilometers. The entire land structure consists of an undulating Plateau, with major rivers in the State as River Kaduna, River wonderful in Kafanchan and River Gurara. Kaduna State has 23 LGAs it lies within the Derived Guinea Savannah zone of Nigeria. The State extends from the Guinea Savanna in the South-Central to the Sudan Savanna in the North Central. The grassland is a vast region covering the southern part of the State. There are two marked seasons in the State: the rainy (wet) season and the dry windy season. The wet season is usually from May to October with great variations in different areas of the State from 600 mm to 1500 mm. On the average, the State enjoys a rainy season of about 5 months. The length of the growing periods varies from 100 to 200days. The dry season starts from November to April Temperature in the State ranges between 28^0C and 34^0C (Nigerian Metrological Station, 2012). Farming is the main occupation of the people, with emphasis on the crops grown which include maize, sorghum, rice, millet, wheat, cotton, yam, cassava, pigeon pea, cowpea, soya bean and groundnut. They also grow vegetable crops like tomato, pepper, onion and carrot. Livestock is also important in the economy of the State and the livestock kept include cattle, sheep, goats and poultry.

Kano State: The State is located between latitudes of 10º3' and 12º 37´ North and longitudes 7º3´ and 9⁰ 5´ East of the Greenwich meridian. It has a total land area of 20, 760 square kilometres with 1,754,200 hectares of fertile agricultural land, of which 86,500 is exclusively *Fadama* land. About 75,000 hectares is made up of grazing lands (Olofin *et al*., 2008). The State which have 44 LGAs is also the most populous State in Nigeria with a population of 9,383,682 (NPC, 2006).The dry season is usually from November to April, while the rainy season begins from June to October with an annual rainfall of 134.4 mm Kano. Farming is the main occupation of the people, with emphasis on the crops grown which include maize, sorghum. They also grow vegetable crops like tomato, pepper, onion and carrot. Livestock is also important in the economy of the State and the livestock kept include cattle, sheep, goats and poultry

Sampling Techniques: Multi-stage random sampling procedure was employed for the study. It involves identification of LGAs where there are evidences of contract farming participation by smallholder maize farmers, First stage was random selection of communities with evidence of contract farming using systematic random method. Second stage was selection of two communities from the list of systematic randomly selected contract farming communities through balloting. In the third stage, raosoft sample size formula was used to determine sample size from sample frame of maize farmer's population of each community participating in contract farming. Finally, in the fourth stage a 233 contract farmers were randomly selected systematically from the sampling frame as shown in Table 1.

Table 1: Sampling Size Selection Plan of the Study

State	*LGAs*	*Communities*	*Selected communities*	*Sample Frame*	*Sample Size*
Kaduna	Ikara	10	Saulawa	52	20
			Kurmin Kogi	54	21
	Makarfi	8	Mayere	35	14
			Dorayi	42	17
	Soba	12	Gimba	67	27
			Awai	70	28
Sub-total	3	30	6	320	127
Kano	Bebeji	7	Alkalawa	38	15
			Damau	59	23
	Rano	10	Yalwa	37	15
			Doka	47	19
	Bunkure	9	Danhassan	40	16
			Barge	46	18
Sub-total	3	26	6	267	106
Total	**6**	**56**	**12**	**587**	**233**

Source: Field Survey, 2019

Method of Data Collection: Primary data used for the study was collected through the use of well- structured questionnaire, administered to farmers by well-trained enumerators that have better understanding of farmer's local language. The data collected includes information on features of maize contract farming model and problems associated with contract farming participation.

Analytical Technique: The tools of analysis that were used to achieve objectives of the study was Descriptive Statistics. It involves the use of measures of central tendency such as mean, frequency and percentages to describe the socio-economic characteristics of contract farmers, describe characteristic of maize contract production and measure the constraints to contract farming participation in the study area.

Result and Discussion: Firms Promoting Maize Production Contract: Result for firms promoting maize production contract in the study area was presented in Table 2. The result showed that majority (88%) of smallholder farmers in Kaduna State had contract with Babbangona contracting firm while remaining 12% of them had contract with Afex-Agra, Bunkasa manoma and Manoma links contracting firms; on the other hand in Kano State all the farmers 100% of them had contract farming agreement with BabbanGona firm. The result implies that Babbangona is the most dominant maize production contracting firm in study area; this may be because as stated by farmers as being the most notable firm with maize contract farming and was among first contracting firms to be established in the areas of Kaduna and Kano State for contract farming.

Table 2: Maize Production Contracting Firms

Contracting Firms	Kaduna		Kano	
	Frequency	Percentage	Frequency	Percentage
Afex Agra	6	5.0	-	-
BabbanGona	88	76.0	117	100
Bunkasa Manoma	15	13.0	-	-
Manoma (Links)	7	6.0	-	-
Total	116	100	117	100

Source: Field Survey, 2019.

Portfolio Features of Maize Contract Farming: Description of the contract operation features between the smallholder maize farmers and the contracting firm was presented in Table 3. The result indicates that uniform features of contract operations in the study area were; payment of commitment fee and season of contract (raining) as reported by 100% of the farmers in both Kano and Kaduna State. This implies that commitment fee amount payment is equal to all the farmers and maize contract farming operation in the study area took place during raining season. All the contract farmers in Kaduna State signed the agreement formally while only 42% of the farmers in Kano State signed the contract formally; the informal agreement made by farmers in Kano State may be due to the fact that the formal agreement is being carried out through their cooperative group leaders who represent them in signing the agreement with the contracting firm. Majority (98%) of the farmers in the study area received their production inputs in kind, remaining 2% of them received their inputs in cash; this happen only when the quantity supplied is finished as Stated by the farmers during the survey. Regarding nature of inputs disbursement majority of the farmers received their inputs through phase disbursement as Stated by 95% and 67% of the farmers in Kaduna and Kano State respectively. The remaining 4.17% of the farmers in Kaduna received their inputs once at a time, while 39%, farmers in Kano State received their inputs two times during the contract. Phase disbursement being the major disbursement method shows the extent of efficient utilization of inputs at each stage of maize production activity.

Decision on price per bag of maize was Stated to be made by 95% of farmers in Kaduna State and less than 18% of farmers in Kano State based on the average market price as agreed by the firm, while price decision by contracting firm was Stated to be made by 5% of farmers in Kaduna State and by majority (82%) of the farmers in Kano State. this implies differential pricing decision among farmers in the States; the reason as given by the farmers is that, for Kaduna State the farmers are allowed to participate in the survey to come up with the average market price which is usually being used as the price of maize grain per bag, while for Kano State the contracting firm carried out the market survey and come up with the price per bag of maize grain.. Production management is controlled by the farmers as reported by 70% of the farmers in both locations, 14% of them reported production management control by the contracting firms while 15% of them reported it as being controlled by both farmer and contracting firm. This implies that the production management control is mostly by the farmer and the intervention of the contracting firm is limited to supervision through farm visit in the study area. Transportation of maize produced by the farmers was found to be responsibility of farmers as Stated by 94% and 58% of farmers in Kaduna and Kano State, respectively. Meanwhile transportation of maize produced by the firm was reported by 16% of the farmers only in Kano State while as responsibility carried out jointly by the firm and farmers was reported by only 6% of the farmers. This implies that farmers are mostly the ones that provide transport to the firm collection center after harvest.

Table 3: Portfolio features of maize contract farming

Contract Portfolio features	Kaduna		Kano	
	Frequency	Percentage	Frequency	Percentage
Commitment fee payment	116	100	117	100
Season of contract (Rain)	116	100	117	100
Agreement type (Formal)	116	100	67	57.3
Agreement type (Informal)			50	42.7
Production Inputs (kind)	114	98.28	115	98.3
Inputs disbursement (Once)	6	5.17	8	6.8
Inputs disbursement (Twice)			45	38.5
Inputs disbursement (Phase basis)	110	94.83	57	48.7
Inputs disbursement (When needed)			7	5.98
Price Decision (Farmers)	110	94.83	57	48.7
Price Decision (Firm)	6	5.172	96	82

Management control (Farmer)	110	94.83	54	46.2
Management control (Firm)			33	28.2
Management control (Both)	6	5.17	30	25.6
Transportation (Farmer)	110	94.83	68	58.1
Transportation (Firm)			39	33.3
Total	116	100	117	100

Source: Field Survey 2019.

Services Offered by Contracting Firms to Maize Farmer: Services offered by contracting firms to maize farmers in the study area were presented in Table 4. The results indicates that extension training, farm supervision, good quality seed, fertilizer, Agro-chemicals, transportation of harvested maize, bagging, soil test, market for harvested maize and fertilizer recommendation based on the soil test were received by 100% of the farmers in Kaduna State. However, only 34% of them received insurance provision service and none of them received money cash for labor activity. On the other hand, contract farmers in Kano State, over 70% of them also received extension training, farm supervision, good quality seed, fertilizer, agro-chemicals, transportation of harvested maize, bagging, and soil test from contracting firm; however, the least services received by them were fertilizer recommendation base on the soil test by 31% of them, insurance service provision by 17% and money in cash by 10%. The result implies that contract farmers in Kaduna State received more services than farmers from Kano State, this may be due to the fact that Kaduna State is centralized location of the contracting firms; the result further implies that maize contract farming model in the study area provided services that are paramount to improving farmers productivity and hence their welfare.

Table 4: Services Offered by Contracting Firms to Maize Farmers

Services Received	**Kaduna**		**Kano**	
	Frequency	Percentage	Frequency	Percentage
Extension training	116	100	100	85.47
Farm supervision	116	100	95	81.2
Good quality seed	116	100	108	92.31
Good quality fertilizer	116	100	112	95.73
Good quality agro-chemicals	116	100	112	95.73
Transportation cost	116	100	78	66.67
Bagging	116	100	70	59.83
Money in cash			12	10.26
Soil test	116	100	87	74.36
Fertilizer recommendation	116	100	31	26.5
Market for harvested maize	116	100	117	100
Production Insurance	40	34.48	17	14.53
Total	116	100	117	100

Source: Field Survey, 2019

Challenges Faced by Maize Contract Participating Farmers : Result for challenges faced by farmers participating in maize contract production was presented in Table 5. Result shows that excessive control on pricing by contracting firm and inadequate insurance provision are the 1st and 2nd major challenges faced by the farmers; the excessive control on pricing by contracting firm was due to the larger quantity of harvested maize that is collected by the firm and their dominance on price decision and inadequate insurance provision was as a result of contracting firms forcing the farmers to provide or pay for the required quantity even in the case of crop failure as a result of pest and disease or drought incidence and the farmers have no insurance to protect them. lower pricing of harvested maize by firm was ranked as 3th and delay in payment of farmers benefits as 4th challenge, the lower pricing was Stated by the farmers as because the firm always possess highest power in deciding the price to be paid per bag of harvested maize and is mostly below market price, while the delay in payment of farmers benefits was due to the fact that after harvesting the farmers are not given their profit after company deducted their services fees and credit in time. Low quality fertilizer and herbicide was ranks 5th and high transaction cost as 6th, the low inputs quality was related to the quality of production inputs supplied to the farmers and the likely production inputs diversion by the farmers and yield they produced less than expected. While the high transaction cost were realized by the farmer as a result of small amount of money they received as final payment from company and the number of bags given per hectare to contract firm as signed initially in the contract. limited farm monitoring by contracting firm agent was ranked 7th this was Stated by the farmers as because the firms staffs number of visit to their farm is limited to only time of input supply and the harvesting periods.

Table 5 Challenges Faced by Maize Contract Participating Farmers

Challenges	Kaduna		Kano		Pooled		Rank
	Frequency	%	Frequency	%	Frequency	%	
Excessive pricing control by contracting firm	99	85.34	87	74.36	186	79.83	1st
Inadequate insurance provision	95	81.9	87	74.36	182	78.11	2nd
Lower pricing by contacting firm	89	76.72	87	74.36	176	75.54	3rd
Delay in payment of farmers benefits	90	75.86	84	71.79	172	73.82	4th
Low quality fertilizer and herbicide	90	77.58	78	66.67	168	72.10	5th
High transaction cost	88	75.86	74	63.25	162	69.53	6th
Poor farm monitoring by contracting firm agent	21	18.10	65	55.56	86	36.91	7th
Total	116	100	117	100	233	100	

Source: Field Survey, 2019

Conclusion and Recommendation: Maize contract farming is dominated by a single firm in the study area. Meanwhile portfolio features of maize contract farming involves informal arrangement during raining season between farmers groups and the contracting firm, usually validated operation of the arrangement is signifies by commitment fee payment by the interested farmers. Major services offers by the contracting firms were training on innovative practices, supervision, and access to improve inputs and market for their products. The most critical challenges faced by farmers participating in the contract were excessive control on pricing by firm, inadequate insurance provision, lower pricing of harvested maize, and delay in payment of farmers benefit. Therefore it is recommended that efforts shall be made by the government to facilitate bargaining power of the farmers, and regulation of contract farming operation towards improved pricing of maize produced by farmers and ensuring prompt payment of the farmers at the end of the season.

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Effects of Fuel Subsidy Removal on Agricultural Production and Agro Allied Industries. Potentials of Bio Energy in Alleviating the Effect of fuel subsidy removal

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Abstract

The Nigerian economy is greatly influenced by fuel including the agricultural production and its value addition chains. Fuel subsidies, a policy keeping consumer prices for goods or services below market rates, were implemented to alleviate the burden on the masses. The removal of subsidy has led to significant increases in fuel costs and subsequent price hikes across various sectors impacting agricultural activities. There is need to investigate alternative energy sources like: Solar energy, Bio energy, Wind energy, Hydro power e.t.c in order to reduce these negative effect of the fuel subsidy removal on agriculture and general livelihood in Nigeria especially energy sources derived from plant or animal origin, such as trees, crops, grasses or animal waste.

***Key words**: Fuel subsidy, Agricultural production, Agro allied industries, Alternative energy and Biofuel.*

Introduction: The main sources of energy in Nigeria are fossil fuels such as petroleum and coal and for several decades, Nigeria was the largest producer of crude oil in Africa, until recently, when it dropped to the 4th position behind Angola, Algeria and Libya (OPEC 2022) The economy of the country is greatly influenced by fuel, it is even deemed to be the "life-blood" of the Nigerian economy the prices of which has been kept low in form of subsidy. (Adekoya, 2021). Subsidy means benefit given by the government to individuals or businesses whether in form of cash, tax reduction or by reducing the cost of goods and services. The purpose of subsidy is to help individuals and businesses purchase/acquire essential goods and services that they may not be able to afford, under normal circumstances (Aderonke, 2013).. Fuel subsidies began in the 1970s and became institutionalized in 1977, following the promulgation of the Price Control Act which made it illegal for some products (including petrol) to be sold above the regulated price. Fuel subsidies, a policy keeping consumer prices for goods or services below market rates, were initially implemented during the military era to alleviate the burden on the masses. The concept of subsidy is noble, but its administration in Nigeria has been plagued with serious allegations of corruption and mismanagement (Omoniji, 2012) .Also considering the significance amount committed to funding the subsidy regime the government decided to remove the scheme.

The abrupt announcement of the end of fuel subsidy on May 29th 2023 has led to significant increases in fuel costs and subsequent price hikes across various sectors. Fuel is a critical input in agriculture, and subsidy removal, increasing the overall cost of production. The removal of fuel subsidies has far-reaching consequences, affecting various sectors like transportation, agriculture, and overall economy. The withdrawal of subsidies also presents challenges such as inflation, diminished household income, and reduced competitiveness (Ocheni,2015). Studies have shown that subsidy removal leads to increased transport costs and fares, impacting both agricultural and nonagricultural commodities. According to survey of Sennuga (2023) on relationship between transportation cost and price of farm produce, he discovered that the higher the cost of transportation, the higher the price of produce. (Table1).

Table 1: Relationship between transportation cost and price of farm produce

Constrains	**SA (%)**	**A (%)**	**SD (%)**	**D (%)**
High cost of transportation affect price of produce	67.4	24.6	4.0	4.0
Distance between farm and market affect transportation	42.5	25.8	11.3	14.5
Availability of reliable transport mean will affect farmers expenses	49.2	30.6	6.5	10.5

Source: Sennuga, 2023

SA**:stronglyagree,**A**:Agree,**D**:Disagree,**SD**:Stronglydisagree**

Some Observed Effects of the Removal of Fuel Subsidies on Agricultural Production and Agro-Allied Industries in Nigeria

1. Higher transportation costs: Farmer and other Agricultural value chains are facing higher costs of transportation which is causing reduction in their profit margins.

2. Increased production costs: Agro-allied industries, such as food processing and manufacturing, rely heavily on fuel for power generation and production processes. A higher fuel cost has increased their production expenses.

3. Reduced profitability: Higher fuel costs has lead to reduced production and reduced profit margins for industries, potentially affecting their ability to invest in new technologies, expand operations, or hire new employees.

4. Increased prices of products: producers have passed on the increased costs to consumers through higher prices, potentially reducing demand and affecting sales.

5. Reduced competitiveness: A higher production cost has make agro-allied industries less competitive in the global market, potentially leading to reduced exports and market share.

6. Reduced mechanization and irrigation: Higher fuel costs has lead to reduced use of machinery and irrigation which potentially has decrease efficiency, productivity and crop yield.

7. Reduced production and Job losses: In some cases, the increased costs and reduced profitability has lead to job losses in the agro-allied industries

Alternative Energy: Alternative Energy refers to energy sources other than fossil fuel, these includes all renewable energy sources. There is need to investigate alternative energy sources in order to reduce these negative effect of the fuel subsidy removal on agriculture and general livelihood in Nigeria.

Some Alternative Energy Sources : Solar Energy: This is a popular alternative energy source, especially for those living in rural areas.

Bio Energy: This energy source is derived from plant or animal origin, such as trees, crops, grasses or animal waste. It can be solid biomass from wood, agricultural residues, animal waste, communities waste etc, or liquid fuel from plant oils

Wind Energy: This source of energy is harnessed through wind dynamos, turbines, generators or machines that convert energy into motion.

Hydropower: This source of energy is harnessed from permanent rivers, streams or waterfalls.

Biofue: The most practicable and promising of all the possible alternatives currently available is the bio-fuel obtainable from the plant kingdom.This sustainable energy source has the potential to significantly reduce our reliance on fossil fuels, mitigating climate change and promoting energy security. Being renewable and environment friendly, biodiesel is currently the best substitute for petro-diesel and is accepted worldwide. Supplementing or replacing diesel with biodiesel not only helps in saving fossil fuel, but also in fighting global warming as it generate less carbon monoxide, sulphur and other polluted gasses (Demirbars, 2005). Biofuels which are produced from plant have the potential to liberate Nigeria from over dependence on fuel importation and the rural dwellers from poverty. Nigeria is the most populous country in Africa with a population of 225,082,083 which grows by 2.53 %. The arable land area in Nigeria is 34 million hectares out of which 6.5 million hectares are designated for permanent crops, and 28.6 million hectares for meadows and pastures

Nigeria has a biomass resource of more than 200 billion kg/yr culminating from agricultural wastes, municipal solid wastes, human and animal wastes. The biomass resources of Nigeria include agricultural waste, municipal solid waste, human and animal wastes. These biomasses can be used as feedstocks to produce biofuel in order to complement the energy obtained from other sources. Biofuel in Nigeria can be produced from: sugarcane, oil palm, corn, soyabeans Jatropha, Sun flower among others.

Types of Biofuels: Ethanol: Produced from fermented plant materials like corn, sugarcane etc; Biodiesel: Derived from vegetable oils or animal fats, often used in diesel engines; Biogas: A mixture of methane and carbon dioxide, generated through anaerobic digestion of organic waste.; Synthetic Biofuels: Produced through gasification or pyrolysis of biomass, mimicking traditional fossil fuels.

Benefits of Biofuels Renewable and Sustainable: Biofuels are made from organic matter, which can be replenished quickly, unlike finite fossil fuels.; Reduced Greenhouse Gas Emissions: Biofuels produce significantly less CO2 and other pollutants compared to traditional fuels.; Energy Security: Biofuels can be produced locally, reducing dependence on foreign oil imports.; Job Creation and Economic Growth: The biofuel industry is generating new employment opportunities and stimulating local economies

Challenges and Limitations associated to the use of Biofuel: Land Use for food production versus Fuel production: Large-scale biofuel production can lead to land competition with food crops and ecosystems.; Water and Energy Requirements: Biofuel production can demand significant water and energy resources.**;** Cost and Infrastructure: Widespread adoption of biofuels requires significant investment in infrastructure and technology.

Jatropha Curcas as Case Study: *Jatropha curcas* L a deciduous large shrub that is 3-5 m tall has been recognized as the most suitable oil bearing plant species because of some of its properties. For instance, it has the ability to produce high amount of good quality oil (Openshaw, 2002). The plant is hardy, early maturing, and is able to survive in various agro-climatic zones. In addition, *Jatropha* can control soil erosion and serve as habitat for wildlife. It can be grown successfully on marginal waste or arid land without displacing food crops unlike other sources of bio-fuel which is the major constains associated with the of food crops in producing biofuel (FAO, 2008).In a research carried out by Adeniji et al (2020) on production and yield of Jatropha curcas using organic amendments, it was discovered that a plant can produce up to 20 fruits which will translate to about 60 seeds. Further more about 150ml of oil was extracted from 350g of seeds (Table 2**)**

Table 2: Influence of poultry manure and cowdung on yield of Jatropha curcas

Treatments	Number of fruit/plant	Weight of fruit(g)	Oil yield(ml)/350g of seed
M0	8.25	89.95	158.5
P10	11.75	139.33	161.1
P20	16.75	215.66	163.0
P40	20.75	317.34	159.8
C10	10.75	130.80	159.5
C20	19.27	301.06	158.7
C40	19.00	296.09	162.1

Source: Adeniji et al (2020)

M0: control

P10: Poultry manure @ 10t/ha C10: Cow dung @ 10t/ha

P20: Poultry manure @ 20t/ha C20: Cow dung @ 20t/ha

P40: Poultry manure @ 40t/ha C40: Cow dung @ 40t/ha

Conclusion: The removal of Subsidy has stated by the government will make revenue available to be used in providing amenities in the country. To reduce the hardship caused by Subsidy removal, there should be sensitization on exploration of renewable energy sources there by reducing dependence on fossil fuels.

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Assessment of Gender Roles on Agricultural Extension Programme Delivery to Cassava Farmers in Imo State

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Abstract

Agricultural extension plays a crucial role in disseminating improved technologies and practices to enhance productivity among smallholder farmers. However, the effectiveness of extension services is influenced by gender dynamics. This study assessed the gender roles and challenges faced by male and female extension agents in delivering cassava extension programs to farmers in Imo state, Nigeria. The research employed a descriptive survey design using quantitative and qualitative methods. Data was collected from 150 extension agents (75 males and 75 females) through questionnaires, interviews and focus group discussions. The results revealed significant gender differences in the roles performed by extension personnel. Female agents were more involved in mobilizing and reaching out to women farmers due to shared gender identities. In contrast, male agents dominated technical advisory roles like plot inspections and provision of technical services, reflecting gender stereotypes. The perceived effectiveness of extension delivery methods also varied by gender, with female agents rating higher on interactive approaches than mass media channels. Regression analysis showed that the role of women farmer mobilization performed by female agents significantly influenced program effectiveness. Both genders faced constraints like limited training and resources, but female agents additionally faced challenges related to institutional gender biases, social norms and work-life balance issues. The study concludes that promoting gender equity, overcoming stereotypes and adopting gender-sensitive strategies within extension systems is crucial for effective program delivery to male and female cassava farmers. Based on the findings of this research work, it was recommended that Gender mainstreaming in extension programs should be strengthened to understand and cater to the distinct needs, constraints and preferences of male and female farmers.

Keywords: Gender Role, Agricultural Extension, Programme Delivery, cassava farmers.

Introduction: Cassava is an important staple crop in many parts of Africa, including Nigeria. It is processed into various food products and is a major source of carbohydrates and income for smallholder farmers (Manfre et al., 2013). However, cassava yields in Nigeria remain below potential. One of the factors identified as limiting productivity is inadequate extension services and technology transfer to farmers (Khursheed et al. 2020). Agricultural extension is a vital service for advancing rural progress and agricultural development. It serves as an instrument to enhance the sustainability of farming systems, promote diversification of agricultural production systems, foster food security, and assist farmers in adapting to changing markets (Saito and Weidemann, 1990, Kuyper and Schneider, 2022). In this regard, extension advisors act as important catalysts for economic growth in both developed and developing countries (Aker, 2021). Agricultural extension delivery includes the supply of modern inputs such as seeds, fertilizers, and other associated inputs to farmers, which is essential for promoting agriculture among millions of small-scale farmers in Nigeria (Abegunde, 2020).

Gender assessment is a tool for understanding and gaining insight into the activities of both males and females in society, the opportunities and challenges they face in performing their activities. Gender, as a concept in social sciences, defines the roles and activities of males and females. According to Olawoye et al. (2002), gender is a social construct that identifies the socially expected rights, responsibilities, and obligations of males and females. This underscores the imperative to firmly establish a gender perspective in extension program delivery to contribute to achieving agricultural extension goals. Across many African countries, it has been observed that a larger percentage of extension personnel are male, while the agricultural workforce is predominantly female farmers. As such, the insufficient number of female extension officers is often cited as a challenge to improving the delivery of agricultural services to women farmers and achieving a food-secure society (Mamun-ur-Rashid et al., 2017). Increasing the role of women as extension workers can help boost agricultural productivity, which is and will continue to be the economic cornerstone for African countries, recognizing its considerable contribution to local and export earnings in these countries (Msuya et al., 2017).
In agricultural extension, women stand side by side with men. However, women's prospects have not been fully explored, and their services and capabilities are not equitably rewarded (FAO, 2019; Khursheed et al. 2020). Despite their important role and extensive contribution to agricultural production and food security, women extension advisors and village level paraprofessionals (indigenous people who work as change agents at a village level) are poorly incorporated into mainstream extension activities and operate on an unequal basis with men (FAO, 2019). They are often said to be underpaid as compared to their men counterparts (FAO, 2019). According to Kilic et al (2015), the sources of gender gaps vary across developing and developed countries. Executing extension activities or priorities without the participation of female extension personnel and female farmers risk having negative impacts on the attainment of food security, rural livelihoods, sustainable agriculture and economic development (Manfre et al., 2022).

Objective of the Study: The study therefore, examines the gender roles on Agricultural extension programme delivery to cassava farmers in Imo state; . It specifically aims to;; examine the social-economic characteristics of agricultural extension agents.; describe the different gender roles in extension programme delivery on cassava production.; determine the effectiveness of the roles perform by male and female extension agents.
determine the effect of socio-economic characteristics of the agents on extension programme delivery.

Research Methodology: Research Design: The study utilized a descriptive and inferential survey research design to describe the gender dynamics in extension service delivery. Both qualitative and quantitative data were collected. **Study Area**: The study was carried out in Imo state, located in the south-eastern agro-ecological zone of Nigeria. Imo state has high cassava production potential but yields remain below attainable levels. **Population and Sampling**: The target populations were male and female extension agents in Imo state. A random sampling technique was used to distribute questionnaire to the extension agents at their state headquarter in Owerri.

Data Collection: Primary data were collected using pre-tested interview schedules and a structured questionnaire. Focus group discussions were also conducted to get qualitative insights. Secondary data were obtained from published and unpublished sources.

Data Analysis: Both quantitative and qualitative data analysis methods were employed. Quantitative data were analyzed using descriptive (frequencies, percentages) and inferential statistics like regression analysis.

Results and Discussion: This section presents the results and discussion from the study on assessment of gender roles of extension agents in programme delivery to cassava farmers in Imo state

The results provide insights into the roles and perspectives of male and female extension agents, as well as the constraints faced in programme delivery.

Table 4.1: Socio economic Distribution of the male and female Respondents

Age Group	Male (n=75)	Female (n=75)	Total (N=150)	Percentage (%)
20-30 years	10 (13%)	15 (20%)	25	16.7%
31-40 years	25 (33%)	30 (40%)	55	36.7%
41-50 years	30 (40%)	20 (27%)	50	33.3%
51-60 years	10 (13%)	10 (13%)	20	13.3%
Total	75 (100%)	75 (100%)	150	100%
Education Level	**Male**	**Female**	**Total**	**Percentage (%)**
Secondary school	5 (7%)	10 (13%)	15	10%
Diploma	10 (13%)	15 (20%)	25	16.7%
Bachelor's degree	50 (67%)	45 (60%)	95	63.3%
Master's degree	10 (13%)	5 (7%)	15	10%
Total	75 (100%)	75 (100%)	150	100%
Years of Experience	**Male**	**Female**	**Total**	**Percentage (%)**
0-5 years	15 (20%)	30 (40%)	45	30%
6-10 years	25 (33%)	20 (27%)	45	30%
11-15 years	20 (27%)	15 (20%)	35	23.3%
>15 years	15 (20%)	10 (13%)	25	16.7%
Total	75	75	150	100%

Field survey 2024

Table 4.1 presents the socio-economic distribution of the 150 extension agents surveyed, comprising 75 males and 75 females in identifying the key trends and differences between the segregated gender of the extension agents. The result revealed that majority of both male (73%) and female (67%) agents were in the 31-50 years age bracket. However, a higher proportion of females (60%) were in the younger 20-40 years range compared to males (46%, this indicates more recent entry of women into extension services, aligning with trends of increased female participation in extension services (Adekoya & Tologbonse, 2005). On the side of educational level, most agents held a bachelor's degree (67% males, 60% females). However, more females had lower secondary (13%) and diploma (20%) qualifications compared to males (7% and 13% respectively). This corroborates studies showing persisting gender gaps in access to higher education, especially in rural areas (Okunlola et al., 2016).
Looking at the years of experience, Male agents tended to have more years of experience on average compared to females. 53% of males had over 10 years of experience versus only 33% of females, 40% of females were relatively new entrants with 0-5 years of experience, compared to 20% of males. The higher average experience of males reflects the historically male-dominated nature of extension services (Rivera & Alex, 2004).

In summary, the socio-economic profile reveals persisting gender inequities, with women extension agents being younger, less educated, and having fewer years of experience compared to their male counterparts. Addressing these gaps through equal opportunities in education, recruitment, and career development is crucial for enhancing gender parity and performance in extension services.

Table 4.2: Multiple Responses on Gender Differences in Roles and Responsibilities of the extension agents

Roles	Male Frequency and Percentage	Female Frequency and Percentage
Women farmer mobilization	15 (10%)	135 (90%)
Plot inspections	140 (93%)	10 (7%)
Provision of technical advice	122 (81%)	38 (19%)
Farmer trainings	85 (57%)	65 (43%)
Information dissemination	81 (54%)	69 (46%)
Facilitating inputs/credit	80 (53%)	70 (47%)
Farmer feedback	50 (33%)	100 (67%)
Demonstrations/trials	90 (60%)	60 (40%)

Field survey 2024

Table 4.2 presents the survey results on gender differences in the roles and responsibilities performed by male and female extension agents. A stark difference is observed in the role of mobilizing and outreaching to women farmers. 90% of female extension agents reported being involved in this activity, compared to only 10% of male agents. This aligns with previous studies that have found female extension workers are more effective in connecting with women farmers due to shared gender identities and fewer socio-cultural barriers (Manfre et al., 2013; Ragasa et al., 2013). Male agents dominated technical roles like plot inspections (93% for males vs. 7% for females) and provision of technical advice (81% vs. 19%). This disparity likely stems from persisting gender norms and biases that associate technical competencies more with men (Chapman & Slaymaker, 2002; Rivera & Alex, 2004).

For farmer training and information dissemination roles, both genders had relatively high involvement, though a higher percentage of males (57% and 54% respectively) compared to females (43% and 46%). Input/Credit Facilitation and Feedback: Female agents showed higher participation in facilitating access to inputs/credit for farmers (47% vs. 53% for males) and collecting feedback from farmers (67% vs. 33% for males).

The findings reveal how gender influences the types of responsibilities undertaken by extension personnel, shaped by socio-cultural factors and institutional biases. Promoting gender equity by overcoming stereotypes and building technical capabilities of female agents is crucial for inclusive and effective extension services.

Table 4.3: Multiple responses on Perspectives on Program Delivery Methods by Gender

Program Delivery Method	*Male Agents*		*Female Agents*	
	Utilizing Method (%)	Effectiveness Rating	Utilizing Method (%)	Effectiveness Rating
Farmer Field Days/Demos	70	4.5	75	4.7
Group Training Sessions	65	4.2	70	4.4
Individual Farm Visits	60	3.8	65	4.1
Radio/TV Programs	65	3.8	40	2.9
Print Materials	65	3.5	40	2.7

Researcher Computation, 2024

Based on the perceived effectiveness ratings, an interesting divergence emerged in how male and female agents rated the effectiveness of different delivery methods on a 1-5 scale. Both genders viewed interactive approaches like farmer field days (4.5 for males, 4.7 for females) and group trainings (4.2 for males, 4.4 for females) as highly effective ways to engage farmers. However, male agents gave significantly higher average ratings for the effectiveness of radio/TV programs (3.8) and print materials (3.5) compared to the lower ratings of 2.9 and 2.7 respectively by female agents. This perception gap likely stems from the lower accessibility and receptiveness of female farmers to mass media extension delivery, as noted by Mudukuti & Miller (2002). Based on their field experiences, female extension agents found these one-way communication channels less impactful compared to interactive approaches. The findings highlight how gender norms, preferences and realities shape the perspectives of male and female extension personnel on optimal program delivery strategies (Ragasa, 2014). Considering these gender perspectives is vital for inclusive agricultural extension planning.

Table 4.4: Regression Analysis of Gender Differences in Roles and Responsibilities

Variable	Coefficient	Standard Error	t-statistic	p-value
Gender (1=male, 0=female)				
Women farmer mobilization	-0.20	0.05	-4.00	0.001***
Plot inspections	0.15	0.04	3.75	0.002***
Provision of technical advice	0.15	0.06	2.50	0.018**
Farmer trainings	0.10	0.07	1.43	0.159
Information dissemination	0.10	0.05	2.00	0.054*
Facilitating inputs/credit	0.10	0.06	1.67	0.105
Farmer feedback	0.05	0.04	1.25	0.218
Demonstrations/trials	0.10	0.05	2.00	0.054*

Note: ***p<0.01, **p<0.05, *p<0.1

In order to ascertain the effect of the roles of the extension agents as segregated by gender on program delivery, the regression analysis explained that women farmer mobilization showed to be significant at the three level of the critical value, the finding that female extension agents are more involved in women farmer mobilization aligns with past research showing that women extension workers are often better at reaching and engaging women farmers compared to men (Manfre et al., 2013). Social and cultural norms in many developing country contexts restrict interactions between women farmers and male extension agents, whereas female agents face fewer constraints in interacting with women farmers and understanding their needs (Ragasa et al., 2013). Studies from Nigeria (Adekoya & Tologbonse, 2005), Kenya (Kiptot & Franzel, 2015), and India (Glendenning et al., 2010) have also reported greater effectiveness of female extension agents in serving women farmers.

The greater participation of male extension agents in technical roles like plot inspections and provision of advisory services reflects gender stereotypes and biases that associate men with higher technical aptitude and competence (Rivera & Alex, 2004). Women extension workers often face discrimination and obstacles in skills training, promotion and assignment of complex technical tasks (Chapman & Slaymaker, 2002). Ensuring equal access to professional training and capacity building can help address these gender gaps in technical capabilities (FAO, 2017). Evidence from Bangladesh and India shows that with adequate training, female extension agents can perform technical advisory roles just as effectively as their male counterparts (Ragasa et al., 2013).

The study findings add to the body of literature on the influence of gender norms, biases and stereotypes on the responsibilities assigned to extension agents. As argued by Rivera (2001), agricultural extension organizations need to be more gender-sensitive in designing job roles and providing equal opportunities to male and female workers. Promoting gender equity within extension systems is vital for ensuring effective service delivery to both male and female farmers.

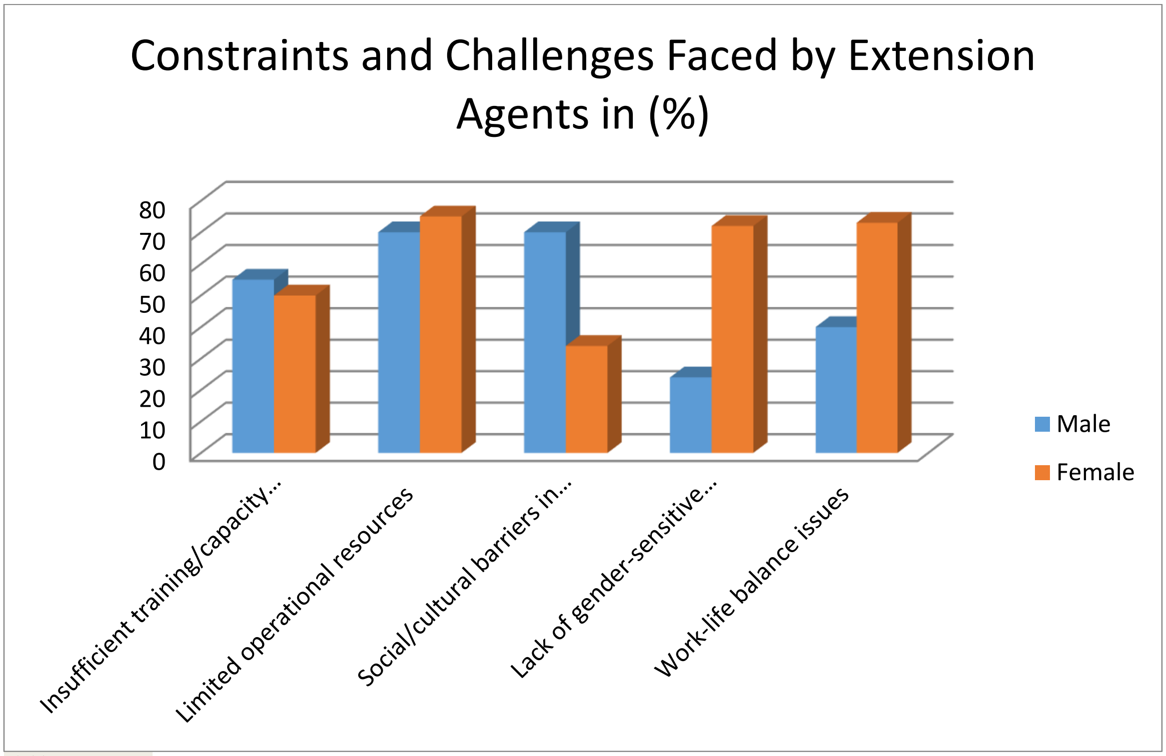
Table 4.5: the effect of Socio-economic characteristics of the extension agents on gender roles

Variable	Coefficient	Standard Error	t-value	P-value
Constant	2.15	0.24	8.96	0.000
Age	-0.02	0.01	-2.55	0.011*
Education	0.08	0.04	1.98	0.048*
Experience	-0.12	0.05	2.61	0.009*

R-squared: 0.57
F-statistic: 18.22
Significance: 0.000
***, **, * indicate significance at 1%, 5% and 10% respectively

The results indicated that the model explains 57% of the variation in gender roles. Variables like education and experience positively and significantly affect gender roles. On the other hand, age had a negative effect. This demonstrates the importance of socioeconomic factors in explaining gender differences. The model provides useful insights on areas of focus to promote equitable extension delivery.

Chart 1: Multiple responses on Constraints and Challenges Faced by Extension Agents



Field survey, 2024

The chart presents data on the constraints and challenges faced by male and female extension agents., Both male (55%) and female (50%) extension agents reported facing constraints due to lack of sufficient training and capacity building opportunities. Continuous training is crucial for agents to update their knowledge and skills in new agricultural technologies and extension methods. Similarly, a high proportion of both male (70%) and female (75%) agents cited limited operational resources as a major constraint. This could include inadequate transport, demonstration materials, information and communication tools etc., hindering their ability to effectively reach out to farmers. 70% of male agents reported facing social/cultural barriers in accessing and interacting with farmers, compared to only 34% of female agents. This likely reflects gender norms that make it easier for female agents to approach female farmers. Similarly, only 24% of male agents perceived lack of gender policies as a constraint, while 72% of female agents highlighted this as a major challenge.

The data clearly shows that while some constraints like limited resources affect both genders, female extension agents face distinct challenges related to institutional gender biases, social norms and household responsibilities.

Conclusion: Based on the findings of this research work, it was concluded that there are significant gender differences in the roles and responsibilities undertaken by male and female extension agents in Imo State, shaped by socio-cultural norms, institutional biases and gender stereotypes. Female extension agents are more effective in mobilizing and reaching women farmers due to shared gender identities and fewer socio-cultural barriers compared to male agents. Similarly, Male agents dominate technical advisory roles like plot inspections and provision of technical advice, reflecting biases that associate technical competencies more with men. However, both genders face constraints like limited training, operational resources, but female agents additionally face distinct challenges related to institutional gender policies, social norms and work-life balance issues. And lastly, Socio-economic factors like education and experience significantly influence the gender roles and effectiveness of extension agents.

Recommendations:: Gender equity should be promoted within extension systems by providing equal training, capacity building and career advancement opportunities for both male and female agents.;Gender stereotypes and biases should be addressed through sensitization programs and develop gender-sensitive policies within agricultural extension organizations.; Adequate operational resources and enabling working conditions should be provided, especially measures to support work-life integration for female agents.;Gender mainstreaming in extension programs should be strengthened to understand and cater to the distinct needs, constraints and preferences of male and female farmers.;Conduct further research on intersections of gender with other social identities like age, ethnicity, disability etc. in shaping extension experiences.

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Determinants of Farm Income among Vegetable Farmers in Asa Local Government Area of Kwara State, Nigeria

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Abstract

The potential of vegetable farming in promoting rural household income is crucial in improving rural livelihoods in developing countries. This study examined the determinants of farm income among vegetable farmers in Asa Local Government Area of Kwara State, Nigeria. The study employed data from a survey of 120 vegetable farmers to establish the factors influencing farm income among the vegetable farmers in the study area. The results showed that the majority of the farmers are female, married, fairly educated, have a low farm size, and 80% of them have over 10 years of farming experience. The results showed that the factors influencing the farm income of vegetable farmers at the household level were identified to include; vegetable production in terms of its output at a 5% level of significance, education of the household head, the farm size, and the farming experience at 1% level of significance each. Better education for household heads, increased farm size, and more experience in vegetable farming are therefore recommended to increase the farm income of vegetable farmers in the study area.

Keywords: Farm Income, Vegetables, Farmers, Regression, Kwara State

Introduction*:* Vegetable crops are produced in different agroecological zones of Nigeria at subsistence and commercial levels thereby providing employment and income to farmers. The potential of vegetable production in improving the livelihood of farmers has made them produce it for their consumption, and also for sale (Asadu *et al*., 2018). Therefore, vegetable production can be embarked upon to enhance household income and improve food nutrition and security in developing nations. Vegetable production provides more employment per hectare of land, than other agricultural enterprises. Also, it serves as a means of livelihood for many intermediaries such as wholesalers, retailers, and farm agents who are involved in its value chain and responsible for its movement from the farmers to the consumers (FAO, 2020). Thus, vegetable production has the propensity to ensure food security and limit the problem of malnourishment, and the high poverty rate among rural people (Mukaila *et al*., 2022; Imathiu, 2021).. Vegetables require little production inputs to be grown, contain antioxidants and phytochemicals, and are rich in vitamins and minerals which help to supply the body with nutrients to support a healthy life (Mukaila *et al*., 2021).

In Sub-Sahara Africa, Nigeria inclusive, fruit vegetable crops such as tomatoes, okra, and pepper; and leafy vegetables such as plumed or silver cock's comb, green amaranth, cabbage, jute, water leaf, fluted pumpkin, and melon among others are widely cultivated by small scale farmers and contributes significantly to household income and the nutritive diet of many households (Mukaila *et al*., 2022; FAO, 2020). Thus, vegetable production has the propensity to ensure food security and limit the problem of malnourishment, and the high poverty rate among rural people (Mukaila *et al*., 2022; Imathiu, 2021). Due to the increasing involvement of smallholder farmers in the commercial production of vegetables as an economic crop, and in generating employment and livelihoods, however, there is a need to investigate its contribution to household income and livelihood. For this reason, this study aimed to fill the research gap by assessing the effect of vegetable production on rural households' income of smallholder farmers in Asa Local Government Area (LGA) of Kwara State. Specifically, the study described the socioeconomic characteristics of the vegetable farmers; and investigated the determinants of vegetable farmers' income in the study area.

Materials and Method: This study was conducted in Asa LGA of Kwara State, Nigeria. Its headquarters is Afon. The LGA is located in the western part of the State. It covers a total area of 1,286 square kilometers and a population of 126,435 as of the 2006 census. Asa LGA has two distinct seasons: the rainy and dry seasons and it is known for cultivating a wide range of crops such as rice, corn, coconut, and vegetables. Trading, cloth weaving, and dyeing are other key economic enterprises in the area (Kwara State Government, 2020). Most inhabitants in the area are predominantly farmers and are involved in subsistence agriculture (Adio *et al*., 2022; KWSG, 2020). The main arable crops cultivated are rice, guinea corn, millet, maize, yam, cowpea, soybeans, cassava, and vegetables like *amaranthus* (tete), pepper, tomato, okra, melon, *Corchorus olitorus* (ewedu), and spinach. The main tribe in the local government area is the Yoruba ethnic group (Adio *et.al*., 2022).

The population for this study comprises all vegetable farmers in Asa LGA. A 3-stage sampling technique was used to select the respondents in the study area. Firstly, Asa LGA was selected on purpose due to the area's predominance and abundance of vegetable farmers. Secondly, six communities were randomly selected from Asa LGA, they were; Otte, Lasoju, Balla, Afon, Ogele, and Laduba. Thirdly, from each of the six communities, 20 vegetable farmers were randomly selected, giving a total of 120 respondents. Data were obtained with the aid of a well-structured and pretested questionnaire. Descriptive statistics and the multiple regression model were used to analyze information obtained from the respondents. Descriptive statistics, including frequency counts and percentages, were used to describe the socio-economic characteristics of respondents while the determinant of farm income was modeled using the ordinary least squares (OLS) regression method. The model was implicitly expressed as:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + e_i$$

Where: Y = Annual income (₦);

B_0 = Intercept; B_i = Slope (coefficient) of the independent variables; X_i = Sets of explanatory variables; and e_i = Error term.

The explanatory variables are specified as follows: X_1 = Vegetable output (Kg/Ha); X_2 = Education of household head (Years); X_3 = Farm size (Ha); X_4 = Household size (Numbers);

X_5 = Farming experience (Years); and U = Error term.

Results and Discussion: Socio-economic characteristics of the respondents The results presented in Table 1 revealed that female farmers (71.67%) dominated vegetable farming in the study area. This finding conforms with the study of Mukaila *et al*., (2022) that the few males involved in vegetable production in the study area usually grow fruit vegetables such as okra and tomatoes, while the female farmers usually grow leafy vegetables.

According to Oluwalana *et al*., (2019), the age of the respondents is an important factor that affects their level of productivity by influencing the level of physical work on the farm. The ages of the vegetable farmers ranged between 31 and 60 years. The majority of the vegetable farmers were within the age bracket of 51-60 years and this indicates that they were already aging and getting old. Also, the majority of the farmers were fairly educated with 35.83%, 19.17%, and 7.5% having attained primary, secondary, and tertiary education respectively. Only 13.33% had a Quranic form of education, while 24.17% had no formal education. This agrees with Oluwalana *et al*., (2019) and Jatto *et al*., (2020) that farmers had a minimum level of education that could enable them to improve their knowledge and rate of skill acquisition about farming activities.The result further showed that 71.67% of the vegetable farmers were married, 5.83% were single, and 22.50% were widowed, divorced, and/or separated. This shows that most of the farmers are married, and being married is believed to lead to an increase in the production and total output of vegetables in the study area as a result of the potential of having a large household size (Adio *et al*., 2020). The total household size of the respondents includes the fathers, the wives, children, and all other dependents. More than half (54.17%) of the respondents comprised 5-8 5-8persons, this large household size could assist them in the production of vegetables and other farming activities.

Farm sizes varied with 80.00% of the respondents cultivating less than 2 hectares while 16.67% operated a farm size of between 3 and 4 hectares while the remaining 3.33% cultivated more than 4 hectares. This finding is an indication that most of the farmers cultivated on low hectares of farmland. The farming experience of the vegetable farmers ranged between 1 and 20 years with most of them (80%) having more than 10 years of experience (Table 1). The many years of farming experience shows that the farmers are relatively experienced which could indicate some level of specialization that would help in cost minimization and achieving greater efficiency (Oluwalana *et al*., 2019).

About 78.33% of the respondents have access to credit facilities. This is in contrast with the findings of Mukaila *et al*., (2022) who reported a low access to credit among vegetable farmers. The high level of access to credit facilities could be attributed to loan offers from FINTECH companies among mobile communication device users. The total household monthly income distribution of the respondents shows that the majority (54.17%) of the respondents earned between ₦41,000 and ₦60,000 monthly while a few of them (8.33%) earned above ₦80,000 per month. Lastly, Table 1 also shows that 51.67% of the respondents engaged in farming as their primary occupation. The result is similar to findings by Oluwasola (2015) among vegetable farmers in Oyo State. The remaining 47% had other jobs and were probably into vegetable farming to augment their income. About 23% were into trading, 15.83% were artisans while the remaining 9.17% were salary earners.

Table 1: Socio-economic characteristics of the respondents

Variables	*Category*	*Frequency (n=120)*	*Percent (%=100)*
Gender	Female	86	71.67
	Male	34	28.33
Age of household head	31-40	13	10.83
	41-50	26	21.67
	51-60	46	38.33
	Greater than 60	35	29.17

Education of household head	No Formal	29	24.17
	Quranic	16	13.33
	Primary	43	35.83
	Secondary	23	19.17
	Tertiary	9	07.50
Marital status	Single	7	05.83
	Married	86	71.67
	Widowed/Separated	27	22.50
Household size	1-4	36	30.00
	5-8	65	54.17
	9-12	19	15.83
Farm size (Ha)	1-2	96	80.00
	3-4	20	16.67
	Greater than 4	04	03.33
Farming experience	1-10	24	20.00
	11-20	65	54.17
	Greater than 20	31	25.83
Access to credit	With access	94	78.33
	Without access	26	21.67
Total household income/month (₦)	21,000-40,000	25	20.83
	41,000-60,000	65	54.17
	61,000-80,000	20	16.67
	Greater than 80,000	10	08.33
The primary occupation of household head	Farming	62	51.67
	Trading	28	23.33
	Artisans	19	15.83
	Employed	11	09.17

Field Survey, 2024

Determinants of farm income

The determinants of farm income among the sampled vegetable farmers were analyzed using an Ordinary Least Squares regression analysis to model the farm income as a function of the output realized from vegetable production, the level of education of the household head, the farm size, the household size, and the farming experience. The regression estimate is shown in Table 2.

The Linear production function was chosen as the lead equation which was based on *a priori* expectation of the sign of regression coefficients, the significance of the independent variables as stated by their t-values, the magnitude of the coefficient of multiple determinations (R^2), and the significance of the overall production function as stated by the f-value. The (R^2) of the fitted function is 0.584, this indicates in the function that the independent variables in the model explain 58.4% of variability in the farm income of vegetable production. The F value of 28.46 was highly significant at a 1% level indicating a well-fitted model.

Table 2 shows that the coefficients of all independent variables are positive in compliance with *a priori* expectations. The result from the OLS estimates of determinants of farm income also shows that vegetable production in terms of its output is significant at a 5% level of significance. A 1% increase in vegetable output will increase the farm income by 0.18%. Education of the household head, farm size, and farming experience are significant at a 1% level of significance each meaning that, a 1% increase in the level of education, farm size, and farming experience will increase farm income by 0.24%, 0.22%, and 0.21% respectively. This indicates that the level of education, farm size, and farming experience have a positive impact on the farm income of vegetable farmers. The level of significance of education shows the importance of education in vegetable production, this could help the farmers adopt better technology and acquire better skills. Farming experience affords the farmers to gain better knowledge of the production and could result in efficient resource management and improved production.

Table 2: OLS estimates of determinants of farm income

Variables	Coef.	t-value
Vegetable output	0.182**	1.864
Education (Year)	0.244***	2.631
Farm size	0.221***	2.423
Household Size	0.036	0.416
Farming Experience	0.214***	2.334
Constant	98.817	0.958
R^2	0.584	
F value	28.456	

Note: The dependent variable is the farm income of vegetable farmers. **, *** indicate coefficient significance at 5% and 1% levels respectively

Conclusion: The study has shown that the factors influencing the farm income of vegetable farmers at the household level were identified to include; vegetable output, education of the household head, farm size, and farming experience. These factors play a positive and significant role in increasing the farm income of vegetable farmers in the study area. Policies that would promote these factors should be encouraged. Better education for household heads, increased farm size, and more experience in vegetable farming should be promoted as these tend to increase the farm income of vegetable farmers in the study area.

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Addressing the Naira's Free-fall in the Wake of Energy Subsidy Removal: A Policy Roadmap for Nigeria's Democracy

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Abstract

This research review paper explores the complex relationship between the removal of energy subsidies and the depreciation of the Nigerian naira under the current democratic government. Energy subsidies have long been a point of contention in Nigeria, with successive governments grappling with the economic, social, and political implications of their removal. The removal of energy subsidies has been touted as a necessary measure to free up government revenue for development projects, but it has also triggered inflation, social unrest, and a free fall of the naira in the foreign exchange market. This review paper examines the historical context of energy subsidies in Nigeria, their impact on the economy, and the theoretical and conceptual frameworks that explain the interaction between subsidy removal and currency depreciation. It also delves into the current administration's policies on subsidy removal, the challenges posed by the free fall of the naira, and potential strategies for mitigating these issues. The paper concludes with recommendations for sustainable economic reform, focusing on balancing fiscal responsibility with social equity in a democratic context.. ***Keywords**: Currency; Devaluation; Energy; Economy; Subsidy removal; Nigeria*

Introduction: Energy subsidies in Nigeria have been a contentious issue for decades, deeply entrenched in the socio-economic fabric of the country (Jesuola, 2024). Introduced initially to alleviate the burden of high energy costs on consumers and protect the poor, these subsidies have since become a drain on the national budget (Mbanefo, 2024). According to the Nigerian National Petroleum Corporation (NNPC), subsidies cost the government billions of dollars annually, diverting funds that could be used for critical infrastructure development, healthcare, and education (Fyneroad, 2024). The debate over whether to remove energy subsidies has been reignited under the current democratic government, particularly in the context of Nigeria's deteriorating fiscal position and the free fall of the naira. The naira, Nigeria's official currency, has experienced significant depreciation over the past few years, driven by several factors, including low oil prices, dwindling foreign reserves, and economic mismanagement. The removal of energy subsidies is seen by many as a necessary step to stabilize the economy, but it has also led to increased inflation, higher living costs, and widespread public discontent.

The issue of energy subsidies in Nigeria remains a highly polarizing topic, with deep implications for the country's economic stability, social welfare, and political landscape. Initially introduced to make energy more affordable for Nigerians, particularly the poor, these subsidies have become a fiscal burden that consumes a substantial portion of the national budget (NNPC, 2023). The Nigerian government spends billions annually to keep fuel prices artificially low, even as the country faces pressing challenges such as decaying infrastructure, underfunded healthcare systems, and inadequate educational services (Ogundele and Ibrahim, 2024). In recent years, the debate over the removal of energy subsidies has gained momentum, largely due to Nigeria's deteriorating fiscal position and the weakening of the naira. The cost of maintaining subsidies has escalated with the global rise in oil prices, further straining government finances. According to some analysts, Nigeria is spending as much on fuel subsidies as it is earning from crude oil exports, leading to a fiscal imbalance that threatens the country's economic sustainability (Adewale and Yusuf, 2023). The Nigerian government's democratic administrations have repeatedly attempted to remove these subsidies, viewing it as a necessary measure to reduce the fiscal deficit and ensure long-term economic stability. In particular, President Bola Tinubu's administration has taken steps toward subsidy removal, citing the urgent need to free up resources for infrastructure development and social services (Akinola, 2023). However, these moves have consistently been met with widespread public opposition, as fuel price increases lead to higher inflation, rising living costs, and a disproportionate impact on low-income households (Adamu and Hassan, 2024). The removal of energy subsidies has macroeconomic implications for Nigeria. On one hand, it is seen as a way to reduce economic distortions, encourage investment in the energy sector, and address the inefficiencies caused by subsidized fuel prices, which often lead to smuggling and market distortions (Usman and Garba, 2023). Additionally, it could help curb the large-scale corruption that has historically plagued the subsidy system, where billions of dollars were reportedly siphoned off through fraudulent claims by oil marketers (Bello and Musa, 2023).

On the other hand, the immediate effects of subsidy removal are often felt by ordinary citizens, as the increase in fuel prices leads to higher transportation costs, which ripple through the economy, affecting the prices of goods and services (Ogunleye and Salisu, 2023). For a country where a significant portion of the population lives below the poverty line, these price hikes exacerbate economic inequality and fuel social unrest. The Nigerian Labour Congress (NLC) and other civil society groups have been vocal in their opposition, arguing that without adequate social safety nets, removing subsidies will disproportionately harm the most vulnerable populations (Idris and Lawal, 2024).

The depreciation of the naira has further complicated the debate. The weakening of Nigeria's currency, driven by a combination of low oil prices, dwindling foreign reserves, and macroeconomic mismanagement, has increased the cost of imported goods and services, further fueling inflation (Olawale and Ajiboye, 2023). As the cost of living rises, public tolerance for subsidy removal diminishes, placing the government in a difficult position of balancing fiscal responsibility with social stability.

This paper aims to explore the intersection of energy subsidy removal and the free fall of the naira, providing a comprehensive analysis of the economic and political factors at play. The review will also highlight the potential way forward for Nigeria, focusing on the role of the current democratic government in managing the delicate balance between fiscal austerity and social welfare. Consequently, the specific objectives are as follows:To assess the historical context of energy subsidies in Nigeria.; To assess the impact of subsidy removal on the economy.; To assess the role of the democratic government.; To highlight the potential way forward.

Theoretical Framework; To understand the implications of energy subsidy removal and the depreciation of the naira, it is essential to ground the analysis in relevant economic theories. Two key theories provide the foundation for this discussion: the theory of subsidies and the theory of exchange rates.

Theory of subsidies; The economic theory of subsidies suggests that government intervention in the form of financial aid to producers or consumers is intended to lower the cost of goods or services (Sambo & Sule, 2024). In the context of energy subsidies, governments typically provide financial support to energy companies, allowing them to offer products like fuel or electricity at below-market prices. This intervention is often justified by the need to ensure affordability for the population (Chukwunonso *et al*., 2024), particularly in developing economies where energy poverty is prevalent.

However, subsidies can lead to inefficiencies in the market by distorting price signals. In the case of Nigeria, the government's long-standing fuel subsidy program has led to a situation where energy prices do not reflect the true cost of production, leading to overconsumption, inefficiency, and waste. Furthermore, subsidies represent a significant fiscal burden on the government, diverting resources away from other critical areas of the economy. The removal of subsidies is thus seen as a necessary corrective measure to restore market efficiency and reduce fiscal deficits.

Research Methodology: In generating a useful insight for this study, policy documents of Nigerian government, international organizations and academic articles/research papers were analysed to understand the official rationale behind subsidy removal and the strategies proposed for mitigating the negative impact on the economy. Below are the content analyses of the used policy documents, i.e., secondary data:

1. **Government reports and policy documents**: These include budget reports, economic recovery plans, and subsidy reform policies from the Ministry of Finance, the Nigerian National Petroleum Corporation (NNPC), and the Central Bank of Nigeria (CBN).
2. **Academic articles and research papers**: Peer-reviewed journal articles, working papers, and economic analyses related to energy subsidies, fiscal policy, and currency depreciation in developing economies, specifically Nigeria, were reviewed.
3. **International financial institution reports**: Data from the International Monetary Fund (IMF), the World Bank, and other relevant organizations that monitor economic trends and provide policy advice for Nigeria.
4. **Historical data and statistics**: Historical economic data such as inflation rates, foreign exchange reserves, naira exchange rates, and fuel price fluctuations obtained from institutions like the Nigerian Bureau of Statistics (NBS), the World Bank, and IMF databases were synthesized.

Results and Discussion: Historical context of energy subsidies in Nigeria

Nigeria's energy subsidy program has a long history, dating back to the 1970s when the government sought to shield citizens from the volatility of global oil prices (Esekpa *et al*., 2024). At the time, Nigeria was a major oil exporter, and the government's revenue was heavily dependent on oil exports. The subsidies were justified as a means of redistributing the country's oil wealth to its citizens, ensuring that even the poorest Nigerians could afford fuel and electricity (Idris *et al*., 2024). Over time, however, the subsidy program became a significant drain on government resources. According to a 2020 report by the World Bank, Nigeria spent over $5 billion annually on fuel subsidies, representing a significant portion of the national budget (Jesuola, 2024). This spending crowded out investment in critical infrastructure, education, and healthcare, contributing to the country's slow economic development.

Despite several attempts to remove or reduce subsidies, successive governments have faced stiff opposition from the public and labor unions, leading to widespread protests and strikes (Afunugo & Chukwukamma, 2024). The most notable of these was in 2012 when the government of President Goodluck Jonathan attempted to remove fuel subsidies, leading to the Occupy Nigeria movement (Joshua *et al*., 2024). The protests forced the government to partially reinstate the subsidies, highlighting the political sensitivity of the issue.

The impact of subsidy removal on the economy: The removal of energy subsidies is often seen as a necessary step to restore fiscal discipline and promote economic growth (Njoku *et al*., 2024). In theory, subsidy removal should lead to more efficient resource allocation, as prices reflect the true cost of production (Aigbe & Oshoma, 2024). This should encourage investment in the energy sector, leading to increased supply and lower prices in the long run.

However, in the short term, the removal of subsidies can have significant negative effects on the economy. In Nigeria, the removal of fuel subsidies has led to a sharp increase in the price of fuel, which in turn has driven up the cost of transportation, food, and other goods (Aruofor, & Ogbeide, 2024). This has contributed to inflation, reducing the purchasing power of Nigerians and increasing the cost of living.

The inflationary effects of subsidy removal are compounded by the depreciation of the naira (Oboro & Agbamu, 2024). As fuel prices rise, the demand for foreign exchange to import fuel increases, putting further pressure on the naira (Aruofor, & Ogbeide, 2024). The Central Bank of Nigeria (CBN) has struggled to stabilize the currency, with the naira losing over 30% of its value in 2023 alone (Ogundele and Ibrahim, 2024). This depreciation has made it more expensive for Nigeria to import goods, leading to higher inflation and a further decline in living standards.

The role of the democratic government: The current democratic government, led by President Bola Tinubu, has taken steps to remove energy subsidies as part of a broader economic reform agenda. In 2023, the government announced the full removal of fuel subsidies, citing the need to reduce the fiscal deficit and free up resources for development projects. This move was welcomed by international financial institutions like the International Monetary Fund (IMF) and the World Bank, which have long advocated for the removal of subsidies. However, the removal of subsidies has also led to widespread public discontent, with many Nigerians protesting the higher cost of living. The government has attempted to mitigate the social impact of subsidy removal by introducing social welfare programs, including cash transfers to vulnerable households. However, these programs have been criticized as insufficient, with many Nigerians struggling to cope with the rising cost of fuel and food.

The democratic nature of Nigeria's government adds a layer of complexity to the subsidy removal debate. Unlike authoritarian regimes, which can implement unpopular policies with little regard for public opinion, democratic governments must balance economic reform with social stability. The government's ability to manage the fallout from subsidy removal will depend on its ability to communicate the long-term benefits of the policy while providing short-term relief to those most affected.

The way forward: The way forward for Nigeria in addressing the challenges posed by subsidy removal and the free fall of the naira requires a multifaceted approach. First, the government must prioritize fiscal discipline by ensuring that the savings from subsidy removal are reinvested in critical sectors like infrastructure, education, and healthcare. This will help to build public trust in the government's reform agenda and demonstrate that the removal of subsidies is in the long-term interest of the country. Second, the government must work to stabilize the naira by addressing the structural weaknesses in the economy that have contributed to its depreciation. This includes diversifying the economy away from oil exports, improving foreign exchange management, and encouraging investment in the non-oil sector. The CBN should also adopt a more flexible exchange rate policy, allowing the naira to adjust to market conditions while intervening when necessary to prevent excessive volatility. Third, the government must strengthen social safety nets to protect the most vulnerable Nigerians from the negative effects of subsidy removal. This could include expanding cash transfer programs, improving access to affordable healthcare, and providing targeted subsidies for essential goods like food and transportation. Finally, the government must engage in a broader dialogue with stakeholders, including labor unions, civil society, and the private sector, to build consensus around the need for subsidy removal and economic reform. This will help to reduce the risk of social unrest and ensure that the government's policies are seen as legitimate and fair.

Conclusion and Recommendation: The removal of energy subsidies and the free fall of the naira represent two of the most significant economic challenges facing Nigeria today. While the removal of subsidies is necessary to restore fiscal discipline and promote long-term economic growth, it has also led to short-term inflationary pressures and a decline in living standards. The depreciation of the naira has compounded these challenges, making it more difficult for Nigerians to afford basic goods and services. The current democratic government must navigate these challenges carefully, balancing the need for economic reform with the need to maintain social stability. This will require a coordinated response that includes fiscal discipline, exchange rate management, and targeted social welfare programs. The government must also engage in a broader dialogue with stakeholders to build consensus around its reform agenda and ensure that the benefits of subsidy removal are shared equitably across society.

In conclusion, while the removal of energy subsidies and the depreciation of the naira present significant challenges, they also offer an opportunity for Nigeria to reset its economic trajectory and build a more sustainable and equitable future. The way forward will require bold leadership, careful planning, and a commitment to both economic reform and social justice.

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Challenges of Food Security in the Advent of Insecurity and Climate Change In Nigeria

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Abstract

Food security remains one of the most pressing challenges facing Nigeria, a nation with over 200 million people. The interplay between food security, insecurity, and climate change has exacerbated the food crisis, particularly in rural and agrarian communities where agriculture is the primary source of livelihood. The effects of climate change, manifested through unpredictable weather patterns, droughts, floods, and soil degradation, have significantly impacted agricultural productivity. Coupled with widespread insecurity caused by insurgencies, banditry, and herder-farmer conflicts, these challenges have led to food shortages, inflation, displacement, and heightened hunger. This research review explores the nexus between food security, climate change, and insecurity in Nigeria. It examines the theoretical and conceptual frameworks guiding food security studies, analyzes current policies, and provides recommendations on how Nigeria can navigate the dual threats of insecurity and climate change to achieve sustainable food security. ***Keywords:*** *Climate change; Conflicts; Displacement; Food security; Nigeria*

Introduction: Food security is a multidimensional concept that involves access to sufficient, safe, and nutritious food for all people at all times (Olunusi, 2024). In Nigeria, food insecurity has become a critical issue, driven by a combination of factors including climate change (Umenze *et al*., 2024), poverty, economic instability, and more recently, heightened insecurity. The country, despite its vast arable land and potential for agricultural productivity, faces significant challenges in ensuring food security for its population. According to the Food and Agriculture Organization (FAO), food security encompasses four major pillars: availability, accessibility, utilization, and stability (Nwosu *et al*., 2024). Unfortunately, each of these pillars is under threat in Nigeria.

The onset of climate change has brought about erratic weather patterns, affecting crop yields, livestock production, and fisheries (Nwosu *et al*., 2024). Droughts and floods have become more frequent, destroying farmlands and causing long-term damage to agricultural systems. Meanwhile, insecurity-driven by Boko Haram insurgency, banditry, kidnapping, and violent conflicts between herders and farmers-has displaced millions, disrupted agricultural activities, and hindered the movement of goods across the country (Olanrewaju-Elufowoju, 2024). The combination of these factors has led to inflation in food prices, increased hunger, malnutrition, and widespread poverty, especially in northern Nigeria.

In addition to the significant impacts of climate change and insecurity on food security in Nigeria, socio-economic challenges like **poverty** and **inadequate infrastructure** further exacerbate the crisis. A large portion of Nigeria's population lives below the poverty line, which reduces their ability to purchase sufficient and nutritious food. This lack of purchasing power, combined with rising food prices due to inflation and supply chain disruptions, makes food accessibility a persistent challenge for millions of Nigerians (Popoola & Popoola, 2024).

Moreover, the **displacement of farmers** due to insurgencies, banditry, and herder-farmer conflicts has significantly reduced food production in several parts of the country, particularly in the North. The displacement also impacts rural communities that depend on agriculture for their livelihoods. When farmers are forced to flee their homes, agricultural land is left uncultivated, reducing food availability (Mashi & Husaini, 2024). Additionally, roads and infrastructure critical for food distribution have been destroyed or rendered unsafe due to the activities of insurgents and criminal groups. This has further constrained the movement of agricultural produce from farms to markets, worsening food scarcity (Gana *et al*., 2024).

The **disruption in market systems** and inadequate government interventions in the agricultural sector have worsened the situation. Poor access to agricultural inputs, such as seeds and fertilizers, and lack of financial support for farmers, has diminished productivity and food availability (Ogwu *et al*., 2024). Although government policies like the Agricultural Promotion Policy (APP) and initiatives from international organizations such as the **World Food Programme (WFP)** aim to address food insecurity, the implementation and coordination of these interventions have been limited, especially in conflict zones (FAO, 2024). The lack of long-term planning and resilience strategies to cope with climate-induced challenges, including floods and desertification, leaves Nigerian farmers vulnerable to repeated crises (Adegbaju *et al*., 2024).

Lastly, **climate change adaptation measures** have been insufficient. For instance, drought-resistant crops, efficient water management systems, and other climate-resilient agricultural technologies remain underutilized due to poor dissemination and adoption, particularly in rural areas (Kitole et al., 2024). Consequently, Nigeria's agricultural sector continues to face persistent productivity challenges, further deepening food insecurity.

Succinctly, the convergence of climate change, insecurity, poverty, and infrastructural deficits have created a multifaceted food security crisis in Nigeria. Addressing these challenges requires an integrated approach involving policy reform, investment in climate-smart agriculture, improved security measures, and strengthened social safety nets for the most vulnerable populations. This research review will explore the interrelationship between food security, climate change, and insecurity in Nigeria. It will analyze the socio-economic and environmental factors contributing to the food crisis and assess government policies aimed at addressing these challenges. The paper will conclude with policy recommendations to strengthen Nigeria's food security in the face of on-going threats.

Theoretical Framework: To understand the dynamics of food security in Nigeria, this research employs several theoretical perspectives that provide insights into the complex relationships between food availability, climate change, insecurity, and socio-economic conditions. The following theories form the foundation of this analysis:

The Theory of Food Security: The theory of food security centers on the idea that food security exists when all individuals have access to sufficient, safe, and nutritious food to maintain a healthy and active life. This theory, as defined by the FAO, involves four key dimensions: food availability, food accessibility, food utilization, and food stability (Sambo & Sule, 2024). In Nigeria, these dimensions are under strain due to the combined impact of climate change and insecurity (Popoola & Popoola, 2024). Food availability is compromised by reduced agricultural output, while food accessibility is limited by inflation, poverty, and displacement caused by insecurity.

The theory emphasizes the importance of both short-term measures, such as emergency food assistance, and long-term strategies, such as improving agricultural productivity and resilience to climate change. It also highlights the role of policy in ensuring that the most vulnerable populations are protected from hunger and malnutrition.

Climate Change and Agricultural Adaptation Theory: The climate change and agricultural adaptation theory suggests that agricultural systems must evolve to cope with the impacts of climate change (Popoola & Popoola, 2024). This theory is grounded in the understanding that climate change introduces new risks to agriculture, such as changes in rainfall patterns, temperature extremes, and increased frequency of natural disasters (Toromade *et al*., 2024). For countries like Nigeria, where agriculture is primarily rain-fed, adapting to these changes is crucial for maintaining food security. Adaptation strategies include diversifying crops, improving irrigation infrastructure, promoting climate-resilient agricultural practices, and enhancing early warning systems for extreme weather events (Gana *et al*., 2024). The theory also emphasizes the role of government and international organizations in supporting farmers to adopt new technologies and practices that can mitigate the effects of climate change.

Conflict Theory: Conflict theory, rooted in the work of Karl Marx, posits that competition over scarce resources can lead to social unrest and conflict. In Nigeria, this theory is particularly relevant in understanding the violent clashes between herders and farmers over land and water resources. Climate change has exacerbated these conflicts by reducing the availability of arable land and water, pushing herders further south into farming communities, leading to violent confrontations (Gana *et al*., 2024). The Boko Haram insurgency and the rise of banditry in northern Nigeria are also driven by economic inequality, poverty, and lack of access to resources (Mashi & Husaini, 2024). Conflict theory helps explain how these forms of insecurity disrupt food production, displace farmers, and undermine efforts to achieve food security.

Political Ecology Theory: Political ecology theory explores the political, social, and economic factors that shape environmental issues, including food security and climate change. In Nigeria, political decisions, governance structures, and power dynamics significantly influence how climate change impacts are managed and how food security is addressed. The mismanagement of natural resources, poor agricultural policies, and corruption are key political factors contributing to food insecurity (Onoja *et al*., 2024). Political ecology theory underscores the need for equitable resource distribution and inclusive governance as part of the solution to the food security crisis.

Conceptual Framework: The conceptual framework for this study integrates the relationship between food security, climate change, and insecurity in Nigeria. The framework is built on the premise that food security is influenced by several interconnected factors, including environmental conditions, socio-political stability, and economic policies. In Nigeria, the interplay between climate change and insecurity exacerbates food insecurity, with climate change directly affecting agricultural production and insecurity hindering access to food markets and disrupting farming activities.

Key Components of the Conceptual Framework:

1. **Food Availability**: This refers to the physical presence of sufficient quantities of food through domestic production or imports. Climate change affects food availability by reducing crop yields, while insecurity disrupts the supply chain and restricts farmers' access to their lands.
2. **Food Accessibility**: This involves the ability of individuals to access food, which is often linked to income levels, food prices, and infrastructure. In Nigeria, insecurity and displacement limit access to markets, while inflation driven by climate-related crop failures increases food prices, making it difficult for low-income households to afford basic necessities (Stavi *et al*., 2021).
3. **Food Utilization**: Food utilization refers to the body's ability to ingest and metabolize nutrients, which depends on food quality, health care, and sanitation. Displacement due to insecurity leads to poor living conditions and inadequate nutrition, while climate change impacts, such as droughts, can lead to malnutrition due to the scarcity of nutrient-rich food (Kalu, 2024).
4. **Food Stability**: Stability encompasses the ability of individuals to access food consistently over time, without disruptions caused by economic shocks, conflict, or environmental changes. In Nigeria, the instability caused by climate change and insecurity has created a situation where food stability is under constant threat (Okolie *et al*., 2024).

This conceptual framework will guide the analysis of the data and the identification of key areas where policy interventions are needed to improve food security.

RESEARCH METHODOLOGY

The present study used data collected from journals, articles, conference proceedings, book chapters, internet sources etc. Subsequently, the data were systematically synthesized to generate insightful findings.

Results and Discussion: The Impact of Climate Change on Food Security in Nigeria: Nigeria's agricultural sector, which employs over 70% of the population, is highly vulnerable to climate change (Adegbaju *et al*., 2024). The country's reliance on rain-fed agriculture makes it susceptible to variations in rainfall, temperature fluctuations, and extreme weather events such as floods and droughts. In recent years, unpredictable weather patterns have led to reduced agricultural output, particularly in staple crops such as maize, rice, and millet.

- **Droughts and Desertification**: Northern Nigeria, particularly the Sahel region, has experienced severe droughts and desertification, reducing arable land and pasture for livestock (Gana *et al*., 2024). This has forced many farmers and herders to migrate in search of fertile land, often leading to conflicts with local communities. The decline in crop yields has led to food shortages and increased reliance on imported food, contributing to food inflation.
- **Flooding**: In the southern and central parts of Nigeria, flooding has become more frequent due to heavy rains and poor drainage infrastructure (Echendu, 2022). Floods have destroyed farmlands, displaced communities, and disrupted transportation networks, further compounding the food security crisis.
- **Soil Degradation**: Soil fertility has been declining due to over-farming, deforestation, and poor agricultural practices. Climate change exacerbates these issues by reducing the natural regeneration of soil nutrients, making it harder for farmers to sustain crop production.

Insecurity and its Impact on Food Security: Insecurity, particularly in northern Nigeria, has been a major driver of food insecurity (Bello *et al*., 2024). The Boko Haram insurgency, which began in 2009, has devastated the region, displacing millions of people and disrupting agricultural activities (Fosudo, 2024). Farmers have been forced to abandon their lands due to fear of attacks, while markets and trade routes have been cut off, limiting the distribution of food.

- **Farmer-Herder Conflicts**: The long-standing conflict between farmers and herders has intensified due to climate change, which has reduced the availability of pasture and water resources (Kitole *et al*., 2024). Herders, particularly from the northern regions, have migrated southwards in search of grazing land, leading to violent clashes with farmers. These conflicts have led to the destruction of crops, livestock, and farm infrastructure, further compounding the food security crisis.
- **Banditry and Kidnapping**: In recent years, banditry and kidnapping for ransom have become widespread in Nigeria, particularly in the northwest. These criminal activities have disrupted farming communities, leading to the abandonment of farmlands and reduced agricultural output. The fear of attacks has made it difficult for farmers to access their lands, contributing to food shortages.

Government Policies and Food Security in Nigeria: The Nigerian government has implemented several policies aimed at addressing food security, climate change, and insecurity (Aliyu *et al*., 2021). However, these policies have faced significant challenges in terms of implementation and effectiveness.

- **The Agricultural Promotion Policy (APP)**: The APP, also known as the Green Alternative, was launched in 2016 with the aim of diversifying Nigeria's economy and boosting agricultural productivity (Ogwu *et al*., 2024). The policy focuses on improving access to credit, enhancing agricultural infrastructure, and promoting mechanized farming. However, the policy has faced implementation challenges, particularly in conflict-prone areas where insecurity has hindered agricultural activities.
- **The National Food Security Council**: In 2018, the Nigerian government established the National Food Security Council to coordinate efforts to address food security challenges (El Bilali *et al*., 2024; Bollam *et al*., 2024). The council focuses on improving food production, ensuring the availability of food reserves, and addressing issues related to climate change and insecurity. However, the effectiveness of the council has been limited by bureaucratic inefficiencies and a lack of coordination between government agencies.
- **Climate Change Adaptation Strategies**: The Nigerian government has developed several climate change adaptation strategies, including the National Adaptation Strategy and Plan of Action on Climate Change (NASPA-CCN). These strategies aim to promote climate-resilient agricultural practices, improve water management, and enhance early warning systems for extreme weather events (Ojo *et al*., 2022). However, the implementation of these strategies has been slow, and many farmers remain unaware of climate change adaptation techniques.

The Role of International Organizations and NGOs: International organizations such as the FAO, World Food Programme (WFP), and International Fund for Agricultural Development (IFAD) have played a critical role in supporting Nigeria's efforts to address food insecurity. (Augustina & Nkechi, 2023) These organizations provide technical assistance, funding, and capacity-building support to improve agricultural productivity, enhance climate resilience, and address the humanitarian needs of displaced populations.

Non-governmental organizations (NGOs) have also been instrumental in providing emergency food assistance to communities affected by insecurity and climate change. NGOs such as Action Against Hunger and the International Rescue Committee have implemented programs aimed at improving nutrition, promoting sustainable agriculture, and building community resilience to climate change.

Conclusion: The challenges of food security in Nigeria are multifaceted, with climate change and insecurity being the two most significant factors contributing to the current food crisis. Climate change has reduced agricultural productivity through droughts, floods, and soil degradation, while insecurity has displaced millions, disrupted farming activities, and hindered access to food markets. Despite government efforts to address these challenges through policies such as the Agricultural Promotion Policy and climate change adaptation strategies, significant gaps remain in implementation and coordination.

Recommendations:

1. **Strengthen Climate Resilience in Agriculture**: The Nigerian government should prioritize the promotion of climate-resilient agricultural practices, such as drought-resistant crops, improved irrigation systems, and sustainable land management techniques. This will help farmers adapt to the changing climate and maintain productivity in the face of environmental challenges.
2. **Enhance Security in Agricultural Regions**: The government must intensify efforts to address insecurity in agricultural regions, particularly in the north. This includes increasing the presence of security forces, improving intelligence gathering, and fostering dialogue between farmers and herders to reduce conflicts.
3. **Promote Inclusive Governance and Policy Coordination**: The government should ensure that policies aimed at addressing food security, climate change, and insecurity are well-coordinated and inclusive. This involves engaging local communities, civil society

organizations, and international partners in the policy-making process to ensure that policies are tailored to the needs of vulnerable populations.

4. **Expand Social Safety Nets and Food Assistance Programs**: To mitigate the short-term impacts of food insecurity, the government should expand social safety nets and food assistance programs, particularly for displaced populations and low-income households. These programs should be designed to provide immediate relief while also promoting long-term food security through livelihood support and agricultural training.
5. **Invest in Research and Development**: The Nigerian government should invest in research and development to promote innovation in agriculture, particularly in areas related to climate change adaptation and food security. Research institutions should be supported to develop new technologies and practices that can improve agricultural productivity and resilience to climate change.

By addressing the interconnected challenges of climate change, insecurity, and food security, Nigeria can chart a path towards sustainable development and improved livelihoods for its population.

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Relationship between Organic Matter and Selected Soil Properties in the Nigerian Environment

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Abstract

Soil organic matter is a critical component of tropical soils especially within the context of Nigerian soils. This is because of its role in soil conservation, productivity, and fertility. The objective of this study was to access the relationship between organic matter and selected soil properties within the scope of the Nigerian environment. 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: Soil organic matter is one of the most important components of Nigerian soils especially within the context of the tropics. Organic matter serves as a reservoir of plant nutrients and water, it improves soil tilth, reduces compaction and surface crusting, and plays a major role in soil structure development and stability (Brady and Weil, 1999). These 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 that 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 indicates 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. Within the context of the Nigerian environment, more information is needed to fully understand organic matter distribution and relationships with soil characteristics and factors in the various ecosystems. Therefore, the objective of this study was to access the relationship between organic matter and selected soil properties within the scope of the Nigerian environment.

Materials and Methods: **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). One way analysis of variance was used to compare data predicted from regression equations and primary soil data obtained by laboratory analysis. Descriptive statistics was 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 year 2001 was used because most of the secondary soil data used for this study were obtained around that period.

Results and Discussion: **Relationships between Soil Characteristics and organic matter**: Figure 1 shows distribution of soil sample points obtained from the African soil data base and variation in vegetation characteristics across the Nigerian landscape. Vegetation characteristics is largely a function of climate and soil types and as such gives an overview of the gross variation in ecosystem characteristics within the Nigerian environment. Healthy vegetation growth, such as forests, will yield high NDVI values closer to one, while low vegetation will yield values close to 0.2 (Menesses – Tovar; 2011)). Vegetation is the major source through which soil acquire its organic matter content. 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):

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

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

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

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

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 was1.44% 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.

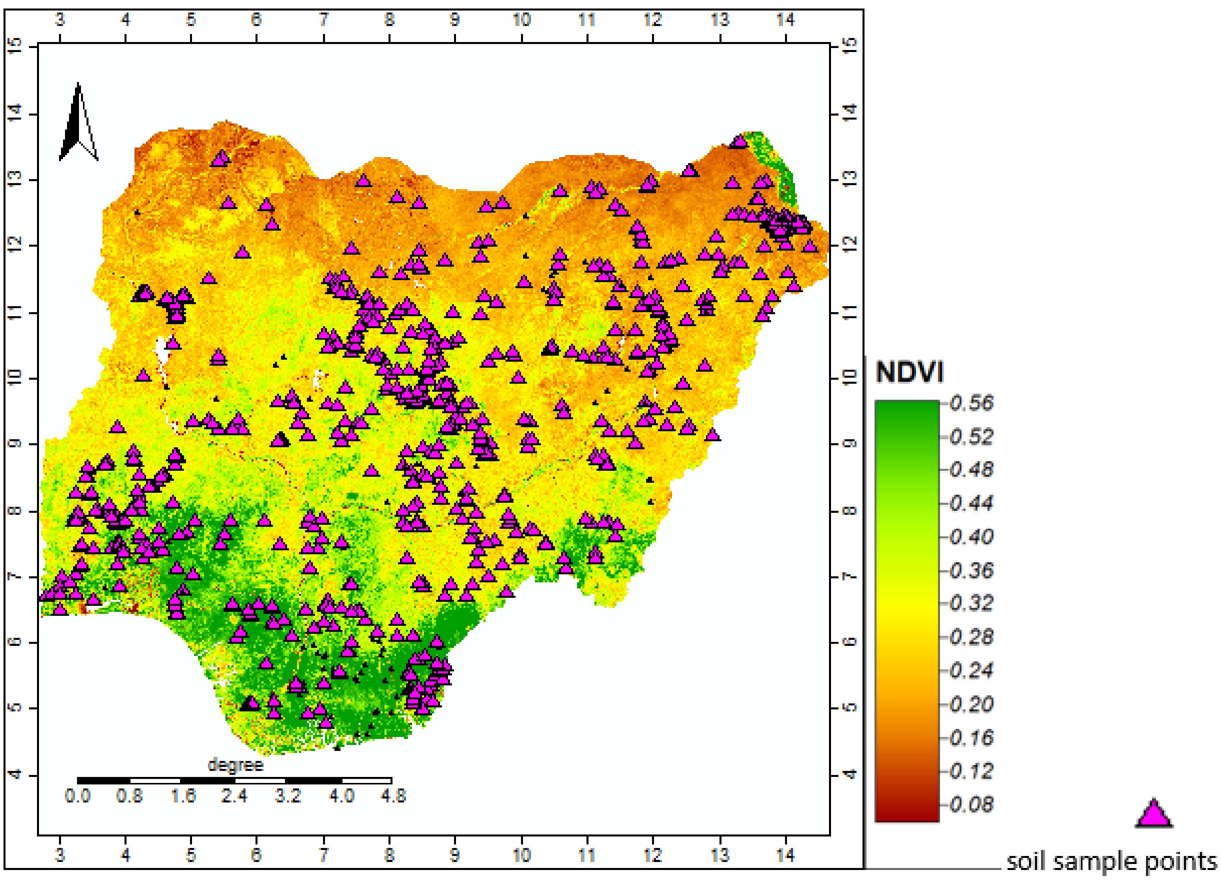

Figure 1: Distribution of soil sample points from African soil data base and vegetation characteristics within the Nigerian environment

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).

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

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

N	E	Profile No.	Horizon	average depth (cm)	GMWD	N (%)	OM (%)
9.48714	9.12178	11	Ap	12.50	0.22	0.038	1.34
			B1	37.50	0.22	0.035	1.21
			B2	75.00	0.22	0.017	0.59
			B3	126.50	0.22	0.005	0.17
9.4861	9.12197	12	Ap	10.00	0.62	0.059	2.03
			B1	47.50	0.62	0.062	2.12
			B2	122.50	0.62	0.013	0.45
			B3	185.00	0.62	0.054	1.86
9.49915	9.11882	13	Ap	19.00	0.40	0.055	1.90
			Bc1	51.50	0.40	0.047	1.62
			Btc	76.00	0.40	0.032	1.10
			Bc	103.5Page | 3290	0.40	0.030	1.08
9.11882	9.14671	14	Ap	7.50	0.40	0.042	1.45
			Bc1	57.50	0.40	0.037	1.28
			Bc2	150.00	0.40	0.024	0.82
9.50693	9.11926	15	A	7.50	0.60	0.120	4.16
9.510165	9.102373	16	A	12.50	0.41	0.100	3.51
			Bc1	45.00	0.41	0.080	2.76
			Bc2	92.50	0.41	0.042	1.45
9.78431	8.97315	17	A	11.50	0.23	0.083	2.85
			AC	86.50	0.23	0.023	0.79
9.7985	8.97542	18	A	11.50	0.32	0.067	2.32
			B	46.50	0.32	0.014	0.54
			BC	110.00	0.32	0.010	0.33
9.84796	8.97508	19	A	10.00	0.31	0.083	2.85
			B1	32.50	0.31	0.066	2.28
			B2	82.50	0.31	0.029	0.99
				150.00	0.31	0.084	2.90
9.769479	8.851754	20	A	11.50	0.53	0.094	3.23
			C	31.50	0.53	0.065	2.23
9.784176	8.832954	21	A	15.00	0.29	0.058	1.99
			AB	40.00	0.29	0.032	1.12

			B	70.00	0.29	0.053	1.82
			C	120.00	0.29	0.022	0.74
9.792597	8.830599	22	A	7.50	0.53	0.073	2.52
			B1	22.50	0.53	0.008	0.29

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

N	E	Profile No.	Horizon	average depth (cm)	GMWD	N (%)	OM (%)
7.15805	7.50006	23	A	12.50	0.87	0.048	1.64
			BA	38.50	0.32	0.029	0.99
			B	101.00	0.24	0.011	0.37
7.1568	7.50397	24	A	7.50	0.83	0.039	1.35
			AB	32.50	0.34	0.032	1.09
			B	100.00	0.32	0.074	1.05
7.1575	7.51213	25	A	7.50	0.62	0.043	1.47
			AB	42.50	0.44	0.028	0.98
			B	110.00	0.33	0.064	2.20
7.15517	7.51097	26	A	7.50	0.58	0.018	0.62
			AB	35.00	0.80	0.079	2.73
			B	102.50	0.47	0.014	0.50
7.16709	7.51696	27	A	20.00	0.60	0.079	2.73
			AB	57.50	0.62	0.027	0.94
			B	82.00	0.49	0.025	0.87
			C	94.50	0.48	0.058	1.99
7.16442	7.51774	28	A	7.50	0.83	0.068	2.33
			AB	42.50	0.63	0.031	1.06
			B	110.00	0.63	0.060	2.08
7.16632	7.51714	29	A	12.50	0.87	0.076	2.61
			AB	40.00	0.62	0.033	1.14
			B	102.50	0.64	0.029	0.99
7.16978	7.46412	30	A	12.50	0.83	0.069	2.39
			AB	40.00	0.64	0.037	1.29
			B	102.50	0.48	0.068	2.36

Table 4: Summary statistics for validation data

Soil Nitrogen (%)	N	Mean	StDev	95% CI
Observed	104	0.04283[d]	0.02416	(0.03638, 0.04927)
Predicted N from equation 1	104	0.06974[c]	0.04067	(0.06329, 0.07618)
Predicted N from equation 2	104	0.04184[d]	0.02440	(0.03540, 0.04828)
Predicted N from equation 3	104	0.17561[b]	0.03523	(0.16916, 0.18205)
Predicted N from equation 4	104	0.18525[a]	0.03895	(0.17881, 0.19170)

Pooled StDev = 0.0334420

Means that do not share a letter are significantly different (P≥0.05)

Note: CI=Confidence interval; StDev=standard deviation; N= number of samples

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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Copper, Nickel, Iron, Manganese, Zinc and Boron Micro-Nutrients in Paddock Soils on the Jos Plateau

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Abstract

Micronutrients are essential elements that are required by plants for growth and to complete their life cycle. The objective of this study was to determine the concentration of available iron, manganese, zinc, copper, boron and nickel in paddocks of the livestock investigation Department (LID) of the National Veterinary Research Institute (NVRI) Vom. Field study involved taking soil samples at depths of 0 – 15 and 15 – 25 cm from ten (10) paddocks. Each set of three sample were bulked to form a composite sample. For laboratory analysis, dilute acid extractions method for available iron, manganese, zinc, copper and nickel was employed in this study. Hot water extraction method was used for determination of available boron. The result indicated that iron, manganese, boron, zinc and copper contents were at optimum levels whereas nickel contents were at moderate levels in the soils. Mean concentration of iron in these soils ranged from 174 to 179 mg/kg whereas mean concentration of manganese in these soils ranged from 14.14 ± 4.98 to 19.59 ± 8.60 mg/kg. Also, mean concentration of zinc in these soils ranged from 12.3 to 13.2 mg/kg. Likewise, mean concentration of boron in these soils ranged from 2.0 to 2.1 mg/kg. Analysis of data implies that the variation in available contents of these elements in soils across each of the paddocks is low. In addition, there would be very sufficient amount of these nutrients in these soils for plants growth.

Keywords: *Paddocks, micronutrients, copper, boron, nickel, zinc, iron, manganese.*

Introduction : Micronutrients constitute crucial plant nutrients that are required for plant growth and development but are found in trace amounts in tissue. Plant nutrition would be hampered without these nutrients, possibly resulting in a reduction in plant productivity. Eight of the seventeen components required for plant growth are micronutrients. Boron (B), Chlorine (C), Copper (C), Iron (Fe) Manganese (Mn), Molybdenum (Mo), Zinc (Zn), Nickel (Ni). Maintenance of soil nutrients remain prerequisite in ensuring sustained crop yields (Campbell, 1998). Usually, macronutrients required in large quantities are focus of many interventions unlike micronutrients that are required in small quantities (Brady and Weil, 2010). In sub-saharan Africa, soil infertility remains one of the key factors responsible for declining crop production. Challenges of soil infertility caused by various factors such as reduction in crop diversity have led to application of various interventions including use of organic fertilizers and agro-forestry practices that deploy leguminous species (Akinnifesi *et al.,* 2007 and Leakey, 2014). Normally, concentration of soil nutrients is affected by soil types, climate, topography and management practices (Maitima, et al., 2009). For instance, declined vegetation cover and heavy precipitation may accelerate micronutrients leaching (Huang, et al., 2011).

Copper (Cu) as a micronutrient activates enzymes and catalyzed reactions in several plant growth processes. The presence of copper is closely linked to vitamin A production, and it helps to ensure successful protein synthesis. Also, nickel (Ni) was added to the list of essential plant nutrients in 20th century. Nickel is important in Plant Nitrogen metabolism. Without the presence of Ni, urea conversion is impossible. It is required in very small amount with critical level appearing to be 1.1 ppm. Because iron is vital to nearly every metabolic activity in life, including respiration, photosynthesis, and DNA synthesis, it is considered an important micronutrient. Furthermore, many metabolic pathways are activated by iron, and it is a prosthetic group constituent of many enzymes. The main causes of iron chlorosis are an imbalance between the amount of soil-available iron and the amount of iron that plants require. Iron is present in most well-aerated soils, but its biological activity is modest because, at neutral pH levels, it mostly forms very insoluble ferric complexes. Iron plays a significant role in various physiological and biochemical pathways in plants (Rout and Sahoo, 2015). Similarly, as a metal having catalytic properties in biological clusters or as an enzyme cofactor, manganese (Mn) is an important element found in almost all living organisms (Andresen, et al., 2018). However, in high pH soils, magnesium shortage can be a major plant nutritional problem (Boadlay *et al*, 2012).

Zinc [Zn] is taken up by plant as the divalent $2n+^{2}$ cation. It is one of the first micronutrient recognized as essential for plant and they are most commonly limiting yields although Zn is required only in small amount high yield are impossible without it. On the other hand, Boron (B) is a micronutrient critical to the growth and health of all crops. It is a part of the reproductive organs and cell walls of plants. It is a mobile nutrient within the soil, meaning it is prone to movement within the soil (Dell and Huang,1997).

The paddocks of the Livestock Investigation Department (LID) of the National Veterinary Research Institute (NVRI), Vom have been under continuous grazing for over 30 years. Its therefore imperative to investigate the status of available iron, manganese, zinc, copper, boron and nickel micronutrients in these soils. The objectives are to evaluate the concentration of plant available iron, manganese, zinc, copper, boron and nickel in paddocks of the Livestock Investigation Department (LID) of the National Veterinary Research Institute (NVRI), Vom.

Materials and Methods : Study area: The study area is located at the Livestock Investigation Department (LID) the National Veterinary Research Institute (NVRI),Vom; which is located on the Jos Plateau. The study area is located between latitudes 9º 42' 51.61" N and 9º 43' 25.40" N; and longitudes 8º 48' 18.44" E and 8º 48' 37.26" E. Ten paddocks were identified for the study as shown in Figure 1. The paddocks are enclosed areas where cows are kept for grazing purposes. The total area of the study site is 23.03 hectares. The area of each paddock was as follows:

1. P1 = 0.08 hectares
2. P2 = 1.57 hectares
3. P3 = 2.15 hectares
4. P4 = 2.78 hectares
5. P5 = 1.30 hectares
6. P6 = 4.70 hectares
7. P7 = 3.79 hectares
8. P8 = 2.80 hectares
9. P9 = 1.42 hectares
10. P10 = 2.44 hectares

The geology of the study site consists of younger granites and basement complex rocks (Directorate of Overseas Surveys, (1977). Furthermore, Jos metropolis experiences Aw climatic type and falls within the koppens Aw climatic sub-region. Generally, weather conditions are warmer during the rainy season (April-October) and much colder during the hammattan period (December-February) (Ariyo, 2000). The mean annual temperature of the city ranges between 20^0 C and 26^0 C. These temperature ranges are due to influences of rainfall, relief and cloud cover at different periods and seasons of the year. Relative humidity is lower during the dry season between November to March and is very high during the wet season with the peak values of between 81% and 84% in July and August (Bingel, 1978, Ariyo, 2000,). Precipitation on the Jos Plateau ranges from 1236.54 to 1524.19 mm (Owonubi, 2017a).

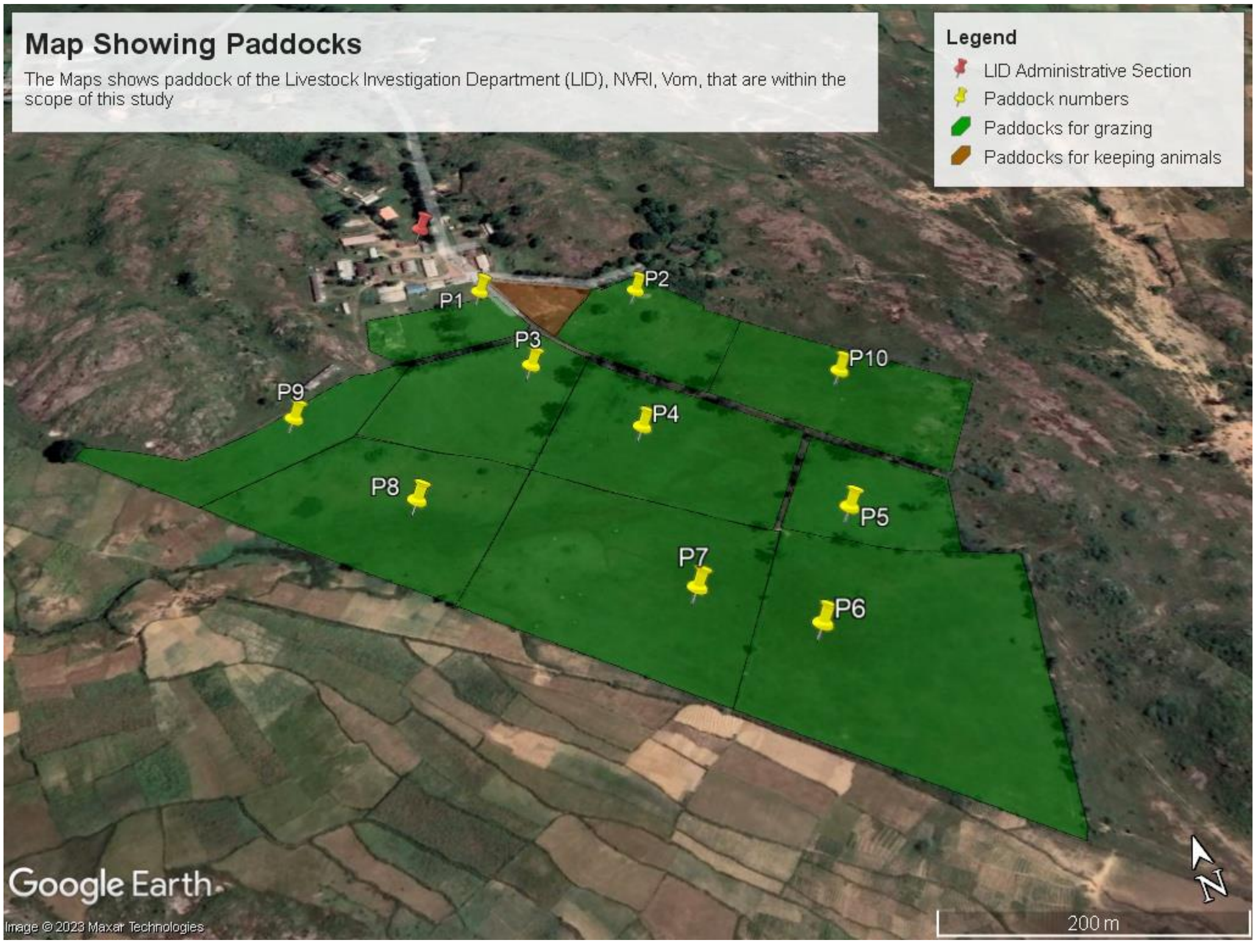

Figure 1: Map of the study site

Field Study : Three samples were collected at random at depths of 0-15 and 15-25 cm and bulked to form a composite sample for each paddock. Soil samples will be collected in each paddock with the aid of a soil auger.

Laboratory Analysis: Dilute acid extraction method for Cu, Zn, Fe, Mn and Ni micronutrient as described by Owonubi (2017a) is most applicable to acid and slightly acid soils was used for this study. Available boron was extracted using hot water. The following is the procedure for the dilute acid extraction employed:

- 5g of <mm sieved soil sample was weighed into 100-ml centrifuge tube and 50ml of 0.1 NHCL Solution would be added.
- The suspension was shaken in a reciprocating shaker for 30minutes after which it will be filtered through what man no, 40 filter paper.
- Cu, Zn, Fe, Mn, Ni and B in the filtrate was determined by atomic absorption spectrophotometry. A standard curve was constructed for each of the elements to determine their concentration.

Statistical Analysis: Independent T test was used to compare, data between soil depth. Also, descriptive statistics was used to analyze soil data.

Results and Discussion: General Characteristics of the Soil: The soils are shallow and about 30cm deep on very rocky terrain. Consequently, they are classified as Entisols. Furthermore, soils have very coarse texture and low organic matter content in most cases. Soil consistency is very friable, non-sticky and non-plastic. Land-use is exclusively for grazing and for a period of over 30 years. The geology of the area is predominantly basement complex as documented by the Directorate of Overseas Surveys (1977).

Copper and Nickel Concentration in Soils: The concentrations of coper and nickel in paddocks is presented in Table 1. The level and concentration of Cu in surface soil was shown to be all high throughout the ten paddocks as displayed and also for sub-surface soils. Concentrations of Cu in the surface soils ranged from 1.56 - 3.96 mg/kg and for sub-surface soil, it ranges from 1.56 – 3.48 mg/kg. The highest mean of Cu is 2.560 ± 0.843 mg/kg and the lowest is 2.444 ± 0.814 mg/kg. The standard deviation of copper concentration in the soils (Table 2) indicated very low variation in copper levels for both surface and subsurface soils. In addition, there were no significant difference in nickel contents between surface and subsurface soils (Table 3). Result of copper studies (238.33 µg/g to 623.7 µg/g) obtained by Odoh et al. (2011) were found to be higher than Cu levels obtained in the paddocks. Improper disposal of waste lubricant and other anthropogenic activities was discovered to be responsible for copper levels found in street dusts. Results obtained in this study, are however below the permissible limits set by Great Britain (100 mg/Kg), Canada (100 mg/Kg), Japan (125 mg/Kg) and Poland (100 mg/Kg) (Wang et al., 2015).

TABLE 1: Available micronutrients (mg/kg) in Paddocks

Soil Depth	Paddocks	Copper	Nickel	Iron	Manganese	Zinc	Boron
Surface	1	3.96	1.62	193.26	35.40	25.18	1.83
	2	1.58	0.70	185.96	27.78	11.26	2.21
	3	1.62	4.80	205.42	24.08	23.72	2.11
	4	1.56	1.54	198.02	18.00	9.68	2.12
	5	2.36	6.92	169.56	17.24	6.66	1.46
	6	2.30	6.22	159.68	12.68	6.96	1.71
	7	2.50	6.44	198.58	15.96	5.92	2.29
	8	3.04	5.86	123.20	6.04	10.64	2.07
	9	3.08	10.32	179.24	19.10	19.16	2.76
	10	2.36	6.92	169.56	17.24	6.66	1.46
Sub-surface	1	1.56	2.42	183.90	20.92	12.32	1.62
	2	1.56	2.42	183.90	20.92	12.32	1.62
	3	1.60	4.64	137.90	4.56	8.34	1.30
	4	3.00	6.88	193.60	10.38	11.64	1.71
	5	2.44	7.66	193.34	13.72	11.22	1.80
	6	2.44	7.66	193.34	13.72	11.22	1.80
	7	3.48	9.84	160.66	14.34	14.40	2.60
	8	3.48	9.84	160.66	14.34	14.40	2.60
	9	3.48	9.48	160.66	14.34	14.40	2.60
	10	2.44	7.66	193.34	13.72	11.20	1.80

Nickel Concentration in Soils: Nickel concentration was shown to be at medium levels for surface soils of nine (9) paddocks (Table 1) and found to be high in one paddock specifically the 9th paddock. However, for sub-surface soil, nickel concentration was at medium levels all through. The values of Ni in surface soil were found to be within the range of 0.70 - 10.32 mg/kg and 2.42 - 9.84 mg/kg for the sub-surface soil. The highest mean value for Ni is 6.80 ± 3.01 mg/kg and the lowest is 4.94 ± 3.13 mg/kg (Table 2). Values for standard deviation indicated that variation in nickel content in these soils are low for both surface and subsurface soils. In addition, there were no significant difference in nickel contents between surface and subsurface soils (Table 3). The mean concentration of nickel was lower than the world-wide value (50-100µg/g) (Fergusson and Kim, 1991) although Iyaka (2011) reported that nickel content in world soils varied widely between 3 to 1000 mg/kg.

TABLE 2: Descriptive statistics for soil data

	Depth	Mean	StDev	SE Mean	CoefVar	Minimum	Maximum
Nickel	0-15	4.94	3.13	1.0	63.34	0.70	10.32
	15-25	6.80	3.01	1.0	44.19	2.42	9.84
copper	0-15	2.444	0.814	0.27	33.28	1.560	3.960
	15-25	2.560	0.843	0.28	32.92	1.560	3.480
Iron	0-15	179.2	25.7	8.6	14.32	123.20	205.42
	15-25	174.2	19.9	6.6	11.42	137.90	193.60
Manganese	0-15	19.59	8.60	2.9	43.90	6.04	35.46
	15-25	14.14	4.98	1.7	35.22	4.56	20.92
Zinc	0-15	13.24	7.48	2.5	56.45	5.92	25.18
	15-25	12.25	1.99	0.66	16.24	8.340	14.400
Boron	0-15	2.094	0.383	0.13	18.30	1.460	2.760
	15-25	1.961	0.501	0.17	25.55	1.300	2.600

Iron Concentration in Soils : Following the classification provided by Buchholz (2004), the levels of available iron in these soils are rated high. These implies there would be very sufficient amounts of these nutrients in these soils for plant growth. Mean concentration of iron in these soils (Table 2) ranged from 174 to 179 mg/kg also with a standard deviation ranging from 19.9 to 25.7 mg/kg. This implies that the variation in available iron contents in soils across each of the paddocks is low. In addition, the distribution of available iron contents in between depths of 0 – 15cm and 15 – 25 cm were statistically similar ($P > 0.05$) as shown in Table 3. The values of available iron in these soils are much higher than those reported by Owonubi (2017b) for basement complex soils in the northern guinea savanna. Nonetheless, the findings are less than the plinthic soil levels reported by Yaro (2005) (range: 80,000 to 304,000 mg/kg; mean: 150,400 mg/kg).

TABLE 3: Independent T-Test for Surface versus Sub-surface Soils

	T-Value	DF	P-Value
Nickel	-1.29	15	0.217
Copper	-0.30	15	0.771
Iron	0.46	15	0.651
Manganese	1.65	12	0.126
Zinc	0.38	9	0.710
Boron	0.63	14	0.536

Manganese Concentration in soils : The concentration of available manganese in surface and subsurface soils are also presented in Table 1. These soils have high quantities of accessible manganese, according to Buchholz's (2004) categorization. This suggests that these soils contain high of manganese for plant growth. Mean concentration of manganese in these soils (Table 2) ranged from 14.14 ± 4.98 to 19.59 ± 8.60 mg/kg. This implies that the variation in available manganese contents in soils across each of the paddocks is low. In addition, the distribution of available manganese contents in between depths of 0 – 15cm and 15 – 25 cm were statistically similar ($P > 0.05$) as shown in Table 4. Available manganese contents in theses soils were generally higher than those reported by Owonubi (2017b) for northern guinea savanna soils. They are however within the range reported by Yaro (2005) for some plinthic soils (range: 1.0 to 27.2 mg/kg; mean: 8.63 mg/kg).

Zinc Concentration in Soils: Based on Buchholz's (2004) classification, these soils have high quantities of zinc that are readily available. This suggests that these soils would contain very high concentrations of zinc to sustain plant growth. Mean concentration of zinc in these soils (Table 2) ranged from 12.25 to 13.24 mg/kg also with a standard deviation ranging from 1.99 to 7.48 mg/kg. This implies that the variation in available zinc contents in soils across each of the paddocks is low. In addition, the distribution of available zinc contents in between depths of 0 – 15cm and 15 – 25 cm were statistically similar ($P > 0.05$) as shown in Table 3. The values of available zinc in these soils are much higher than those reported by Owonubi (2017b) for basement complex surface soils in the northern guinea savanna. Also, the values are higher than those reported by Olowolafe (2002) for soils derived from granite (range: 0.65 to 6.5 mg/kg; mean: 2.61 mg/kg) in the northern guinea savanna area of Nigeria.

Boron Concentration in soils : Boron concentrations have been shown to be very sufficient in these soils according to ratings provided by Buchholz (2004). The levels of available boron in these soils are rated high. Consequently, adequate amounts of boron in these soils would be accessible for plant growth. Mean concentration of boron in these soils (Table 2) ranged from 1.961 ± 0.501 to 2.094 ± 0.383 mg/kg. This implies that the variation in available boron contents in soils across each of the paddocks is low. In addition, the distribution of available boron contents between depths of 0 – 15cm and 15 – 25 cm were statistically similar ($P > 0.05$) as shown in Table 3. Available boron contents in theses soils were generally higher than those reported by Owonubi (2017b) and also by Oyinlola and Chude (2010) for northern guinea savanna soils (range: 0.04 – 0.28; mean: 0.14mg/kg).

Conclusion: The study assessed the level of available iron, manganese, zinc, copper, boron and nickel in paddocks of the Livestock Investigation Department (LID) of the National Veterinary Research Institute (NVRI), Vom, Plateau State. The result indicated that these elements were at sufficient levels. To sustain the level of micronutrients in these soils, over grazing should be prevented while practicing longer fallow periods in each paddock. In addition, biochar should be utilized to improve productivity of soils in the paddocks.

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Harnessing Potentials of Forest Food Resources in our Environment

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Abstract
The plant resources play major roles both in human healthcare and environmental management. Forest fruit/food resources have contributed immensely in saving food hunger in the land by always complementary arable crops during off- farming seasons. Forest food/fruit resources as one of the components of biodiversity resources is disappearing at alarming rate in the natural ecosystem due several anthropogenic actions and its multipurpose functions. Due to economic important of these Non Timber Forest Products (Citrus spp, Mangifera indica, Dacryodes edulis, Garcinia kola, Dennettia tripetala, Synsepalum dulcificum, Persia americana, Kola lepidota, Annona muricata, Chrysophyllum albidum, Irvingia species and Cola accuminata etc) resources, this paper highlighted the needs for preservation and sustainable management of these categories of plant resources for its future uses

Introduction: Tropical forest is abounding with a lot of plant genetic resources. The plant resources play major roles both in human healthcare and environmental management. Nigeria is blessed with several forest fruit species, the commonly utilized one within our communities are shown in Table 1. Majority of these plant species are collected from the wild, while some fractions are derived from homegardens or farm yards and scattered/isolated farms. Forest fruit/food resources has contributed immensely in saving food hunger in the land by always complementary arable crops during off- farming seasons. All forest fruits do not bear fruits at the same time, examples (*Citrus spp, Mangifera indica, Dacryodes edulis, Garcinia kola, Dennettia tripetala, Synsepalum dulcificum, Persia americana, Kola lepidota, Annona muricata* and *Cola accuminata* etc), that is they have various season of flowering, fruiting and riping/maturity. It has been observed that the edible fruits from forest plants are mostly available at the seasons of the year when food crops are not yet mature (Ikojo *et al*, 2005). Forest food plants with strong cultural, religious, traditional or nutritional relevance are sourced from the wild or undomesticated/uncultivated when compared to domesticated/cultivated field crops like yam or maize and of which benefits and use are only known and appreciated within the 338native range (Okonkwo *et al.,* 2024 and Leakey, 2019). Most rural dwellers depend on forest fruit species not only as food but for herbal medicine, though some forest fruits are yet to be discovered. Forest fruits have acquired more usefulness in keeping with their multipurpose character in the areas of carbon sequestration, on-farm biodiversity increment(Gouwakinnou, 2011), and soil nutrient replenishment in agroforestry systems (Batish *et al.*, 2008).

Some common IFFPs in Nigeria

Botanical name	Common name	Family
Allanblackia floribunda	Allanblackia	Coriacea
Dacryodes edulis	Butter fruit	Burseraceae
Irvingia gabonensis	Sweet bush mango	Irvingiaceae
Irvingia wombulu	Bitter bush mango	Irvingiaceae
Cola parchycarpa	White monkey kola	Malvaceae
Cola lepidota	Yellow monkey kola	Malvaceae
Cola lateritia	Red monkey kola	Malvaceae
Pentaclethra macrophyla	African oil bean	Fabaceae
Treculia Africana	Bread fruit	Moraceae
Chrysophyllum albidum	Star apple	Sapotaceae
Parkia biglobosa	Oil bean	Fabaceae
Pterocarpus millbreadhii		Fabaceae
Plukenetia conophora	African walnut	Euphorbiaceae
Adansonia digitata	Baobab	Bombacaceae
Vitellaria paradoxa	Shea butter	Sapontaceae
Annona muricata	Sour sop	Anonnaceae
Artocarpu saltilis	Bread fruit	Moraceae

Sources: (Awodoyin *et al.*, 2015 and Okonkwo *et al.,* 2024)

The reduction in forest resources distribution, availability between and within species variation is negatively affecting the environment, because of environmental degradation like deforestation, soil erosion and climate change. Forest food/fruit resources as one of the components of forest genetic resources is disappearing at alarming rate in the natural ecosystem due to its multipurpose functions. According to Adeola, (2015) the farmers have always used multipurpose (MPTs) trees as part of their production and these trees have assisted in addressing some problems of environmental degradation.

Needs For Fores Fruit/Food Resources In Our Environment: Apart from provision of food, medicine, fuelwood, timber and other industrial/raw materials, Akachuku, (2016) reported that forest food resources play important role in environmental management as summarized below:

Purification of air- by trapping and holding dangerous pollutants and at the same time off-setting the building of CO_2 in the air and fighting the greenhouse effect that could lead to global warming. Its widely documented that forest food trees in acre can produced or supplied enough oxygen each day for 18 people.

Improvement of climate-forest fruit/food species provides shade, releasing moisture to ease the build-up of heat in urban areas and increasing humidity in the dry climate. It also protects people from strong wind and cold, blocking glare from sun.

Forest fruit/food species conserve resources- by reduction of erosion (surface run-off and wind), increase air moisture, shading of streams, rivers, lakes and stabilizing temperature for aquatic life.

Aesthetic Values- forest fruit/food resources add beautification and aesthetic values to our landscapes, aids in absorbing and blocking noise as well as caution harsh weather conditions.

Forest food species ease the mind and body- by connecting us to nature, inspiring us spiritually, and make people relaxed their mind and recovery from illnesses fast.

Forest fruit/food enhances nutrients cycling- through leaf litters production and decomposition both primary and secondary mineral are added to soil to improve fertility. Forest litter is an important stage in habitat conservation providing nutrient return and organic matter replenishment (Nsien *et al.*, 2020 and Ogbonna *et al.,* 2010).

Human Menaces Leading to the Alarming Rate of Forest Fruits Disappearance in the Forests: There are several anthropogenic actions which enhancing disappearance of forest food/fruits resources in their natural habitats, these include:

Intensive cultivation- continuous expansion of farmland and shifting cultivation has led to forest resources loss and consequently lost of habitats by the forest fruits/food.

Bush burning-indiscriminate burning of bush is one of the cardinal indices of forest destruction. For instance forest fruits like *Dacryodes edulis* and *Synsepalum dulcificum* are prone to bush fire,that is even ordinary severe smoke from bush burning will surely kill these species.

Lumbering- both legal and illegal exploitations of forests fruits, examples Garcinia kola Ivingia species and Allanblankia floribunda etc culminated in winning up of these species in the forests.

Boundary Disputes- boundary crisis or disturbance between two States or Local Government Areas always lead to wanton destruction or damaged of biodiversity which forest fruit/food genetic resources is among.

Population Growth- increase in population has led to a continuous decrease in our natural fruit resources. Akachuku, (2016) noted that the present world population which stands at over seven (7) billion is expected to rise to over nine (9) billion by the year 2050. This implies that forest fruits among other trees will undergo severe damages in nearest future.

Inadequate government policy- lack of government policy guidelines on forest resources conservation, protection and preservation has negatively affects the availability of forest fruits.

Oil spillage- oil pollution in the rich states (Niger Delta of Nigeria) has hindered the growth of forest fruits species that are rich in carbohydrate, proteins and vitamins etc.

Extraction of medicine- Due to haphazard harvesting and collection of medicinal plants from the wild, many species are threatened and even endangered. The most serious proximate threats generally are habitat loss, habitat degradation, over-harvesting, invasive species, pollution, and anthropogenic climate change (Lawal *et al.*, 2022).

Important of Forest Fruit/Food Resources Classification: As our forest biodiversity varies globally, forest fruit/food resources also changes a long ecological zones. Forest fruits have multifunctional use - values adapted to diverse areas and cultures. There are many different means or ways of classifying plants and forest food inclusive. Abridged importance and classification of plants vis-a-via the forest food/fruit is noted by Joshi, (2018) as follow:

- For easy and quick cultural operations
- For the breeding purpose and to develop new varieties
- For facilitating propagation of crops
- For effective control of pest and diseases
- For cultivating crops suitable to different climatic conditions
- To enhance utilization more efficiently and effectively
- To help communicate similar ecological adaptations and cultural requirements
- To establish plant origins and relationships
- To uniformly categorize the plant species and varieties
- To avoid confusion when referring to a particular plant
- To get information about each group and sub-groups
- To present the full knowledge in a nutshell
- To recognize helpful plants for the advantage of mankind
- To show the relationship between the individual crop
- To systemize the presentation and make the remembrance of the plants easy and convenient
- For identifying and cataloging the large volume of information
- To help identify plants across different cultures and languages.

Akachuku, (2016) classified forest food/fruits species under the following headings:

Condiments- examples:Ivingia spp (bush mango) and Parkia biglobosa (African locust beans) which save as soup thickner.

Fresh fruits and seeds-examples: wall nut, Dialium guineensis, Chrysophyllum abidum, Ivingia gaboneensis.

Stimulants-examples: cola accuminata, cola nitida and Garcinia kola (commonly white, red and bitter kola respectively).

Nuts-examples: *Treculia africana* (Ukwa) in Ibo and Wall nut (Ekporo) in Ibibio.

Forest fruit/food as supplements-examples: *Pentaclethra macrophylla* and *Dacryodes edulis* commonly known as African oil beans and African pear (locally called Ube in Ibo and Eben in Ibibio dialects respectively).

Forest fruit/food as Edible oil- examples:*Dacryodes edulis*, *Poga olegea* and *Elaeis guineensis* etc.

Forest fruit/food as leafy vegetables-examples: Gnetum africana (Ukazi/Afang in Ibo/Akwa Ibom, *Heinsia crinita* (Atama), *Lasinthera africana* (cat leaf /Editan), *Vernonia amygdalina* (bitter leaf/Etidot) etc.

Forest fruit/food as fruits and alcoholic drinks-examples *Dialium guineensis, Tamarindus indica, Elaeis guineensis,* and *Raphia species*.

Forest food/fruit as *sweetners*-examples*:*T*hermautococus danielli, Synsepalum dulcificum, Dioscoreophylium cumminis* etc.

Spices-examples: *Occimum gratissimum* (sense leaf), *Dennittia tripetala* (Mimi/Nkarika), *Piper guineensis* (Odusa/Uziza). This classification made rural communities to values forest fruits/food resources within their domain and also protect and conservation of species from fast disappearing or going extinct thereby assisting in sustainable production and management.

Conclusion: Forest fruit/food resources like others plants species has contributed in different dimensions to balanced the nature, play major role in the diets and economic emancipation of rural dwellers in terms of providing food and nutritional needs for man, creating sustainable environment in area of nutrients cycling, carbon sequestration and improvement of soil fertility. Forest fruits as Non Timber Forest Products (NTFPs) complement the timbers need of the people (*Garcinia kola* and *Irvingia species* etc) and also creates micro-climate for wildlife.

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Factors Affecting Wood Sawdust Handling in Ungogo Local Government Area of Kano State

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Abstract

Sawdust is a wood waste, with economic potentials. This study assessed factors affecting sawdust handling in Ungogo local government, Kano State. Two stage sampling technique was used to select respondents. Data was collected using structured questionnaires, administered to sixty timber handling sheds in Ungogo, using snowball sampling. Data were subjected to descriptive and inferential analysis. Result showed all timber handlers to be males, 80 % married and full time traders, and 63% with non-formal education. Age distribution showed 31 - 40 years old (33%), 41 – 50 years (26.67%), 21 – 30 years (12%) and 51 – 60 years old (8%). Also, 53 % have 1-10 years experience in timber handling. Circular saw machines were the commonest (57%), with 70% of them being 1 - 5 years old. It was also observed that 53 % produce 41 to 50 bags of sawdust monthly. Sawdust was disposed by storing (27 %), regular sales (70 %), and by burning off (3 %). Also, 43% of sawdust buyers use it for cooking. Sawdust was chosen for its relative cheapness (50%), availability (16%) and simplicity (7%). Age and experience of timber handlers were significant factors influencing sawdust utilization in the study. Bulkiness / storage problem (40%), pollution (33.33%), and transportation (10%) were major challenges facing sawdust handling in the study area. The study suggests the provision of financial aids and technical supports for sustainable timber management, provision of cheap and safer cooking energy, production of sawdust cooking briquettes, and wood-based panel industries for efficient waste utilization.

Keywords: Sawdust, Timber sheds, Disposal, Handling, Circular saws

Introduction: Sawdust is among the most abundant wood wastes generated in sawn timber operations in Nigeria (Ogunbode *et al*, 2013; Nnaji & Udokpoh, 2022). Circular saw, the common machine in timber handling sheds, have thicker blades, multiple teeth, and larger (swage) kerfs, resulting in large sawdust generation, during wood splitting and cross cutting operations (Silveira da Silva, 2022). To attain sustainability in waste management and lumber recovery, it is essential to monitor the amount of major wood wastes generated. Proper wood selection; proper machine selection, blade setting and installation; regular maintenance, and prompt replacement when the need arises, are essential steps in sustainable timber and waste handling (Ogunwusi, 2014). The greatest waste in Nigeria is from sawmilling, followed by small scale furniture industries (Ogunwusi, 2014). Waste generation is increasing in Nigeria because of factors ranging from species to human and technological factors; such as, timber geometry and anatomy, newly introduced species that are unpredictable, outdated technology and financial constraints (0gunwusi, 2014). Kukogho *et al,* (2011) reported a significant difference between sawdust generation and tree species. An appraisal of these variables is necessary to achieve sustainable wood conversion and utilization. The objective of this study is to identify the socio economic characteristics of timber handlers (who handle wastes), sawdust disposal and utilization methods, factors influencing sawdust handling, and the problems facing its efficient handling and utilization in the study area. The study makes use of primary data collected through personal observations, structured questionnaires and secondary information sources.

Materials and Methods: Description of the study area: The study was carried out in Ungogo, one of the 8 local government areas in Kano metropolis. Ungogo is located between latitudes 12º 05" 26' and 12º 09" 06' N, longitudes 8º29"48' and 8º 49"67' E. The total land area is 204 km², with a human population of 369,657 (NPC, 2006). It has eleven wards. It borders with Dawakin Tofa to the North, Dala to the west and Minjibir to the South. Eastern Ungogo local government falls within the Sudan Savanna agro-ecological Zone. There are two seasons (dry and wet season). The dry season comprises of harmattan period (low temperature, dry, windy, dust and sometimes with low visibility), sunny and hot, usually between November and April, while wet season is usually warm, humid and variable rainfall, usually between May and October of the year (Tukur *et al*, 2022). The annual temperature in Kano ranges between 56 ^{0}F and 101^{0}F and is rarely below 51^{0}F or above 106^{0}F, while the annual rainfall ranges between 0.5 inches and 6.8 inches, usually between April and August (Weather Spark, undated).

Method of Sampling: Purposive multistage sampling technique was adopted in the study. Four wards were purposively selected from Ungogo local government, based on timber marketing and handling activities. An inconsistent figure on the population of timber marketers (handlers) precludes the use of a sampling frame. Snowballing was used to select a total of sixty (60) small scale timber selling / handling sheds from the 4 wards (table 1). Each shed manager/operator was chosen to serve as the timber handler/seller (respondent).

Table 1: Selected respondents in Ungogo local Government area

Selected wards	No of selected timber handling/marketing sheds

(Study area)	n=60
Rijya Zakki	22
Ungogo town	12
Bachirawa	16
Gayawa	10

Field survey, 2023

Method of Data Collection : The study was preceded by a reconnaissance visit to the study area, to identify timber marketing/ handling and waste handling activities. Data was collected using structured questionnaires. Questionnaires were administered to sixty (60) small scale sawn timber handling / marketing sheds, using snowball sampling technique. Data was collected on: socio economic characteristics of timber/sawdust handlers, technical factors affecting sawdust yield and, problems facing timber / sawdust handling in the study area. The timber seller/handler was chosen as the major respondent in the study.

Method of Data Analysis: Data collected was analyzed using descriptive statistical tools of frequency counts, percentages and modal counts, in form of tables and charts. A multiple linear regression analysis was carried out to identify factors actually influencing sawdust handling in the study area. Data was entered and analyzed using excels software. Sawdust handler's monthly income (Y) was regressed against demographic variables (X_1, X_2, X_3, X_4 and X_5). Y is the dependent variable (monthly income), while X are independent variables (age, sex. marriage, education and experience).

Result and DiscussioN: Assessment of sawdust handlers socio economic characteristics : Socio economic information is important in the management of resources. Table 2 showed socio economic variables affecting the handling and utilization of sawdust in the study area, to include: age, gender, marital status, major occupation, ethnicity, level of education and handling experience. Age is an important driver of resource management and skills. Table 2 showed that most (33 %) timber handlers/traders were 31 – 40 years old. This showed they were in their productive ages, as timber handling activities requires strength and agility. Babatunde *et al,* (2020) reported most timber marketers in Ife East local government area to be 40 - 49 years old and, Diwe *et al* (2016), reported most timber workers in South East Nigeria to be 20 - 39 years old. This revealed timber handling activities are dominated by young and middle aged people that have the strength and agility to cope with the stress.

The table also showed that all (100%) timber handlers were males. The nature of timber handling activities is usually masculine in nature. This is in line with Diwe *et al*, (2016) who observed 95.9% of timber workers in South Eastern Nigeria to be males. Babatunde *et al,* (2020) reported most timber marketers in Ife East to be males and, Babatunde *et al,* (2017) reported most timber workers in Ondo sawmill to be males. The result is at variance with Babatunde *et al*, (2022) who reported majority of timber marketers in Kajola Local Government area of Oyo State to be females. The dominance of males in the study area may also be connected with the culture and nature of the society involved. More so, the study was conducted in Kano, Northern Nigeria, where most women are involved in household chores and men engaged in laborious activities, due to the culture of the region. Espada and Kainer (2023) stated that gender norms that guide what men and women are expected to accomplish are socially constructed, reflecting the society in which they are embedded. Schmink and Gomez - Garzia (2015) stated that programs and policies seeking to promote community timber management often focus on male members.

Also, 80 % of the respondents were married, while 16 % were single. Timber trades are seen to be generally lucrative enterprises (Babatunde *et al*, 2020) in which married people are more engaged, because they're more responsible, aspiring to care for their household. This result agrees with Diwe *et al*, (2016) who observed most timber workers in South Eastern Nigeria to be married and Babatunde *et al*, (2017) who reported most timber marketers in Ondo sawmill to be married. Babatunde *et al*, (2020) stated that marriage influences household size, available labour supply, family income and savings pattern.

Furthermore, 63 % of respondents have non-formal education. This disagrees with Diwe *et al*, (2016), with 93.1% timber workers having primary/secondary education in South East Nigeria and, Alawode and Jimoh (2021), who observed that all timber workers in Ibadan were literates with varying levels of education. Babatunde *et al*, (2020) asserted that higher education status brings better profit from the use of sound business principles and wise business decisions. Faleyimu (2014) asserted that formal education is advantageous over some deficiencies in non-formal education, and could influence the adoption of innovation and increase peoples level of awareness and perception. Alawode and Jimoh (2021) asserted that education is not a prerequisite for venturing into timber business but could be an added advantage.

Equally, 53 % of respondents have 1 - 10 years experience in timber handling trade, indicating majority are new in the business. Little experience may affect timber handling efficiency and consequently, leading to poor lumber recovery (Aghimien *et al*, 2020). The result disagrees with Alawode and Jimoh (2021) who reported 57% of timber traders in Bodija market having 21 - 30 years experience in timber trading. Adedokun *et al*, (2017) identified years of experience as one of the factors affecting timber marketing. Aremu *et al*, (2015) asserted that experience is a vital skill needed in achieving good returns on investment by producers and marketers. Aghimien *et al*, (2020) stated that machine operator's skill and experience can significantly influence lumber recovery (waste reduction). Alagbada (2021) reported that machine operator's expertise knowledge contributes to lumber recovery, consequently, waste reduction.

Table 2: Socio – economic characteristics of timber/sawdust handlers in the study area

Variables	Frequency N=60	Percentage %	Modal variable
Age of Respondents (years)			
21-30	12	20.00	
31-40	20	33.33	31 - 40
41-50	16	26.67	
51-60	8	13.33	
Above 60	4	6.67	
Sex			
Male	60	100.00	Male
Marital Status			
Married	48	80.00	Married
Single	10	16.67	
Widow	2	3.33	
Level of Education			
Non formal	38	63.33	Non formal education
Secondary	20	33.33	
Tertiary	2	3.33	
Years of Experience			
1-10	32	53.33	1 - 10 years
11-20	12	20.00	
21-30	10	16.67	
31-40	6	10.00	
Monthly Income from sawdust			
40,000-50,000	20	33.33	
Above 50,000	40	66.67	Above 50,000 naira
Price of sawdust (50kg bag)			
100-500	24	40.00	
Unavailable	30	50.00	Unavailable
Monthly sawdust production			
Per shed / (50 kg bags)			
31-40	22	36.67	
41-50	32	53.33	41 - 50
Unavailable	6	10.00	
Sawdust sales frequency			
Daily	36	60.00	Daily
Weekly	20	33.33	
Monthly	4	6.67	

Source: field survey, 2023

Assessment of sawdust handling in the study area: Figure 1 showed that 70 % respondents dispose their sawdust through regular sales, 27% store sawdust for booking while, only 3% burn off their sawdust. On the contrary, Nnaji and Udokpoh (2022) observed that open dumping (76.75%) and burning off (71.7%) were the commonest sawdust disposal method in Enugu timber market. 21.7% waste was collected by households and 10% by poultry farmers in the study. Nyemba *et al*, (2018) reported that 51% and 34% of wood wastes were used for cooking and poultry farming, respectively, in Cameroun. Okorie (2021) reported that waste disposal in Akure was mainly by open air burning. The result also revealed that, 50 % of sawdust handlers indicated that their customers prefer sawdust as their cooking fuel because of its relative cheapness and affordability. Onochie *et al*, (2020) reported that sawdust abundant availability as wood industrial wastes makes it to be one of the most promising cooking fuel materials.

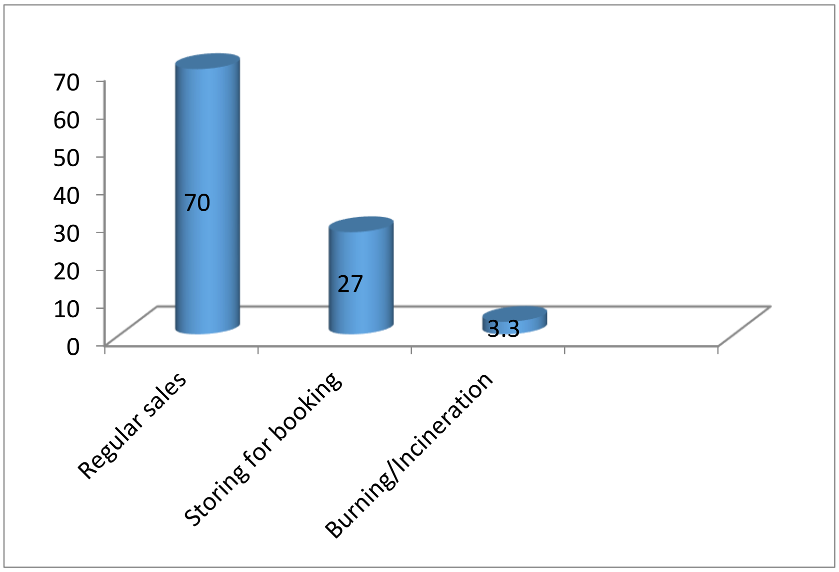

Figure 1: Major sawdust disposal methods in the study area

Uses of sawdust

Figure 2 revealed uses of sawdust, according to the handlers as, domestic users (43%), poultry/animal bedding (33.30%), industrial uses (6.7%), and undisclosed uses (16.7%).

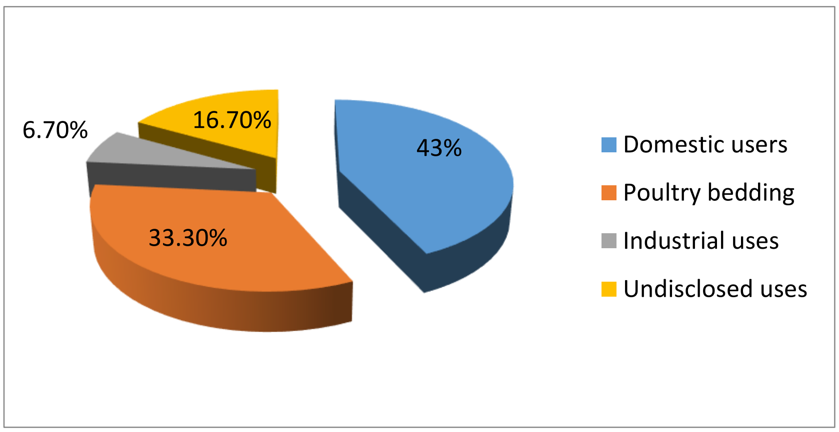

Figure 2: Users of sawdust in the study area

Reasons behind user's preference for sawdust

Figure 3 showed the reasons behind user's preference for sawdust. The result revealed that 50 % of sawdust handlers indicated that their customers prefer sawdust as their cooking fuel because of its relative cheapness and affordability. Onochie *et al*, (2020) reported that sawdust abundant availability as wood industrial wastes makes it to be one of the most promising cooking fuel materials.

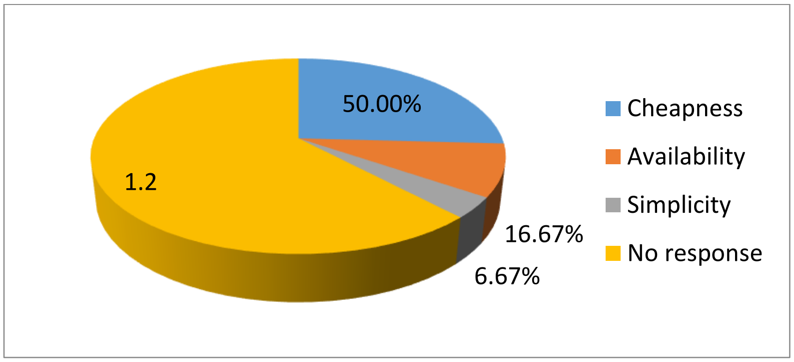

Figure 3: Users preference for sawdust in the study area

Technical factors affecting sawdust handling: Table 3 showed the technical factors affecting sawdust handling in Ungogo. Some identifiable technical factors in the study include type of wood handling/conversion machinery, machine age, timber supply, operator’s skill and experience, and nature of sawn timber species. Machinery type and operators skill have been identified among important causes of wastes in conversion operations (Aghimien *et al*, 2020). A proper understanding of the waste generated due to the type of wood processing machinery contributes to waste management and quality control and its possible utilization as industrial raw materials. (Dias Júnior *et al*., 2014). The type of saw blade and number of teeth can lead to different amounts and formats of waste, and consequently they may have different destinations. Table 3 showed circular saws as the commonest wood conversion machine in the study area (57%). Bello (2017) stated that circular saws produce substantial density of sawdust, followed by chain saws and band saws Circular saw is among the commonest machine in timber crosscutting, trimming and edging in timber handling and marketing sheds.

Machine age affect its performance efficiency. In same light, 70 % of the wood conversion machines were not more than 5 years old. Adhikari and Ozarska (2018) stated that an improved and new variety of machinery, instead of old and obsolete ones, helps in reducing wood wastes. He further stated that the major causes of wood wastage are either technology-based factors such as the use of obsolete equipment and inefficient procedures and production methods. Aghimien *et al* (2020) reported that most wastes found in selected sawmills in Kajola local government area of Oyo State were due to old age machines used and, the form and shape of the wood.

Many respondents (57%) receive their timber supply within 5 and 8 weeks intervals. A regular supply of timber is necessary for operations to proceed smoothly and, consequently, obtain the final products. Due to variations in wood anatomy and chemistry and, consequently, its density and other mechanical properties, the waste generated varies with species. Silveira da silva *et al*, (2022) reported that difference in species anatomy affects wood processing time. He reported that a longer processing time implies more exposure to the effects of the saw blade teeth. He also added that the effects of softwood or hardwood may also influence waste generation. (Ogunwusi, 2014) reported that among the causes of voluminous wastes is the introduction of new lesser known timber species whose properties are not well understood. *Chrysophylum delavayi* is a new species in the markets, whose properties have not being fully examined. Silveira da silva *et al*, (2022) reported that *Pinus caribaea* var. *hondurensis* wood generates a higher waste compared to *Tectona grandis* wood. Kminiak and Gaff (2015) reported that the surface quality of the processed wood material also affects waste generation.

Table 3: Technical factors affecting sawdust handling

Variables	Frequency N = 60	Percent %	Mode
Type of machine			
Circular saw	34	56.67	Circular saw
Band saw	8	13.33	
Tie rod cutter	18	30.00	
Age of machine			
1-5 years	42	70.00	1 – 5 years
6-10	8	13.33	
11-15	2	3.33	
Timber Supply frequency			
1-4 weeks	20	33.33	
5-8 weeks	34	56.67	5 – 8 weeks
Undetermined	6	10.00	

Sawdust yield from species			
Brachystegia eurycoma (Eku)	26	43.33	
Tectona grandis (Teak)	18	30.00	
Funtumia elastica (Ire)	16	26.67	
Chrysophylum delavayi (Ashwali)	40	66.67	Ashwali

Source: field survey data, 2023

Factors influencing sawdust handling in the study: Table 4 revealed that handler's age and handling experience are statistically significant at 1% and 5%, respectively. Age was negatively related to handler's monthly income, while experience was significant and positively related to handler's income. This implies that a unit increase in years of experience increases monthly income by 974.282, i.e, sawdust sales (monthly income) is a function of years of experience in the study area, i.e. experienced people make more income from sawdust in the area. An increase in handlers age decreases monthly income by 597.6365, i.e, aged people handle/sell less sawdust (make less income by selling less sawdust)

Table 4: Regression analysis of factors influencing sawdust handling in the study area

Variables	Coefficients	Stdd Error	Tvalue	P>|t|
Age	-597.665	59.0496	-1.66	0.110*
Sex	-3590.705	12690.26	-0.28	0.780^{ns}
Marriage	-454.11463	5264.025	-0.09	0.932^{ns}
Education	2782.76	3388.757	0.82	0.420^{ns}
Experience	974.282	385.001	2.53	0.019**
Constant	40463.16	16289.98	2.48	0.021

***: significant at 0.01 level   **: significant at 0.05 level   ns: not significant**

Challenges of sawdust handling in the study area: The major challenges facing sawdust handling and disposal, in order of ranking, include: sawdust bulkiness / storage space (40 %), environmental pollution (33 %) and, high handling and transportation costs (10 %). Nnaji and Udokpoh (2022) identified lack of transportation to take wastes to designated dump sites as one major limitation of sawdust disposal in Enugu. Ogunwusi (2014) identified lack of incentives for wood waste utilization and inadequate information on economic returns of wood waste utilization, as major constraints to effective wood waste utilization in Nigeria.

Table 5: Challenges facing sawdust handling in the study area

Sawdust handling problems	Frequency	Percentage	Ranking
Bulkiness/storage space	**24**	**40.00**	**1st**
Pollution (smoke and odour)	**20**	**33.33**	**2nd**
Handling and Transportation costs	**6**	**10.00**	**3rd**
Undetermined	**6**	**10.00**	**4th**
Seasonality of timber	**4**	**6.67**	**5th**

Field survey, 2023

Conclusions: Sawdust is an enormous waste in timber handling, which can support livelihoods. Timber workers need more education and experience to excel in the endeavor. Sawdust is regularly disposed in the study area through regular sales for domestic cooking. Substantial income is realized from sawdust sales. Major challenges facing the handling of sawdust wastes are bulkiness in storage, environmental pollution, and high transportation costs. Despite the small scale of operations in the area, sawdust has the potentials to generate substantial income, stimulate small scale industries, and support domestic energy needs in the region.

The study recommends proper technical training for timber workers in modern timber handling and waste management techniques, provision of good transportation network, provision of modern timber handling machines at affordable rates, establishment of wood based industries that can efficiently utilize wood wastes to generate energy and manufacture composite materials for rural development.

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Spatiotemporal Dynamics Influencing Farmers' Adaption and Social Capital in Farming Systems Resilience to Climate Change

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Introduction: Climate disasters including unseasonal rainfall, drought, degradation of soil resources, plant pest and disease outbreaks, with economic, political crises, and exponential population growth are adding pressure to the global food systems. Farming systems, farmers' livelihood and agriculture in general are highly vulnerable to these risks, thus leading to food and nutritional insecurity worldwide (Jayadas & Ambujam 2021). These constraining factors, particularly, climate change will continue to affect global agricultural systems, which may lead to a lack of diversity and low productivity in agricultural farming systems (Andatia *et al.,* 2022, Amaechina *et al.,* 2022, Le Goff *et al.,* 2022, Tao *et al.,* 2023). This research articles address the complex interplay between climate change, the social construct to resilience, and agricultural resilience as a whole by reviewing findings in various published articles to meet its objective.

The concept of interconnected social (-economic) risks considers the underlying drivers of risks in terms of their social, economic, and human interactions. The social construction of risks implies that vulnerable groups at specific social groupings are particularly susceptible to climate and disaster risks. The interconnections between multiple social-economic risk drivers increase vulnerability and reduce the adaptive capacity of farmers' resilience. The different degree of groups against the various hazards which may change with time as consequence of different factor represents multi vulnerability (Lauriena *et al*., 2022). Climate change is now having a pronounced impact on all aspects of our social life, including income and food security, and found an attributed intensified rate of environmental degradation. In turn, this has negative upstream effects on the national economy (Son *et al*., 2019). In particular, climate disasters, including flash floods and prolonged absence of rains during the rainy seasons, floods are either leading to waterlogging in fields thus depleting soil nutrients for crops or hindering water availability to crops within the growing seasons when rains rescinds for a longer duration as observed in many farmers in the Nigerian agricultural production zones. Even after the flood waters recede, crops face disease and pest attack, erosion problems, and competition from weeds, leading to multi-vulnerability amongst agriculture practicing households. The challenge here is to make farming systems and the farmers be able to fulfil their goal even in the presence of such random, unpredictable changes.

In recent years, the concept of resilience has been used increasingly to address such challenges faced by farmers in agriculture production systems (Jayadas & Ambujam 2021). Limited adoption of transition management, agile planning, and adaptive modelling in agricultural resilience to climate change is accounting for spatiotemporal dynamics. The study proposes an enhanced understanding of agricultural resilience for climate uncertainty by systematically integrating resilience principles.

Methodology: The study was conducted through a comprehensive literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A thorough examination of 217 agricultural resilience research articles was undertaken, with specific attention to farmers' spatiotemporal dynamics influencing farming systems resilience centred on farmers' adaptation and social capital. Findings were synthesized from peer-reviewed journal publications, and a literature matrix was devised to streamline the selection process using key terms such as agricultural resilience, climate risk, farmers' vulnerability, adaptation and social capital.

Result and Discussion: Farm Systems Resilience and Climate Change Adaptation: Climate change has been increasingly affecting farming and food system, hence, fostering importance of resilience discourse in farming systems research to improve farming households wellbeing. Focus on assessing the resilience of farming systems, addressing conceptual and methodological ambiguities as researched by Van der Lee *et al*., (2022) systematically review 123 papers. They identified four theoretical positions ("lenses"), and suggests five design choices for resilience assessment. Their findings suggest the conflation of resilience definitions and measures in the literature. Lenses including traditional, vulnerability, capacities, and agroecology identified offered a novel causality framework. There is Lack of a shared understanding, particularly when comparing findings within and across systems. Understanding the influence of climate trends on productivity growth can inform strategies for enhancing resilience.in different domains including disaster risk reduction, agriculture, and the wider community. The studies collectively emphasize the importance of participatory approaches, context-specific strategies, and comprehensive planning to build resilience in the face of climate change.

Even though the adoption of climate tolerant technologies proofs to be beneficial to farmers prone to climate disasters, there has been disparity in the mode of adoption of these technologies based on equity in its distribution. Sanogoa *et al*, (2023) pointed out that gender disparities in the adoption of agricultural technologies are widely recognized, stemming from factors such as poverty, geographical distance, lack of infrastructure, minority language group affiliation, land ownership, employment, and income. Whilst these may vary in context their implications to wider agricultural practicing networks cannot be overlooked. Wanjira *et al.*, (2022) reveal the adoption of climate-smart maize varieties and their impact on household income in Kenya. They found that adoption of climate-smart varieties positively influences household income, suggesting benefits from technology adoption. Considering gender, wealth, and control of household decisions Jones *et al*., (2014) examines the relationship between farm production diversity and household dietary diversity in Malawi. They posit that, increased farm diversity is positively associated with dietary diversity, especially in woman-headed households and wealthier households. The relationship is complex and influenced by various factors. The study suggests that diverse production systems contribute to diverse household diets, emphasizing the role of gender, wealth, and household decisions in this relationship.

A thorough scrutiny of the obstacles to adaptation arising from the lingering effects of losses and damages linked to risk factors arising from climate extreme events has been inferred by Amaechina *et al.,* (2022). Limited exploration of the role of social capital in sustaining poverty escapes and compensating for adverse social norms has been highlighted. Further, investigation into the motivations and barriers for farmers adopting context specific technologies may be beneficial to farming system research in the face of climate change. Limited research on the assets and capabilities approaches in understanding wellbeing and health in rural communities also constitute challenges in farming systems research.

To tackle climatic hazards and resultant crop loss, adaptation in the production system has evolved as a vital policy response for reducing climate vulnerability while protecting the livelihood and agri-food system of underprivileged farmers. Kihiu (2016) analyses the effects of basic capabilities on households' decisions to participate in collective management of pastoral resources in Narok County, Kenya. They found increased basic capabilities reduce cooperation levels in collective management. Social capital, neighbourhood social influences, resource system characteristics, socioeconomic factors, and institutional factors were identified as important determinants. The study encourages strategies to build social capital and facilitate the adoption of improved range management technologies, emphasizing the role of an enabling environment and policy implications. There is however lack of attention to the social events sustaining social capital and their implications for debt and migration for resilience of farms. Sitko *et al*., (2021) examines the relationships between food aid and the adoption of climate-adaptive agricultural practices (CAPs) in smallholder households in Ethiopia and Malawi. They found that food aid increases the adoption of resource-intensive practices (soil and water conservation, livestock holdings) by easing capital and labour constraints and enabling greater risk-taking.

Farmers are already adopting numerous adaptation strategies, such as the modification of resource management, improving farm management practices, purchasing crop insurance, and the diversification of production activities (crop–mix) (Bairagia *et al*., 2020; Sitko *et al*., 2021). For less risky practices (organic fertilizer use, legume intercropping), food aid has negative effects, indicating a substitution effect triggered by food aid. Analyses heterogeneous impacts based on transfer values and levels of low rainfall risk exposure highlights the value of leveraging existing social assistance interventions for climate adaptation. Gao *et al*., (2022) investigates hog farmers' motivations to adopt genomics for breeding African Swine Fever (ASF)-resistant hogs in China. Examining the impact of risk preferences and peer effects on adoption time frames, they found that risk-averse farmers are more likely to delay adoption. The delay in adoption highlights the findings by Sitko *et al*., (2021) where their findings has revealed that without possible aids farmers are sceptical about risk taking. Social network status does not affect adoption time frames, but closely related farmers' time frames are positively correlated. The study highlights the influence of risk preferences and peer effects on technology adoption, offering implications for local governments and companies promoting new technologies.

Farm resilience in different contexts has been under studied by Le Goff *et al*., (2022) which shows that farmers' resilience in Uganda and Switzerland is negatively influence by climate change challenges. Resilience in Uganda relies on local connections and agroecological practices, while Swiss farmers depend more on institutional support and technology. The need for flexible yet consistent tools based on participatory approaches to understand and strengthen farm resilience is identified. Njuki *et al*., (2022) in their study on weather and long-run climate trends on farm productivity has reveals that climate variability influences farmers' productivity. The study emphasizes the need to consider different sources of productivity growth, including climate adaptation efforts.

The Interlock between Social Capital and Climate Disaster Resilience Planning: The resilience of agricultural livelihoods examined by Shah *et al*., (2017) emphasizes the intangible and non-material dimensions of resilience. They challenge the central focus on tangible capitals and advocates for a more nuanced understanding of emotional and affective indicators of resilience. Tschakert *et al*., (2023) explores the intersection of development pathways, climate change responses, and resilience, emphasizing power, agency, and social justice. They highlight the transformative role of alliances, resistance, shared learning, and inclusive approaches in building political capabilities for just climate action. A shift in resilience thinking need to address agency, power, and difference in socio-ecological resilience as argued by Carr (2019).

Several studies collectively contribute to understanding resilience in different contexts, including agriculture, social dynamics, livelihoods, and climate change responses. The various reviewed article here highlights the need for nuanced approaches, considering both tangible and intangible dimensions of resilience, and the importance of equity, agency, and social justice in building resilience to climate-related stressors. The significance of diverse interventions, adaptive strategies, and transformative actions for enhancing climate resilience at various levels has been emphasized—from farming systems to community livelihoods. Eakin *et al*., (2015) identifies predictors of maize land use and livelihood outcomes for smallholder farmers in three regions of Mexico. Their result shows that regional and inter-regional heterogeneity in farmers' responses underscores the importance of regionally specific policy interventions. The significance of regionally specific policies in understanding and addressing diverse livelihood outcomes is emphasized.

The competition between cash and food crops, specifically, the impact of eucalyptus plantation as research by Bazzana (2021) reveals that government environmental policies can play a key role in improving awareness of ecological effects, contributing to ecological and climate resilience. Limited analysis of negative externalities of eucalyptus on soil fertility in fragile socio-economic contexts. Urban planning and climate uncertainty have been researched by Krishnan *et al*., (2023) in two distinct locations including urban areas in the Global North (Amsterdam) and Global South (Mumbai) which infers the locations to face uncertainties due to climate change. Planning responses in both regions are incremental, emphasizing "bouncing back," but there's a need for more comprehensive approaches. Kalkuhl *et al*., (2020) investigates the effect of climate conditions on the prevalence of sharecropping as a form of traditional land tenure. They found that sharecropping acts as a form of insurance in areas with low precipitation. The role of sharecropping in reducing the need for costly risk management strategies where formal insurance is unavailable has been highlighted. Forsyth *et al.,* (2022) explores equitable resilience in western Nepal, emphasizing the influence of equity framings on resilience efforts. They point out the limitations of state-led efforts that may not reflect local experiences of risk, particularly social exclusion. There is need for a more critical understanding of normative framings of equity in resilience interventions.

Long-term development pathways effects on community resilience have been researched by Stotten *et al*., (2021) in two villages in the Austrian Alps. They posit different development pathways lead to economic, structural, and political lock-ins, reinforcing path dependencies. They found potential challenges and reinforcing effects of specific development trajectories that interplays economic, social, cultural, political, and natural domains in community resilience. Zugravu-Soilita *et al*., (2021) empirically investigates social relations (structural social capital) and cultural values (intangible cultural capital) on tribal agricultural production in New Caledonia. Findings suggest agriculture and social capital are interlinked, and cultural values affect tribal social relations, indirectly influencing economic performance. There is complementarity between different forms of capital and the essential role of this complementarity in sustaining tribal agriculture and social ties for climate resilience sustenance.

The resilience of Hu village (Sichuan, China) in the face of multiple disturbances, including globalization and modernization has been assessed by Wilson *et al*., (2018). Their result shows Hu village is moderately resilient, with tendencies for further weakening, especially in natural and political domains. the impact of industrialization, deagrarianization, and changing stakeholder expectations on community resilience, emphasizing the need for realigning government policies for improvement. The changing role of agriculture and farming practices in contributing to sustained escapes from poverty in rural Kenya in the context of climate change as investigated by Eichsteller *et al*., (2022) revealing links between accumulation of assets and poverty escapes are ambiguous, and climate change shocks exacerbate difficulties in conversion processes. The challenges in conversion structures and processes, emphasizing the need for interventions to improve existing structures for sustainable poverty reduction.

Limited attention to the impact of changing sociopolitical contexts on community resilience and social capital has been observed in this various research. Insufficient exploration of the potential trade-offs and synergies between different forms of capital (social, cultural, economic) in influencing agricultural practices and climate resilience outcomes is highlighted. Demont (2022) investigates how Indian Self-Help Groups (SHGs) enable households to withstand rainfall shocks in Jharkand, East India. They found that, SHGs operate well under large covariate shocks, providing counter-cyclical credit access during droughts. Credit access and peer networks contribute to increased food security and migration as risk management strategies. These demonstrates the role of local self-help and financial associations in helping farmers cope with climatic shocks, emphasizing the importance of credit access and peer networks. Limited exploration of the role of social capital in shaping responses to agricultural resilience, and diversification strategies has been identified as possible area for exploration. Insufficient attention to the intersection of social-ecological resilience and social capital, hindering a comprehensive understanding of how social factors influence resilience outcomes.

Recognises the interconnectedness of social capital, cultural values, and economic performance in shaping resilience outcomes cannot be overemphasized. Few studies explicitly investigate the long-term impact of interventions on multiple dimensions of resilience and well-being, particularly in diverse geographical and climatic contexts. Emphasis on the need for disaggregated indicators and experiences to understand the complexities of water security, agricultural resilience amidst climate realities, and food and nutrition security highlight the spatiotemporal dynamics involved in overall agricultural resilience discourse amidst climate change. The recognition of potential conflicts between short-term and long-term resilience goals, highlighting the importance of considering temporal and spatial factors in policy and intervention design. The importance of integrated approaches, combining financial support, social protection, and climate information, to enhance resilience and well-being in diverse contexts may be further explored.

Examining the heterogeneous impacts of credit on households in Vietnam based on factors such as relative poverty, loan volumes, access to agricultural extension services, and ethnicity, Luan and Bauer (2016) found that, credit access affects recipient groups differently, with positive impacts on non-farm income but no effect on farm income. Effects vary based on economic conditions, ethnicity, and credit volumes received. The research highlights the need to consider the heterogeneity in the impacts of credit access on different household groups and the importance of economic conditions in benefiting from rural credit. Scognamillo and Sitko (2021) on their part assesses the interactions between participation in Malawi's public works program (MASAF) and climate-smart agriculture (CSA) practices, highlighting the synergy between social protection and agricultural interventions. They found that, MASAF participation increases the adoption of CSA practices, contributing to sustained adoption. The joint effect enhances households' productivity and welfare, reducing sensitivity to low precipitation. The synergistic benefits of integrating social protection interventions with the promotion of CSA practices, demonstrating the potential for skill transfer from public works to farmers' fields.

Limited exploration of the role of social capital in the effectiveness of saving promotion interventions calls for attention. The studies also revelled insufficient attention to the social and governance dimension in farm sustainability research. There is need for further investigation into the long-term impacts of resilience-building interventions amidst climate variability. The contribution of social capital to sustained poverty escapes in Ethiopia.as explored by Woldehanna *et al*., (2022). They inferred the role of material wealth, human, political, and social capital, and the impact of adverse social norms. The research posits that better-off households possess a combination of capital underpinned by an enabling environment. Social events sustaining social capital can be a double-edged sword, leading to debt and migration. They suggest that social capital helps families during shocks but also highlights challenges, providing policy suggestions such as promoting public discussion and group-based insurance. Clay and King (2019) investigates how development transitions, such as the adoption of 'green revolution' agricultural policies in sub-Saharan Africa, intersect with cross-scale social-environmental processes to shape smallholders' adaptive capacities and pathways. The found that, adaptive capacities vary across livelihood groups due to evolving environmental, social, and political-economic processes. Social institutions play key roles in shaping differential adaptation pathways by enabling or constraining opportunities for smallholders. Rwanda's Crop Intensification Program enables wealthier households to adapt through commercial agriculture, while deactivation of local risk management institutions reduces options for most households. Access to capitals (land, labour, nonfarm income) is crucial for negotiating new institutions and pursuing alternate livelihood practices. The research emphasizes the dynamic and context-specific nature of adaptive capacity, illustrating how social institutions and power structures influence smallholders' capacities to adapt to climate change.

Conclusion: The wellbeing of farming households is often described in terms of assets, community support networks, and capabilities adapted to rural life. Climate variability influences farmers’ productivity. Hence, understanding the nature of interactions between weather, land quality, and yield can inform strategies for enhancing climate resilience in farming systems research. Participation in government intervention programmes increases the adoption of CSA practices, contributing to sustained adoption. The joint effect enhances households’ productivity and welfare, reducing sensitivity to low precipitation. The synergistic benefits of integrating social protection interventions with the promotion of CSA practices, demonstrating the potential for skill transfer from public works to farmers’ fields. Risk-averse farmers are more likely to delay adoption of technologies when faced with climate realities; however, social network status does not affect adoption time frames, but closely related farmers' time frames are positively correlated. Sharecropping, however, has been identified as a form of insurance in areas with low precipitation. The role of sharecropping in reducing the need for costly risk management strategies where formal insurance is unavailable has been highlighted. The adaptive capacities of farmers vary across livelihood groups due to evolving environmental, social, and political-economic processes.

Social institutions play key roles in shaping differential adaptation pathways by enabling or constraining opportunities for smallholders. There has been lack of structured consideration of multiple resilience dividends from planning to evaluation stages. The study revealed that farmers’ resilience varies in different geographical locations as seen in the case of Uganda and Switzerland farmers where their resilience was negatively influence by climate change challenges. Whilst resilience of farmers in Uganda relies on local connections and agroecological practices, Swiss farmers depended more on institutional support and technology. However, strategies to enhance short-term farm resilience may conflict with long-term regional resilience.

Past exposure to climate shocks influences current diversification levels. Weather anomalies are associated with increased social distress, and cultivating export crops partially mitigates the effects and long term impacts. Furthermore, the impact of industrialization, deagrarianization, and changing stakeholder expectations on community resilience, points to the need for realigning government policies for improvement with emphasis on the multifaceted nature of resilience, incorporating economic, social, cultural, political, and natural dimensions. Recognising the interconnectedness of social capital, cultural values, and economic performance in shaping resilience outcomes for farmers and their households, the review shows that credit access affects recipient groups resilience differently, with positive impacts on non-farm income but no effect on farm income. Impacts vary based on economic conditions, ethnicity, and credit volumes received. The research highlights the need to consider the heterogeneity in the impacts of credit access on different household groups and the importance of economic conditions in benefiting from rural credit.

Recommendation: Based on the findings resulting from this study, there is need for a more critical understanding of normative framings of equity in resilience interventions. Identifying preferred climate services and integrating them with financial and market information can enhance resilience among farmers especially the small-scale ones. The need for flexible yet consistent tools based on participatory approaches to understand and strengthen farm resilience is identified. Empirical evidence in several countries as observed in this research demonstrates the effect of spatial and temporal factors on farming system resilience outcomes. The research points to the need for a more comprehensive understanding of resilience, considering social-ecological aspects, and addresses the potential conflicts arising from divergent strategies. The various studies highlight the need for nuanced approaches, considering both tangible and intangible dimensions of resilience, and the importance of equity, agency, and social justice in building resilience to climate-related stressors. The significance of diverse interventions, adaptive strategies, and transformative actions for enhancing climate resilience at various levels has been emphasized—from farming systems to community livelihoods

Recognition of the importance of tailored interventions considering gender, economic conditions, and cultural factors may be beneficial to long term sustainability in farming systems resilience discourse. Emphasis on understanding and mitigating the impact of climatic shocks on vulnerable populations call for synergies between social protection programs and agricultural interventions in enhancing resilience and well-being. The study encourages strategies to build social capital and facilitate the adoption of improved range management technologies, emphasizing the role of an enabling environment and policy implications. The role of farming systems diversification in building resilience against climatic shocks is highlighted, emphasizing the importance of climate information and considering both livestock and crop diversification. The recognition of potential conflicts between short-term and long-term resilience goals, highlights the importance of considering temporal and spatial factors in policy and intervention design.

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Exploring the Role of Emotions in Climate Change Communication for Climate Action

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Abstract:

Climate change is arguably one of the major global challenges of the 21st century, as it poses a significant threat to livelihood, health, and food security. Effective and strategic communication is crucial to mitigating the impacts of climate change on humans and the environment. Literature has shown that emotions are vital in shaping human perceptions of risk and influencing behaviour. Emotions, such as fear and happiness, can drive individuals to take action. Therefore, climate change communication can effectively utilise negative emotional appeals; particularly fear appeals, to prompt the desired behavioural response. However, it is essential to ensure that the level of fear induced by the communication is strong enough to motivate action but not so overwhelming as to result in denial or maladaptive responses. Ultimately, communication efforts should equip individuals and communities with coping mechanisms to address the challenges posed by climate change effectively if the fear appeal is to be successful.

Keywords: Climate Change; Emotions; Fear-Appeal; Communication; Mitigation

Introduction: Literature has established that climate change is a major threat to all humanity, which has become a serious global concern because of its threat to livelihood and security (Onwutuebe, 2019). In the middle 1900s, scientific measurements began to ascertain if human-produced carbon dioxide was accumulating in the atmosphere and other earth systems, like forests and the oceans. Between the end of the 1900s and the early 2000s, the theory of Anthropogenic Climate Change was confirmed with evidence from thousands of ground-based studies and continuous satellite measurements of land and ocean. The result revealed that the temperature is increasing and that humans are causing most of the current changes to climate by burning fossil fuels such as coal, oil, and natural gas Johnson, Affolter, Inkenbrand, and Mosher, (2022). The need to create awareness to encourage massive participation in positive environmental actions became necessary, giving rise to what is known as climate change communication. Moser, (2010) supports the affirmation by alluding that eliciting positive environmental behavioural change certainly requires the strategic integration of insights from all professional disciplines relevant to the subject matter. This paper attempts to look from published literature at how efficiently emotionally induced communication can elicit positive climate action.

Climate Change: In addition to other natural climate variability over periods, human activities, principally through emissions of greenhouse gases, have undeniably caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have been on the increase, with ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals, Inter-Governmental Panel on Climate Change (2023). O'Neill (2012), observes that the rise in temperatures, inconsistent rainfall patterns, leading to floods, drought and desertification, extreme and unpredictable weather patterns leading to intense natural disasters, and the melting of glaciers and polar ice-caps, resulting in rising sea levels and coastal erosion, leaving low-lying areas uninhabitable has resulted to death, injury, and damage to health through an increase in infectious diseases, physical and mental stress, and the loss of medicinal plants and biodiversity. The global effects of climate change will negatively impact communities at multiple levels, threatening the security, economic, and human rights conditions of people worldwide. The impact could be slow, but irreversibly harmful to the environment and humans if not checked.

The Intergovernmental Panel on Climate Change (2023) opines that it is no longer news to discuss whether the climate is changing but rather how much change can be committed to and how fast this will occur. For the globe to avoid a major catastrophe, the 2015 Paris Agreement commits countries to limit the global average temperature rise to well below 2°C above pre-industrial levels, and to aim for 1.5°C.

Climate Change Impact: In many parts of the world, the impacts of climate change have resulted in increased intensity of disasters such as drought, famine, and floods. It is estimated that about 4 million people were displaced and 16 million were affected by Typhoon Haiyan in the Philippines in 2013. Also, 6,000 people were killed by the Indian Monsoon in 2014, while in the same year, $2 billion and thousands of jobs were lost due to drought in California (Anatsui, and Adekanye, 2015). In Africa, the effects of climate change are mostly felt in the inconsistencies in rainfall and temperatures, which have affected agricultural production leading to food insecurity. Babekir (2008) decries the harsh realities of climate change as having affected the lives and survival of the African community. For instance, cyclone Idai in 2019 displaced over 3 million people in Mozambique, Madagascar, Malawi, and Zimbabwe, as well as resulted in the death of over 1000 people. Over 4.5 million people suffered starvation and more than 70,000 individuals (mostly women and children) died in 1993 in Sudan.

In Nigeria, over six million people have been displaced by climate change events and disasters between the years 2008 to 2021, Flooding has become an annual event in Nigeria, with over 600 deaths and millions displaced in 2022 alone, (Ibrahim, 2022). The adverse effects of climate change and global warming have affected crops and livestock production, fisheries, forestry, and post-harvest activities due to alterations in the regimes and patterns of rainfall. Furthermore, floods have devastated farmlands, and increased temperature and humidity have brought about pests, diseases, and other natural disasters such as droughts and erosions Chigbu, (2010). The over-reliance on wood for domestic energy supply has aggravated deforestation, which is a contributing factor to desertification in northern Nigeria (Nasiru, 2010). It is important to note that the annual deforestation rate is estimated at around 3% per year, which is equivalent to the loss of 410,000 hectares of forest land annually (Gujba, Mulugetta, and Azapagic, 2015).

Anthropogenic Sources of Greenhouse Gases: There is a strong scientific consensus, with the overwhelming majority of climate change experts that human activities are causing rapid changes in the climate. Published peer-reviewed scientific journals showed that 97 per cent of climate scientists agree that climate warming is from human activities, National Oceanic and Atmospheric Administration (2005). Most leading scientific organizations endorse this position, including the U.S. National Academy of Science which was established in 1863 by an act of Congress under President Lincoln. Congress charged the National Academy of Science "with providing independent, objective advice to the nation on matters related to science and technology" National Academy of Sciences, (2016). It has been documented that the Industrial Revolution led to an increase in greenhouse emissions due to economic and population growth, resulting in a gradual rise in atmospheric temperature. The human-generated concentrations of the primary greenhouse gas, carbon dioxide, have reached unprecedented levels in the past 800,000 years. While the pre-industrial level of carbon dioxide was estimated to be around 278 parts per million (ppm), by 2016, carbon dioxide levels had surpassed 400 ppm for the whole year for the first time. This underscores the importance of effectively utilising communication strategies to promote behavioural change towards environmental sustainability among all stakeholders (Johnson et al., 2022).

Climate Change Communication: Moser and Dilling (2007) define climate change communication as any form of public engagement that effectively simplifies an intended behavioural, organizational, political, and other social change consistent with known mitigation or adaptation goals. Despite increased communication about the impacts of climate change, public engagement in climate change issues has not increased as reported by Spence, Venables, Pidgeon, Poortinga, and Demski (2010). O'Neill and Hulme (2009) noted that understanding climate change is challenging for lay audiences because it unfolds over a long period, rather than happening suddenly. Therefore, effective communication should use clear, simple metaphors, imagery, and mental models, as well as compelling framing, to facilitate better cognitive processing. Oke, Adeyinka, and Oluseyi (2018) suggest that utilizing various forms of communication arts, including posters, handbills, and signage, is crucial for disseminating disaster risk reduction messages to broader communities. Additionally, they recommend incorporating emotions into persuasive communication.

The rise of capitalism, as explained by Akanni and Dakyes (2015), has led to a heavy reliance on advertising in global economies to promote products and services to potential consumers. Both local and global corporations utilize various advertising media to achieve their objectives, as advertising allows them to reach a large audience within a short period. According to Yakubu (2017), billboard displays are particularly effective in reaching numerous consumers due to their strategic exposure. Therefore, billboard advertisements are favoured tools for advertisers and marketers, making them ideal for climate change communication campaigns to capitalize on. Additionally, Azi (2013) suggests that for grassroots mobilization, any communication content, including images, must be relevant and culturally sensitive to the target audience. Thus, there is a need to utilize graphic design techniques to create communication solutions that embody the elements and principles of design, as well as employ creative thinking processes (Ogunwole, 2018).

Challenges of Climate Change Communication: According to O'Neill, et al, (2009), one of the reasons among many other reasons why climate change communication has not been effective could be that much of the early communication was focused on scientific findings and synthesis reports and images, (as published periodically by the Intergovernmental Panel on Climate Change, IPCC) which may not be interpreted easily by ordinary people. The need to explicitly explain climate change for the target audience to understand was not a priority. It focused on educating the public about the human causes of climate change in hopes that more knowledge would lead to changes in attitudes and behaviour. However, it was later found that people's beliefs and ideologies, rather than their knowledge, were the best predictors of their attitudes and behaviour toward climate change. Individuals with more scientific knowledge were the most divided on the issue. On realising that evidence-based arguments were not always effective in persuading all audiences, recent research has shifted focus to the use of emotional appeals in communication and persuasion (Nabi, Gustafson, and Jensen 2018).

The challenges of achieving effective climate action were also discovered to have stemmed from the fact that many people are not actively involved in creating solutions for social and political climate change issues. This can lead to a concept known as the 'finite pool of worry' by Evensena, Whitmarshb, Bartiec, Devine-Wrightd, Dickiee, Varley, Ryderd, and Mayer, (2020), where individuals have a limited capacity for concern. Once a certain level of worry is reached on a particular issue, it becomes harder to generate additional worry for other problems. As a result, significant events such as natural disasters, economic downturns, and security threats can divert attention away from climate change, reducing the willingness to engage in positive climate action. Therefore, effective climate change communication must present realistic facts and expectations in a way that personally resonates with the target audience.

Using Emotions in Climate Change Communication: People are less likely to act upon information that is abstract, unfamiliar, and hard to grasp, but they are more likely to respond to information that is infused with emotional significance. This is because messages driven by emotions can influence human perception of risk. Emotion is a complex state of feeling that results in psychophysiological changes, which in turn influence thoughts and behaviour and is usually expressed through fear or happiness (Van Der Linden, 2015). Emotions are deep and complex feelings that cause psychophysiological changes, and climate change communication can take advantage of this, as is common with advertisers who use emotions to influence opinions, attitudes, and decisions regarding their products and services. According to Böhm, (2003), environmental behaviours are guided by so-called 'perspective' and 'retrospective' consequence-based emotions, such as fear and worry, which also happen to be the most intense emotions associated with environmental risks, consequently, feelings of fear and worry can be effectively channelled in the communication of climate change issues to elicit behavioural change.

Relationship between Experience, Emotions and Risk: The relationship between experience, emotions, and risk perception in the context of behaviour change is paramount in the issues of climate change communication. This is because experiences can stir strong memorable feelings, possibly making them very prominent in processing information. For example, an individual who has been exposed to a direct threat of a flood in the past can display strong intuitive emotions such as fear and anxiety that will subsequently guide his immediate behaviour and response to another potential flood. This can be regarded as *a fear-flight response*, Smith, and Leiserowitz, (2012). The expected practical response to the threat of flooding would be to move away from the danger zone, which is aimed at mitigating immediate threats, and not necessarily because of the broader climate change impacts concept in itself. Such an individual can actively and practically engage in reducing his GHG emissions if he can link flooding as a consequence of GHG emissions into the atmosphere Helgeson, Linden, and Chabay, (2012), but most time is not always the case. Weber (2006) opined that direct experience with flooding may not spur individuals to actively engage in the reduction of GHGs into the atmosphere because there is a disassociation between the cognitive information that informs the individual that there is a risk to be worried about an inability for many people to experience this risk in their direct environment.

Inflating personal worry among the general public through measures that do not require actual personal experience could be effective in eliciting climate change behaviour change. According to Spence, Poortinga, and Pidgeon, (2012), this can be achieved through negative emotional appeals, where the centre of focus revolves around fear appeals. For this method of using fear-appeal to elicit behaviour change to be successful, the level of fear induced by the communication must be sufficiently strong enough to function as a drive, and recommendations must be included in the communication, highlighting ways of averting the negative consequences. This is very important because individuals have two ways of resolving unpleasant emotional tension, 'adaptive responses' (i.e., use behavioural changes) or 'maladaptive responses. While adaptive response tries to control fear through a change of behaviour, the maladaptive resort to denial, leaving the actual threat intact. Rogers (1975, 1983), further stated in his Protection Motivation Model (PMM) which mostly applied to concepts of understanding fear appeals, that PMM postulates that a threat-related message will only be effective if it satisfies the individual of the reality of the threat (threat appraisal), and the individual can avert the threat (coping response). People continue to engage in maladaptive behaviours (climate change denial) if the rewards (convenience) of that behaviour exceed both the perceived ruthlessness of the threat (e.g. climate change) and the individual's perceived susceptibility to that particular threat (low). The intention to protect one's self then depends on whether the threat can be averted; if the threat may reoccur; if the coping response is effective; and if the individual can respond (Witte, 1991).

Using Images to Emotionally Climate Change Communication: Images as tools for conveying important and urgent information transcending linguistic and geographical barriers have been used in the past with success (Gyang 2015). Scholars have also adopted the use of images in communicating the impacts of climate change. But how effectively has the use of images elicited behaviour change among people? According to Amedu (2017), images are powerful communication tools that can connect with people at emotional and belief-system levels, thus good for persuasive communication.

O'Neill and Nicholson-Cole (2009) identify two dimensions of global warming images as external images communicated via the media, and the visual imaginations people have with the issue in their minds. This study focuses on external images in climate change communication as commonly used climate change communication. Images of climate change have been featured in a fairly large range of media including newspapers and magazines Van Der Linden, (2015. This emphasis on media as a veritable tool for communicating climate through images is mostly because of its role as a gatekeeper. As the "gatekeepers" of climate change information, Billett (2010) asserts that it is the media that translates and interprets scientific knowledge into popular discourse and as such, helps people to make sense of the many complexities relating to climate change science and governance that sub-consciously shape our lives. The previous communication on climate change heavily relied on text-based messages, but these were not very effective in conveying the exact messages as images could have been. There has been a debate about whether climate change imagery and text-based messages convey the same story. While Smith and Joffe (2009) believe they share a common narrative, DiFrancesco and Young (2011) found evidence to suggest otherwise.

In 2009, a study was conducted to explore public engagement with climate imagery in the United Kingdom, Australia, and the United States of America (O'Neill, et al, 2009). The study revealed that dramatic, sensational, fearful, and shocking imagery can effectively capture people's emotions and attention regarding the issue of climate change, emphasizing the importance of addressing climate change issues. The study used Q-methodology workshops in Melbourne (Australia), Boulder (United States of America), and Norwich (United Kingdom). The newspaper content analysis included images from all three countries. Participants were asked to do two Q-sorts: first, for salience; how important they felt climate change was based on the images, and second; how empowered they felt to do something about climate change based on the images. The results were consistent across all three countries, possibly due to a dominant, mainstream climate imagery discourse. The analysis revealed that some images emphasize the importance of climate change but diminish self-efficacy, while images of future energy sources enhance self-efficacy. Additionally, images of politicians and climate change celebrities strongly diminish both saliency and self-efficacy.

These widely replicable findings have significant implications for global climate change communication and engagement. The results strongly suggest that using imagery in climate change communication can significantly increase the sense of importance (saliency) and promote feelings of being able to take action (efficacy). The study found that using imagery that emphasizes the importance of addressing climate change and promotes the belief that individuals can make a difference and may be effective in changing behaviour. Creating imagery that is striking, memorable, and attention-grabbing can enhance the success of climate change campaign messages. The effects of climate change and global warming have been portrayed in a wide variety of visual formats, including photographs, charts, graphs, cartoons, illustrations, and videos. These visuals have been used in magazines, television, and films, as well as on an increasing number of websites, all to highlight the impacts of climate change. Some of these images aim to evoke emotions to capture attention. However, it is challenging to determine whether some of these images have been successful in prompting positive behavioural change (Braasch, 2015). Kevin Carter, a photojournalist, was assigned by the New York Times Magazine to cover the 1993 famine in Sudan, which was one of the many consequences of climate change in Africa. One of his most famous photographs, depicting a very emotional scene, was published in the New York Times Magazine in 1993. The picture captured by Carter showed a vulture patiently waiting for a hungry, weak, and malnourished girl to die so that it could feast on her dead body.

Fig. 1 Malnourished child: Picture by Kevin Carter (1993)
Source: https://www.pinterest.com/pin (2016)

The photograph sparked widespread controversy. Kim and Kelly (2014) observed that both readers and journalists believed Kevin Carter's image accurately captured an important social issue emotionally. However, they also felt that the photographer should have done more to help the girl in the photo. (Carter was instructed not to touch any of the malnourished children due to health reasons). While the picture evoked emotions about the people's plight, the responses it generated in viewers may not have been empathy, but rather horror and disgust, mainly directed at the photographer and not the photograph. Consequently, the image could be said to have failed to convey the message of the impact of climate change. In a later radio interview, Carter was asked about the child in the photo. He replied that he couldn't wait to find out after taking the shot because he had a flight to catch. The caller reportedly replied, "I put it to you that there were two vultures on that day, one had a camera." Two months after being awarded the Pulitzer Prize for the photograph, Carter tragically committed suicide by carbon monoxide poisoning in Johannesburg (Kim and Kelly, 2014). The picture was negatively perceived, possibly because the photographer didn't show any human instinct by not helping the victim. However, the image did succeed in drawing the world's attention to the impact of climate change. Therefore, the image can be seen as effective in conveying the intended message.

Conclusion: In summary, the study has demonstrated that the climate is changing, mainly due to human activities in energy generation. This has resulted in higher global temperatures, irregular rainfall patterns, and widespread heat waves, leading to food insecurity, famine, flooding and various airborne diseases. The impacts of climate change are particularly acute in developing countries like Nigeria because of a lack of awareness and effective strategies to mitigate these effects. Despite increased dissemination of information about climate change, the level of action taken does not match the amount of information available. This has given rise to what is now known as climate change communication. While trying to communicate the effects of climate change, it became evident that people were not acting upon this information. Experts believe this is because the scientific nature of communication is not easy for everyone to understand. The communication is not explicit enough for the general public, and they are not involved in developing solutions to climate change. This has led to a lack of concern about climate change. In developing countries, the "finite pool of worry" concept comes into play, where economic and social issues divert attention from climate change. For example, people may not relate a woman cooking with firewood to a flood that wiped out a village. Effective climate change communication should present realistic facts and expectations in a way that resonates personally with the target audience.

Since evidence-based arguments are not always effective in persuading all audiences to participate in climate change action, research has shifted focus to the use of emotional appeals in communication and persuasion (Nabi, *et al,* 2018). In the area of health, emotional appeal has been used successfully in communication. For example, the use of negative fear appeal in communicating the dangers of HIV/AIDS was able to instil fear among sexually active persons. It was also used to communicate the COVID-19 pandemic, and the entire world stood still for many months because of the fear of COVID-19. Emotions have a significant influence on people's perceptions and actions. Evoking negative emotions can increase people's intentions to take action and can impact risk perception and perceived collective control. There is a need to explore the use of negative emotions in climate change communication, as this may lead to behaviour change if individuals can connect with the potential dangers of climate change affecting them personally, especially images that conveys emotions.

Recommendations: The study recommends that using negative emotions, particularly fear, is important when communicating the impact of climate change, this is because they do not realize how their actions contribute to climate change. For example, a woman cooking with firewood may not realize the connection to famines in the community. However, it is important to be cautious when using fear as a motivator. While fear can effectively communicate risks, it may not sustain long-term interest and engagement. In addressing climate change issues, it is important to offer positive alternatives to help reduce threats and make them easily accessible. This is because fear-inducing messages can lead to unhelpful responses and leave people feeling helpless and disengaged.

Employing emotionally impactful images on posters, handbills, billboards, and other graphic communication media is recommended for climate change communication. Images can effectively convey important and urgent information, transcending linguistic and geographical barriers. Scholars have successfully utilized images to communicate and influence behaviours because they can connect with people on an emotional and belief-based level, making them effective for persuasive communication.

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Phytosociological Characteristics of Weed Biotypes of Cucumber (*Cucumis sativus* L.) as Influenced by Weed Control Strategies and Staking

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Abstract

Weed interference is a significant crop productivity hindrance that necessitates management strategies to ensure sustainable farming practices and increase yield by preventing their interaction with intended crops. Against this backdrop, a field trial was carried out during the 2021 dry season at the Research and Teaching Farm (Orchard) of the Faculty of Agriculture, Bayero University, Kano (11º59'N; 8º25'E; 466 m above sea level), located within the Sudan savannah ecological zone of Nigeria, to evaluate the phytosociological attributes of weed biotypes as impacted by management practices on cucumber yield. According to their respective importance value index (IVI), Amaranthus spinosus (57.4), Eleusine indica (46.6), and Cynodon dactylon (43.5) were the three most common weeds identified by the phytosociological analysis. The study also assessed the effectiveness of various weed control techniques when combined with stakes, such as hand weeding and herbicides. Results indicated that weed-free conditions and the application of herbicide in the form of Butachlor 1.5 + Imazethapry 1.5 at kg a.i. ha^{-1} POE or Metolachlor 1.5 + Imazethapry at 1.5 kg a.i. ha^{-1} POE, coupled with staking, significantly ($p < 0.001$) enhanced cucumber fruit yield (11083 and 11027 kg ha^{-1}) and number of fruits per plant (8.97 and 8.15) compared to the weedy check (5722 kg ha^{-1} and 4.55). These findings emphasize the critical role of integrated weed management and plant support systems in optimizing cucumber production.

Key words: cucumber, weed management strategies, herbicides, staking, fruit yield

Introduction: Cucumber (*Cucumis sativus* var. *sativus* L.) (2n = 2x = 14), a monoecious annual vegetable crop in the Cucurbitaceae family, has been cultivated for over 3,000 years and ranks fourth in Asia in terms of economic and biological importance (FAOSTAT, 2016), with China, Turkey, and the Islamic Republic of Iran as the top three highest producers globally with 54,315,900, 1,754,613, and 1,754,613 metric tons, respectively (WorldAtlas.com, 2016). Cucumber is a popular vegetable crop cultivated for its immature fruits, and it is the second most extensively grown vegetable after tomatoes and watermelon (Jia and Wang, 2021). According to Okafor and Yaduma (2021), the five highest cucumber-producing states in Nigeria are Plateau, Kaduna, Katsina, Kano, and Benue. Despite its increasing importance, the cultivation declines persist in Nigeria and Africa. Cucumber yields are low due to various factors including inappropriate farming systems, climate change, weed, disease, pest infestation, and poor agronomic management (Umeh and Orijiako, 2018; Victor and Julius, 2018; Falaiye *et al.,* 2021).

Weed infestation is a notable factor among those that limit cucumber yield. Research conducted by Daramola (2021) and Landu *et al*. (2021) shows that under different agroclimatic conditions, weed interference causes a substantial yield reduction of 45–95%. Weed interference poses a significant challenge to the agricultural production, necessitating efforts to improve production and ensure sustainable agriculture by combating their interaction with desired crops (Shittu, 2023; Shittu *et al*., 2023). Ndukwe (2018) identified broad-leaved, sedges, and grasses as significant challenges in the yield and full expression of traits in cucumber. Therefore, an effective weed management strategy becomes a necessity for economically feasible cucumber production (McGowen *et al*., 2018). This study aims to assess the phytosociological attributes of weed biotypes in Nigeria's dry land ecology, focusing on the need for effective weed management strategies for economically feasible cucumber production.

Materials and Methods: A field trial was carried out at the Research and Teaching Farm (Orchard) of the Faculty of Agriculture, Bayero University, Kano (11º59'N; 8º25'E; 466 m above sea level) situated within the Sudan savannah ecological zone of Nigeria during the 2021 dry season in order to assess the phytosociological attributes of weed biotypes as impacted by weed control strategies and staking. The experiment comprised eight weed control treatments (weed-free, weed-check, butachlor at 1.5 kg a.i. ha, metolachlor at 1.5 kg a.i. ha^{-1}, butachlor at 1.5 kg a.i. ha^{-1} + S.H.W. at 6 WAS, metolachlor at 1.5 kg a.i. ha^{-1} + S.H.W. at 6 WAS, butachlor at 1.5 kg a.i. ha^{-1} + Imazethapyr at 1.5 kg a.i. ha^{-1} POE, and metolachlor at 1.5 kg a.i. ha^{-1} + imazethapyr at 1.5 kg a.i. ha^{-1} POE.) and two stakings (staked and unstaked), which were replicated three times in a split plot design. The staking was assigned to the main plot, while weed control was assigned to the sub plots. The experimental field was harrowed twice to a fine tilt before sowing. A plot measuring 2 x 3 meters was mapped out, with subplots, main plots, and replications separated by 0.5, 1.0, and 1.5 meters, respectively. Two seeds were sown per hole which were later thinned to one plant per stand. Herbicides were applied one day after sowing using a 16-liter capacity knapsack sprayer fitted with a green deflector polyjet nozzle calibrated at a pressure of 2.1 kg m-2 to give a spray volume of 250 liters per hectare. Herbicides were applied on a treatment basis. Based on recommendation, the fertilizer was applied at a rate of 200 kg/ha using NPK 15:15:15 at 3 WAS, with N applied in two split doses using Urea at 6 WAS. The application of a broad-spectrum insecticide Ampligo, was carried out across all treatments at 4, 6, and 9 WAS at a dosage of 30 g per 16 liters of water to control phytopagous organisms. Regular weeding was done on weed-free (positive check) plots, and supplementary hoe weeding was done on plots that needed it. Weedy check plots were left unweeded for the duration of the experiment as the control (negative check).

Observation and Data Collection: *Weed phytosociological characters*: Weeds species harvested from 1m^2 quadrant placed randomly in each plot were harvested and identified using Hand Book and other standard procedure described by Akobundu *et al*., 2016) and Rana and Rana (2018), respectively. Those that could not be positively identified are packaged and transported to the herbarium section of the Department of Plant Science at Bayero University in Kano, Nigeria. Hence, the phytosociological attributes of the weeds were computed using the following:
Weed Density: This was summed up by the composition of weed species samples found within the total number of quadrants used.

$$\text{Weed Density} = \frac{\text{Total number of weed species in all quadrants}}{\text{Total number of quadrants studied}}$$

Weed relative density: The relative weed density was calculated by the following formula:

$$\text{Weed Relative Density} = \frac{\text{Density of weed species}}{\text{Total density of all weed specie studied}} \times 100$$

Weed frequency: This refers to the number of times any certain weed species occurs in the field. These were determined by the formular below.

$$\text{Weed Frequency} = \frac{\text{Number of quadrants to which weed specie occured}}{\text{Total number of quadrants used in the study}}$$

Weed Relative Frequency: This was also computed using the formular below.

$$\text{Weed Relative Frequency} = \frac{\text{Frequency value of a weed species}}{\text{Total frequency of all weed specie studied}} \times 100$$

Weed Abundance: This was computed using the formular below.

$$\text{Weed Abundance} = \frac{\text{Total number of weed species in all quadrants}}{\text{Sum of quadrants in which specie occured}} \times 100$$

Weed Relative Abundance: This was computed using the formular below.

$$\text{Weed Relative Abundance} = \frac{\text{Abundance of a weed species in all quadrants}}{\text{Total abundance of all specie studied}} \times 100$$

Important Value Index (IVI): This is a reasonable measure to assess the overall significance of a species since it considers several properties of the species in the vegetation. The IVI was calculated as described by Curtis and McIntosh (1950). The parameters assessed for the purpose were density, frequency, and abundance, while the importance value index (IVI) was calculated as:

IVI = Relative Frequency (RF) + Relative Density (RD) + Relative Abundance (RA).

Data Analysis: The data collected from the field were subjected to analysis of variance (ANOVA) using GENSTAT (17^{th} edition). Means showing significant differences were separated using Student Newman-Keuls Test (SNK) at 5% level of probability.

Results and Discussion: Phytosociological characteristics of weed biotypes : Table 1 presents the weed phytosociological characteristics and their important value index (IVI) of various weed species. The index is used to determine the relative importance of each weed species in a given ecosystem based on their abundance, frequency, and density. The higher the index value, the more important the weed species is considered to be. According to Aminpana *et al*. (2013), Weed important value index is useful in quantifying the impact of different management strategies on weed populations and crop yields. Based on the results, *Amaranthus spinosus* had the highest important value index (57.4), indicating that it is the most important weed species in the ecosystem under consideration. This could be due to its high abundance, frequency, and coverage in the area. With just 1-2 plants of *Amaranthus spp.* per square yard growing with cucumber throughout the crop life cycle can reduce yield by 10%, while 5-7 plants of same species per square yard can reduce cucumber yield by 50% as reported by McDonald *et al*., (2006). The *Eleusine indica* (46.6) and *Cynodon dactylon* (43.5) are also important weed species in the ecosystem and also having the highest relative frequency were found to be similar with the findings of Bonham (2013). The findings is also similar to the research of Mahmood *et al*., (2015) where *E. indica* had reduced the yield of watermelon field to about 55%, which implies it requires much attention and employing integrated weed management would manage it better. *Pupalia lappacea* (27.2) and *Cyperus rotundus* (22.5) have moderate important value index values, indicating that they are relatively important weed species in the ecosystem, findings from Ekeh *et al*., (2015) recommends the use of non-chemical methods such as hand and hoe weeding in controlling them. *Axonopus compresus* (11.6), *Fimbristylis littoralis* (12.6), *Eragrostis minor* (16.3), and *Echinochloa colona* (17.5) have lower index values, *Polypogon viridis* (3.3) and *Eragrostis cilianensis* (10.5) have the lowest important value index values, indicating that they are the least important weed species in the ecosystem under consideration. The major feature of these weed species is their widespread existence and difficulty in management, rapid spread, production of many seeds, high efficiency in water use and net photosynthesis (McGowen *et al.*, 2018). The effectiveness of herbicides on different weed species is influenced by factors such as herbicide type, dosage, weed growth stage, and environmental conditions. Predicting a specific weed's response to a herbicide can be challenging due to these variables. Generally, herbicides designed for broadleaf weeds may be less effective on grassy weeds, and vice versa. Additionally, weed resistance to herbicides is a growing concern. The presence of diverse weed populations can accelerate this resistance, reducing herbicide efficacy (Heap, 2021). Thus, a combined approach involving chemical, cultural, and mechanical control methods is essential for successful weed management.

Table 1: Phytosociological characteristics of weed biotypes of cucumber during 2021 dry season at BUK.

Weed biotypes	*M/L*	*TNI*	*WD*	*WF*	*WA*	*RF%*	*RD%*	*RA%*	*IVI*
Amaranthus spinosus *(L.)*	BA	63	2.6	33.3	9	13.3	8.2	5.72	57.4
Axonopus compresus *(Sw.)* *P.Beauv.*	GP	13	0.5	4.2	13	1.7	1.6	8.3	11.6
Cynodon dactylon *Pers*	GP	131	5.5	46	12	18.4	17.5	7.6	43.5
Cyperus esculentus *(L.)*	SP	8	0.3	4.2	8	1.7	0.9	5.1	7.7
Cyperus rotundus *(L.)*	SP	51	2.1	29.2	6.4	11.7	6.7	4.1	22.5

Digitaria ciliaris *(Retz.) Koeler*	GP	35	1.5	8	18	3.2	4.8	11.5	19.5
Echinochloa colona *(L.) Link*	GA	37	1.5	17	9.3	6.8	4.8	5.9	17.5
Eleusine indica *(L.) Gaertn.*	GP	153	6.4	41.7	15.3	16.6	20.3	9.7	46.6
Eragrostis cilianensis *ex Janchen*	GP	16	0.7	8	8	3.2	2.2	5.1	10.5
Eragrostis minor *ex Janchen*	GA	32	1.3	13	11	5.2	4.1	7.0	16.3
Fimbristylis littoralis *(L.) Vahi*	SP	14	0.6	4.2	14	1.7	1.9	9.0	12.6
Polypogon viridis *(Gouan) Breistr.*	GA	2	0.1	4.2	2	1.7	0.3	1.3	3.3
Pupalia lappacea *(L.) Juss.*	BA	209	8.7	37.5	23.2	15	27.6	14.8	27.2

M, Morphology; (B; Broadleaf, G; Grasses, S; Sedge) L, Lifecycle; (A; Annual, P; Perennial), TNI, Total Number of Individual; WD, Weed Density; WF, Weed Frequency; WA, Weed Abundance; RF, Relative Frequency; RD, Relative Density; RA, Relative Abundance; IVI, Important Value Index

Impact of Weed control strategies on Number of fruits plant-^{1}, Fruit yield plot-^{1} and Fruit yield ha-$^{1:}$ The number of fruits per plant, Fruit yield per plot and Fruit yield per hactare as influenced by weed control strategies and staking methods is presented in Table 2. Although weed-free plants produced the highest fruits per plant, the application of Butachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE significantly produced highest number of fruits per plant in comparison to other with control strategies while weedy check recorded the least number of fruits per plant. Similarly, the fruit yield per plot and fruit yield per hectare were significantly higher under the weed free condition, however, amongst the herbicidal treatments, the application of Butachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE and Metolachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE outperforms other strategies in terms of the aforementioned yield characters compared to weedy check that resulted the least performance.

On the other hand, the staked cucumber significantly ($p<0.001$) resulted in producing a greater number of fruits per plant, a higher fruit yield per plot, and a higher a higher yield per hectare at harvest. A highly significant interaction was observed between weed control strategies and staking on yield per plot and yield per hectare, as shown in Table 3. Although the weed-free plots under staked resulted in the heaviest fruit yield per plot and per hectare, the application of Butachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE and Metolachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE when staked significantly resulted in a higher yield per plot and per hectare compared to the rest of the interaction effects.

Weed control methods and staking significantly impacted fruit yield and number of fruits in cucumbers. The combination of staking and effective weed control strategies (especially with herbicides like Butachlor 1.5 + Imazethapry 1.5 a.i. ha^{-1} POE and Metolachlor 1.5 + Imazethapry 1.5 a.i. ha^{-1} POE resulting in the highest fruit yield could be attributed to season long weed control due to integrated approach as reported by Daramola et al. (2021) and Sadiq et al. (2021). On the other hand, the staked cucumber improved plant growth by allowing better sunlight exposure, leading to increased photosynthesis and fruit production which corroborates with the findings of Pradhan *et al*., (2021). The resultant effect was also obtained in the interaction effects of fruit yield.

Table 2: Influence of weed control and staking on the number of fruits per plant, fruit yield per plot, fruit yield per hectare of cucumber grown during dry season of 2021 at BUK.

Treatments	*Number of fruits plant^{-1}*	*Fruit yield plot (Kg ha-^{1})*	*Fruit yield hectare (Kg ha^{-1})*
Weed control strategies (WCS)			
Weed free	9.17^{a}	6.88^{a}	11472^{a}
Weedy check	4.55^{d}	3.43^{e}	5722^{e}
Butachlor at 1.5 kg a.i. ha^{-1}	6.58^{c}	5.18^{d}	8639^{d}
Metolachlor at 1.5 kg a.i. ha^{-1}	6.62^{c}	5.22^{d}	8694^{d}
Butachlor at 1.5 kg a.i. ha^{-1} + SHW at 6 WAS	8.22^{b}	6.02^{c}	10027^{c}
Metolachlor at 1.5 kg a.i. ha^{-1} + SHW at 6 WAS	8.10^{b}	5.98^{c}	9972^{c}
Butachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE	8.97^{a}	6.65^{b}	11083^{b}
Metolachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE	8.15^{b}	6.62^{b}	11027^{b}
Probability level	<.001	<.001	<.001
S.E (±)	0.077	0.037	61.1
Staking (S)			
Staked	8.17^{a}	6.44^{a}	10736^{a}
Unstaked	6.92^{b}	5.05^{b}	8423^{b}

Probability level	<.001	<.001	<.001
S.E (±)	0.138	0.015	25.5
Interaction			
WCS x S	0.540	<.001	<.001

Mean (s) followed by same letters in a column are significantly different at 5% (SNK). WAS = Weeks after sowing, POE= Post emergence

Table 3: Interaction between weed control strategies and staking on fruit yield per plot and fruit yield per hectare of cucumber grown during 2021 dry season at BUK.

	Fruit Yield per Plot		*Fruit Yield (Kg ha^{-1})*	
Weed control (W)	Staked	Unstaked	Staked	Unstaked
Weed free	7.90^{a}	3.93^{h}	13166^{a}	9778^{d}
Weedy check	3.93^{h}	2.93^{i}	6555^{h}	4889^{i}
Butachlor at 1.5 kg a.i. ha^{-1}	5.70^{e}	4.67^{g}	9500^{e}	7778^{g}
Metolachlor at 1.5 kg a.i. ha^{-1}	5.67^{e}	4.77^{g}	9444^{e}	7944^{g}
Butachlor at 1.5 kg a.i. ha^{-1}+ SHW at 6 WAS	6.63^{c}	5.40^{f}	11055^{c}	8999^{f}
Metolachlor at 1.5 kg a.i. ha^{-1}+ SHW at 6 WAS	6.67^{c}	5.30^{f}	11111^{c}	8833^{f}
Butachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE	7.53^{b}	5.77^{de}	12555^{b}	9611d^{e}
Metolachlor at 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE	7.50^{b}	5.73^{de}	12499^{b}	9555d^{e}
SE (±)	0.048		79.6	

Mean (s) followed by same letters in a column are significantly different at 5% (SNK). WAS = Weeks after sowing, POE= Post emergence.

Conclusion: The present study revealed that *Amaranthus spinosus* was the most dominant weed species in the cucumber ecosystem, followed by *Eleusine indica* and *Cynodon dactylon*. These weeds significantly affected cucumber growth and yield. Effective weed management practices are crucial for optimizing cucumber production. Similarly, the integration of weed control measures, particularly the combination of herbicides like Butachlor 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE and Metolachlor 1.5 + Imazethapry 1.5 kg a.i. ha^{-1} POE, with staking significantly improved cucumber yield. This study underscores the importance of a comprehensive weed management strategy to mitigate the negative impact of weeds on cucumber productivity. There is need to prioritize the control of key weed species such as *Amaranthus spinosus*, *Eleusine indica*, and *Cynodon dactylon* through integrated weed management strategies and encourage the use of herbicides with proven efficacy and minimal environmental impact as well as promote the adoption of staking practices for optimal cucumber growth and yield.

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Studies on the Soil Toxicity Levels Of Aquagrain on Vegetable Amaranth (*Amaranth tricolor)* Production

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Abstract

This research investigated the impact of varying aquagrain applications on vegetable amaranth (Amaranthus tricolor) growth, development, and yield. The study also assessed if aquagrain could potentially harm the soil. The experiment was conducted in pots under controlled conditions at Bayero University, Kano. Ten aquagrain levels (0, 100, 150, 200, 250, 300, 350, 400, 450 and 500 kg/ha) were tested on amaranth plants in a Complete randomized design with three replications. Plant characters such as height, leaf area, stem girth, chlorophyll content, fresh and dried weights, and soil properties like nitrogen, phosphorus, potassium, and moisture were all examined in the study. The results of the experiment revealed significant variations in vegetable amaranth growth and development among the different treatments, with the highest application levels (500 kg ha^{-1}) producing the highest values in some parameters such as plant height, number of leaves, leaf area, chlorophyll content, soil K content, fresh weight, and dry weight. Findings revealed that the production of vegetable amaranth is greatly influenced by the application of aquagrain in the soil, with large concentrations having little effect on the soil. Since organic aquagrain is non-toxic, plants grow well on it and produce more biomass and leaves with a deeper green color. Aquagrain significantly boosted amaranth production without harming the environment. Therefore, promoting aquagrain use can help reduce synthetic fertilizer dependency and improve soil health.

***Key words**: Aquagrain, soil toxicity, vegetable amaranth, Soil, N, P and K.*

Introduction: Soil toxicity, caused by pollutants like heavy metals, pesticides, and industrial chemicals, can lead to decreased soil fertility, crop yields, and contamination of groundwater and surface water resources (Alengebawy *et al.*, 2021). Heavy metals, pesticides, and industrial chemicals pose significant health risks to soil organisms, humans, and the environment. These toxic substances accumulate in the food chain and can persist in soil, causing harm to non-target organisms (Xing *et al.,* 2020; Zhang *et al*., 2022). Elevated levels of fertilizer in the soil can cause nutrient imbalances, affecting plant growth and health. This can result in decreased root growth, reduced pest resistance, and reduced yield. Excess nitrogen and phosphorus can leach into groundwater, causing eutrophication and toxic algal blooms. Changes in the soil's chemistry can also impact plant development. To prevent these negative effects, the use fertilizers in moderation and consider alternative strategies such as the use of organic matter or cover crops (Anas *et al*., 2020; Bisht *et al*., 2021; Sharma *et al*., 2022). Synthetic superabsorbent materials can cause soil toxicity, negatively impacting plant growth and reducing microbial activity by leaching acrylic acid and sodium polyacrylate, according to Zhang *et al.* (2018) and Jia *et al*. (2019).

Growing vegetable amaranth, which is well-known for its health and nutritional advantages, may present problems with soil toxicity. Aquagrain is a biodegradable hydrogel made from organic waste streams, providing organic matter, nutrient support, and efficient irrigation. Its biocompatibility and less rigid structure reduce climate change impact and population expansion (Aquagrain.co.uk, 2019; Biomation Limited, 2019). Given that protein-based superabsorber materials help retain water, it is imperative to look into how they affect soil toxicity. There are limited studies on the effects of protein-based superabsorber materials on soil toxicity, thus more investigation is needed to evaluate the hazards to the environment and public health and to design safe, sustainable agricultural practices. Therefore, this study aims to determine the toxic level of Aquagrain that can hinder amaranth's growth and development on conventional tropical soil.

Materials and Methods: Experimental site : The experiment was conducted on pots at the screen house of Center for Dryland Agriculture (CDA) Annex, in the faculty of Agriculture of Bayero University, Kano (latitude 11.9765^{0N,} longitude 8.42483^{0}E) in the Sudan Savannah. The range of annual rainfall and temperature is between 787mm-960mm and 21ºC-39ºC respectively (KANRDA, 2001). The experiment was conducted from 23rd March, 2022 to 5th May, 2022.

Treatments and Experimental design: The treatments consisted of ten (10) different rates of Aquagrain application (0, 100 150, 200, 250, 300, 350, 400, 450, and 500 kg/ha) applied to green amaranths (*Amaranthus tricolor*) and replicated three times in a Completely Randomized Design (CRD). The treatment was applied 10 days after sowing of the seeds.

Agronomic Practices: ***Soil and Pot Preparation:*** The soil was obtained from a field located opposite Center for Dryland Agriculture livestock farm. The pots were filled with 8 kg of the soil each; the total number of pots used for the experiment are thirty (30).

Seed Source, Sowing and Thinning : The seed was obtained from CDA farm and sown using broadcasting method insides the pots containing the soil on the 23rd March, 2022. Seedlings were thinned to two plant per stand at 2 weeks after sowing (WAS).

Water Application and Weeding: Water was applied regularly in each pot to maintain optimum moisture condition throughout the experiment while weeding was carried by regular hand pulling to keep the plants in a weed free condition.

Harvesting: *This practice was conducted when the plant started flowering and the amaranth was harvested manually by cutting it from the base using knife. Each stand was cut into three portions (including the stem and the leaves) and two stands were harvested from each pot.*

Crop and Soil Data Collection: The data was collected using the following parameters; plant height, number of leaves, leave area, chlorophyll content and stem girth moisture content, fresh and dry weight, soil moisture content, N, P and K levels in the soil.

Data Analysis: The data collected were subjected to analysis of variance (ANOVA) using GENSTAT version 16. Significant means were separated using student Newman Keuls' Tests (SNK).

Results and Discussion: The effect of aquagrain concentration on plant height, number of leaves, leaf area, chlorophyll content, and stem girth of vegetable amaranth is presented in Table 1. According to the results, taller plants and stem girth were statistically similar when 100–500 levels of Aquagrain were applied, as opposed to the shortest plant in the control group. When 500 kg ha^{-1} was applied, the number of leaves, leaf area, and chlorophyll content increased significantly while remaining comparable to other rates; in contrast, the control produced the lowest values for each of these parameters.

Plant height is not the sole determinant of amaranth plant growth; other growth traits, including as stem girth, leaf count, and chlorophyll content level, are also employed to predict development in addition to plant height. According to Lancíková *et al*. (2020) and Segun and Abdul Waheed (2022), these morphological and physiological criteria provide a precise estimation of amaranth growth and development. The elevated nitrogen level caused the plants to grow taller as they matured. This is in line with research by Di Mola *et al*. (2020), who found that sufficient N fertilizer increases vegetable crop plant height and leaf count. Taller plants activated more auxiliary buds at high aquagrain treatment rates, which produced more branches and leaves overall. This led to a notable increase in the number of leaves and leaf area. The number of leaves per vegetable plant increased when enough organic fertilizer was applied to the soil, according to studies by Oduwaye *et al*. (2016) and Abd El-Fattah *et al*. (2022). Similar findings were also obtained for leaf area (Hossain and Ryu, 2017). Aquagrain-fertilized crops display greenish, high photosynthetic ability, aligning with Silva et al.'s (2017) lettuce plant study, and amaranth plants consistently show higher chlorophyll content compared to commercially grown crops.

Amaranth's unique C_2 photosynthetic system and the range of low to high soil nitrogen levels are responsible for the plant's high chlorophyll concentration. A vital component of chlorophyll is nitrogen, as Zayed *et al.* (2023) pointed out. Thicker stems allow the plants to carry more branches and leaves without lodging, as observed across the aquagrain rates compared to the control. However, this can vary depending on soil characteristics and agronomic practices adopted. A study by Oduwaye *et al*. (2016) found that stem girth of the same amaranth variety varied in Nigerian areas with similar soil fertility levels. As seen throughout the aquagrain rates in comparison to the control, the plants' ability to support more branches and leaves without lodging is facilitated by their thicker stems. However, this can change based on the agronomic techniques used and the properties of the soil. According to a study by Oduwaye *et al*. (2016), across Nigerian regions with comparable soil fertility levels, the stem girth of the same amaranth species differed.

Table 2 shows the effect of aquagrain concentration on properties such as soil moisture content, nitrogen, phosphorus, and potassium concentration of vegetable amaranth. The findings showed that the different aquagrain rates did not significantly affect the quantities of soil moisture content, nitrogen or potassium. However, the phosphorus concentration in the soil varies significantly, with the application of 500 kg ha^{-1} producing the highest concentration, which is also comparable with other rates. The aqua grain's phosphorus content boosts plant growth and quality, as it increases plant height and stem diameter. Amaranths, with high growth rates and high P demand, benefit from adequate P supply, leading to good root and shoot growth. He *et al*. (2019) and Khan *et al*. (2023) documented comparable results on the function of phosphorus in controlling physiological processes in plants. The effect of aquagrain concentration on the fresh and dry weights of vegetable amaranth is presented in Table 3. The findings indicate that the application of 300 and 500 kg ha^{-1} of Aquagrain produced fresh weights that were significantly higher (12.8 and 128.9 grams), while still comparable to other rates, as compared to the control (0 kg ha^{-1}), which produced the lowest fresh weight (38.4 grams). Aquagrain, on the other hand, produced a much higher dry weight at all rates than the control, which produced the lowest dry weight (5.5 grams). When compared to the control, the fresh and dry weight acquired across the different aquagrain concentrations was significantly higher. This could be attributable to higher rates of increased nutrient concentration, which facilitated crop growth and development. This supported the results of Adekiya *et al*. (2022) on the influence of organic nutrient sources on grain amaranth performance and soil characteristics.

Conclusion and Recommendation: Studies show that the production of vegetable amaranth is greatly influenced by the application of aquagrain in the soil, with large concentrations having little effect on the soil. Since organic aquagrain is non-toxic, plants grow well on it and produce more biomass and leaves with a deeper green color. This implies that the risk of phytotoxicity is low. Therefore, an organic soil enhancer called aquagrain helps plants develop earlier and thrive in conditions where moisture is scarce. To reduce the usage of synthetic fertilizers, farmers should be made aware of its significance and its role in improving soil structure.

Table 1: Effect of Aquagrain concentration on Plant height, Number of leaves, Leaf area, Chlorophyll content and Stem girth of Vegetable Amaranth at 6 WAS during 2020 dry season at BUK

Treatment	*Plant height (cm)*	*Number of leaves (#)*	*Leaf area (cm^2)*	*Chlorophyll content (%)*	*Stem girth (mm)*
Aquagrain Concentration (Kg ha^{-1})					
0	46.3b	12.7c	37.1d	0.2c	5.9b
100	85.0a	16.3ab	90.6ab	0.24bc	9.7a
150	79.5a	15.4bc	78.7bc	0.2bc	8.5a
200	80.6a	14.9bc	93.5ab	0.2bc	7.7a
250	84.2a	16.7bc	92.8ab	0.2bc	10.0a
300	86.0a	16.3bc	92.2ab	0.3ab	9.6a
350	89.5a	15.7bc	61.7c	0.3ab	8.2a
400	79.8a	18.6ab	89.1ab	0.3ab	9.2a
450	86.2a	18.3ab	79.4bc	0.3ab	8.4a
500	96.1a	21.4a	108.1a	0.3a	9.5a
P value	<.001	0.002	<.001	<.001	0.003
SED±	5.86	1.494	8.06	0.0162	0.812

Means followed by the same letter (s) on the same column are not significantly different at 5% level of probability using Student Newman Keuls Test. WAS = Weeks after sowing

Table 2: Effect of Aquagrain concentration on Soil moisture content, Nitrogen, Phosphorus and Potassium Concentration of Vegetable Amaranth at 6 WAS during 2020 dry season at BUK

Treatment	*Soil moisture content (%)*	*Nitrogen concentration (mg/kg)*	*Phosphorus concentration (mg/kg)*	*Potassium concentration (mg/kg)*
Aquagrain Concentration (Kg ha^{-1})				
0	0.5	7.3	5.0b	18.7
100	0.5	5.7	5.4b	15.01
150	0.5	5.0	6.0ab	13.4
200	0.5	5.3	6.3ab	17.3
250	0.5	5.3	6.7ab	14.0
300	0.5	6.3	6.4ab	13.8
350	0.5	4.7	7.0ab	15.0
400	0.5	5.3	7.3ab	16.0
450	0.5	5.9	7.3ab	16.3
500	0.5	6.1	8.7a	19.6
P value	0.679	0.126	0.03	0.132
SED±	0.017	0.79	0.89	2.177

Means followed by the same letter (s) on the same column are not significantly different at 5% level of probability using Student Newman Keuls Test. WAS = Weeks after sowing.

Table 3: Effect of Aquagrain concentration on Fresh weight and Dry weight of Vegetable Amaranth at 6 WAS during 2020 dry season at BUK

Treatment	*Fresh Weight (g)*	*Dry Weight (g)*
Aquagrain Concentration (Kg ha^{-1})		
0	38.4c	5.9b
100	106.7ab	18.9a
150	94.3b	17.4a
200	92.2b	15.4a
250	112.7ab	19.4a
300	126.8a	23.4a
350	98.4ab	17.2a
400	104.6ab	21.5a
450	105.7ab	19.3a
500	128.9a	23.4a
P value	<.001	<.001
SED±	9.77	2.647

Means followed by the same letter (s) on the same column are not significantly different at 5% level of probability using Student Newman Keuls Test.

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Adaptation to Climate Change: An Assessment of Soybean Production and Sustainability in Bassa Local Government Area, Plateau State

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Abstract

This study examined climate change adaptation and sustainability in soybean production in the Bassa Local Government Area, Plateau State, Nigeria. Specifically, it described the socio-economic characteristics of soybean farmers in the area and ascertained their perception of climate change's effects on soybean production. The study also examined the adaptation strategies employed by farmers to cope with climate change impacts. A purposive sampling method was used to select 140 respondents from two districts. Data collected through structured questionnaires and interviews were analyzed using descriptive statistical tools. The findings revealed that female (63.6%), middle-aged ($\bar{x}$=39 years), and married farmers (52.9%) with varied educational backgrounds are primarily responsible for soybean production. Despite their relatively low incomes (₦421,671 per annum) and average household sizes (6 persons), they are aware of climate change's impacts on soybean production, including lower yields, soil water loss, and stunted growth. The study also revealed that farmers have adopted strategies like crop rotation, cover cropping, and crop diversification. However, there is a need to promote irrigation, climate-smart agriculture, agroforestry, and drought-tolerant seeds to enhance resilience. The study concludes that promoting irrigation, climate-smart agriculture, agroforestry, and drought-tolerant seeds can enhance resilience. Furthermore, government support for drought-tolerant seeds, farmer cooperatives, regular extension services, and a comprehensive policy framework can enhance climate resilience in soybean production.

Keywords: Adaptation, Climate Change, Soybean Production, Sustainability

Introduction: Climate change is a pressing global issue, with significant impacts on agriculture, food security, and sustainable development. According to the Food and Agriculture Organization of the United Nations (FAO, 2015), climate-related risks at the national level can lead to shocks in agricultural production and food availability, potentially disrupting markets and having broader economic and social impacts (Intergovernmental Panel on Climate Change, IPCC, 2013). climate change is projected to lead to persistent water and resource scarcity, exacerbating soil degradation, disease and pest outbreaks in crops and livestock, sea-level rise, and other impacts. According to Rao and Kumar, (2022) vulnerable regions are expected to suffer decline in agricultural productivity, mainly due to reduced crop yields, disproportionately affecting low-income communities. In Nigeria, agriculture is a vital sector, employing about 70% of the labor force and contributing significantly to the country's GDP. The agricultural sector in Nigeria plays a crucial role, accounting for around 23% of the nation's GDP and providing employment opportunities for about 70% of the workforce (FAO, 2019). Agriculture is a significant contributor to the national economy in Nigeria and the influence of shifting weather patterns are already being felt (Nwajiuba, 2017).

Soybean production, in particular, is vulnerable to climate-related stressors such as rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events (Adejuwon, 2006). Soybean is a vital crop in the Plateau State region, specifically in the Bassa zone, playing a crucial role in ensuring food security and economic stability for the local community (Plateau State Government, 2020). However, the region's agricultural sector faces significant challenges in adapting to the changing climate (Ekeleme et al., 2019). While existing studies have explored the broader implications of climate change on agriculture in Nigeria, a more nuanced understanding of its impacts on soybean production and sustainability in the Bassa Local Government Area is essential to inform localized strategies and interventions. This research seeks to explore the effect of climate variability on soybean production and long-term sustainability in the Bassa Local Government Area. By analyzing the social and economic profiles of soybean farmers, their understanding of climate change consequences, and the coping mechanisms they use, this study aims to inform the development of tailored solutions to minimize the adverse effects of climate variability and ensure sustainable food production in the region. The study aims to; describe the socio-economic characteristics of soybean farmers in Bassa Local Government Area, Plateau State, and; ascertain farmers perception of the effects of climate change on soybean production in the study area.; examine the adaptation strategies employed by soybean farmers to cope with climate change impactsThe findings of this study will contribute to the development of targeted adaptation strategies and policy interventions to support soybean farmers in Bassa Local Government Area and similar regions in Nigeria, ultimately enhancing the resilience of soybean production systems to climate change.

Materials and Methods: This study was conducted in Bassa LGA, Plateau State, Nigeria. Two districts, Kishika and Mafara, were purposively selected as they are the major soybean-producing areas. A total of 140 soybean farmers were selected from the two districts (Seventy farmers from each district). Data was collected using a structured questionnaire and an interview schedule. A Descriptive statistical tool (mean) was used to analyze the data.

Results and Discussions: The findings in Table 1 showed a higher percentage (63.6%) of the soybean farmers were female, while only 36.4% were male. The findings indicate that females carry out the majority of the soybean farming activities in this area. This may be due to soybean production being labor-intensive, requiring careful attention often provided by women (Adeoye et al., 2017). Women may also find soybean production more accessible due to constraints in accessing land and resources for other crops (Peterman et al., 2014).

Table 1: Distribution of Respondents according to Socioeconomic Characteristics

	Variable	Frequency	Percentage	Mean (x̄)
Sex	Male	51	36.4	
	Female	89	63.6	
	Total	**140**	**100**	
Age(years)	18-38 Years	77	55.0	39 years
	39-58 Years	49	35.0	
	59 and above	14	10.0	
	Total	**140**	**100**	
Marital Status	Single	33	23.6	
	Married	74	52.9	
	Separated (Divorced Widow/Widower)	33	23.6	
	Total	**140**	**100**	
Educational Level	Primary	67	47.9	
	Secondary	38	26.9	
	Tertiary	18	12.9	
	No normal education	17	11.9	
	Total	**140**	**100.0**	
Household size	1-5 persons	66	47.1	
	6-10 persons	65	46.4	6 persons
	11 persons and above	9	6.5	
	Total	**140**	100.0	
Farming experience(yrs)	1-5 years	45	32.1	7 years
	6-10 years	67	47.9	
	11-15 and above	28	20.0	
	Total	**140**	**100.0**	
Farm size	1-5 ha	81	57.9	6 hectares
	6-10 ha	40	28.6	
	11ha and above	19	13.6	
	Total	**140**	**100.0**	
Annual income (₦)	₦50,000 - 100,000	45	32.1	₦ 421,671
	₦101,000-150,000	37	26.4	
	₦151,000-200,000	32	22.9	
	₦201,000 and above	26	18.6	
	Total	**140**	**100.0**	

Field Survey, 2024

The mean age of the respondents was 39 years old, indicating that the majority of soybean farmers in the study area are middle-aged adults. According to a study by Abdul-Rahim et al. (2018), the typical farming age in Nigeria is around 40 years, which aligns with our finding of 39 years. This age group typically possesses sufficient physical energy to engage in labor-intensive soybean farming activities, enabling them to adapt to and combat the effects of climate change. The finding that 52.9% of soybean farmers are married has implications for climate change adaptation. Married farmers may benefit from shared responsibilities and resources, but marital obligations can also divert resources, highlighting the importance of considering socio-economic characteristics in adaptation efforts. This finding is consistent with a study by Mugi-Ngenga et al. (2019), which found that married farmers had improved climate change adaptation capacity due to shared responsibilities and access to additional resources. The high percentage of soybean farmers with varied educational backgrounds (primary 47.9%, secondary 26.9%, and tertiary 12.9%) suggests that they may have a range of knowledge and skills to adapt to climate change. However, the presence of 16% without formal education and 47.9% with only primary education may indicate a need for targeted training and capacity-building programs to enhance their understanding of climate change and adaptation strategies, ensuring that all farmers have the necessary skills to adapt effectively. The mean household size of soybean farmers in the study area was 6 persons, indicating a household size slightly above average. Soybean farmers with slightly above-average households may have additional labor available for farming activities, potentially enhancing adaptation efforts, but may also face slightly increased pressure on resources, potentially diverting resources away from climate-resilient practices. This finding is consistent with a study by Bryan et al. (2013), which found that households with slightly above-average sizes in rural Africa had increased labor availability for farming, but also faced higher resource demands, affecting their ability to adapt to climate change.

The average farm size of 6 hectares (Table 1) indicates small to medium-scale soybean farmers. This modest farm size may limit economies of scale and resource access. The average of 7 years of farming experience indicates that the soybean farmers in the study area have some level of experience and familiarity with farming practices. However, However, compared to others with 10-30 years of experience, 7 years may be relatively less and possibly insufficient to adapt to climate change. The findings align with Apata et al. (2015), who found that Nigerian soybean farmers with smaller farms and less experience were more vulnerable to climate change, requiring capacity building and support to adapt. The finding revealed that the mean annual income of soybean farmers in the study area was 421,671 Naira (approximately 1,200 USD), suggesting that they have relatively low incomes. This finding is consistent with a study by Oladejo and Awoyemi (2017), which reported that smallholder soybean farmers in Nigeria earned an average annual income of 450,000 Naira, underscoring the prevalence of low incomes and economic vulnerability among this group. The results of the study on farmers' perception of the consequences of climate variability on soybean production in the study area presented in Table 2 indicate that they agree with all the effects listed, with varying degrees of severity. Specifically, lower soybean yield is perceived as the most significant impact ($\bar{x}$=3.4), ranking 1st, followed closely by easy loss of water from the soil ($\bar{x}$=3.3) and stunted growth in soybean crops ($\bar{x}$=3.1). Additionally, extreme weather events ($\bar{x}$=3.1), increased pest and disease pressure ($\bar{x}$=3.0), and increased weed growth ($\bar{x}$=2.9) are also recognized as significant challenges. In contrast, loss of farmland to flood and erosion is perceived as a lesser but still significant impact.

Table 2: Farmers' perception of the effects of climate change on soybean production in the study area

Effect of climate change	Strongly Agree (4)	Agree (3)	Disagree (2)	Strongly Disagree (1)	Mean ($\bar{x}$)	Ranking
	F (%)	F (%)	F (%)	F (%)		
Lower soya beans yield	78 (55.7)	43(30.7)	16(11.4)	3 (2.1)	3.4	1st
Easy loss of water from the soil	70 (50.0)	40(28.6)	25(17.9)	5 (3.6)	3.3	2nd
Causes stunted growth in soyabeans crops	54 (38.6)	53(37.9)	25(17.9)	8 (5.8)	3.1	3rd
Extreme weather events (droughts, floods, heatwaves) have reduced soybean productivity	50 (35.7)	57(40.7)	31(22.1)	2 (1.4)	3.1	4th
increased pest and disease pressure on soybeans	45(32.1)	58(41.4)	29 (20.7)	8 (5.5)	3.0	5th
Increase in growth of weed	38(27.1)	56(40.0)	39 (27.9)	7 (5.0)	2.9	6th
Loss of farmland to flood and erosion	34(24.3)	42(30.0)	50 (35.7)	14(10)	2.7	

Field Survey, 2023 **Mean score ≥ 2.50 = Agreed**

These findings are consistent with existing literature, which highlights the vulnerability of soybean production to climate change (Adejuwon, 2006; Ekeleme, et al. 2019; Rao & Kumar, 2022; and IPCC, 2013). Climate change is projected to lead to persistent water and resource scarcity, exacerbating soil degradation, disease and pest outbreaks in crops and livestock, sea-level rise, and other impacts (FAO, 2015). The adaptation strategies employed by soybean farmers to cope with climate change impacts in the study area are presented in Table 3. The results show that strategies such as crop rotation, cover cropping, crop diversification, and minimum tillage were widely adopted by farmers, with mean scores of 2.5 and above. These findings are consistent with Snapp (2010), who observed that cover crops are an effective way to enhance soil health, reduce off-farm inputs, and protect natural resources. In contrast, farmers exhibited a poor attitude towards irrigation, climate-smart agriculture, agroforestry, and drought-tolerant seeds. This reluctance is likely attributed to the high costs, complexity, and limited knowledge associated with these strategies

Table 3: Adaptation strategies employed by soybean farmers to cope with climate change impacts

Adaptation strategies employed by smallholder farmers	Strongly Agree (4)	Agree (3)	Disagree (2)	Strongly Disagree (1)	Mean ($\bar{x}$)	Ranking
	F (%)	**F (%)**	**F (%)**	**F (%)**		
I use irrigation to cope with droughts and water scarcity	2 (1.4)	31(22.1)	57(40.7)	50 (35.7)	1.9	
I Practice climate-smart agriculture	5 (3.6)	25(17.9)	40(28.6)	70 (50.0)	1.4	
I use agroforestry practices to reduce soil erosion and increase biodiversity.	13 (3.9)	11(15.0)	37 (19.3)	79(56.5)	1.7	
I practice crop rotation to improve soil fertility and reduce pests and diseases.	54 (38.6)	53(37.9)	25(17.9)	8 (5.8)	3.1	2nd
I diversify my crops to reduce dependence on a single crop and increase resilience.	56(40.0)	38(27.1)	39 (27.9)	7 (5.0)	3.0	3rd
I use cover crops to reduce soil disturbance and improve soil health.	79(56.5)	27 (19.3)	21(15.0)	13 (3.9)	3.2	1st
I use drought-tolerant seeds	14(10)	34(24.3)	50 (35.7)	42(30.0)	2.1	
I use minimum tillage to avoid soil disturbance	45(32.1)	8 (5.5)	58(41.4)	29 (20.7)	2.5	4th

Field Survey, 2023 Mean score ≥ 2.50 = Agreed

The findings suggest that soybean farmers are adopting strategies like crop rotation and cover cropping to cope with climate change, but are hesitant to adopt others like irrigation and drought-tolerant seeds due to high costs and limited knowledge, highlighting the need for education and support.

Conclusion: In conclusion, this study on soybean production in Bassa Local Government Area, Plateau State, reveals that female, middle-aged, and married farmers with varied educational backgrounds are primarily responsible for soybean production. Despite their relatively low incomes and average household sizes, they are aware of climate change's impacts on soybean production, including lower yields, soil water loss, and stunted growth. To adapt, farmers have adopted strategies like crop rotation, cover cropping, and crop diversification, but there is a need to promote irrigation, climate-smart agriculture, agroforestry, and drought-tolerant seeds to enhance resilience. This study's findings highlight the importance of targeted interventions to support soybean farmers in adapting to climate change, ensuring sustainable production, and improving their livelihoods. **Recommendations:** Farmers should be advised to invest in soil conservation and fertility management, utilize local knowledge and traditional practices, develop entrepreneurial skills for market access, and join farmers' cooperative for collective action to complement external support.**;** Government Agencies, NGOs, Local Authorities, and Agricultural Extension Services should establish a comprehensive support system for soybean farmers by promoting crop insurance, setting up demonstration plots, and strengthening extension services to provide climate information, technical assistance, and support.**;** Research institutions and seed companies should ensure the availability of drought-tolerant seed at all times and at a reduced cost. This is to encourage and boost farmers' interest on the continuous use of drought-tolerant seed**;** Governments and NGOs should provide training and capacity-building programmes for farmers on climate-resilient agricultural practices, support agricultural insurance programs to protect farmers from climate-related crop failures, and develop and implement climate-smart agriculture policies**;** The Government should establish a comprehensive policy framework and set up meteorological institute to address farmers need on climate variation and advice.

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Physicochemical Characteristics of Surface Water and Sediment in Tidal Flood Plain during Wet Seson in Selected Oil Producing Areas of Akwa Ibom State

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Abstract

Tidal flood plain sediments are important in the ecosystem survival which supports human wellbeing because of their immense biological resources, but this plain has been negative affected by human activities along the coast. Hence, determination of the physicochemical characteristics of surface water and sediments of tidal flood plains in Akwa Ibom State. To ascertain that, sediment and water samples were collected from five different locations for analyses using laboratory techniques. Results show that all physicochemical characteristics of surface water and sediment exhibited a significant difference ($p<0.05$) between the five sampling locations in the study area. The highest mean concentration of physicochemical parameters across all water and sediment samples were 7.35 (pH), 105.15mg/l (Cl), 0.62mg/l (K), 2.59mg/l (PO_4), 0.06mg/l (F), 36.70mg/kg (P), 0.028% (N), 0.59% (OC), 1.019% (OM), 4.60mg/kg (Ca), 3.00mg/kg (Mg), 0.174mg/kg (K), 0.138mg/kg (Na), 2.80 (EA), 10.26 (ECEC), 89.94% (BS), 0.54mg/kg (Zn), 26.97mg/kg (Ni), 11.00mg/kg (Mn), 7.00mg/kg (Fe), 0.84mg/kg (Cu), 0.87mg/kg (Cr) and 0.72mg/kg (Cd). Physicochemical parameters were generally higher in sediments samples than in the corresponding surface water samples. This study recommends regular assessments of surface water and sediment quality to evaluate the effectiveness of pollution control measures.

Keywords: *Sediment, Tidal Flood Plain, Pollution and Physiochemical parameters*

Introduction

The tidal flood plain sediment serves as water sink for a number of nutrients due to industrial wastes, water effluents, inorganic leachates from refuse dumpsites, fertilizers, runoffs among others.(Chmeilewska and Medved, 2001), and are well known for their sensitive indicators between natural and anthropogenic variables. Tidal flood plains are areas where sediments from river runoff, or inflow from tides deposit mud or sand. They are usually sandwiched between marine, freshwater and land environments and are found in areas where there are low slopes and regular flooding occurs (Mackinnon et al., 2012; Miththapal, 2013). There are global concerns over the rate at which water bodies and tidal flood plains are being polluted. High population growth, mostly in the developing countries, has given rise to increased human activities which in turn results to indiscriminate dumping of refuse and waste disposal among others in water bodies thereby making it difficult to have access to clean and uncontaminated water (Duru and Nwanekwu 2012). Surface water appear to be the most threatened by human activities of all the natural water bodies. Water may be available in adequate quantities but may not be of good quality thereby limiting what we can do with the available water. Naturally, ecosystems such as tidal flood plains and water bodies will be in harmony with each other and their qualities but any significant alterations to quality of any usually disrupts the ecosystem.

Water and its environments require adequate and proper conservation in other to continue in sustaining life. Since the advent of the discovery and exploration of crude oil in Nigeria, so many wastes have been introduced into our environment, mostly the water environment. These wastes comprise of various heavy metals and other nutrients. According to Tam and Wong (2000) and Li et al., (2007) environmental contamination arising from rapid urbanization and industrialization has become a serious concern worldwide. The contamination is very significant especially in sediments of the estuarine and coastal areas through adsorption onto suspended matter and subsequent sedimentation. Sediments are composite materials, which consist of inorganic components, mineral, particulate and organic matter in various stages of decomposition. They are well known for their sensitive indicators between natural and anthropogenic variables (Devanesan et al., 2017). Pollutants in sediments can be released back to water strata by the process of resuspension. This gets the chemical compound or pollutant trapped in the sediment to be reabsorbed (Lick, 2009).

Tidal flood plains experience complicated problems like pollution and encroachment that have almost suffocated valuable lifelines of the surroundings.

Study Area: This study was carried out in Akwa Ibom State, Nigeria. Akwa Ibom State lies between Latitudes 4º32' to 5º33'N and Longitudes 7º25' to 8º25'E with a landmass of 8412sq km and population of 3,920,208 (NPC, 2006). Its 129 km coastline happens to be the longest in the country and is a very rich source of wide varieties of fishes and sea foods (Wikipedia).

Climate: Rainfall in Akwa Ibom is usually heavy ranging between 2000mm and 3000mm annually. The rainfall pattern is bimodal, starting in March and ending in November. There is also, a short period of less moisture in August which is traditionally referred to as August break. The temperature ranges between 26º and 28º C throughout the year with slight variations. It has the vegetation of the tropical rainforest (AKSG, 2023) The state is largely made up of peasant farmers, fishermen and traders with some civil servants and entrepreneurs. The hospitality industry thrives well in Akwa Ibom as there are quite some tourism centres that attract tourists to the State. (AKSG, 2023).

Sampling And Sample Collection: Sediments and water samples were collected from five different locations namely; Ibeno, Eket, Esit-Eket, Ikot-Abasi and Eastern Obollo in Akwa Ibom State for physicochemical analysis using systematic sampling method and with the aid of stainless auger and scooper. Water samples were taken in clean sterile tubes with caps in duplicates, using hand gloves. Dissolved oxygen bottles were used to collect samples for dissolved oxygen determination. The samples were put in plastic bags and transferred to soil science laboratory for further analysis (Soil Survey Staff, 2010). Sediment samples were analyzed according to the Association of Official Analytical Chemists (AOAC, 2004). Sediment texture and organic carbon content were determined by Hydrometer method and Walkley Black (Jacob and Clarke, 2002). A factor of 1.72 was multiplied with organic carbon content to determine Sediment Organic Matter (SOM). EDTA Systronics Spectrophotometer-2202 was used to determine the parameters Jenway (model type HANNA 1910) multipurpose tester temperature, pH and conductivity were determined in situ using the HM digital meter-COM-10 and Equip-tronics EQ-614-A, respectively. Turbidity was determined using attenuated radiation method. Chemical oxygen demand was determined according to APHA (2005) method. Taste was determined by the panel method following Ukaga and Onyeka (2002).

Statistical Analysis: ANOVA was used to compare means across the test parameter intervals. Duncan multiple post hoc test was used for the specific significant differences among the sampling intervals. The analysis was computed using IBM SPSS Statistics Version 26.0.

Results and Discussion: **Physicochemical Properties of Surface Water** : As contained in table 1, all physicochemical properties of surface water exhibited significant differences (p<0.05) between the surface water samples from the five sampling locations in the study area. Hydrogen ion (pH) ranges from 4.35 at Esit-Eket to 8.30 at Eket. The pH values showed a significant difference (p<0.05) across all sampling locations. Chlorine (Cl) ranges from 11.87 mg/l at Eket to 112.76 mg/l at Eastern Obolo. The chlorine values showed a significant difference (p<0.05) across all sampling locations. Potassium (K) ranges from 0.416 mg/l at Ibeno and Ikot-Abasi to 0.607 mg/l at Eket. The K values showed a significant difference (p<0.05) across all sampling locations. Phosphate (PO_4) ranges from 0.001 mg/l at Ibeno to 2.507 mg/l at Eket. The PO_4 values showed a significant difference (p<0.05) across all sampling locations. Fluorine (F) ranges from 0.001 mg/l at Eket to 0.048 mg/l at Eastern Obolo. The Fluorine values showed a significant difference (p<0.05) across all sampling locations.

Parameters	**SAMPLING LOCATION**				
	Ibeno	**Eket**	**Esit -Eket**	**Ikot- Abasi**	**Eastern Obolo**
pH	$7.45^{b} \pm 0.071$	$8.30^{a} \pm 0.283$	$4.35^{d} \pm 0.071$	$6.95^{c} \pm 0.071$	$8.15^{a} \pm 0.071$
Cl (mg/l)	$66.14^{c} \pm 6.307$	$11.87^{e} \pm 0.226$	$25.535^{d} \pm 0.035$	$78.61^{b} \pm 0.566$	$112.76^{a} \pm 3.606$
K (mg/l)	$0.416^{c} \pm 0.021$	$0.607^{a} \pm 0.006$	$0.581^{a} \pm 0.00$	$0.43^{c} \pm 0.028$	$0.479^{b} \pm 0.001$
PO_4 (mg/l)	$0.001^{e} \pm 0.00$	$2.507^{a} \pm 0.135$	$1.152^{b} \pm 0.07$	$0.225^{d} \pm 0.034$	$0.54^{c} \pm 0.00$
F (mg/l)	$0.01^{b} \pm 0.001$	$0.002^{b} \pm 0.001$	$0.001^{b} \pm 0.00$	$0.003^{b} \pm 0.001$	$0.048^{a} \pm 0.014$

Table 1: Mean ±SD of Physicochemical Properties of Surface Water .

x ± SD = average mean generated from values across the sampling location, ± standard deviation; post hoc = values with different superscripts (a > b > c > d > e) are significantly different (p < 0.05) while values with same superscript are not significantly different (p > 0.05).

Physicochemical Properties Of Sediment Samples From The Study Area: Table 2 shows Physicochemical parameters such as pH, P, Ca, Mg, K, Na, EA, ECEC and BS exhibited a significant difference (p<0.05) between the sediment samples from the five sampling locations in the study area, while N, OC and OM showed no significant difference (p>0.05) between the sediment samples from the five sampling locations in the study area. Result shows that the percentage of Sand, Silt and Clay in the sediment samples varied significantly (p<0.05) across all sampling locations. pH ranges from 4.48 at Esit Eket to 7.40 at Ibeno. The pH values showed a significant difference (p<0.05) across all sampling locations.

Phosphorus (P) ranges from 15.40 mg/kg at Ibeno to 35.75 mg/kg at Esit Eket. The P values showed a significant difference (p<0.05) across all sampling locations. Nitrogen (N) ranges from 0.011 mg/kg at Eket to 0.018 mg/kg at Esit Eket. Organic Carbon (OC) ranges from 0.041 mg/kg at Esit Eket to 0.44 mg/kg at Esit Eket. Organic Matter (OC) ranges from 0.159 mg/kg at Esit Eket to 0.915 mg/kg at Esit Eket. The N, OC and OM values showed no significant difference (p>0.05) across all sampling locations. Calcium (Ca) ranges from 1.45 mg/kg at Ikot Abasi to 3.555 mg/kg at Ibeno. Magnesium (Mg) ranges from 1.005 mg/kg at Ikot Abasi to 2.69 mg/kg at Ibeno and Eket. Potassium (K) ranges from 0.007 mg/kg at Mobil to 0.073 mg/kg at Esit Eket. Sodium (Na) ranges from 0.004 mg/kg at Eket. to 0.101 mg/kg at Ibeno. Exchangeable Acid (EA) ranges from 0.575 at Eastern Obolo to 1.90 at Eket. Effective cation exchange capacity (ECEC) ranges from 3.06 at Ikot Abasi to 9.26 at Eket. Base saturation (BS) ranges from 60.645 % at Esit Eket to 85.26 % at Eastern Obolo. The Ca, Mg, K, Na, EA, ECEC and BS values showed a significant difference (p<0.05) across all sampling locations.

Table 2: Physicochemical Properties of Sediment Samples from the Study Area.

Parameters					
	Ibeno	**Eket**	**Esit Eket**	**Ikot Abasi**	**Eastern Obolo**
Sand (%)	$90.35^{a} \pm 0.00$	$88.30^{c} \pm 0.00$	$89.35^{b} \pm 0.071$	$90.39^{a} \pm 0.00$	$89.825^{ab} \pm 0.742$
Silt (%)	$0.253^{c} \pm 0.349$	$3.01^{a} \pm 0.014$	$1.80^{b} \pm 0.00$	$0.251^{c} \pm 0.353$	$1.50^{b} \pm 0.707$
Clay (%)	$2.81^{a} \pm 0.00$	$2.81^{a} \pm 0.00$	$3.39^{a} \pm 0.82$	$0.92^{b} \pm 0.707$	$1.92^{ab} \pm 0.707$
pH	$7.40^{a} \pm 0.424$	$4.75^{bc} \pm 0.354$	$4.48^{c} \pm 0.042$	$5.35^{b} \pm 0.354$	$5.10^{bc} \pm 0.00$

P (mg/kg)	15.40^{c} ± 0.566	23.95^{b} ± 5.728	35.75^{a} ± 0.212	18.00^{bc} ± 0.141	31.745^{a} ± 0.205
N (%)	0.013^{a} ± 0.00	0.018^{a} ± 0.00	0.011^{a} ± 0.01	0.016^{a} ± 0.004	0.017^{a} ± 0.001
OC (%)	0.125^{a} ± 0.009	0.44^{a} ± 0.58	0.041^{a} ± 0.049	0.205^{a} ± 0.136	0.253^{a} ± 0.072
OM (%)	0.286^{a} ± 0.105	0.767^{a} ± 0.924	0.915^{a} ± 1.025	0.159^{a} ± 0.063	0.471^{a} ± 0.081
Ca (mg/kg)	3.555^{a} ± 0.219	3.20^{a} ± 0.283	3.20^{a} ± 0.283	1.45^{b} ± 0.636	2.805^{a} ± 0.276
Mg (mg/kg)	2.69^{a} ± 0.028	2.69^{a} ± 0.028	2.345^{a} ± 0.516	1.005^{b} ± 0.007	2.345^{a} ± 0.516
K (mg/kg)	0.007^{e} ± 0.001	0.045^{b} ± 0.001	0.073^{a} ± 0.00	0.026^{c} ± 0.001	0.016^{d} ± 0.001
Na (mg/kg)	0.101^{a} ± 0.001	0.004^{b} ± 0.001	0.019^{b} ± 0.023	0.037^{b} ± 0.001	0.031^{b} ± 0.028
EA	0.765^{b} ± 0.078	1.90^{a} ± 0.00	1.25^{ab} ± 0.495	0.71^{b} ± 0.00	0.575^{b} ± 0.601
ECEC	7.665^{c} ± 0.064	9.26^{a} ± 0.00	8.675^{b} ± 0.318	3.06^{e} ± 0.00	7.05^{d} ± 0.00
BS (%)	79.94^{b} ± 1.245	62.715^{c} ± 0.035	60.645^{d} ± 0.474	80.92^{b} ± 0.00	85.26^{a} ± 0.014

x ± SD = average mean generated from values across the sampling location, ± standard deviation; post hoc = values with different superscripts (a > b > c > d > e) are significantly different ($p < 0.05$) while values with same superscript are not significantly different ($p > 0.05$).

Discussion: The physicochemical properties of water bodies are crucial to aquatic ecosystem and human life at large. Particle size distribution is one of the vital factors determining the extent of sediment contamination with pollutants (Adeyi and Babalola, 2017). Generally, sediment in this study was dominated by sand, followed by clay, and then silt in all the study locations. The sandy nature of the sediment of the study areas makes it highly permeable and might allow pollutants from oil exploration to pass through, thereby had a potential of polluting the surrounding underground water. The high sand fraction in the study could be attributed to the parent material dominant in the area which is coastal plain sand since the texture of soil is highly influenced by the parent material over time (Abida *et al*., 2009). The result from this study is in tandem with Anju and Banerjee, (2012) who observed similar textural characteristics on coastal plain soil and sediment in Owerri, Southeastern Nigeria. The textural classes ranged from silt loam to silty clay loam.

The pH values indicate the strength of acidity or alkalinity of the water (Nwankwo *et al*., 2015).The result from the study showed that the pH values were relatively similar and were acidic with a range of 3.45 – 7.35. Studies have shown that pH does not only affect the growth of plants indirectly by affecting nutrients availability, but also the presence of toxins and the growth of soil microorganisms (Dedeke *et al*., 2015). Therefore, pH range as obtained in this study might have implications on nutrient availability in the polluted soils and could be influenced by the presence of dissolved substances and biochemical developments in the water medium (Bahrami *et al*. 2019).

The average mean of phosphorus across this study showed a significant difference ($p<0.05$) across the study areas ranging from 15.50 – 36.70 (mg/kg) as seen in the tables. This prevailing condition of phosphorus content in this study areas may suggest the utilization/complexation of the nutrients by resident microflora as well as sediment degradation process such as volatilization or leaching (Nwankwo *et al*., 2015). The P values result agrees with a study conducted by Butler *et al*, 2008. However, Nweke and Ukpai, (2016) recorded a higher K of 89.77 mg/kg in Goi Creek in Ogoni land. Phosphate values recorded in this study were significant and can be attributed to the leaching of fertilizer residues from agricultural farms along the river. The PO_4 in this study was low compared to the study of Okorafor *et al.* (2014), who attributed their results to the influence of flooding. Edori *et al.* (2019) recorded lower values of 0.08 mg/l in water of Silver River in Bayelsa State when compared to this study.

Oghenenyoreme and Njoku (2014) obtained higher values of 259.6 mg/l for Chlorine in a selected part of Oji River and its environs, Enugu State. Edori and Nna (2018) recorded similar range values of 18.32 - 123.75 mg/l for Cl in effluents at discharge points into the New Calabar River along Rumuolumeni Axis, Rivers State. As per Fluoride, this study agrees with the findings of Osuji and Nwoye (2017), who obtained a similar concentration of F value of 0.03 mg/l in surface water in the Niger Bayelsa mangrove creek. Otari and Dabiri (2015) also obtained similar values of 0.04 mg/l in surface water samples from Nembe River, while Nnoli *et al*. (2021) recorded a higher F value of 1.86 mg/L in Goi Creek in Ogoni land.

The average mean percentages of nitrogen across the study area were relatively similar and showed no significant difference ($p>0.05$) between the study areas. This prevailing condition of low nitrogen content in this study may suggest that soil degradation process such as volatilization or leaching was higher (Kuppusamy *et al*., 2017). Organic matter is the most important source of N used by plants (Nazir *et al*., 2015). This result is in line with a study by Nwachukwu *et al*. 2013. Organic carbon (OC) is a measurable component of organic matter (OM). The variability of organic carbon of sediment obtained from the study reflects the intensity of human activities in the study areas (Dudka and Miller, 2019).. Exchangeable bases (Ca, Mg, K and Na) content of sediment had significant differences ($p<0.05$) across the study location for these exchangeable bases. The finding in this study is in line with the study of Ogboi, (2012) who obtained similar values for exchangeable bases. Other researchers found different results and opined that there is an increase in exchangeable Ca and Na contents as a result of crude oil and can be attributed to rapid decay and mineralization of organic and mineral materials in the sediment (Onwukeme and Etienajirhevwe, 2020). Orhue and Usi, (2015) recorded a higher Ca, Mg, K and Na of 8.55, 6.17, 2.23 and 3.26 mg/kg respectively in Goi Creek in Ogoni land when compared with this work.

The Exchangeable Acidity (EA) showed significant difference ($p<0.05$) across the study areas. The highest exchangeable acidity value of 2.80 cmol/kg was obtained from Eket whiles the least exchangeable acidity value of 0.575 cmol/kg was obtained from Eastern Obolo. The Effective cation exchange capacity (ECEC) content showed a significant difference ($p<0.05$) across the study areas. The highest ECEC value of 10.26 cmol/kg was obtained from the Eket whiles the least exchangeable acidity value of 3.06 cmol/kg was obtained from Ikot Abasi. This result confirms the findings of Oseji *et al*, (2018) who recorded an exchangeable acidity of 8.30 cmol/kg.

The results of the percentage base saturation (BS) showed a significant difference ($p<0.05$) across the study areas. This result confirms the findings of Biruk *et al*, 2017 who recorded a similar BS range of 70.12 – 90.11%. Generally, the low soil carbon, total nitrogen and organic matter contents indicates poor soil fertility (Osuji and Nwoye, 2017). High base saturation could be attributed to increase in exchangeable bases and organic carbon. The sediments in this study had more concentration of physicochemical parameters than in corresponding surface water samples. Across the sampling locations, whether within the water column or bottom sediment, the lowest and highest concentrations of the analysed parameters were obtained at Ikot Abasi and Eket, respectively. This was possible due to the significant anthropogenic activities and its proximity to the community, which, combined with run-off from agricultural fields.

Conclusion: The comprehensive assessment of physicochemical parameters in water bodies is critical for understanding environmental health and human well-being. The study investigated the quality status of the coastal environment for the sustainability of same for aquatic organisms and man's survival in particular. The analysis covers various parameters such as particle size distribution, pH, K, Na, Ca, Mg, organic carbon, exchangeable bases. The pH of the soil is moderately acidic, influencing nutrient availability and pollutant fate. Soil organic carbon and organic matter content are significantly low in the study area, indicating intense anthropogenic activities and slow mineralization. Nitrogen and phosphorus levels vary across study areas with implications for soil fertility. Exchangeable bases content, exchangeable acidity, effective cation exchange capacity, and percentage base saturation are analyzed to understand soil fertility and nutrient availability. These parameters show variations across study areas, influenced by both natural processes and anthropogenic activities.

Recommendation: Based on this study, it is recommended that stringent regulations must be implemented and monitoring mechanisms should be in place to checkmate human activities along the coastline .

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Organic fertilizer and growth inhibitors influencing the chlorophyll content of *Amaranthus cruentus* (L.) under drought conditions

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Abstract

Fertilizer and water availability are two major environmental requirements that can deteriorate plant growth, and when combined, their effects can either intensify or reduce grain amaranth performance. The objective of the trial was to analyze the influence of fish guano (FG) and abscisic acid (ABA) on leaf chlorophyll content under varied stress conditions. Treatments consisted of moisture stress stages (vegetative, flowering, and grain filling), FG (0, 0.1, and 0.2 kg), and ABA concentrations (0, 20, and 50 µmolL-1) laid out in a split-plot design and replicated three times. Moisture stress was applied to the main plots, while FG and ABA treatments were applied to the subplots. Findings revealed that moisture stress, FG, and ABA significantly influenced the leaf chlorophyll content of grain amaranth across the sampling periods and seasons, respectively. Water stress imposition at the vegetative significantly reduced leaf chlorophyll, and the application of 0.2 kg FG recorded significantly ($p < 0.05$) higher leaf chlorophyll content. The result showed a progressive increase in leaf chlorophyll with increasing ABA concentrations. There was a significant interaction between stress and ABA at BUK as well as between FG and ABA at Wudil. Thus, the application of 0.2 kg of FG and ABA at 50 µM can help reduce the effect of moisture stress on the leaf chlorophyll content of grain amaranth and enhance the photosynthetic efficiency of the crop.

Key words: *organic fertilizer, growth inhibitor, leaf chlorophyll, amaranth, moisture stress.*

Introduction: Grain amaranth contains more minerals, vitamins, carotenoids, and bioactive components (Pasko et al., 2009). The chlorophyll content, one of the major components of chloroplasts, is positively related to the photosynthetic rate. Numerous studies have shown that drought stress can significantly decrease photosynthetic pigment content (Chl a, Chl b, and Chl a+b) (Dias *et al*., 2018; Mohammed *et al*., 2021). Under drought-stress conditions, the decrease in chlorophyll content could be considered a typical symptom of oxidative stress as a result of pigment photo-oxidation and chlorophyll degradation (Anjum *et al.,* 2011; Ashraf and Harris, 2013). Drought causes oxidative stress through a reduction in CO_2 assimilation, which induces an excess of excitation energy and electron flux to O_2, giving rise to photo-oxidative stress and reactive oxygen species (ROS) overproduction (Zou *et al*., 2009). ROS are highly reactive species that damage proteins, chlorophylls, membrane lipids, and nucleic acids (Halliwell and Gutteridge, 2007).

Fish guano provides complete and balanced nutrition while reducing the risk of losses through leaching (Angibaud, 2016). Fish guano could be considered a better alternative organic fertilizer than other organic fertilizers. Abscisic acid, an isoprenoid phytohormone, regulates various physiological processes, including stomatal opening and protein storage, and provides adaptation to many plant stresses (Sah *et al*., 2016).
Studies have reported a reduction in grain yield under water deficit, and this harmful effect is mainly observed in the arid and semi-arid zones, where agriculture remains the main source of employment (Anjum *et al*., 2011; Mlakar *et al.,* 2012). Under moisture stress conditions, when the uptake of nutrients can be challenging due to reduced root activity, the application of fish guano can provide readily available nutrients to support the plant's physiological processes (Angibaud, 2016). Exogenously applying Abscisic Acid can enhance the plant's ability to cope with moisture stress by triggering various physiological and biochemical changes, such as osmotic adjustment, antioxidant activity, and stomatal regulation (Sellamuthu *et al*., 2022). The present study was carried out to boost the cultivation and use of unexplored or alternative crops for grain amaranth production in a moisture-deficient environment.

Materials and Methods: Experimental site: The experiments were conducted during the 2021 and 2022 dry seasons at Teaching and Research Farm Faculty of Agriculture Bayero University Kano (110 97′ 98.6″N 80 42′03.7″′E) and Aliko Dangote University of Science and Technology Farm Wudil (11̊25′N and Long. 9̊E) situated in the sudan Savanna ecology of Nigeria.
Treatments and experimental design: Treatments consisted of induced moisture stress at (vegetative, flowering and grain filling), fish guano [FG] (0, 0.1 and 0.2 kg) and ABA concentration (0, 20 and 50 $\mu molL^{-1}$) and laid out in a split plot design with three replications. Induced moisture stress was assigned to the main plot while FG and ABA were factorially combined and assigned to the sub plot.
Preparation and application of materials: Fish guano powder 200g was suspended in 4 Liter of distilled water. It was mixed thoroughly, and serially diluted to the prescribed rates and sprayed across seedlings using the hand-held watering can (Angibaud, Derome and Specialties, 2016). A stock solution was prepared by mixing 100 mg ABA powder in1ml ethanol. A weighed quantity of ABA (as per treatment) was added in a graduated cylinder and 1 L volume was made in a volumetric flask by adding distilled water. Solutions were immediately foliage applied with a hand sprayer (Phyto Technology, Laboratories 2016).
Cultural practices: Land preparation: The experimental sites were cleared manually, ploughed, and harrowed to obtain a fine-tilt soil. The site was divided into plots of 3 x 4.5 m (13.5 m^2) with 6 rows each. A spacing of 1.5 m between replications and 1 m between blocks was left as an alley. The distance between sub-plots was 0.5 m.
Sowing and transplanting: Seeds were sown in mid-January 2021 in a nursery bed for 4 weeks by the drilling method. Seeds were covered with soil and mulched to speed up the germination period. Seedlings were transplanted to the field manually; 10 seedlings were transplanted on each of the 6 rows at a depth of 2 cm with a spacing of 75 cm by 30 cm between stands.
Crop protection: Weeds were controlled manually using a hoe**.** Garlic extracts were applied thrice to mitigate the infestation of leaf miner *Liriomyza huidobrensis*.

Harvesting: The Amaranth grains were harvested from the net plot by uprooting using a hoe at 12WAT. Threshing was done manually.

Data collection and Analysis: Data was collected on leaf chlorophyll at the vegetative stage, the flowering stage, and grain filling at 4, 8, and 12 weeks after transplanting using the SPAD-502 meter KONICA MINOLTA and subjected to analysis of variance (ANOVA) using Genstat 17th edition. Significant treatment means were separated using the Student Newman-Keuls test at a 5% level of probability.

Result and Discussion: The effect of moisture stress, fish guano (FG), and abscisic acid (ABA) on leaf chlorophyll of grain amaranth at 4, 8, and 12 WAT at BUK and Wudil in the 2021 and 2022 seasons is presented in Table 1. The results revealed that moisture stress had a significant effect ($p < 0.05$) on leaf chlorophyll at 8 WAT at Wudil in 2022 only. Stress imposed at the vegetative stage significantly influenced leaf chlorophyll at 8WAT in 2022 at Wudil. Stress imposed at the flowering stage recorded lower chlorophyll content than stress imposed at the vegetative and grain filling stages. This could be due to the young and tender leaves at the vegetative stage, which contain fully active chloroplasts, unlike older leaves at the flowering or grain-filling stages. This agrees with the findings of Li *et al*. (2018), who reported that chlorophyll contents are higher in crops at the early vegetative stages when compared to the mid- and late-seasons of production. Datta *et al*. (2018) noted that amaranth contains maximum chlorophyll content at tender ages, and variation of chlorophyll content in relation to leaf age is often considered a comparatively late mechanism of photosynthetic adaptation.

Fish guano had a significant ($p<0.05$) effect on the leaf chlorophyll content of grain amaranth at 8 and 12 WAT in 2021 at both locations, as well as 8 WAT in 2022 at Wudil. Leaf chlorophyll of grain amaranth increased progressively with increasing rates of FG at both locations and seasons. The application of 0.2 kg FG recorded significantly higher leaf chlorophyll content than 0 and 0.1 kg FG, which were significantly similar to each other across all sampling periods. The physiological role of FG in assisting the growth and development of plants and many other factors (locations, environment, and light, among others) are responsible for influencing leaf chlorophyll (Li *et al*., 2018). The increasing chlorophyll content of organic fertilizer treatments under drought stress conditions may be due to the increased activity of drought-responsive enzymes (Majidia et *al*., 2015). Abscisic acid significantly influences the leaf chlorophyll content of grain amaranth at all sampling periods in both seasons and locations, except at 12 WAT in 2022 at BUK and 4 WAT in 2021 at Wudil. There was a linear and progressive increase in leaf chlorophyll with increasing ABA concentrations at all sampling periods in both seasons and locations. This may be due to the physiological role of ABA in promoting the growth, development, and productivity of plant species by reducing the effect of moisture stress.

Table 1: Effect of Moisture Stress, Fish Guano and Abscisic Acid Concentrations on Leaf Chlorophyll (µmolm^{-2}) per plant of grain Amaranth at BUK and Wudil during the 2021 and 2022 dry seasons

	BUK						Wudil					
	2021			2022			2021			2022		
	Weeks after transplanting (WAT)											
Treatments	4	8	12	4	8	12	4	8	12	4	8	12
Stress (S)												
Vegetative	23.05	27.06	28.99	24.42	25.21	41.57	22.81	25.14	27.43	55.4	98.3a	79.9
Flowering	22.69	25.19	29.55	26.21	26.81	44.77	22.15	22.55	23.21	50.8	74.2b	77.1
Grain Filling	21.84	26.12	28.31	25.69	27.00	43.66	24.13	23.17	24.13	60.2	93.4a	72.5
p-value	0.750	0.242	0.688	0.210	0.736	0.342	0.464	0.102	0.204	0.548	0.020	0.383
SE±	1.11	0.64	0.96	0.59	1.70	1.36	1.04	0.65	1.42	5.63	3.65	3.38
Fish Guano (F) (kg)												
0	22.56	25.09b	27.27b	25.24	26.50	42.07	22.66	21.96b	23.34b	55.9	81.1b	71.0
0.1	22.25	24.87b	28.37b	26.71	26.49	44.59	21.83	22.44b	23.51b	55.2	91.6a	76.9
0.2	22.77	28.41a	31.20a	24.38	26.03	43.35	24.60	26.47a	27.92a	55.4	93.3a	81.6
p-value	0.849	0.004	0.005	0.280	0.940	0.264	0.077	0.005	0.018	0.990	0.024	0.059
SE±	0.65	0.79	0.83	1.03	1.06	1.07	0.86	1.00	1.24	3.37	3.29	3.07
ABA (A) (µM)												
0	17.90c	17.98c	17.51c	19.47c	19.50c	43.46	19.37c	10.72c	12.42c	52.3	73.5b	64.2b
20	22.09b	27.47b	31.54b	26.35b	27.11b	42.89	23.21b	26.49b	26.67b	54.9	91.7a	79.7a
50	27.59a	32.92a	37.79a	30.50a	32.40a	43.66	26.51a	33.66a	35.69a	59.3	100.6a	85.6a
p-value	<.001	<.001	<.001	<.001	<.001	0.872	<.001	<.001	<.001	0.347	<.001	<.001
SE±	0.65	0.79	0.83	1.03	1.06	1.07	0.86	1.00	1.24	3.37	3.29	3.07
Interaction												
S*F	0.245	0.386	0.653	0.639	0.392	0.587	0.439	0.891	0.378	0.982	0.844	0.332
S*A	0.119	0.266	0.167	0.496	0.020	0.145	0.500	0.346	0.881	0.372	0.500	0.118
F*A	0.740	0.073	0.164	0.480	0.138	0.233	0.022	<.001	<.001	0.588	0.007	0.508
S*F*A	0.155	0.620	0.839	0.059	0.189	0.541	0.058	0.426	0.989	0.541	0.872	0.284

Mohammed *et al.* (2020) reported that the application of ABA to the lettuce plants under Cd^{2+} stress maintained the contents of chlorophyll similar to the unstressed plants. Seed treatment with different concentrations of ABA increased the contents of chlorophyll a and b and total chlorophyll in pea seedlings that were exposed to Cd^{2+} (Lu *et al*., 2018). There was a significant interaction between stress and ABA at 8 WAT in 2022 at BUK as well as FG and ABA at 4, 8, and 12 WAT in 2021 and 8 WAT in 2022 at Wudil. The interaction between stress and ABA on leaf chlorophyll at 8 WAT in 2022 at BUK is presented in Table 2. Leaf chlorophyll of grain amaranth increased significantly as the ABA concentrations increased at all stages of moisture stress. The application of 50 µM ABA recorded the highest leaf chlorophyll at all moisture stress stages. The application of 20µM ABA produced significantly more leaf chlorophyll content when applied to plants imposed with stress at flowering stages than vegetative and grain filling stages, but when 50µM ABA was applied to plants imposed with stress at vegetative and grain filling stages, the leaf chlorophyll was similar but higher than stress imposed at flowering stages.

Table 2: Interaction between Stress x Abscisic Acid interaction on leaf chlorophyll (µmolm^{-2}) of grain Amaranth at 8WAT at BUK during 2022 dry season

	ABA(µM)		
Treatments	0	20	50
Stress			
Vegetative	17.16d	25.98bc	32.49a
Flowering	19.50cd	31.11ab	29.82ab
Grain filling	21.84cd	24.24bc	34.90a
SE±	2.274		

Means followed by the same letter(s) in a column within treatment group are not significantly different at 5% level of probability

The interaction between FG and ABA at 4, 8, and 12 WAT in 2021 at Wudil is presented in Table 3. The leaf chlorophyll obtained from 0 kg FG significantly differs with the application ABA concentrations. However, the leaf chlorophyll obtained from plots treated with 0 kg FG and 0 µM was higher than other treatment combinations. A similar trend was observed at 0.1 and 0.2 kg FG, respectively. At 8 WAT, the leaf chlorophyll obtained from 0 kg FG is statistically similar with increasing ABA concentrations. However, the leaf chlorophyll obtained from plots treated with 0.1 kg FG increases significantly with an increase in ABA concentrations. A similar trend was observed at 0.2 kg FG, respectively. At 12 WAT, the leaf chlorophyll obtained from 0 kg FG is statistically similar with increasing ABA concentrations. However, the leaf chlorophyll obtained from plots treated with 0.1 kg FG increases progressively with an increase in ABA concentrations. A similar trend was observed at 0.2 kg FG, respectively. The significant interaction was due to the essential nutrients released from applied FG, which increased the plant's capacity to produce energy through photosynthesis, flower set, and grain formation (Senjobi *et al.,* 2010), and the effect of ABA on the plant's resistance to abiotic stress by regulating plant growth by increasing stomatal resistance to control transpiration and CO_2 uptake (Nilson and Assmann, 2007). This corroborates the report of Darini *et al*. (2024), who reported that ABA concentrations combined with organic manure could be considered an effective strategy to improve growth and water use efficiency to alleviate the adverse effects of drought stress on sesame.

Table 3: Interaction between Fish Guano x Abscisic Acid on leaf chlorophyll of grain Amaranth at 4, 8 and 12WAT at Wudil during 2021 dry season

		ABA(µM)	
Fish-guano (kg)	0	20	50
		4 WAT	
0	20.43a	11.56d	12.84cd
0.1	19.48ab	11.38d	14.14c
0.2	18.20b	9.22e	10.28de
SE±		1.499	
		8 WAT	
0	23.12c	23.92c	22.63cd
0.1	22.31d	27.47b	27.91b
0.2	24.20c	28.09ab	29.46a
SE±		1.746	
		12 WAT	
0	24.41c	30.39bc	34.56b
0.1	23.71c	28.49bc	28.48bc
0.2	31.41b	42.09a	44.02a
SE±		2.149	

Means followed by the same letter(s) in a column within treatment group are not significantly different at 5% level of probability

Conclusion and Recommendation: Application of fish guano at 0.2 kg and Abscisic acid concentration at 50 µM acid could potentially increase the chlorophyll content in grain amaranth leaf under limited water conditions and therefore could be recommended during various growth stages to mitigate the effect of drought stress on the chlorophyll content in order to enhance the photosynthetic efficacy of the crop.

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Contributions of Third National FADAMA Development Additional Funding (AF) Project on Food Security among Small Holder Fermers in Kebbi State, Nigeria.

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Abstract

The study was conducted to examine the contribution of third national Fadama development additional funding (AF) programme on food security among smallholder farmers in Kebbi state, Nigeria. A multistage sampling procedure was used to randomly select 180 participant farmers to constitute the sampling size for the study. Primary data and secondary source of information were used and the data were collected with the aid of structured questionnaire. Descriptive statistic like frequency, percentage and mean score were used to analyze the data, food security score line tool was used to determine the farmer's food security status/level. The result revealed that 45.1% of farmers were within the age bracket of 31-50 years, with the mean years of 45.6. Majority of participant farmers representing 67.2% were males while 32.8 were females. A total of 43.9% of the participant farmers had 6-10 members in their household, and the average household size was 12.2 members. It was revealed in the result that greater proportion of 31.6% of participant farmers had 11-20 years of farming experience and the average farming experience of 22.1. About 86% have been involved in Fadama membership for 6-15 years, with average membership years of 10.9. The study found that after the programme, 71.6% participants were food secured and 28.4% were food insecure. The study concludes that the majority of the respondents were food secured. The age, income, farm size, farming experience were major factors that influence the respondents food security status. The study recommended that there is need for Fadama participants to have access to credit as financial assistance from Fadama project cannot meet their demand for inputs, various stake holders including farmers should be involved in planning, execution, monitoring and evaluation of the programme, and the programme should be sustain

.**Keywords**: Contributions, Third National Fadama, Development, Programme, Additional Funding, Food security, Smallholder farmers, Kebbi state. Nigeria

Introduction: The National Fadama Development Project (NFDP) was established to guarantee all-year round growing of crops and promotion of simple and low-cost improved irrigation under a World Bank financing. Food crops grown on the Fadama include rice, leafy vegetables, okra, maize and other crops including root and tuber. Fadama projects aim at reducing poverty by increasing farm productivity and income of farmer participants (Bello, 2008). The projects so far (NFDP I and NFDP II) were adjudged successful by both national and international assessors culminating in Federal Government of Nigeria requesting the World Bank for implementation of the third National Fadama Development Project (NFDP III) (Ezeh,2007 and Ike, 2012). The scope of the Third National Fadama Development Project (NFDP III) was extended to involve all 36 states in the federation and the Federal Capital Territory (FCT) as a tripartite funded intervention of the World Bank, the Federal Government of Nigeria and participating States. Funding is by World Bank contributing 55.6%, Federal Government of Nigeria, 5.1%; participating States and Local Governments contributing 17.1% and 8.9% respectively.

The World Bank had provided the sum of $200m US Dollars for Nigeria Fadama III project as at August 2013 (World Bank, 2013). The NFDP III is aimed at sustainably increasing income of beneficiary groups such as Fadama Users Groups (FUGs) and Fadama Community Associations (FCAs) in all the states, by directly delivering resources to them, empowering them to take decisions collectively on how to effectively and efficiently allocate and manage resources for their livelihood activities (Osondu *et al*., 2014). By doing this the project would help reduce rural poverty, increase food security and contribute to the achievement of a key millennium development goal. The project which started from July 2008 and has an end line to June 2013 has been extended to 2017, and ended in December 2017. The programme strategy included investing in public infrastructure, asset acquisition using matching grants and advisory services on best ways of improving group management mechanisms to avoid and resolve conflict(s) within participating groups (FMARD, 2003). In this regard facilitators had been deployed to Nigerian communities to provide training and technical support to all categories of Fadama resource users. To improve performance of the programme in each state and ensure welfare delivery, statutory and independent assessments need to be made with evidences gathered from farmers themselves (Mohammed *et al.*, 2014).

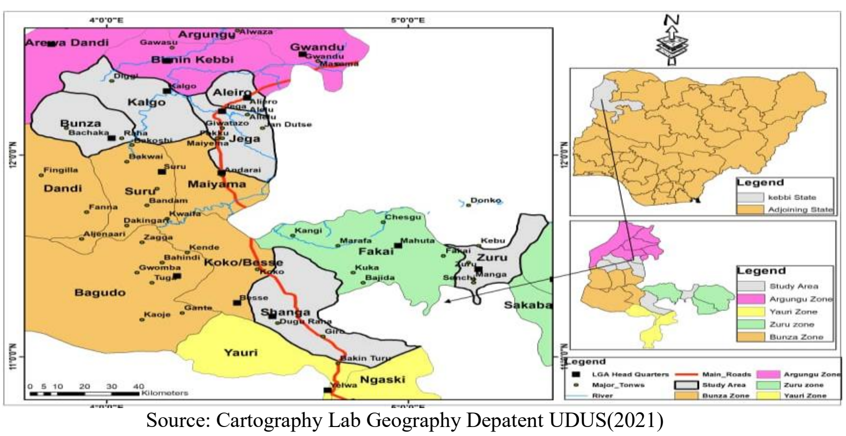
It is worthy of note that the desire to harness the verse potentials of Fadama in Nigeria culminated in the design of National Fadama Development Projects I, II, III and then Fadama III – Additional Financing. Fadama III Additional Financing, which was an extension of Fadama III, aimed at sustaining an increase in the income of users of rural land and water resources (Agunloye, Fasina, and Akinnagbe, 2017). The project was to scale up the impacts and the development effectiveness of a well-performing project by aligning it more closely with the new Agricultural Transformation Agenda, which was adopted by the Government of Nigeria in 2011. The project has been consistent with the development objective of the parent project and as such, no major changes were made to the Project Development Objective, design or implementation arrangements of the original project. Nevertheless, the main difference is that instead of national coverage as in the case under the parent project, the AF had a narrow geographical focus on clusters of farmers in selected states with comparative advantage and high potential to increase production and productivity of cassava, rice, sorghum and horticulture value chains and link them to better-organised markets. (NFCO, 2018; Dayo, Olumuyiwa, Yarama, Malomo and Ekong, 2018)

In Nigeria, despite agricultural policies and strategies, the population of food insecure households in Nigeria keeps increasing and higher in the subsequent years, It is a fact widely acclaimed that no country can achieve economic development without agricultural development. This is achieved through achieving food security and sustainability in the provision of abundance crop and livestock (food accessibility, food affordability, food utilization and food quality), to meet local consumption, raw materials for the processing industries, national reserves and export (Ayinde, 2019). For Nigeria to develop, food security growth must be sustained. Nigeria, according to World Data Lab (6 May 2020) has an estimated population of 205,323,520 persons and has 102,407,327 people living in extreme poverty (50% of the total population) (World Data Lab, 2020). Even though, International Fund for Agricultural Development (IFAD) rated Nigeria the highest producer of cassava, yam and cowpea globally in 2012 and currently the highest producer of cassava and yam globally, the country still persistently remained food insecure and heavily import-dependent. A vast majority of the rural household population still engages in subsistence farming which can barely feed their immediate families. Lack of infrastructural facilities such as good roads has heightened rural poverty disconnecting rural farmers from needed inputs and markets for their produce (Otekunrin and Sawicka 2019). It is quite alarming that the poverty situation in Nigeria is increasing. As of 6 May 2020, 102.4 million Nigerians live in extreme poverty implying that an additional 15.5 million Nigerians have plunged into poverty in 24 months (World Data Lab, 2018; 2020).

Food insecurity in Nigeria is currently at alarming rate calling for urgent and immediate intervention. Smallholder agriculture involves about 95% of Nigerian farmers, while the corporate and government supported large-scale farms account for the 5 percent. Although, concerted efforts have been made by past and present governments of Nigeria towards improving agricultural productivity and production efficiency and in alleviating poverty among the rural farmers, millions of people in Nigeria are still poor and hungry (Simonyan *et al*., 2010). Studies have been carried out in different parts of Nigeria and on different aspect of the impact analysis of the National Fadama Development Project. For example, Bajoga *et al,* 2006, Adeoye *et al* 2011 and Ugwumba and Okechukwu, 2014) etc, showed that a lot of studies have been conducted on Fadama development project on the living standard of dry season farmers, small-scale farmer's income, poverty alleviation among farmers, rural infrastructure and profitability of farmers, FUGs mid-term performance of the programme, poverty and food security among rice farming beneficiaries in Nigeria. But majority of these studies were conducted on Fadama I and II while few of them were on Fadama III, and this create a gap. Thus, this current study is determined to fill the gap as it is focus to determine the contribution of Fadama III on food security among small holder farmers in kebbi state. Therefore, the need to evaluate and validate this claim became necessary and this necessitated this study . Hence, the study seeks to provide answers to the following research questions: What are the socio-economic characteristics of Fadama III AF participating farmers?; .What is the food security status of the farmers before and after participating in Fadama III AF programme?; .What are the factors influencing food security status of the Fadama III AF participating farmers

Research Methodology: Description of the Study Area: The research was conducted in Kebbi state. It lies in north western region of Nigeria with its capital in Birnin kebbi. Based on projection from 2006 census figure, kebbi state is estimated to have a population of 4, 629,880 (NPC, 2006: projected to 2017). Kebbi state is made up of 21 local government area (LGAs). It has four (4) emirate councils (Gwandu, Argungu, Yauri, and Zuru) and has four (4) agricultural zones namely Agungu, Bunza, Yauri and Zuru zones respectively, for ease of administration. Kebbi state falls between latitude 12 46N and 12 27N and longitude 4 19E and 4 11E. Agriculture is the main occupation of people of the state especially in the rural areas. Crops produced are mainly grains like rice, millet, sorghum etc. The weather of the state is often dry with lots of sunshine. The wet season last from May to October, while the dry season lasts for the remaining period of the year. Mean annual rainfall is about 800mm-1000mm. Temperature is generally high with mean annual temperature of about 26 C and above in all location of the state. This climatic peculiarity allows for meaningful investment in agriculture.

Figure 1 Map of the Study Area



Source: Cartography Lab Geography Depatent UDUS(2021)

Sampling Technique and Sample Size: The study sample was drawn from rural communities in Kebbi State. The population of this study comprises of Fadama III participanting farmers in Kebbi State, Northwest of Nigeria. Kebbi State is divided in to four (4) Agricultural Zones (Emirate Councils) namely: Gwandu (Bunza) Zone, Argungu Zone, Zuru Zone, and Yauri Zone. Selection of sample for the study was done using multi-stage sampling technique. At the first stage, Proportionate sampling was used in each of the agricultural zones to select a total of six (6) local government across the state using 30%, considering the variation and disparity in number of local governments in agricultural zones. (Number of local governments divided by 100 multiplied by 30 to arrive at number of local government). At the second stage, Purposive sampling was employed to reach out to the targeted Fadama participating farmers, where one cluster was randomly selected from each local government as sampling frame. At the third and final stage, a simple random selection of thirty (30) Fadama III participating farmers from each selected cluster was done, giving a sample size of one hundred and eighty (180) Fadama participating farmers.

Method of Data Collection : Both primary and secondary data was used for the study. The primary data for the study was gathered through field survey with the use of a structured questionnaire designed in line with the objectives of the study. The secondary information includes those sources from journals, bulletins and other literature materials from the internet etc. The questionnaire for the study was used to collect information on: socio-economic characteristics of Fadama III participating farmers, food security status of the farmers before and during Fadama III programme, Factors influencing food security status of Fadama III AF participating farmers in the study area, improved technologies provided by the Fadama III agency and adopted by the farmers, activities engaged in by the Fadama III participating farmers, and problems faced by Fadama III programme participating farmers.

Method of Data Analysis: Data analysis was carried out using descriptive and inferential statistics to analyse the data generated using SPSS version 20. Descriptive such as frequency distribution, percentages, mean as well as mean weight were used to analyse the data in the table, this was used to describe the socio-economic characteristics of the Fadama III AF participating farmers, improved technologies provided by the Fadama III AF agency and adopted by the farmers, activities engaged in by the Fadama III AF farmers as well as the problems faced by Fadama III AF farmers in the study which are objective 1, 4, 5 and 6 respectively. Food security score line was used to determine the food security status of the Fadama III farmers which is objective 2, while multiple regression analysis was used to determine the factors influencing food security status of Fadama III AF participating farmers in the study area, which is objective 3

Research Hypotheses : In order to provide empirical bases for relationship that exist between the variables of this study, the following hypothesis were set in null form.

Ho1 Fadama III AF programme farmers socio economic characteristics has no significant contribution on food security status of participants in the study area.

Multiple regression

The regression model was specified explicitly as follows:

$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \beta_8 X_8 + u$

Y = food security status (very low food security =1, Low food security =2, Marginal food Security = 3 and High food security = 4)

X_1= Age of farmers (years)

X_2= education (education qualification)

X_3 = household size

X_4 = farming experience (years)

X_5 = income (naira)

X_6 = years of FUG membership

X_7 = farm size (hectares)

β_O = intercept

u = error

Results and Discussion: Socio-economic Characteristics of Respondents: This section described the socio-economic characteristics of the Fadama III AF Farmers in the study area. These characteristics include age, gender, marital Status, household size, level of education, farming experience, farm size, years of FUG membership, secondary occupation and income. The result of the study shows that the minimum age of the participant farmers in the study area was 25 years and the maximum age was 72 years with the mean age of 45.75 years. Majority of the participants farmers 67.2% were male, and 84.4% of the participants were married. All farmers had one form of formal education. The mean household size was found to be 12.2 person per household. The minimum and maximum farming experience of participants farmers were 4 and 52 years with mean of 22 years farming experience. The result shows that the minimum and maximum years of membership involvement to Fadama III user groups were 2 and 15 years, with the mean years of 10.9. The minimum and maximum hectares cultivated by the participant farmers before and during the programme were 1 and 5 hectares with mean of 2.6 hectares, and during the programme the minimum and maximum hectares were 1 and 5 with mean of 3.5 hectares. The distribution according to farm size indicate that the Fadama III farmers were made up of small and medium scale farmers. The minimum and maximum of farm income of farmers before the programme was N50,000 and N4,500,000 with mean of N689,794.4, also during the programme the minimum and maximum farm income was N50,000 and N10,000,000 respectively, with the mean of N1,560,816.7. The result indicated that the Fadama III participants had higher income during the programme than before in the study area. The major secondary occupation apart from farming among the participants farmers in the study were trading 42.2%, livestock rearing 26.1%, and civil service 13.9%.

Table 1a : Socio-economic characteristics of Fadaa III AF participating farers (N=180).

Source: Field Survey 2022

Table.1b: Socio-economic characteristics of Fadama III AF participating farmers (N=180). Cont.

Variables	*Frequency*	*Percentage*	*Mean*	*S.D*
Farming Experience				
1-10	36	20%	22.1	11.4
11-20	57	31.6%		
21-30	46	25.7%		
31-40	37	20.7%		
41 and above	4	2 %		
Total	**180**	**100**		
Years of FUG Membership				
1-5	24	13.4%	10.9	3.84
6-10	62	34.4%		

11-15	94	52.2%
Total	**180**	**100**
Secondary Occupation		
Crop farming	26	14.4%
Livestock rearing	47	26%
Civil servant	25	13.9%
Trading	76	42.2%
Artisan	5	2.8%
Others	1	0.7%
Total	**180**	**100**

Source: Field Survey 2022

Variables	Frequency	Percentage	Mean	S.D
Age				
20-30	31	17.3%	45.75	12.34
31-40	40	22.2%		
41-50	41	22.9%		
51 years and above	68	37.9%		
Total	**180**	**100**		
Gender				
Male	121	67.2%		
Female	59	32.8%		
Total	**180**	**100**		
Marital Status				
Single	12	6.7%		
Married	152	84.4%		
Divorced	10	5.6%		
Widow	6	3.3%		
Total	**180**	**100**		
Level of Education				
Arabic Education	31	17.2%		
Adult Education	24	13.3%		
Primary Education	21	11.7%		
Secondary Education	54	30.0%		
Tertiary Education	50	27.8%		
Total	**180**	**100**		
Household Size				
1-5	27	14.9%	12.2	7.54
6-10	79	43.9%		
11-15	23	12.7%		
16-20	21	11.7%		
21 and above	30	16.8%		
Total	**180**	**100**		

Distribution of Respondents Based on Food Security status.: The result of the study in table revealed that the minimum level of food security of Fadama III participating farmers before and after Fadama III programme in the study is very low food security and maximum level is high food security, with mean of 2.4056 and 3.1500 respectively. In the table it was discovered that the food security status of the participating farmers before and after the programme was 32.8% and 5.0% on very low food security level, 25.0% and 23.3% on low food security level, 11.1% and 23.3% on marginal food security level 31.1% and 48.3% on high food security level respectively. This revealed that the greater percentage gap of participating farmers was on marginal food security and high food security level after the programme, having had greater mean of 3.1500 as compared to the mean of 2.4056 before the programme. This implies that there was improvement in farmer's production after participation in the programme. This indicates that Fadama III programme has positive significant effect on food security status of the participants. The implication of this is that a greater percentage of the Fadama `III Farmers have benefitted immensely from their membership in the Fadama III project and are actually moving towards high food security status. Nigeria, like many other African countries, has a comparative advantage in food crops production and the attainment of an acceptable growth rate per capital food production will not only coincide with the attainment of national food security but also greater self-sufficiency in food supply as small-scale/smallholder farmers represent the majority of rural poor populations in developing countries (Abalu, 1990). For greatest impact, agricultural development strategies must target this population. It therefore means that the farmers have been able to properly put the training they got through Fadama Project using the grant they obtained coupled with the input supply (fertilizer, seed and seedlings) to get better yield in quality and quantity, which has invariably boosted their food security status. So there is no doubt that small holder farmers are important in achieving food security.

Table.1c: Socio-economic characteristics of Fadama III AF participating farmers

(N=180). Cont.

	Before Fadama III AF		After Fadama III AF	
Income	**Frequency**	**Percentage**	**Frequency**	**Percentage**
50,000-1,000,000	149	83%	114	62.7%
1,000,001-2,000,000	25	13.4%	24	13.6%
2,000,001-3,000,000	3	1.8%	16	9%
3,000,001-4,000,000	2	1.2%	11	6.2%
4,000,001 and above	1	0.6%	15	8.5%
Total	**180**	**100**	**180**	**100**
	Before Fadama III AF, Mean 689,794.4		**After Fadama III AF, Mean 1,560816.7**	
Farm size (hectre)				
0-1.0	56	31.1%	9	5.0%
1.1-2.0	46	26.2%	43	23.9%
2.1-3.0	15	8.3%	40	22.2%
3.1-4.0	30	16.3%	13	7.2%
4.1 and above	33	18.1%	75	41.7%
Total	**180**	**100**	**180**	**100**
	Before Fadama III AF, Mean 2.6556		**After Fadama III AF, Mean 3.5667**	

Source: Field Survey 2022.

Table 2 Distribution of Respondents Based on Food Security Level.

Variables	Before Fadama III AF		After Fadama III AF	
Food security level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Very low food security	59	32.8%	9	5.0%
Low food security	45	25.0%	42	23.3%
Marginal food security	20	11.1%	42	23.3%
High food security	56	31.1%	87	48.3%
TOTAL	**180**	**100**	**180**	**100**
Souce: Field survey.2022	**Mean 2.4056**		**Mean 3.1500**	

Factors Influencing the Fadama III AF participating Farmers Food Security Status: The result of the Regression Analysis of factors influencing the Fadama III AF participating farmers food security status as presented in table shows, the regression coefficient with respect to age(X_1) and farm size(X_7) were positive and statistically significant at 10% and 1% respectively, implying that increase in these variables by one unit holding other inputs constant will lead to increase in food security status of Fadama III farmers by 0.071 and 1.001 respectively. Age had a regression coefficient of 0.071 at 1% level of significance. This indicate that level of age increase food security status of participating farmers, a unit increase in age participant farmers will lead to increase in food security status by 0.007.This imply that age determined how active and productive the farmer would be. It has also been found to affect the rate of household adoption of innovations, which in turn, affects household food security, productivity and livelihood improvement strategies (Dercon and Krishnan 1996).. Farm size had a regression coefficient of 1.001 at 1% level of significant. This means that as farm size increases households food security status increases/improves; a unit increment in farm size will increase household food security status by 1.001. This is not surprising as increase in farm size will bring about increase in farm output or produce. Thus, household will have more farm produce to consume all year round and sell the excesses to buy other farm produce that they don't produce or other food necessity, which will boost their food security status. This is in line with Kidane *et. al*., (2005) and Amaza *et. al*., (2006) who in their research noted that farmland size is one of the determinants of food security.

The regression coefficients with respect to years of experience(X_4) and income(X_5) were negative but statistically significant at 10% level respectively, implying that increase in these variables by one unit holding the other inputs constant will lead to decrease in (Y) food security status of Fadama III farmers by -0.071 and -0.039 respectively. Years of farming experience had regression coefficient of -0.071 at 10% level significance. This denote that farming experience increase food security status of Fadama III farmers negatively (inverse relationship) in the study area. Farming experience is an important factor determining both the productivity and the production level in farming activities. But the effect of farming experience on productivity and production may be positive or negative. Generally, it would appear that up to a certain number of years, farming experience would have a positive effect; after that, the effect may become negative. The negative effect may be derived from aging or reluctance to change from old and familiar farm practices and techniques to those that are modern and improved (Amaza *et. al*., 2006). Income had regression coefficient of -0.039 at 10% level significance, this means that as the income increases, food security status of Fadama III farmers decreases. This could be attributed to the fact that gains obtain from Fadama III participation may not be adequate to make them food secured. Increase in household incomes are much needed for improving food security and eventually will come from the gains in agricultural productivity through better technology and more productive crops. This implies that as the income of the farmers decreases, food security status of Fadama farmers decreases. Income diversification plays a crucial role in enhancing food security particularly in rural and semi-urban areas. A study conducted in Ethiopia found that households with diversified income sources were significantly more food secured than those relying on a single source of income. The findings revealed that income diversification positively impacts food security by improving household access to food. Thome, *et al,* (2016),

It should however be noted that educational level, household size and years of Fadama user group (FUG) membership were not statistically significant.

Table 3: Factors Influencing Fadama III AF participating Farmers Food Security Status

Variables	Regression Coefficient	Standard Error	T – Value	Significance
Constant	3.661	.437	(-8.844)	0.000***
Age	0.071	.017	(1.881)	0.062*
Educational level	-0.015	.059	(-0.970)	0.333ns
Household Size	-0.016	.016	(-0.738)	0.461ns
Years Farming Experience	-0.071	.015	(-2.214)	0.028*
Income	-0.039	.000	(-1.743)	0.083*
Years of FUG membership	0.020	.034	(0.814)	0.417ns
Farm size	1.001	.089	(44.802)	0.000***

R^2 Value 0.960
F Value 622.730***
Note * Represent 10% level of significance
** Represent 5% level of significance
*** Represent 1% level of significance

Conclusion: The study evaluates the effect of Fadama III programme on food security among small holder farmers in Kebbi State. The study concludes that the majority of the participants farmers were food secured. The age, educational level, income, household size, farm size, membership to FUG, year of farming experience were major factors (socio-economic characteristics of the farmers) that influence their food security status. The improved technologies provided by the agency and adopted by the participant farmers in the study area were the use of improved seeds use of recommended planting spacing, use of inorganic fertilizer, use of pesticides and herbicides, crop rotation, modern irrigation, use of modern storage, pest management and disease control, mixed cropping and mixed farming has connection with the food security status of farmers in the study area. Also the considerable activities engage in by participants farmers, identified were crop production, animal rearing, poultry production, agro-processing and non-agricultural activities.
In the same vein majority of the challenging problems faced by the Fadama III participating farmers were found to be possible problems with grand mean of 3.27 above cut off mean point in the study area.

Recommendation: Based on the findings of this research, the following recommendations are made to improve the food security status in the study area. Government should provide adequate funds for the projects, timely disbursement of farm inputs as well as providing quality extension service delivery to further strengthen the existing positive attitude of the farmers towards Fadama project. This will enhance the adoption of policies and programmes among farmers.**;** There is need for Fadama III participants to have access to credit as financial assistance from Fadama project cannot meet their demand for inputs.**;** Various stakeholders including farmers should be involved in planning execution, monitoring and evaluation of the programme.**;** Female farmers were found to be not active in Fadama III farming in the study area, there is need for more of their participation in Fadama activities to enable them benefit from what is provided by the Fadama III agency **;** Farmers should be advised through agricultural development programmes of Kebbi state, and other agricultural development organization that have the mandate of training, **;** Farmers should be train on resource utilization and farm management skills to further boost their income efficiencies through the adoption of best technologies or techniques on crop cultivation.**;** Educational level of the participant farmers was significant in determining the food security status of farmers, there is need for its promotion as a means of improving food security and in making wise decision in dealing with risk and uncertainties to attain greater production. The federal government should continue with the Fadama project even if the World Bank withdraws from funding.

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Use of Laser-Guided Variable-rate Sprayers for Pest and Disease Management in Fruit and Nursery Crops

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Abstract

Protecting the environment and reducing pesticide use in agricultural production are two goals of laser-guided variable-rate intelligent spray technology. A validation of this technology's capacity to control crop diseases and insect pests is necessary before it can be used in integrated pest management systems. Fruits such as pawpaw, guava, lemon, mango, tamarind, jackfruit, and cashew were used as test crops in this research. The field studies shown that intelligent spray treatments decreased the use of foliar fertilizer and pesticides by an average of 30.02% to 65.17 percent throughout the course of the three-year trials. Meanwhile, when it came to managing pests and diseases on different crops, intelligent spray technology proved just as effective as, if not more so than, traditional spray technology. Based on these findings, intelligent spray technology provides a better and eco-friendlier option for disease and pest control in fruit orchards and ornamental tree nurseries.

Keywords: *environmental protection, pest control, precision sprayer, orchard, sustainable agriculture*

Introduction: Nursery and fruit crop health and productivity are greatly affected by ineffective pest and disease management (Blake et al., 2020). Improving crop protection measures is one area where technology is playing an increasingly important role in modern agriculture. The utilization of state-of-the-art disease and pest management tools, such as laser-guided variable-rate sprayers, is an example of a development in this area. Plant diseases and pests can significantly impact nursery and fruit production, resulting in diminished yields and lower quality produce (Marble, Williams-Woodward, and Windham, 2019). Reduced efficacy, higher expenses, and environmental issues might arise from traditional spraying methods' tendency to under-or over-apply fungicides and insecticides. One precision-driven answer to these difficulties is the use of laser-guided variable-rate sprayers. This type of sprayer can accurately target certain sections of a field or orchard by combining laser technology with variable-rate spraying devices (Shen et al., 2017). In order to minimize chemical waste and maximize chemical efficiency, this tailored strategy guarantees that pesticides and fungicides are sprayed only where they are needed.
The pest populations and crop canopy can be mapped using lasers and sensors in laser-guided devices (Frank et al., 2013). The use of laser-guided variable-rate sprayers in pest and disease management programs is a huge step forward in terms of technology. Improved crop protection, more sustainability, and better economic outcomes are all possible when fruit and nursery farmers adopt these innovations.

Materials and Methods: Two commercial nurseries, Greenfield Agro-Tech and J-Tec Farms, in the Enugu North Local Government Area, as well as a commercial fruit farm, Chuka Farms, in the Enugu East Local Government Area, were the sites of the field investigations. These locations will be called Fruit farm, Nursery-A, and Nursery-B, respectively, for the sake of this study. Fruit Farm chose guavas, mangoes, lemons, and oranges as their test crops. The test was conducted at Nursery-A using tamarind, jackfruit, and cashew, and at Nursery-B using oranges, jackfruit, cashew, and pawpaw. For every crop, we split the field plots in half: half for the intelligent spray treatment and half for the conventional method. A "pot in pot" multiple-row production system was used to cultivate all plants at Nursery-A. Plants and plots used in the experiments were switched annually. All plants at Nursery-B were grown outdoors. All three growing seasons of the experiment, which spanned from 2021 to 2023, employed the identical orange, jack fruit, and pawpaw trees and plots. During the 2021 and 2022 cashew growing seasons, the same plants and plots were utilized. In 2023, the plants and plots were switched. Every 1–3 weeks, the severity of the diseases and the populations of the pest insects were evaluated. Fruit Farm utilized wing-style Pherocon traps with OFM lures from Trece Inc. and Delta Pherocon VI traps with CM-DA COMBO lures from Trece Inc. to monitor the populations of oriental fruit moths in guava plots and codling moths in orange plots, respectively. Pherocon SWD traps with broad spectrum lures (Trece Inc.) were used to monitor spotted wing drosophila in mangoes in 2023 and lemons in 2021 and 2023, respectively. Ensconced within the canopies of every crop in the central row of every treatment plot were three traps, signifying three replicates. Traps were spaced 45 meters apart in the guava and orange plots and 30 meters apart in the mango and lemon plots.

Jasinski (2017) used saturated salt flotation to count the spotted wing drosophila larvae in lemon fruits. Three replications were conducted in Nursery-A and six replications at Nursery-B to monitor the populations of leafhoppers in jackfruits using yellow sticky traps (3 in · 5 in, BASF Corp., St. Louis, MO). The traps were put inside the tree canopies. By picking five trees at random in each treatment and ten branches per tree, we were able to determine the aphid populations in the cashew plots. In order to determine the extent of brown rot infections in guavas, three random places were chosen, and 100 fruits were checked in each spot. The proportion of infected fruits was then recorded. Twenty plants were randomly chosen from each crop and treatment group; the percentage of infected trees, shrubs, or fruits was noted using the following scale: 0% (no symptoms), 10% (some symptoms), and 100% (completely dead plant). After that, the percentage of afflicted fruits, bushes, or trees was used to show the severity of each illness. The AUDPC, or area under the disease progress curve, was calculated using the following formula:

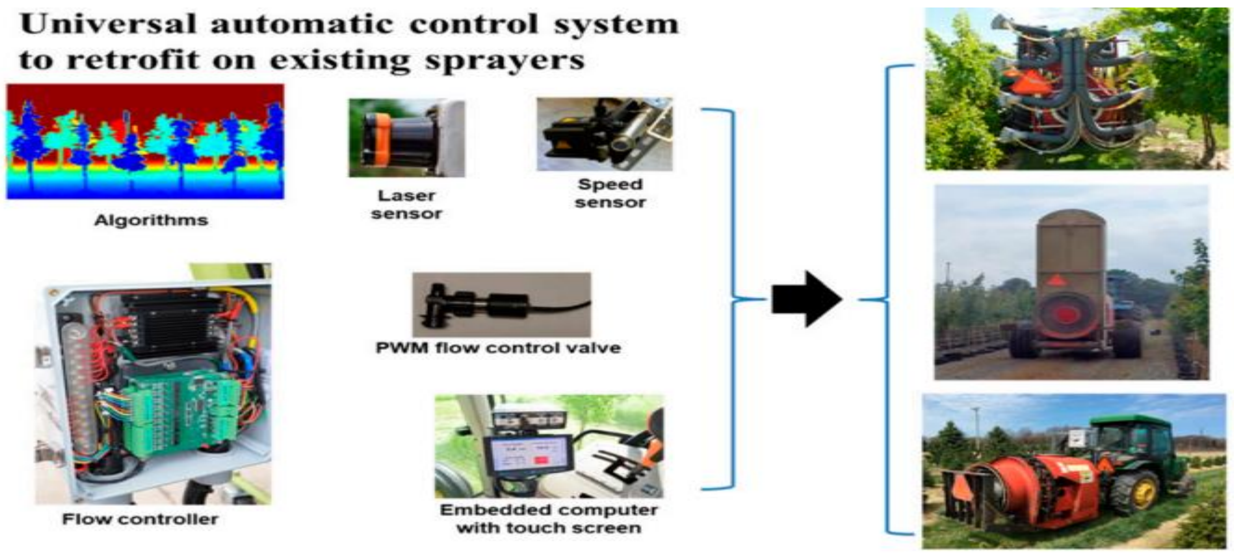

Figure 1. Three air-b1ast sprayers retr0fitted with the inte1ligent spray system used f0r tests at Fruit Farm (t0p), Nursery-A (middle), and Nursery-B (b0ttom).

$$A_k = \sum_{i=1}^{N_i-1} (t_{i+1} - t_i)\frac{Y_{i+1} + Y_i}{2}$$

Where,

$$t = The\ order\ of\ disease\ severity\ observation$$
$$Y_i\ is\ the\ disease\ level\ at\ t = i$$
$$Y_0 = the\ initial\ infection\ or\ the\ disease\ level\ at\ t = 0$$
$$A_k = the\ total\ accumulated\ disease\ level\ for\ AUDPC\ until\ t = t_k$$

Results and Discussion Using a table as a basis, figure 2 shows the average amounts of pesticides and foliar fertilizers used in conventional and intelligent spray treatments at each of the experiment sites. In 2021, when compared to the conventional spray method, the consumption of pesticides and fertilizers was reduced by 52.81% at Fruit Farm, 65.23% at Nursery-A, and 56.41% at Nursery-B thanks to the intelligent spray application. The corresponding decreases for those three sites in 2022 and 2023 were 47.13% at Fruit Farm, 38.87% at Nursery-A, and 44.52% at Nursery-B. The results show that intelligent spray application significantly reduces the usage of pesticides and foliar fertilizers at all three trial sites throughout the course of the three-year study. This reduction is comparable to a 53.3% reduction in spray when compared to traditional spray in oranges. Using intelligent spray technology, Fruit Farm and Nursery-B's spray volume usage increased steadily from 2021 to 2023.

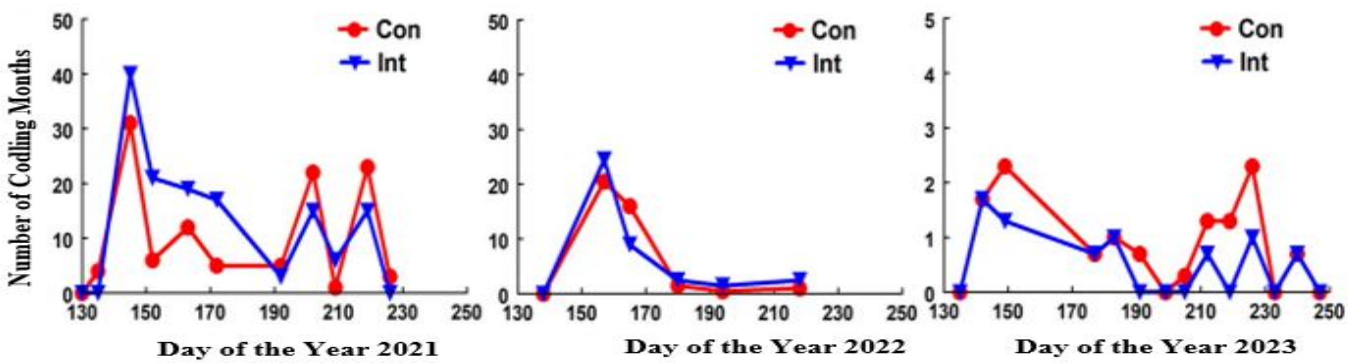

Figure 2. Changes 0f average numbers 0f codling moths in traps in c0nventional constant-rate (C0n) and intelligent variable-rate (1nt) spray orange pl0ts during three consecutive growing seas0ns from 2021 to 2023 at Fruit Farm.

THEME: Effects of Fuel Subsidy removal on Climate Action, Agricultural Production and Agro Allied Industries, Food Security, Sustainable Fisheries, Biodiversity/Soil Conservation and Agricultural Resources.

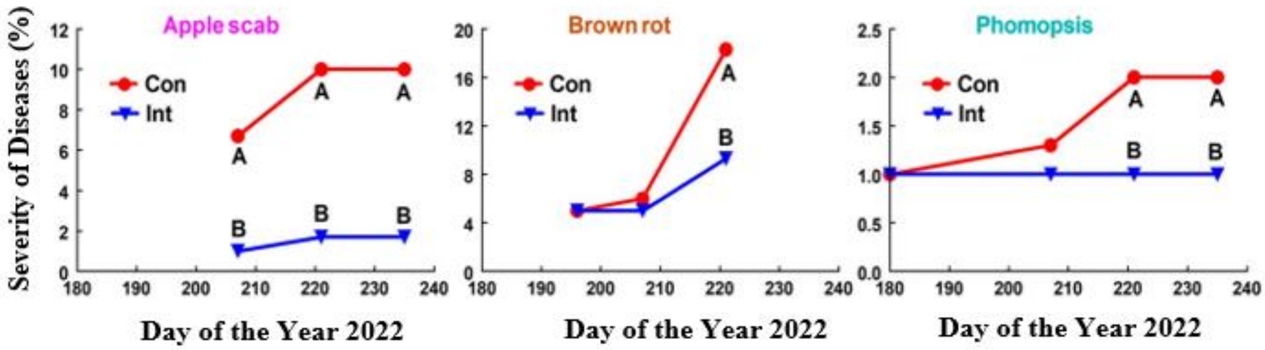

Figure 3: Severity of diseases (%) of scab in orange trees, brown rot in guavas, and phomopsis in lemon plants treated with conventional constant-rate (Con)and intelligent variable-rate (Int) applications in 2023.

The results of the paired t test showing no statistical significance (P<0.05) between the intelligent and conventional therapies on the same date can be seen in figure 2. Figure 3 illustrates the percentage severity of diseases in 2023 for guavas, lemon plants, and orange trees treated with conventional constant-rate (Con) and intelligent variable-rate (Int) applications, specifically brown rot, scab, and phomopsis, respectively.

Using a paired t test, there is a significant difference between various letters in the same date at the P < 0.05 level.

Smart spraying reduced scab on orange trees, brown rot on guava fruits, and phomopsis on lemon plants in 2023 at Fruit Farm (Figures 3). In 2021 and 2022, neither the traditional nor the intelligent treatments detected scab on orange trees or brown rot on guavas. The year 2021 had no cases of phomopsis in lemon plants. The intelligent spray treatment resulted in a decrease (P < 0.05) of phomopsis in 2022; AUDPC was 120 for conventional and 0 for intelligent spray. The conventional and intelligent treatments did not produce any powdery mildew on guava or orange trees or mummy berries on lemon trees from 2021 to 2023. The lack of difference in disease severities compared to conventional spray could be explained by the sufficient pesticide coverage provided by intelligent spray treatments. Considering the decreased application of fungicide to the field during intelligent spray treatment, it's plausible that nonpathogenic fungi were able to flourish and outcompete pathogenic fungus, leading to a decrease in illnesses.

Conclusion: While lowering the use of foliar fertilizer and pesticides by 30% to 65%, laser-guided variable-rate intelligent sprayers were just as effective, if not more so, than conventional spray technology in controlling insect and disease pests in ornamental tree nurseries and fruit farms. Because of this innovation, a lot less of the foliar fertilisers and pesticides that drift to unintended places (such the air and the ground) ended up wasting and polluting the environment. In the end, the fruit production and ornamental nursery industries benefited from intelligent spray technology's low-cost, highly-efficient, worker-friendly, and environmentally-friendly foliar fertilizer and pesticide spraying capabilities

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Fabrication of Yam Minisett Cutting Machine

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Abstract

This study details the design and performance evaluation of a yam minisett cutting machine designed to enhance the efficiency of yam production. The machine replicates traditional projectile cutting methods and includes components such as a frame, speed reducer, pulley, belt, crank mechanism, connecting rod, hopper, seed yam carrier, cutting blades, and a discharge chute. The seed yams used for testing measured approximately 247.80 mm in length and 66.75 mm in breadth. Constructed from locally available materials, the machine demonstrated a performance efficiency of 96.24% and a processing capacity of 28,888 minisetts per hour. Optimal performance was achieved with a crank shaft speed range of 10-80 rpm, a connecting rod length of 470-540 mm, and 13 cutting blades.

Keywords: *Yam Minisett Technology, Mechanization, Food Security, Cutting Machine, Cam Mechanism*

INTRODUCTION: Yam, classified botanically as Dioscorea, is a significant tuber crop in West Africa and the Caribbean. In South Eastern Nigeria and Rivers State, yam is a primary staple food, second only to cassava in terms of cultivation area (Chukwu and Ikwelle, 2000). Nigeria, the world's top yam producer, accounts for approximately 65% of global production, yet its full potential remains underutilized (FAO, 2013). Rich in carbohydrates and essential nutrients such as potassium, manganese, and antioxidants, yam offers superior nutritional benefits compared to other staples like cassava and maize (Akubuilo et al., 2007). Despite its importance, yam production faces challenges including high costs and poor quality of seed yams. Traditionally, seed yams are whole tubers weighing between 500g and 1500g. The high cost and low quality of these tubers contribute to food insecurity in Nigeria (Chukwu and Ikwelle, 2000; Ajieh, 2012). The scarcity of seed yams is exacerbated by the practice of using consumption tubers for planting, leading to competition and inefficiency (Ogbonna et al., 2011b; Oguntade et al., 2010).

To address these issues, the yam minisett technique was developed by the National Root Crops Research Institute (NRCRI) and the International Institute of Tropical Agriculture (IITA). This technique involves cutting large tubers into smaller pieces (minisetts) weighing 25-100g to increase the availability of seed yams. However, the traditional manual cutting process is labor-intensive, inconsistent, and accident-prone. Existing machines for tuber processing are either unsuitable or prohibitively expensive, as they are designed for different crops or use costly materials (Bolaji et al., 2018; Hoque and Saha, 2017; Aung and Auntt, 2019). A specialized, cost-effective yam minisett cutting machine capable of performing both horizontal and longitudinal cuts simultaneously is needed to overcome these inefficiencies and high costs associated with yam seed production.

Materials and Methods: Description of the Developed Yam Minisett Processing Machine The yam minisett cutting machine, depicted in Figure 1, consists of several key components: a frame, speed reducer, pulley, belt, crank mechanism, connecting rod, hopper, seed yam carrier, cutting blades, and a discharge chute.

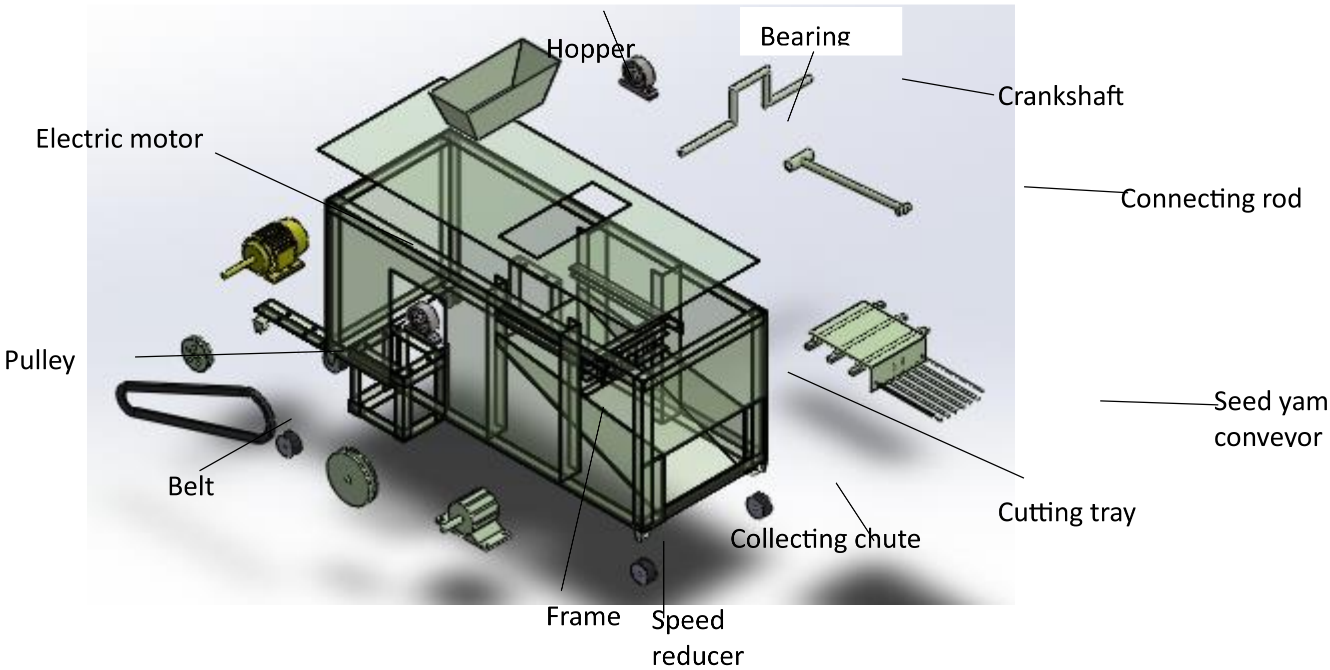

Fig. 1: Parts of the yam minisett processing machine

The yam minisett cutting machine is powered by an AC source from the supply mains. This power is supplied to a 5hp electric motor which in turn provides the energy required to operate the machine. Through the use of an A-type V belt, 150mm pulley on the electric motor and a 300mm pulley on the speed reducer, the rotational motion generated in the electric motor is transmitted to a speed reducer which helps to generate enough torque required to cut the yam into minisetts. It achieves this by reducing the speed of the motor by a ratio of 20:1. The speed reducer is connected to a crank shaft mechanism which converts the rotational motion of the speed reducer into the required translational motion.

The crank shaft is a 25mm diameter mild steel rod with a length of 617mm and is supported on both ends using ball bearings. The translational motion created by the crank shaft moves the connecting rod to and fro the machine (like a piston). The connecting rod is a 5mm thick mild steel bar with a length of 467mm. A metal plate of length 300mm and width 80mm is attached to the free end of the connecting rod. This plate is known as the yam carrier. With the help of the connecting rod, the yam carrier guides the yam from the output end of the hopper to the cutting blade and also provides the force/push required to cut the yam into minisett. The movement of the connecting rod opens and closes the output end of the hopper (closing during its forward movement to the cutting tray and opens when the connecting rod gets back to its initial position).The frame is the main supporting structure upon which other components of this machine are mounted. The frame is a welded section constructed with 2.5mm thick angle iron and covered with a 1.5mm thick mild steel plate. The hopper, shafts, discharge chute, crank mechanism and speed reducer are mounted on the frame while the electric motor is mounted on a motor sitting, welded to the side of the frame. The yam to be cut into minisetts is first cleaned to remove the soil that sticks to its body, through any economic effective means, considering not peeling the outer layer of the yam. After which it is introduced horizontally into the hopper, it fall into the processing tray as the output end of hopper is open. The running machine carried the yam by the yam carrier, the yam guided by the connecting rod and forks like carrier, pushes the yam to the point where the cutting blade is arranged and stationed. Cam mechanism was applied in the machine.

The arm length (or travel distance) of the connecting rod (with the yam carrier attached to it) is designed to be just half an inch less than the distance of the cutting blades position, At the surface of the yam carrier, small poles of about 2.54cm in length were welded to it Together, this system makes sure the yam completely passes through the cutting blade. The cutting blade is designed in a way that allows it cut the yam both horizontal and circular at the same time, into several minisett of about 25g. After being cut into minisett, the processed yam falls out through the other side of the cutting blade into the discharge chute from where it is collected using a container. The yam minisett processing machine is shown in plate 3.

Plate 3: The yam minisett processing machine

Selection of pulleys, belts and determination of their speeds
The machine requires two pulleys; one is mounted on the electric motor shaft while the other was mounted on the speed reducer. Due to its availability, cost and performance, mild steel pulleys with groove angle of 38^0 each were selected. The power developed by the 1600rpm electric motor is transmitted to the speed reducer with a speed ratio of 20:1 through a belt drive comprising of pulleys of diameters, 150mm (mounted on the electric motor) and 300mm (mounted on the speed reducer). These pulley diameters were selected based on standard speed ratio from literature (Khurmi and Gupta 2005).

The speed of the shaft on the speed reducer and the crank shaft were determined as 800rpm and 40rpm respectively using equation 1. (Khurmi and Gupta 2005).

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \qquad (1)$$

Where ;

D_1 = Diameter of the driving pulley

D_2 =Diameter of the driven pulley.

N_1 = Speed of the driving pulley in r.p.m

N_2 =Speed of the driven pulley in r.p.m

The design center distances between the electric motor and the speed reducer was determined as 566mm, using equation (2) (Sharma, P.C. and Aggarwal 2006).

$$C = \frac{1.5D_2}{VR^{1/8}} \qquad (2)$$

while the minimum length of the belts required to drive the speed reducer shaft was determined as 1838.57mm using equations 3.3 (Khurmi and Gupta 2005; Sharma and Aggarwal 2006).

$$L = 2C + 1.57(D_2 + D_1) \quad + \frac{(D_2 - D_1)^2}{4C} \qquad (3)$$

Where:

L = Belt length in inches

C = Center distance between two pulleys in inches

D_1 = Diameter of the driving pulley

D_2=Diameter of the driven pulley.

VR = Velocity ratio of the both pulleys

P = Pitch of the belt

By assumption, the power transmitted by the drive should not exceed 3.75KW (Khurmind Gupta 2005; Degarmo *et al.,* 2003: Sharma and Aggarwal 2006). Hence "type A" V-belt with standard pitch length of 1941mm (IS: 2494- 1974 standard) and coefficient of friction, μ of 0.3 was selected. The actual center distance between the motor and speed reducer pulleys was obtained as 617.2mm using equations 4 - 6 (Khumi and Gupta 2005; Sharma and Aggarwal 2006).

$$C = p + \sqrt{p^2 - q} \qquad (4)$$

$$p = \frac{1}{4} - \frac{\pi}{8}(D_2 + D_1) \qquad (5)$$

$$q = \frac{(D_2 - D_1)^2}{8} \qquad (6)$$

The angle of contact of the driven pulley was determined as 166° using equation 7 while the peripheral velocity of the belt was determined as 12.566m/s from equation 8.

$$\theta = 180 - 2\left[sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)\right] \qquad (7)$$

$$v = \frac{\pi D_1 N_1}{60} \qquad (8)$$

Determination of belts tensions and shaft diameters

Tension in tight and slack sides of the belt ($T_1$and T_2) were obtained as 155.4 N and 10.75 N respectively for the motor and speed reducer respectively using Equations 9 - 13 respectively (Burr and Cheatham 2002; Khurmi and Gupta 2005; Sharma and Aggarwal 2006).

$$T_1 = T_{max} - T_c \qquad (9)$$

$$T_{max} = \sigma \text{ x } a \qquad (10)$$

$$T_c = mv^2 \qquad (11)$$

$$2.3 \log \frac{T_1}{T_2} = \mu\theta cosec\beta \qquad (12)$$

Assuming the grove angle of the pulley, 2β =38° and β=19°
Where:

θ is the angle of contact of the belt between the two pulleys (rad)

T_{max} = Maximum tension on the belt

T_c = Centrifugal tension on the belt

Torque on the crank shaft was determined as 21697.5Nmm using equation 13.

$$T = (T_1 - T_2)\frac{D_2}{2} \qquad (13)$$

Crank shaft:

The crankshaft has a speed reducer on one end, with its other end pivoted on a ball bearing. The connecting rod or conveyor is attached at the center of the crankshaft. The forces acting on the crank at angle of rotation are illustrated in figure 3.

The connecting rod AB is a mild steel circular bar of length 0.470m, width 0.025m, thickness 0.005m and a density of 7850kg/m^3. The length of the connecting rod was chosen in relation to the yam travel distance so as to ensure the complete cutting of the tuber into minisett. The crank has a radius of 0.15m.

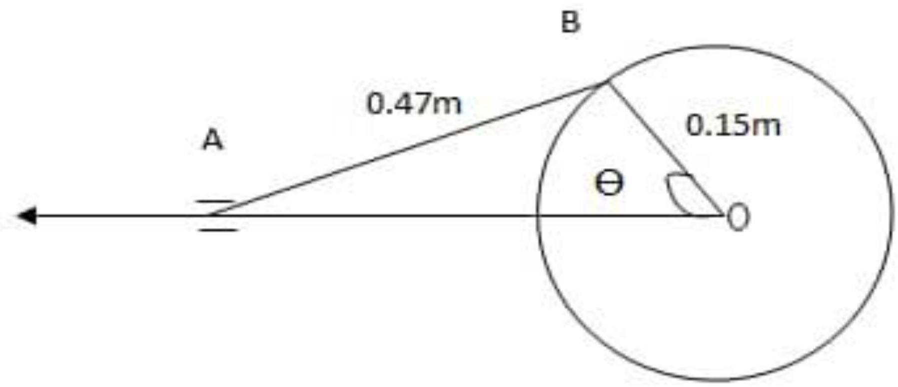

Figure 3: Free body diagram of the crank and the connecting rod

Using the relative velocity method (Kurmi and Gupta, 2005), the velocity V_{AB} of the connecting rod was obtained as 2.7m/s with equation 3.8. The inertia force F_i acting on the rod was obtained using equation 14 and 15 as 4.6N.

$$\rho = \frac{m}{lxbxt} \qquad \textbf{(14)}$$

$$F_i = m \times g \qquad \textbf{(15)}$$

Where,

g = acceleration due to gravity, $10m/s^2$

ρ= density of connecting rod.

l, b, t represents length, width and thickness respectively.

The center crankshaft was designed using the following formulas as obtain from Khurmi and Gupta (2013), Thrust, F_p in the connecting rod which is equal to the weight of the yam on the yam carrier welded to the connecting rod, it was obtained as 109.71N using equation 16

$$F_p = \text{B x L x p} \qquad (16)$$

Where,
B = width of the yam carrier = 80mm
L= length of the yam carrier = 300mm
p= maximum intensity of pressure on the yam carrier = 0.002285 N/m^2

Using equation 17

$$\text{A = L x B} \qquad (17)$$

Where;
L (average length of yam) = 247.80mm
B (average width of yam) = 66.75mm

The cross-sectional area of an average yam was obtained as 0.0175m^2

Bending moment due to belt tension,

$$M_T = H_3' \text{ x } C_1 \qquad (27)$$

M_{wc} and M_T were obtained as 1744.6Nmm and 8158.5Nmm respectively using equations 26 and 27

Resultant bending moment was obtained as 8342.95Nmm using the equation 28

$$M_s = \sqrt{(M_{wc})^2 + (M_T)^2} \tag{28}$$

The diameter of the shaft was obtained by using equation 29

$$d = \left[\frac{16}{\tau\pi}\sqrt{(K_b M_b)^2 + (K_t T)^2}\right]^{1/3} \tag{29}$$

Where;

K_b = Combined shock and fatigue factor for bending (1.5)

K_t= Combined shock and fatigue factor for twisting (2.0)

T = Maximum twisting moment (obtained as 21697.5Nmm)

τ = Shear stress due to twisting moment = 42N/mm^2

M_s = Maximum bending moment

The diameter of this crank shaft was determined as 18mm using Equation (29). Thus, a standard 20mm diameter solid mild steel shaft was obtained for crank shaft which is greater than the calculated value of diameter.

Determination of number of blades

The number of the fixed blades (S_n) were determined as 16 using the expression adapted from Adebayo et al. (2014) as:

$$S_n = \frac{l_s}{s_t} \tag{30}$$

Where:

S_n = the number of blades on the tray

l_s= length of the tray with blades = 320mm

S_t = the desired thickness of minisett (spacing of blades) = 20mm for 25g yam minisett (Akubuo, 2002).

Selection of electric motors: The power required to drive the machine was obtained as the sum of the power required to drive the belt, $P_1$and the power required to drive the crankshaft, P_2.$P_1$was determined as 1.816KW using equation 31 and P_2 was determined as 1.817KW using equation 32. Hence, power required to drive the entire machine was determined as 3.634KW ($\approx$4.86hp) using equation 33 (Khumi and Gupta, 2005; Sharma *et al.,* 1985). Taking care of 10% possible power loss due to drives friction, the power required to drive the yam minisett processing machine, A 5hp single phase electric motor was therefore used as the prime mover of the machine.

$$P_1 = \frac{(T_1 - T_2)V}{1000} \tag{31}$$

where:

V= velocity of the belt

T_1 = Tension in tight side

T_2 = Tension in slack side

P_1 = power to drive

P_2 = power required to drive the crankshaft

$$P_2 = \frac{2\pi N_{CS} T_{CS}}{60} \tag{32}$$

Where:

N_{CS} = speed of crankshaft

T_{CS} = torque on the crankshaft

$$P_T = P_1 + P_2 \qquad (33)$$

Where:

P_T = total power required to drive the machine

Performance testing procedure: The developed yam minisett cutting machine was tested after fabrication to evaluate its performance. Each test performed was carried out in ten (10) different experimental runs for an average weight of 8kg of yam. The test performance indicators evaluated in the tests are Capacity (or Throughput), C_m and efficiency η_c .Two experiments were carried out on the machine, the first was to determine the effect of speed on the efficiency while the second was to determine the effect of speed on the capacity of the machine. Each test involved operating the machine at a constant time duration of five (5) minutes. The length of the connecting rod (i.e. the travel distance of the yam) was also kept constant for each of the experimental run. The speed of the crankshaft was varied from 10rpm to 100rpm using pulleys of different diameter to achieve various speed ratios. The number of yam minisetts produced during each test was recorded. The numbers of well-cut minisett were recorded, and those with improper cuts were also recorded. Yam minisetts with regular sharp cuts, good finishing and an average weight of 25g or more were considered as good one, while those that did not meet the above criteria were considered as scraps but was used in economic viability analysis, (Bolaji, 2018). Each minisett was weighed on a weighing balance to determine its actual weight. Thereafter, the capacity C_m and efficiency η_c of the machine were computed in each case using the following relations in equation 34 and 35

$$C_m = \frac{N_g}{t} \qquad (34)$$

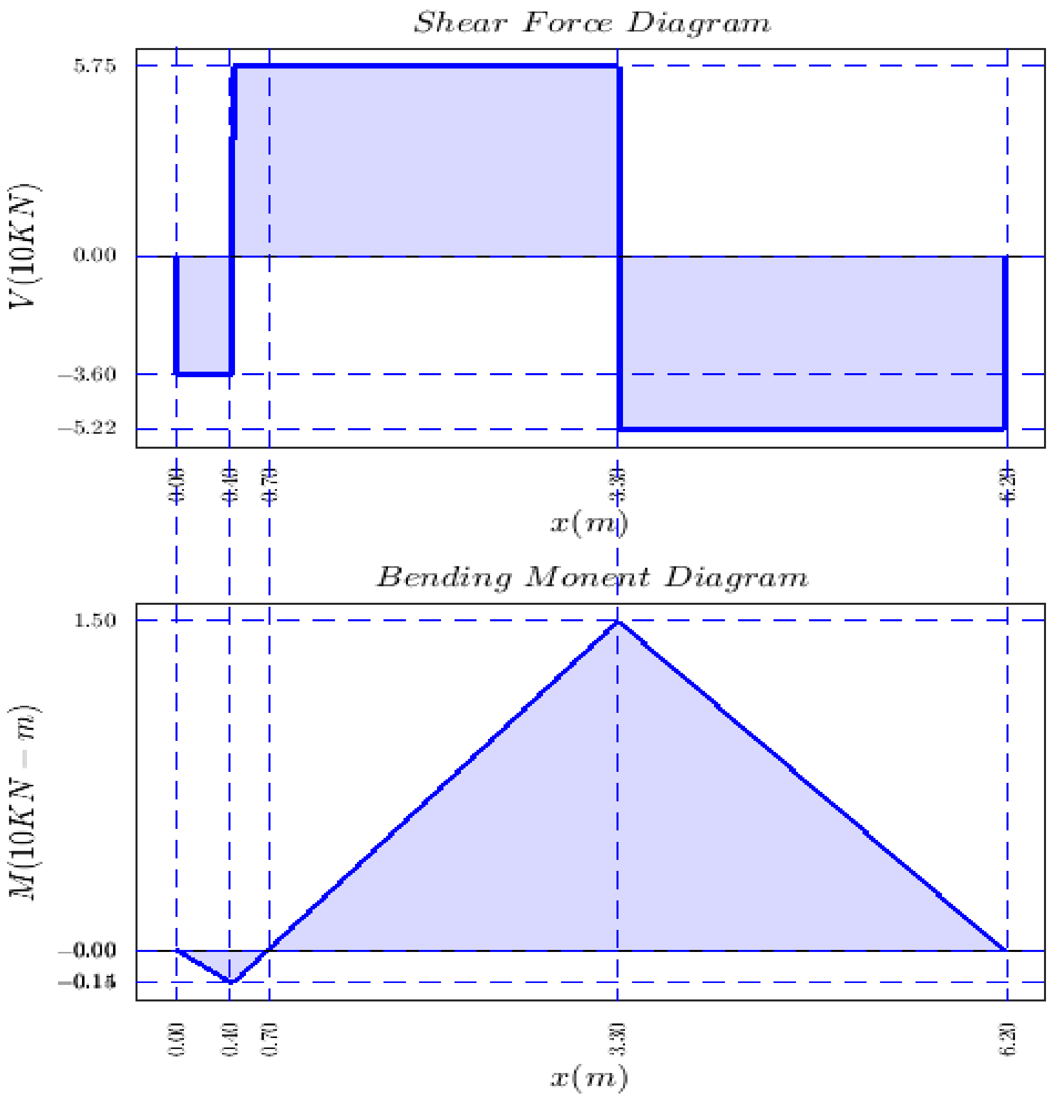

Fig 5 Bending moment and shear force diagram of the crankshaft

$$\eta_c\% = \frac{N_g}{N_T}\ x\ 100\% \tag{35}$$

Where t = Time of the operation = 5 minutes,

N_g = Number of well-cut yam minisetts

N_T= Total number of yam minisetts produced

Result and Discussion : The number of minisetts produced during each test was recorded. The number of well-cut minisetts was recorded, and those with improper cuts were also recorded, and with these values the Capacity and the efficiency of the machine at each experimental run was obtained. Tables 2 and 3 showed the obtained values of capacity and the efficiency of the machine respectively from different experiments.

Table 2: Experimental Analysis of the yam minisett processing machine capacity

Experiment No.	Capacity/mins					
	1	**2**	**3**	**4**	**5**	**Mean**
1	478.59	478.60	478.90	480.20	480.50	479.36
2	481.45	482.01	479.99	480.57	480.98	481.00
3	481.47	481.47	481.39	481.50	480.99	481.36
4	479.98	479.98	482.01	4481.99	480.99	480.99
5	479.99	480.01	481.11	481.55	480.99	480.73
6	480.55	480.92	480.31	481.49	481.48	480.95
7	481.02	480.57	480.39	481.50	481.49	480.99
8	480.97	481.55	481.50	481.47	480.99	481.30
9	481.49	482.01	481.47	481.45	480.98	481.48

Table 3: Experimental Analysis of the yam minisett processing machine efficiency

Experiment No.	Efficiency%					
	1	**2**	**3**	**4**	**5**	**Mean**
1	90.6	91.2	90.78	90.26	91.4	90.85
2	71.9	72.04	70.8	71.42	70.4	71.3
3	96.6	95.6	94.8	96.4	97.2	96.12
4	96.20	96.20	95.99	96.19	96.62	96.24
5	87.5	86.8	87.6	88.02	88.1	87.6
6	87.5	87.4	88.2	86.66	88.01	87.55
7	68.7	69.0	68.8	69.02	68.4	68.78
8	65.6	66.03	64.32	65.1	64.90	65.19
9	63.1	62.64	63.42	63.86	62.84	63.17

Results from ten experimental runs at varying speeds and the corresponding capacity or throughput obtained are tabulated in Table 4. Factors such as length of connecting rod, number of blades and duration of experiment were kept constant at 470mm, 16, and 5mins respectively.

Table 4: Effect of the crankshaft speed on the capacity of the yam minisett processing machine

S/NO.	SPEED OF CRANK SHAFT (RPM)	TOTAL NUMBER OF MINISETT PRODUCED	TOTAL NUMBER OF WELL-CUT MINISETTS	TOTAL NUMBER OF POORLY CUT MINISETT	CAPACITY/MINS
1	10	1924	1922	2	384.4
2	20	1970	1966	4	393.2
3	30	2151	2147	4	429.55
4	40	2278	2275	3	455.00
5	50	2393	2385	8	477.00
6	60	2415	2405	10	481.00
7	70	2441	2425	16	485.00
8	80	2472	2450	22	490.00
9	90	2490	2460	30	492.00
10	100	2527	2485	42	497.00

From Table 4, it can be seen that at crank shaft speed of 100rpm, the largest number of yam minisett (2527) were obtained from the machine, and the machines capacity was calculated to be 497minisett/mins, while at crank shaft speed of 10rpm, the lowest number of yam minisett which was 1924 were obtained from the machine, and the machines capacity was calculated to be 384.4minisett/mins. Table 4 shows that as the speed of the crankshaft increases, the capacity of the machine also increases. Results of the tests carried out to determine the effect of crankshaft speed on the efficiency of the developed machine are displayed in Table 5 Performance tests reveal that a lower crankshaft speed yields better-cut minisetts and higher efficiency, while a higher speed enhances throughput. Additionally, factors like the length of the connecting rod and the number of blades impact efficiency. Specifically, the number of blades affects the quantity of minisetts per batch, and the connecting rod length influences cutting efficiency. The machine is cost-effective, with all materials sourced locally. The total production cost amounts to 218,500 naira, based on material prices in Abia State, Nigeria, from January to December 2021.

Table 5: Effect of crankshaft speed on the efficiency of the yam minisett processing machine

S/NO.	SPEED OF CRANK SHAFT (RPM)	TOTAL NUMBER OF MINISETT PRODUCED	TOTAL NUMBER OF WELL-CUT MINISETTS	TOTAL NUMBER OF POORLY CUT MINISETT	EFFICIENCY%
1	10	16	14	2	87.5
2	20	32	28	4	87.5
3	30	48	44	4	91.7
4	40	64	61	3	95.3
5	50	80	75	5	94.2
6	60	96	86	10	89.5
7	70	112	96	16	85.7
8	**80**	**128**	**106**	**22**	**82.8**

9	90	144	114	30	79.2
10	100	176	134	42	76.1

Table 5 indicates that the machine's efficiency improved as the speed increased from 10 rpm to 40 rpm. However, beyond 40 rpm, efficiency declined with higher speeds. The peak efficiency of 95.3% was achieved at 40 rpm, while the lowest efficiency, 76.1%, occurred at 100 rpm. This decline at 100 rpm, despite the machine's highest capacity, is due to the increased number of poorly cut minisetts at this speed.. **Conclusions:** Development and techno-economic evaluation of a yam minisett processing machine were accomplished in this study. Materials used for the development of this machine are locally sourced. This development is done due to inability of existing root crops cutting/slicing machines to perform simultaneous horizontal and longitudinal cutting operations required for effective yam minisett production as obtained in native technique. Average length and breadth of a yam tuber used for designing the minisett processing machine was also determined as 247.80mm and 66.75mm respectively. The developed machine comprises the frame, speed reducer, pulley, belt, crank mechanism, connecting rod, hopper, seed yam carrier, cutting blades, and discharge chute as major components. The dimensional design of the machine was done with a solid works which was used to get the exploded view of the machine.

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Building Climate Resilience in Nigerian Agriculture: Challenges, Policies, and Sustainable Solutions

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Abstract

Agriculture plays a vital role in Nigeria's economic development and serves as a primary source of livelihood for the majority of the population. However, the sector faces significant challenges from climate change, which threatens food security, crop yields, and rural stability. This paper explores the effects of climate change on Nigerian agriculture, focusing on its impact on both formal and informal sectors, which collectively pursue food security through domestic food supply chains, value addition, and export earnings. This paper examines the success and limitations of current policies and initiatives in building climate change resilience within the Nigerian agricultural sector. It emphasizes the importance of a multifaceted approach, including government investment in Agro-allied resources, improved access to credit and insurance for farmers, and the development of climate-smart practices through education and extension services. Additionally, it explores the role of indigenous knowledge in promoting sustainable agricultural practices alongside scientific innovations. The study concludes by recommending actionable solutions for improving Nigeria's resilience to climate change in agriculture, calling for enhanced collaboration between government agencies, private organizations, communities, and individuals. Achieving climate change resilience in agriculture is essential not only for securing food supply and mitigating humanitarian crises but also for stabilizing the nation's economy and ensuring the well-being of rural populations.

Keywords: *Climate change resilience, Agriculture, Nigeria, Food security, Smallholder farmers.*

Introduction: Agriculture is not just a fundamental means of livelihood in Nigeria but also a key player in the economic growth of the nation, according to the National Bureau of Statistics (NBS, Q1 2023), Agriculture contributes 19.63% to nominal Gross Domestic Product (GDP) in the first quarter of the year 2023 which is even lower than what was recorded in the first quarter of the previous year. Despite its significant contribution to the formal sector, in tandem with what Mayong *et al*., reported in 2005 on identifying opportunities for increased commercialization and investment in Nigeria, it is safe to say that not all the activities in the sector are accurately captured due to the low level of its commercialization, this is because of investor's skepticism about the unpredictability and speculations concerning the impact of climate change on agriculture which makes the venture tricky. Both the formal and informal sectors of agriculture have been able to pursue the goal of food security vigorously through the domestic food supply chain, value addition & export earnings. Agriculture in Nigeria plays a vital role in ensuring stability, through its contribution to the livelihood of a significant portion of the population, food security, poverty reduction, rural and economic development.
However, climate change, which is characterized by changing weather patterns, erratic rainfall, drought & desertification, pest & disease spread, reduced crop yield, loss of biodiversity, and many more is a challenge to the global agricultural system as much as it is to agriculture in Nigeria. The United Nations Environmental Programme (UNEP, 2013) admits that climate change is now widely recognized as the major environmental problem facing the globe which has in turn posed itself as a major threat to the sustenance of humans and the environment. Nigeria has greatly been affected by this menace due to insufficient effort to mitigate its effect on agriculture, it is evident from statistics how agriculture that contributes about 40% to the GDP of Nigeria and employs about 70% of the working population (Odetola and Etumnu, 2013) kept nosediving till present time without effective measures to salvage the situation.

Climate change has interfered with the flow of agricultural systems in Nigeria (Dooley and Roberts, 2020) emphasized that natural disasters immensely undermine food security, community livelihood, and sustainable infrastructure. All related stakeholders must adopt a sustainable policy that will avert all possible food/humanitarian crises/disasters that may be induced by climate change. Hence the need to improve the productivity of agriculture through climate change resilience in Nigeria is very crucial.

Challenges: Although climate change may be adjured to be a natural phenomenon but induced by human activities. Salami (2010) opined that human actions and in particular the burning of fossil fuels and changes in global patterns of land use are major inducing factors of climate change. The danger of climate change to agriculture in Nigeria cannot be downplayed as it poses a serious threat to food security because of crops and livestock infestation by pests and diseases, drought & desertification, erratic rainfall, etc. *Tuta absoluta* was a famous disease of tomatoes that made farmers account for about 80% loss of their tomato farms (Sanda, 2018), the outbreak was combated but unfortunately reoccurring which is just an experience among many of what is facing agriculture in Nigeria. Moreover, the threat of extreme drought in the northern part of Nigeria where pastoralists are predominant forced them to migrate down south where vegetation is favorable for their herds, the process of feeding crops and useful vegetation of arable farmers to their herds led to territorial clashes that degenerated to a prolonged conflict which resulted into the insecurity that made a lot of rural dwellers majorly engaged in agricultural practices scamper for safety, the crisis that emanated from climate change induced drought had a direct impact on the GDP, food security and even led to the loss of lives. Recently, a flood engulfed the Middlebelt of Nigeria where there are high agricultural activities because of erratic rainfall and ill-managed dam control which led to the loss of lives, properties, and farmlands.

Smallholder farmers who constitute more than 80% of the farmers in Nigeria according to Sabo *et al*., 2017 bear the brunt of this menace and are the most vulnerable due to their limited access to resources like land, capital, technology, credit, and insurance, education and training and their dependence on rainfed agriculture. A multifaceted approach is required to resolve various challenges facing the smallholder farmers which include access to land, capital, technology, credit and insurance, education, and training on policies and/or practices that will boost their resilience. The government and other related stakeholders are putting in the effort to ensure that the effect of climate change is being mitigated in Agriculture but unfortunately, the effort is not yielding satisfactory results which makes the discourse worrisome.

Government Policies and Initiatives: The government with inputs from related stakeholders in the agricultural sector of Nigeria has introduced a lot of policies and initiatives to combat threats that climate change poses to the sector and build resilience to increase productivity in agriculture. Some of the policies and initiatives formed are briefly analyzed below.

- **National Climate Change Policy and Response Strategy:** This policy was an improvement on its earlier version of the Climate Change Policy that was introduced in the year 2012 as an outline of the government's commitment to addressing climate change in various sectors, the policy embodied the importance of integrating climate considerations into agricultural planning, research, and activities. This policy was able to arouse the consciousness of the public about climate change but struggles to enjoy holistic implementation.
- **National Agricultural Resilience Framework (NARF):** This focuses on building resilience in the agricultural sector to the impacts of climate change, it emphasizes adaptive and coping practices like soil management practices, crop diversification, watershed management, and rotational cultivation methods. The framework struggles to translate its objectives into actions as a result of several factors like limited data and research, capacity gaps, and bureaucratic hurdles.
- **Climate-Smart Agriculture Initiatives:** This initiative enhances agricultural productivity and resilience in the face of climate change through its programs that promote agroforestry, drought-resistance crop varieties, and conservation agriculture. Effective implementation of this policy hinges on extension personnel who are saddled with the responsibility of encouraging farmers to adopt various innovations under the aegis of Climate-Smart Agriculture Initiatives, the ratio of extension personnel to farmer in Nigeria currently stands between 1:5,000 – 1:10,000 which is far below the recommendation of Food and Agriculture Organization (FAO) of 1:800 in developing countries. The reality of a weak workforce in addition to some farmers being resistant to changes against their orthodox farming method hinders the effective implementation of the Climate-Smart Agriculture Initiative.
- **Climate Information and Early Warning Systems:** Facilities that provide accurate and timely information to farmers were installed; this was vital to them in making informed decisions. The system has been helpful but unfortunately, the maintenance culture of the facilities is poor which has limited its performance.
- **National Agricultural Extension and Research Liaison Services (NAERLS):** This is about the human resources aspect of the effort to combat climate change through effective dissemination of climate-smart practices and technology to the farmers. The extension service personnel serve as an intermediary between the research laboratory and the farmers, they convey information devoid of noise from researchers to the farmers and likewise back to the researcher in the form of feedback. The ratio of extension agents to farmers is very low, which has reduced the effectiveness and efficiency of the sector.

Recommended solutions: Implementation of policies is one of the major setbacks in achieving outright climate change resilience in agriculture in Nigeria, which can be attributed to an array of factors like funds, government bureaucracy, inadequate personnel, and poor monitoring and evaluation among others. Therefore, if there is going to be a sustainable solution to climate change resilience in Nigeria's agriculture, the government, organizations, communities, and individuals must be determined to play their respective roles.

The government should be responsible for reliable financial support through transparent subsidies on agro-allied products (fertilizers, drought resistance seeds, safe chemicals, etc.), low interest rates loans for farmers to improve their accessibility to capital, legislate laws that simplify land tenure system and ownership for agricultural purpose, construction of dam and installation of irrigation facility as an alternative to heavy dependence on rainfed agriculture, recruitment of expertise in a related field for efficient extension service delivery, effective monitoring and evaluation team, also devise effective enforcement agents that will discharge their duty without prejudice to ensure compliance with the regulations/policies.

Various organizations and their hosting communities must corroborate and contribute immensely to the effort of the government on building climate change resilience in agriculture through counterpart funding of climate-related projects/programs, public awareness and educational outreaches, establishment of research centers and institutions that will focus on climate-smart practices concerning the tenets of their society.

Whether it is a top-bottom or bottom-top approach, the pivotal role of individuals in achieving climate change resilience in Nigeria's agriculture cannot be overemphasized. Therefore, extension agents who are the first line of contact must be able to deliver innovations/technologies about climate with absolute clarity devoid of any ambiguity and ensure that farmers efficiently adopt innovations/technologies through his/her persuasive skills. Farmers should not consider research-based solutions with skepticism but rather be open to innovative ideas that prove superior to their orthodox method of farming which has been rendered obsolete because of the effect of climate change. Nevertheless, farmers should be able to inculcate their local and indigenous knowledge on climate change which can provide valuable insight into resilient farming practices without jettisoning the scientific solutions. Finally, judicious appropriation of allocated resources should be sternly done; it will help the farmer to achieve more and encourage the donor to also do more in confidence that it will be used prudently.

Conclusion: It is unfortunate to remark that a lot has been done but little has been felt in a bid to mitigate the effect of climate change and build its resilience in Nigeria's agricultural sector. However, Nigeria stands in a position of strength to achieve great success in building climate change resilience in agriculture, especially if the government and every related stakeholder can go beyond scoring cheap political points to the genuine intention of creating sustainable solutions. There is a need for a synergized effort between the government and other related stakeholders to address grey areas that hinder the holistic implementation of various laudable initiatives formed to build climate change resilience in agriculture will yield better results and create a sustainable template. This action will not only rescue the imminent threat to food security and continuous inflation of food commodities but also avoid humanitarian crises by keeping young people gainfully employed and productive which will successively improve agricultural productivity and its overall contribution to the national Gross Domestic Product growth.

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Nutritional Potentials of Nigerian Plants: A Comprehensive Exploration of Key Nutritional

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Abstract:

This paper explores the nutritional potentials of indigenous plants in Nigeria, leveraging the country's diverse ecosystems. Focusing on key nutritional components, the discussion encompasses protein-rich plants, vitamins and minerals, energy-boosting carbohydrates, healthy fats and oils, fiber from leafy greens, and antioxidant-rich plants. Specific plants, such as African Yam Bean, Moringa Tree, African Spinach, Fluted Pumpkin, Waterleaf, Cassava, Plantain, Shea Tree, Palm Oil, Coconut, Hibiscus, African Star Apple, Soursop, and Bitter Leaf, are analyzed for their unique contributions to human well-being. The versatility and adaptability of these plants within Nigerian cuisine are emphasized, highlighting their potential to enhance health and nutrition.
Keywords: *Nigeria, Plants, Nutritional components, Nutritional potentials.*

Introduction: Nigeria, endowed with diverse ecosystems, boasts an array of indigenous plants with substantial nutritional value (Osawaru *et al*., 2022). This essay delves into the nutritional potentials of Nigerian plants, shedding light on key components that contribute to human well-being. The exploration spans a variety of plant species, each offering unique nutritional benefits, and aims to underscore the significance of incorporating these plants into diets for improved health.

Nutritional Components of Nigerian Plants: An Overview: Protein-Rich Plants: Protein, an essential component for human health, plays a pivotal role in muscle development, immune function, and overall well-being. In Nigeria, a country blessed with diverse ecosystems, various indigenous plants stand out as rich sources of protein, offering a valuable alternative to animal-based proteins (Aworh, 2015).

African Yam Bean (*Sphenostylis stenocarpa*): The African yam bean, often overlooked but nutritionally potent, stands out as a valuable source of protein. This leguminous plant, native to West Africa, produces seeds rich in protein. The protein content in African yam bean seeds makes it a significant dietary inclusion, particularly in regions where it thrives. Boasting a nutty flavor, the seeds are versatile and can be incorporated into soups, stews, or ground into flour for various culinary applications (George *et al*., 2020). The protein content in African yam bean seeds ranges from 18% to 25%, making it comparable to other legumes like soybeans. This protein profile includes essential amino acids such as lysine and tryptophan, making it a well-rounded protein source. Regular consumption of African yam bean seeds can contribute to muscle development, immune support, and overall nutritional balance. African yam bean seeds are celebrated for their versatility in local diets. Whether boiled, fried, or ground into flour, they find their way into traditional soups, stews, and snacks. The plant's adaptability to various culinary preparations makes it an integral part of local diets, ensuring a protein-rich addition to meals (James *et al*., 2020).

Moringa Tree (*Moringa oleifera*):: The moringa tree, often referred to as the "drumstick tree" or "miracle tree," is celebrated for its leaves and seeds that are rich in essential amino acids. The leaves, with a slightly peppery taste, are commonly used in soups and salads. Moringa seeds, on the other hand, can be pressed to extract nutrient-dense oil or ground into a powder to supplement various dishes. The accessibility and adaptability of the moringa tree make it a practical and affordable source of plant-based protein (Maheshwari *et al*., 2020).

Moringa leaves and seeds are rich in protein, with the leaves containing approximately 9 grams of protein per 100 grams. Additionally, moringa leaves provide all essential amino acids, making it a complete protein source. This nutrient profile positions moringa as an excellent option for individuals seeking plant-based protein alternatives. Moringa leaves and seeds seamlessly integrate into Nigerian diets, complementing soups, stews, and salads. The leaves can be dried and ground into a powder for easy incorporation into various dishes. Moringa's adaptability and mild flavor make it an appealing choice for enhancing the nutritional content of meals without overpowering the taste (Kim and Kim, 2019).

Vitamins and Minerals:Vitamins and minerals are essential micronutrients that play a crucial role in maintaining good health. Nigeria, blessed with a rich biodiversity, is home to a variety of indigenous plants that serve as reservoirs of these vital nutrients (Aworh, 2015).

African Spinach (*Amaranthus hybridus*): Commonly known as "Efo Tete" in Yoruba, African spinach is a leafy green vegetable that stands out for its high vitamin and mineral content. Rich in vitamins A and C, African spinach contributes to maintaining healthy skin, vision, and a robust immune system. Additionally, it provides essential minerals such as iron, supporting hemoglobin production and preventing iron-deficiency anemia. The high content of vitamins A and C in African spinach addresses common nutritional deficiencies, particularly in communities where access to diverse foods is limited. The inclusion of this leafy green in diets aids in maintaining healthy skin, good vision, and a strong immune system. Moreover, the iron content supports the prevention of anemia, a prevalent concern, especially among vulnerable populations (Sarkar *et al*., 2022).

African spinach is a versatile ingredient in Nigerian cooking. It finds its way into various soups, stews, and sauces, contributing not only vibrant colors and flavors but also a wealth of vitamins and minerals. Its ability to withstand cooking temperatures ensures that its nutritional content remains intact in traditional culinary preparations.

Fluted Pumpkin (*Telfairia occidentalis*): Fluted pumpkin, locally known as "Ugu," is a popular vegetable in Nigerian cuisine, celebrated not only for its culinary versatility but also for its nutritional richness. It is a good source of vitamins such as vitamin A, which is vital for vision and immune function, and vitamin C, an antioxidant that supports skin health. Fluted pumpkin also contains minerals like calcium and phosphorus, contributing to bone health and overall well-being (Khabo-Mmekoa and Momba, 2019).

Fluted pumpkin's nutritional profile makes it a valuable addition to diets, particularly for individuals seeking to enhance their vitamin and mineral intake. The vitamin A content supports eye health, while the calcium and phosphorus contribute to bone health. Its role in traditional Nigerian dishes ensures that these nutritional benefits are easily accessible to a wide population. Fluted pumpkin leaves are a staple in Nigerian soups and stews. Their slightly bitter taste adds depth to dishes, while their nutritional content enhances the overall health benefits of meals. The adaptability of fluted pumpkin to different cooking methods makes it a favorite in diverse regional cuisines (Akpasi *et al*., 2023).

Waterleaf (*Talinum triangulare*): Waterleaf, a leafy vegetable with succulent leaves, is a treasure trove of vitamins and minerals. Rich in vitamins A and C, waterleaf supports skin health and boosts the immune system. The presence of minerals like potassium contributes to heart health and helps regulate blood pressure. Its incorporation into traditional soups and stews adds both flavor and nutrition to meals. Waterleaf's nutritional richness extends to both vitamins and minerals, making it a holistic addition to meals. The vitamins A and C contribute to skin health and immune function, while potassium supports cardiovascular health. The incorporation of waterleaf into local cuisines exemplifies how traditional dietary practices can align with modern nutritional recommendations (Trifunschi *et al*., 2022). Waterleaf's succulent leaves are prized in Nigerian kitchens, particularly in the preparation of soups. Its inclusion not only imparts a unique texture to dishes but also elevates their nutritional content. The popularity of waterleaf across various regions showcases its culinary versatility.

Energy-Boosting Carbohydrates: In the vibrant tapestry of Nigerian cuisine, carbohydrates stand as the primary energy source, powering daily activities and contributing to the rich diversity of local meals (Niaz *et al*., 2020).

Cassava (*Manihot esculenta*): Cassava, often referred to as the "bread of the tropics," is a starchy root vegetable that has become a dietary staple in Nigeria. Its adaptability to various soil types and resistance to harsh weather conditions make it a resilient crop, thriving in diverse ecological zones across the country. Cassava is a rich source of energy, primarily in the form of complex carbohydrates. Its carbohydrate content, mainly in the form of starch, makes it a valuable dietary component for sustaining energy levels throughout the day. Cassava is gluten-free, offering an alternative to wheat-based products for individuals with gluten sensitivities (Diaz *et al*., 2019). In Nigerian kitchens, cassava takes on myriad forms, showcasing its versatility. It can be peeled, boiled, and served as a side dish or pounded into a smooth, stretchy consistency known as "fufu" – a popular accompaniment to soups and stews. Additionally, cassava flour, derived from dried and ground cassava, is used in making various traditional dishes, including "garri," a staple in many Nigerian households (Apeh *et al*., 2021).

Plantain (*Musa spp*.): The Sweet Sibling of Bananas: Plantain, a close relative of bananas, is another carbohydrate powerhouse widely consumed in Nigeria. Its subtle sweetness, combined with a starchy texture, makes it a versatile ingredient in both savory and sweet dishes. Plantains provide a substantial amount of complex carbohydrates, along with dietary fiber, which aids in digestion and promotes a feeling of fullness. They also contain essential vitamins and minerals, including vitamin A, vitamin C, and potassium. The natural sugars in plantains contribute to their sweet taste, providing a natural source of energy (Sidhu and Zafar, 2018). Plantains can be enjoyed at various stages of ripeness, each offering a unique culinary experience. When green or semi-ripe, plantains can be sliced and fried to make "dodo" or "boli," popular snacks in Nigeria. As they ripen, plantains become sweeter and are often used in the preparation of main courses, desserts, or snacks (Sidhu and Zafar, 2018).

Healthy Fats and Oils: In the mosaic of Nigerian cuisine, the role of fats and oils cannot be overstated. Beyond their culinary importance, these fats play a crucial role in supporting overall health (Stamenković *et al*., 2019).

Shea Tree (*Vitellaria paradoxa*): The shea tree, known as the "Tree of Life," is a cultural and ecological treasure in Nigeria. From its nuts, the renowned shea butter is extracted—a substance highly regarded for its versatility. Shea butter, a source of healthy fats, contains a mix of saturated and unsaturated fats, with oleic acid being a prominent component. Oleic acid, also found in olive oil, is known for its cardiovascular benefits. In Nigerian cuisine, shea butter is not only used in cooking but also in traditional skincare practices, emphasizing its multifaceted significance (Ghimire *et al*., 2021). Shea butter is not only a source of healthy fats but also contains vitamins A and E, making it a nourishing addition to both the body and the skin. The presence of antioxidants in shea butter contributes to the neutralization of free radicals, promoting cellular health. Shea butter is a culinary gem used in preparing soups, stews, and snacks. Its distinct nutty flavor adds depth to dishes, while its creamy texture enhances the mouthfeel. In addition to cooking, shea butter is a primary ingredient in traditional confections, showcasing its versatility in both savory and sweet applications (Tom-Dery *et al*., 2018).

Palm Oil (*Elaeis guineensis*): Palm oil, a staple in Nigerian cooking, is extracted from the fruit of the oil palm tree. Rich in saturated and unsaturated fats, palm oil has been a traditional source of cooking fat for generations. Beyond its culinary applications, palm oil is rich in vitamin E and carotenoids, providing antioxidants that contribute to overall health. Its distinctive red hue adds color and flavor to various dishes, making it an integral part of Nigerian culinary identity (Absalome *et al*., 2020).

Palm oil, in addition to providing healthy fats, is rich in beta-carotene, which the body converts into vitamin A. Vitamin A is essential for vision, immune function, and skin health. The antioxidants in palm oil also play a role in combating oxidative stress. Palm oil, with its vibrant color and distinct taste, is a fundamental component in Nigerian cuisine. It is a key ingredient in the preparation of soups, stews, rice dishes, and various local specialties. Its ability to carry and enhance flavors makes it a cornerstone of traditional recipes (Ibrahim *et al*., 2022).

Coconut (*Cocos nucifera*): The coconut palm, ubiquitous in Nigeria's coastal regions, provides an array of products, including coconut oil. Coconut oil is predominantly composed of saturated fats, particularly lauric acid, which is known for its antimicrobial properties. In Nigerian cooking, coconut oil lends a distinct flavor to dishes and is often used in both savory and sweet preparations. The versatility of coconut oil extends beyond the kitchen; it is also a popular ingredient in traditional hair and skincare practices (Shin *et al*., 2019).

Coconut oil, with its unique composition of fatty acids, offers a quick source of energy for the body. Lauric acid, a major component, is converted into monolaurin in the body, displaying antimicrobial properties. Additionally, coconut oil's potential benefits for heart health have garnered attention in nutritional research. Coconut oil is a favored cooking medium, especially in coastal regions where coconuts thrive. Its sweet aroma and flavor make it a popular choice for frying, sautéing, and baking. Coconut milk, another derivative, is used to prepare both savory and sweet dishes, contributing a rich and creamy texture (Sacks *et al*., 2020).

Fiber from Leafy Greens: Leafy vegetables such as fluted pumpkin (*Telfairia occidentalis*) are rich in dietary fiber. Fiber aids digestion, prevents constipation, and supports overall gut health. Leafy greens stand as nutritional powerhouses, contributing significantly to the health and well-being of individuals. Leafy greens are integral components of traditional Nigerian dishes, adding color, flavor, and, most importantly, essential nutrients to meals (Mogren *et al*., 2018). Among their many nutritional attributes, the role of leafy greens in providing dietary fiber cannot be overstated.

Fluted Pumpkin (*Telfairia occidentalis*): Commonly known as "Ugwu" in Igbo, fluted pumpkin is a leafy green vegetable cherished for its nutritional content. Aside from being a source of vitamins and minerals, fluted pumpkin leaves are rich in dietary fiber. This fiber contributes to digestive health by promoting regular bowel movements and preventing constipation (Adepoju and Aka, 2019). The fiber content in fluted pumpkin leaves aids in regulating bowel movements and preventing constipation. Additionally, dietary fiber promotes a feeling of fullness, which can be beneficial for weight management. The soluble fiber in fluted pumpkin may also contribute to lowering cholesterol levels, supporting cardiovascular health (Adetunde *et al*., 2020). Fluted pumpkin leaves are versatile in the kitchen, finding their way into soups, stews, and porridges. Whether incorporated into the iconic "Ugwu soup" or used to garnish other dishes, fluted pumpkin adds a nutritional punch to meals. The leaves can also be juiced to create a refreshing beverage (Adetunde *et al*., 2020).

Antioxidant-Rich Plants: In the quest for optimal health and well-being, the spotlight turns to nature's arsenal of antioxidant-rich plants found in Nigeria. These plants, laden with potent compounds, play a crucial role in combating oxidative stress, promoting cellular health, and fortifying the body against various ailments. Antioxidants, such as vitamins C and E, flavonoids, and polyphenols, act as defenders against oxidative stress—a process linked to aging, inflammation, and various chronic diseases (Hassan *et al*., 2022).

Hibiscus (*Hibiscus sabdariffa*): Hibiscus, locally known as Zobo, stands as a vibrant symbol of both cultural richness and nutritional prowess. The calyces of the hibiscus flower are a treasure trove of antioxidants, particularly anthocyanins and vitamin C. The infusion of dried hibiscus calyces into a refreshing beverage known as Zobo not only quenches thirst but also provides a burst of antioxidants. These antioxidants combat free radicals, contributing to cellular health and potentially reducing the risk of chronic diseases (El-Shiekh *et al*., 2020). The hibiscus plant's antioxidant content, coupled with its delightful taste, makes it a nutritional powerhouse in Nigeria. These vibrant pigments not only give the hibiscus calyces their rich hue but also offer potent antioxidant properties. Anthocyanins have been linked to improved cardiovascular health and reduced inflammation. As a well-known antioxidant, vitamin C plays a pivotal role in neutralizing free radicals and supporting the immune system. The hibiscus plant provides a natural source of this vital vitamin (Mejía *et al*., 2023).**:** Beyond its nutritional benefits, hibiscus holds a cherished place in Nigerian culinary and medicinal traditions. Zobo, the popular hibiscus beverage, is a staple in Nigerian households, especially during festive occasions. Its tangy flavor, coupled with its vibrant color, makes it a refreshing and visually appealing drink. In traditional medicine, hibiscus is often used to address various health concerns. Its antioxidant properties are believed to contribute to overall well-being, and the infusion is sometimes consumed for its potential blood pressure-lowering effects (Salami and Afolayan, 2020).

African Star Apple (*Chrysophyllum albidum*): The African Star Apple, commonly known as "Agbalumo" or "Udara," is a seasonal fruit that graces Nigerian markets with its unique flavor and nutritional benefits. The fruit is rich in vitamin C, a powerful antioxidant that scavenges free radicals, supports collagen formation, and enhances the immune system. The presence of antioxidants in the African Star Apple contributes to its potential role in promoting skin health and overall well-being. Rich in vitamin C, this fruit supports immune function and skin health. Consumed fresh or used in jams, this fruit is enjoyed during its seasonal availability (OnimawoI, 2020).

Soursop (*Annona muricata*): Known locally as "Ehuru" or "Graviola," the soursop plant boasts not only a distinctive taste but also a wealth of antioxidants. The fruit contains compounds like acetogenins, which exhibit antioxidant properties. Soursop is traditionally consumed as a fruit or in the form of teas, believed by some to contribute to overall health and well-being. Contains acetogenins, contributing to its antioxidant properties and potential health benefits. Beyond its culinary uses, soursop leaves are sometimes brewed into teas, believed to offer health benefits (Balderrama-Carmona *et al*., 2020).

Bitter Leaf (*Vernonia amygdalina*): Bitter leaf, a common vegetable in Nigerian cuisine, is not only valued for its slightly bitter taste but also for its nutritional properties. The leaves are rich in antioxidants, including flavonoids and polyphenols. Bitter leaf is often incorporated into soups and stews, contributing both flavor and antioxidant benefits to traditional dishes. Packed with flavonoids and polyphenols, bitter leaf enhances the antioxidant profile of local dishes. Integrated into soups and stews, bitter leaf is a staple in Nigerian cuisine, celebrated for its distinct taste and potential health contributions (Betty *et al*., 2021).

Conclusion: The nutritional potentials of Nigerian plants are vast and multifaceted. From protein-packed legumes to vitamin-rich leafy greens, these indigenous plants offer a treasure trove of health benefits. Recognizing, preserving, and promoting the consumption of these plants is not only crucial for individual well-being but also for the broader goal of achieving food security and promoting sustainable agriculture in Nigeria. Embracing the nutritional wisdom embedded in traditional practices is key to unlocking the full potential of Nigeria's plant-based riches. From protein-rich African yam beans and moringa to vitamin-packed African spinach and fluted pumpkin, and energy-rich cassava and plantain, each plant contributes to a holistic approach to well-being. The inclusion of healthy fats from shea butter, palm oil, and coconut, along with fiber-rich leafy greens like fluted pumpkin and waterleaf, adds depth to the nutritional narrative. The antioxidant-rich properties of hibiscus, African Star Apple, soursop, and bitter leaf stand as guardians against oxidative stress. This comprehensive overview underscores the potential of Nigerian plants not only as culinary delights but as allies in promoting health, longevity, and cultural richness.

Recommendations: Embracing the wealth of nutritional potential within Nigerian plants calls for a collective effort. Encouraging dietary diversification to include a spectrum of indigenous plants is essential for maximizing health benefits. Public awareness initiatives can enlighten communities about the nutritional richness of these plants, fostering a cultural shift towards healthier eating habits. Research and development investments will propel innovation, uncovering untapped nutritional treasures. Supporting sustainable agriculture ensures the longevity of these resources, safeguarding them for future generations. Culinary integration, blending traditional and modern recipes, caters to diverse tastes. Advocacy for government policies recognizing and supporting indigenous plant cultivation aligns with broader food security goals. Integrating nutritional knowledge into culinary education nurtures an appreciation for local ingredients, empowering chefs and home cooks alike. This collective embrace of the nutritional bounty within Nigerian plants promises a transformative journey towards a healthier, culturally rich society.

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Administration of *Bridelia ferugenea* (Benth) leaves extract regulates pro-inflammatory cytokines and DPP4 mRNA in hepatic tissue of diabetic model rats.

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Abstract

Diabetes mellitus is a metabolic disorder that is threatening the global health, it affects all systems in the body, including the liver. Bridelia ferruginea (Benth) leaves, bark and stem are traditionally used in Nigeria for the treatment of inflammation and diabetes mellitus. Although, the molecular mechanisms behind this effect are yet to be exclusively explored. This research hypothesized that antidiabetic action of Bridelia ferruginea leaves maybe by regulating the expression of proinflammatory cytokines which are interleukin-6(IL-6), interleukin-10 (IL-10), interleukin-1beta (IL-1 β), tumor necrosis factor alpha (TNFά) and inhibition of Dipeptidyl peptidase-4(DPP4) messenger RNA (mRNA) in liver. Diabetic was model using streptozotocin and animals were grouped and treated with extract of Bridelia ferruginea leaves and Metformin. Blood glucose and body weight were monitored after 21 days, animals were fasted overnight and sacrificed. Liver was perfused and harvested. Total RNA was extracted from the liver tissues using TRIzol reagent. The resulting PCR amplicons were subjected to 1% agarose gel electrophoresis. Snapshots revealing the relative density of DNA bands were taken. Diabetic caused a significant increase in the expression of all the proinflammatory and DPP4 genes in the liver compared to control but oral administration of BF significantly suppress the expression compared to diabetic control especially at 100mg/kg body weight. The observed results showed a good and promising drug candidate with anti-inflammatory, antioxidant and antidiabetic action.

Keywords: medicinal plant, diabetes, cytokines, proinflammation, DPP4, Bridelia ferruginea

Background: Diabetes mellitus (DM) is a group of chronic metabolic disorder indicated by an elevated level of blood sugar over an extended period. Symptoms of high blood sugar include urgent urination, polydipsia, and polyphagia. (WHO, 1999) Serious long-term complication includes cardiovascular disease, stroke, chronic liver disease, foot ulcers, and damage to the eye. (WHO, 1999)**.** The liver plays an important part in regulating glucose metabolism since it reserves glycogen in the fed state and produces glucose through the biochemical breakdown of this glycogen under the regulation of phosphorylase kinase and glycogen phosphorylase and produce glucose from lipid and protein in the post absorptive phase. In physiological conditions, hepatocytes are the main site of hepatic glucose metabolism; however, a small, but significant, role in insulin metabolism is played by non-parenchymal liver cells that contribute to insulin degradation and are involved in the modulation of hepatocyte glucose metabolism during inflammatory processes via the release of cytokines (Manna et al. 2010). This is followed by derangement of protein, carbohydrate and lipid metabolism, thus leading to increased oxidative stress and further eliciting the inflammatory cascade, which further contribute to agglomeration of excessive fat cells in the liver which will lead to fatty liver and, resulting to, Non-Alcoholic fatty liver disease in certain cases (Elekofehinti et al.2021)

Previous studies have shown that proinflammatory cytokines (Il-1, Il-2, and TNF- α) play a pivotal role in the pathogenesis of autoimmunity and β-cell damage and the therapeutic relevance of GLP-1 is currently well established since enhancement of the half-life of GLP-1 upon treatment with dipeptidyl peptidase 4 inhibitors (DPP4i) or activation of the GLP-1 receptor by exendin-4 derivatives have been proven efficacious in the treatment of type 2 diabetes (Ejelonu et al. 2021). Therefore, the direct stimulation of intestinal GLP-1 release by DPP4 inhibition could constitute another promising GLP-1-based therapeutic approach for the treatment of metabolic diseases. (Ejelonu et al. 2021). Medicinal plants have long been used for therapeutic purposes, and plant metabolites and their derivatives have provided us with a high proportion of today's successful pharmaceuticals (Akinmoladun et al. 2010) Despite the prominent use of *Bridelia ferruginea* (Euphorbiaceae) as a local herb, serious scientific proof on its medicinal capabilities is still rare and sporadic (Odetola et al. 2006; Hamid et al. 2013). Consequently, more research, scientific explanation and persistent verification are needed to flag its significance in the treatment of diabetes and other associate metabolic conditions.

MethodsPlant collection and preparation of extract: Fresh leaves of *Bridelia ferruginea* were collected from the horticulture garden of the Federal University of Technology Akure. The leaves were washed thoroughly with distilled water and air dried at room temperature (28 ± 3 ◦C). The dried leaves were pulverized into fine powder using an analytically clean blender and extracted according to Ejelonu et al., 2017 method.

Table 1: Reverse transcription-polymerase chain reaction primer sequences.

Genes		Sequence (5′-3′)
IL-6	Forward	TCCTACCCCAACTTCCAATGCTC
	Reverse	TTGGATGGTCTTGGTCCTTAGCC
IL-1β	Forward	CACCTCTCAAGCAGAGCACAG
	Reverse	GAGAGAAGCTGAAGACCCTCTG
	Forward	TCATTCATGGCCTTGTAGACAC
IL-10	Reverse	GCAAGACGTGGGTAATGATG
DPP-4	Forward	AGCCTGGTTGGGTTTGTATG
	Reverse	GGGTTCCATGGTGAAGTCAAC
TNF-α	Forward	AAATGGGCTCCCTCTCATCAGTTC
	Reverse	TCTGCTTGGTGGTTTGCTACGAC
β-actin	**Forward**	**TCA CCC ACA CTG TGC CCC ATC TAC GA**
	Reverse	**CAG CGG AAC CGC TCA TTG CCA ATG G**

Animals : A total of 48 wistar rats of average weight 178 ± 29g were procured and kept in galvanized cages at room temperature in the animal house of biochemistry program Olusegun Agagu university of Science and Technology Okitipupa, Nigeria. The rats had free access to normal rat chow and water ad libitum on a 12 h light/12 h dark cycle. They were handled and used in accordance with the National Institute of Health (NIH) Guidelines for the Care and Use of Laboratory Animals. The rats were grouped and administered with B. *ferruginea* using an oral gavage needle for twenty one (21) days and during the treatment period, the FBG levels of all rats were measured seven days interval. Blood samples were collected from each rat's tail vein, and FBG were measured using Accu check glucometer. The animals were sacrificed by anaesthetization and Liver removed into trizol solution and stored at -20 ◦C till analysis period.

RNA isolation and reverse transcriptase polymerase chain reaction (RT-PCR) : Total RNA was extracted from the liver tissues using TRIzol reagent (Thermofisher Scientific) according to the manufacturer's instruction.

Statistical analysis: The results are expressed as mean ± SD. Statistical evaluation was carried out using ANOVA followed by Dunnett's test between the groups. Differences were considered significant at $p < 0.05$ and highly significant at $p < 0.01$.

Results

Table 2 Effect of oral administration of methanolic extract of *B. ferruginea* on the body weight of the experimental rats per group.

Test groups	Before treatment	7th day After treatment	14th day	21st day
Control	176±0.36	177±0.31	179±0.42	181±0.34
Metformin treated	207±5.90	187±5.30	189±30.42	190±0.39
Diabetic control	192±1.83	170±2.42	166±1.75	142±12.62
Bf 100mg/kg bw	186±5.9	162±2.12	165±2.87	173±60.151
Bf 200mg/kg bw	190±1.08	159±7.66	163±27.34	183±13.40
Bf 500mg/kg bw	177±0.92	151±2.40	155±10.31	169±2.87

*Bf= *Bridelia ferruginea,* bw= body weight, n= 8 = means ± SD

Table 3 Effect of oral administration of methanolic extract of *Bridelia ferruginea* leaves on the fasting blood glucose (mg/dl) of the experimental rats per group.

Test groups	Before treatment	1st day After treatment	7th day	14th day	21st day
Control	98.17±5.95	106±7.24	116±11.15	96±10.30	99±5.95
Metformin treated	90.66±1.16	395±21.20	312±10.10	233±60.10	193±14.75
Diabetic control	92.50±2.20	363±20.43	366±3.46	357±16.30	350±30.29
Bf 100mg/kg bw	95.33±3.71	360±33.91	282±74.12	217±60.22	119±26.55
Bf 200mg/kg bw	101.50±4.52	395±33.51	296±16.10	225±11.20	201±22.51
Bf 500mg/kg bw	97.16±3.63	402±18.79	326±11.10	272±80.10	211±26.90

*Bf= *Bridelia ferruginea;* bw = body weight; FBG in mg/dl, n= 8 = means ± SD

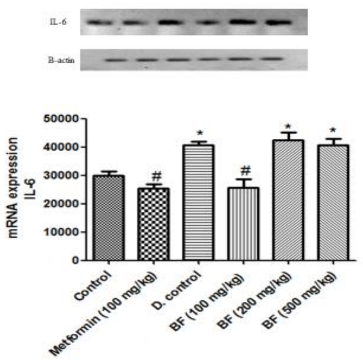

Fig. 1 mRNA expression of IL-6 from the hepatic tissues of control and STZ model diabetic rats treated with *Bf* and metformin. *

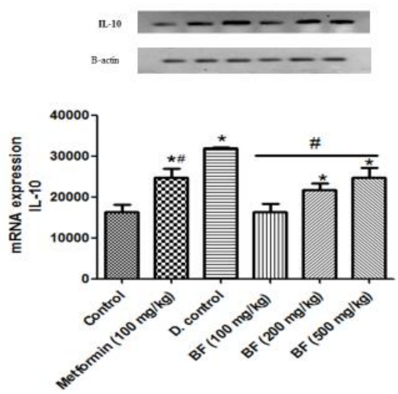

Fig. 2 mRNA expression of IL-10 from the hepatic tissues of control and STZ model diabetic rats treated with *Bf* and metformin

. * Indicate statistical difference (P<0.05) to control while # indicate statistical difference (P<0.05) to diabetic control

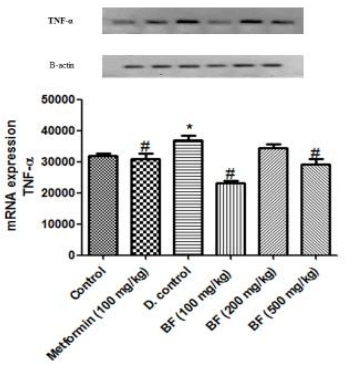

Fig. 3 mRNA expression of TNF-ά from the hepatic tissues of control and STZ model diabetic rats treated with *Bf* and metformin

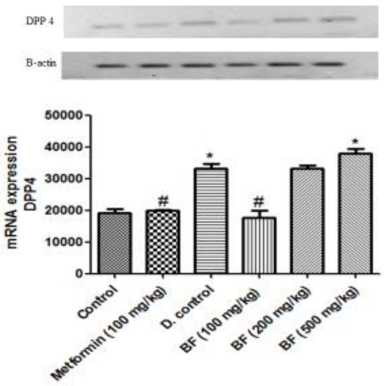

Fig. 4 mRNA expression of DPP4 from the hepatic tissues of control and STZ model diabetic rats treated with Bf and metformin.

* Indicate statistical difference (P<0.05) to control while # indicate statistical difference (P<0.05) to diabetic control. Values are expressed as means ± SD.

Discussion

This study discovered the postulate that methanolic extract of *Bridelia ferugenea* leaves suppressed messenger RNA (mRNA) expression of proinflammatory cytokines, prevent fatty liver, and inhibit DPP4 mRNA expression in the rats with type 2 diabetes induced by streptozotocin. Although previously, several studies that have been carried out already shows the antidiabetic effect of *Bridelia ferugenea* leaves in animal models but none of the research studies investigate clearly these mechanisms of *Bridelia ferugenea* leaves in respect to diabetes.

Effect of oral administration of methanolic extract of *Bridelia ferruginea* on the fasting blood glucose of STZ diabetic model albino rats Table 3 showed that diabetic control rat exhibited significantly ($P < 0.05$) increase in the level of blood glucose on day 7, 14 and 21 compared to normal control rats. The STZ diabetic model rat treated with 100, 200 and 500 mg/bw of *Bridelia ferruginea* showed significant ($P < 0.05$) weekly dependent decrease in the level of blood glucose on day 7, 14 and 21 compared to diabetic control. This result shows that *Bridelia ferruginea* leave has anti-hyperglycemic effect as earlier reported by Oyebode and her research team (Oyebode et al. 2020).

The role of dipeptidyl peptidase-IV (DPP4) as both a regulatory enzyme and a signaling factor has been examined and illustrated in many studies. DPP4 inhibition results in increased blood concentration of the incretin hormones glucagon-like peptide-1 (GLP-1) and gastric inhibitory polypeptide (GIP). (WHO, 1999). This causes an increase in glucose-dependent stimulation of insulin secretion, resulting in a reduction of blood glucose levels (Camilleri et al.2015). In figure 6 there is a substantial difference in DPP4 mRNA expression of BF 100mg/kg body weight compared to diabetic control. The dosage 100mg/kg inhibit the expression of DPP4 mRNA compared to diabetic control and there is no significant difference between this dosage (100mg) and metformin (100mg). This agrees with our previous study and other studies that DPP4 inhibitors activate TGR5 and causes GLP1 secretion thereby leading to insulin release (Ejelonu et al. 2021). Studies has also shown that DPP4 inhibitors represent a very low threat of hypoglycemia development.

An adipocyte derived cytokine which is tumor Necrosis Factor -ά (TNF-ά) plays a key role in type 2 diabetes. TNF- ά blights insulin signaling by impeding the function of Insulin receptor substrate 1 (IRS-1) through serine phosphorylation (Ghanim et al. 2001). Fig. 5 shows mRNA expression of TNF -alpha, BF dosage 100mg/kg bw and 500mg/kg bw significantly suppresses the expression of TNF alpha compared to diabetic control in the hepatocyte of streptozotocin model diabetic rats. Excess production of TNF-ά in the hepatic has been suggested to carry a pivotal part in the morbidity of fatty liver disease (Ghanim et al. 2001). This implies that BF at 100mg/kg body weight concentration and concentration of 500mg/kg body weight compete favorably with metformin 100mg/kg body weight to prevent fatty liver diseases and type 2 diabetes by inhibition of TNF production in the liver. The response of hepatic IL-6 and TNF-alpha mRNA to the treatment of BF in this experiment is an indication that BF is a promising remedy to Treatment of type2diabetes and its associated fatty liver diseases. The proposal by Budavari et al 1996 that the insulin resistance syndrome could be an inflammatory disorder appears particularly relevant.as shown in the mRNA expression of all the proinflammatory genes (IL-1β) , (IL-10) , TNF-ά, (IL-6) response to induction of diabetes by STZ. The treatment with 100mg /kg body weight in all the expression remains constantly significantly different compared to diabetic control. In conclusion, there have been folkloric use of Bridelia ferruginea leaves from time immemorial in treating fever, inflammation and diabetes although concern exist about dosage and mechanism of action. The antidiabetic aftermath of BF was authenticated by the repression of proinflammatory cytokine mRNA expression and by suppressing the expression of DPP4 in STZ diabetic model rats

Conclusion: These findings indicate that *BF* methanolic extract have anti-hyperglycemic and anti-inflammatory effect and is worth applying to human clinical trials although other indices should be measured.

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Quality Assessments of Potato-Based Drinks from Different Varieties of Potatoes

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Abstract

The study was aimed at investigating the physicochemical, microbial and consumer acceptability properties of drinks produced from three cultivars of potatoes (orange-fleshed sweet potato, Irish potato and sweet potato). The physicochemical study shows the pH (6.05 - 6.65), total soluble solid (2.00-4.80), total solids (9.50 - 10.75), and total titratable acidity (0.04 - 0.08) of the potato - based drinks. The result of proximate composition of the potato - based drinks include; moisture (89.25 - 92.09%), fat (0.58 - 0.89%), ash (0.85 - 1.01%), crude fiber (0.75 - 1.03%), protein (1.57 - 2.65%), protein, and carbohydrates (4.39 - 5.37%) respectively. Mineral content of the potato- based drinks were high with potassium (293.90 -347.95 mg/kg), sodium (210.40 -225.85 mg/kg) and calcium (53.95 -81.95 mg/kg). Sensory evaluation results showed that IPD was the most generally acceptable among the potato-based drink

Introduction: One of the world's most significant food crops is potato, a starchy root vegetable. Due to their high nutrient content, potatoes are popular food crop around the world and are known to offer various health benefits. They have been connected to a lower risk of chronic diseases like cancer, diabetes, and heart disease and are an excellent source of vitamins, minerals, and dietary fiber. Depending on the variety, the tubers that develop on the potato plant's roots below ground might have different sizes [1-3]. One of the most popularly grown and eaten vegetables worldwide, potatoes are a significant source of fiber, vitamins, minerals, and carbs for diet [3]. Additionally, potatoes contain wealth of bioactive components, including glycoalkaloids, carotenoids, and phenolic compounds, which have been demonstrated to have anti-inflammatory, anti-cancer, antioxidant, and anti-diabetic effects [4,3]. Carbohydrates, dietary fiber, vitamins, and minerals like iron, potassium, and vitamin C are all abundant in potatoes. They are used in many different meals around the world, including as soups, stews, casseroles, and salads. They can be prepared in a variety of methods, such as boiling, baking, frying, mashing, or roasting [5-6]. A type of sweet potato known as orange flesh sweet potato (OFSP) gets its orange hue from high beta-carotene content, which is a precursor to vitamin A. In some other places, it is also referred to as "kumara" or "yellow sweet potato" [7]. In addition to being delicious, this kind of sweet potato is also very nutrient-dense, serving as a great source of dietary fiber, vitamin A, and other vital micronutrients [7]. Research has indicated that eating orange sweet potatoes may improve blood sugar regulation, lower inflammation, and strengthen the immune system, among other health advantages [8].A common root vegetable in many regions of the world, Irish potatoes (*Solanum tuberosum*) are sometimes referred to as white potatoes or just potatoes. They are an excellent source of dietary fiber, vitamin C, potassium, and vitamin B6 in addition to complex carbohydrates and other vitamins and minerals [9]. Irish potatoes are utilized in many different recipes, such as potato salad, mashed potatoes, French fries, and chips. They can be boiled, baked, roasted, or fried. They are often used as a thickener in soups and stews [9]. One kind of root vegetable that are well-known for its soft texture and sweet flavor are sweet potatoes (*Ipomoea batatas*). They are great source of vitamins, minerals, dietary fiber, and complex carbs [10]. Sweet potatoes are versatile item that may be utilized in a range of dishes in addition to their nutritional worth. They are frequently used in savory and sweet recipes like pies, casseroles, and soups. A number of studies have indicated that sweet potatoes may offer a number of health advantages, including bettering gastrointestinal health, lowering inflammation, and controlling blood sugar [10]. Drinks are beverages that are closely associated with a specific region or culture. They frequently capture the customs, tastes, and ingredients of the region. Drinks can be both classic and contemporary concoctions, and they can be alcoholic or non-alcoholic [11]. Drinks are promoted with benefits such as good heart health, improved immunity, digestion, healthy joints, satiety and energy boosting [12]. Consumers' demands have changed considerably with the realization that foods and drinks contribute directly to good health. Therefore this aim of this study is to evaluate quality assessments of potato-based drinks from different varieties of potatoes.

Materials and Methods: Acquisition of Materials: Orange flesh sweet potatoes were purchased from the international potato demonstration farm, Iloko Ijesa, Osun State, Nigeria. Sweet and Irish potatoes were purchased from Ikole central market, Ikole, Ekiti State and Okitipupa market, Okitipupa, Ondo State, Nigeria respectively.

Preparation of Potato - Based Drinks: Potato - based drinks were prepared using a modified method of [13] with minor modification. Freshly harvested potato tubers were sorted to remove decayed, rotten and bruised parts washed in clean water to remove surface adhering dirts, peeled and cut into smaller sizes, the drinks were then extracted by means of a juicer and filtered with a muslin cloth to obtain a smooth and uniform drinks. The filtered potato-based drinks were packaged in sterilized plastic bottles, pasteurized in a water bath at 72 °C for 15 mins and allow to cool to a temperature of 43 °C.

Determination of Physicochemical Properties of Potato - Based Drinks: The total dissolved solids (TSS) and pH were measured using the [14] technique. Using the [15] approach, the total solid and total titratable acidity (TTA) were determined.

Proximate Composition of the Potato - Based Drinks: The proximate composition of the potato - based drinks were determined according to method of [16].

Determination of Mineral Composition of the Potato - Based Drinks: The standard method described by Association of Official Analytical Chemists was used for mineral composition of the samples [15].

Determination of Sensory Evaluation of Potato -Based Drinks: The potato - based drinks samples were subjected to sensory evaluation within 24 hours of preparation using thirty untrained panelists consisting of members who are familiar with malt drink. The judges scored the samples for colour, taste, mouth feel, flavour and overall acceptability using a 9-point hedonic scale ranging from 1 = dislike extremely and 9 = like extremely [18].

Data Analysis : Statistical analysis Data were subjected to analysis of variance using SPSS (IBM version. 20.0, SPSS Inc., Quarry Bay, Hong Kong) and presented as means (± SEM). Comparisons between different groups was done using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT). Values of $p < 0.05$ were considered as statistically significant.

Results and Discussion: Physichochemical properties of Potato - Based rinks: The physicochemical properties of the potato - based drinks are presented in Table 1. The results revealed that the pH values of different varieties of potato- based drinks vary from 6.05% in IPD to 6.65% in SPD. The acid level observed from the potato drink varieties will help to inhabit the growth of microorganisms [19]. The pH value recorded in this study is greater than the value of 2.85% to 4.81% reported by [20] in zobo drink. The total titratable acidity content values ranged from 0.04%(SPD) to 0.08% (IPD). The value (0.04% - 0.08%) of total titratable acidity recorded in this study was below 1.71% obtained in yoghurt sold Katsina Sate, Nigeria [21]. The total soluble solids (%brix) ranged from 2.00% (IPD) to 4.80%(OFSPD). The total soluble solids (2.00% brix - 4.80% brix) of potato- based observed in this study falls between 3.0-15.0 4.80% brix reported for powdered kunu zaki by [22].Total solids ranged from 7.91% in IPD to 10.75% in SPD. Significant difference existed among the samples. The total solids are used in characterizing the quality of drink and other beverage products [23-24].

Table 1. Physicochemical Properties of Potato - Based Drinks

Samples	OFSPD	IPD	SPD
pH	6.10±0.28 ^{a}	6.05±0.07^{a}	6.65±0.21 ^{a}
Total soluble solids (brix)	4.80±0.00 ^{c}	2.00±0.00 ^{a}	3.10±0.14 ^{b}
Total solids (%)	9.50±0.67 ^{ab}	7.91±0.38 ^{a}	10.75±0.94 ^{b}
Total titratable acidity (%)	0.07±0.01 ^{ab}	0.08±0.01 ^{b}	0.04±0.01 ^{a}

Means of triplicate determinations ± S.D. Means with different superscripts on the same row are significantly different at p≤0.05
Orange Flesh Sweet Potatoes Drink = OFSPD, Irish Potatoes Drink = IPD, Sweet Potatoes Drink = SDP

Proximate composition of the Potato - Based Drinks: The proximate composition of the potato - based drinks is shown in Table 2. The moisture content of the potato - based drink samples ranged from 89.25 in SPD to 92.09% in IPD with a significant difference.. The moisture of the potato - based drinks samples were found to be high and this makes them good sources of fluid to the body when consumed [25]. This observation is similar to [26] who reported high moisture contents from zobo drink with values of 8.24%. Ash is an inorganic residue in any food substance, which directly denotes the mineral content. The ash content of potato drinks (0.85% - 1.01%) reported in this study is similar to (0.775%) in tigernut drink as reported by . Ash plays crucial role in the body by maintaining fluid balance and nerve function. The percentage fat content (0.58% -0.89%) of the three varieties of potato drinks were similar to (0.87%) reported by [26] for zobo drinks. The moisture content has an inverse relationship with the total solid content of the potato drink. The crude fat ranged from ranged from 0.58 in OFSPD to 0.89% in SPD. This result showed that the potatoes drink contains only the trace amount of fat. The fibre contents of the potato drink were significantly (p≤0.05) lower than 5.10% previously reported for orange [27]. The consumption of food with adequate dietary fibre has been linked with the reduced risk of obesity, diabetes and coronary heart diseases [28] The result showed gradual increase in total carbohydrate from 4.39 in IPD to 5.19% in SPD. The increase in total carbohydrate content of the potato drink might be due to the involvement of simple sugars in maillard reaction to form melanoidins during heating process or due to due to the differences in varieties of cultivars.

Table 2: Proximate composition (%) of potato - based drinks

SAMPLES	OFSPD	IPD	SPD
MOISTURE CONTENT	90.50±0.66^{ab}	92.09±0.38 ^{b}	89.25±0.94 ^{a}
CRUDE FAT	0.58±0.03 ^{a}	0.60±0.14 ^{a}	0.89±0.13 ^{b}
ASH	0.99±0.11 ^{a}	0.85±0.05 ^{a}	1.01±0.13 ^{a}
CRUDE FIBRE	0.99±0.01 ^{a}	0.75±0.35 ^{a}	1.03±0.04 ^{a}
CRUDE PROTEIN	1.59±0.76 ^{a}	1.57±0.05 ^{a}	2.65±0.08 ^{a}
CARBOHYDRATE	5.37±0.24 ^{a}	4.39±1.12 ^{a}	5.19±0.72 ^{a}
ENERGY VALUE (KCAL/100ML)	33.06±0.02^{b}	29.24±0.03^{c}	39.37±0.05^{a}

Means of triplicate determinations ± S.D. Means with different superscripts on the same row are significantly different at p≤0.05
Orange Flesh Sweet Potato Drink = OPD, Irish Potato Drink = IPD, Sweet Potato Drink = SDP

Mineral composition of the potato - based drinks: The mineral composition of the potato drinks is shown in Table 3. Micronutrients are essential nutrients present in smaller amounts. The sodium content ranged from 215.20 in OFSPD to 225.85 mg/kg in SPD with significant difference exiting between them. Sodium is found naturally in foods, but a lot of it is added during processing and preparation. Potassium and sodium are responsible for maintenance of body fluid, regulation of body pH, muscle and nerve signals. The potassium content ranged from 293.90 in IPD to 347.95 mg/kg in SPD. There was no significant difference at $p < 0.05$ among the samples. Potassium is an essential mineral that is needed by all tissues in the body. It is sometimes referred to as an electrolyte because it carries a small electrical charge that activates various cell and nerve functions. Calcium content ranged from 26.35 in OFSPD to 28.95 mg/kg SPD. Calcium is essential for proper bone and teeth formation [28]. Calcium helps in the regulation of muscle contractions and transmission of nerve impulses as well as bone and teeth development [29]. The high calcium content of the potato drink observed in this study is an indication that the drink will promote bone development and strong teeth in children. Calcium is crucial in promoting the deposition of hydroxyapatite in bone and serves the mechanical roles of strengthening bones and teeth, it supports the functions of excitable tissues, including nerves and heart muscles, as well as blood clotting. The result showed that the magnesium content ranged from 53.95 in OFSPD to 81.95 mg/kg in SPD with significant difference exiting between them. After potassium, sodium, and calcium, magnesium is the fourth most prevalent mineral in the human body and the second most frequent intracellular cation More than 300 enzyme systems in the body, including those that control blood glucose levels, blood pressure, muscle and nerve function, and protein synthesis, depend on magnesium as a cofactor. The iron content ranged from 7.12 in OFSPD to 10.05 mg/kg in SPD. Iron is an essential mineral element for boosting immunity and prevention of anaemia [30]. Iron is a mineral essential for life and for our diets. Deficiency of iron in the body could result into anaemia. It is well recognized that consuming enough iron in the diet is crucial to lowering the prevalence of anemia. When there is a strong demand for iron and the intake is either quantitatively insufficient or contains substances that prevent the iron from being absorbed, iron insufficiency results [31]. The sodium:potassium ratio (Na/K) of the potato-drinks are in the order 0.72>0.65>0.62 for Irish potato, orange fleshed sweet potato and sweet potato drinks, respectively. Significant differences existed between the Na/K of Irish potato drink and others. The sodium-to-potassium ratio in the diet has been identified as having promising promise in the regulation of blood pressure. [32]. As proposed by [33], if the Na/K ratio of a food value is less than one, it is also very important for the prevention of high blood pressure. Lower sodium and higher potassium intake is helpful in the control of blood pressure in hypertensive people. Due to the observed Na/K molar ratio of the potato-based drinks in this study, consumption of these drinks would help to avoid hypertension and may lower blood pressure.

Table 3: Mineral Composition (mg/kg) of the Potato - Based Drinks

SAMPLES	OFSPD	IPD	SPD
NA	215.20 ± 0.28^{b}	210.40 ± 0.14^{c}	225.85 ± 0.49^{a}
K	323.45 ± 0.50^{c}	293.90 ± 70.43^{b}	347.95 ± 0.64^{a}
CA	26.35 ± 0.21^{b}	22.30 ± 0.42^{a}	28.95 ± 0.21^{a}
MG	53.95 ± 0.63^{a}	76.45 ± 0.07^{b}	81.95 ± 0.07^{a}
FE	7.12 ± 0.07^{b}	5.09 ± 0.00^{c}	10.05 ± 0.07^{a}
NA/K	0.67 ± 0.02^{b}	0.72 ± 0.03^{a}	0.65 ± 0.02^{b}

Means of triplicate determinations ± S.D. Means with different superscripts on the same row are significantly different at $p\leq0.05$

Orange Flesh Sweet Potato Drink = OPD, Irish Potato Drink = IPD, Sweet Potato Drink = SDP

Sensory Acceptability of the Potato - Based Drinks: The colour, taste, mouth feel, flavour, and general acceptability ranges from 6.67 to 6.13, 6.10 to 6.13, 5.27 to 5.50, 5.30 to 5.87, 5.50 to 6.23 and 5.70 6.10 respectively with no significant difference at ($p < 0.5$) among the samples (Table 4). Regarding color, OFSPD had the best score (6.67) and IPD received the lowest score (6.10). The panelists' response to the color determined the appearance. Maillard-type reactions may have been brought on by the presence of reducing sugars, proteins, and amino acids as well as the effect of high processing temperatures on quality qualities and the brown coloration in the potato drink [34]. Regarding the sensory evaluations of flavor of the potato drink samples, comparable patterns were noted; OFSPD received the highest ratings (6.23), followed by SPD (5.93) and IPD (5.93). With overall acceptability scores of 6.07 and 6.10, respectively, OFSPD and SPD scored the highest.

Table 4: Sensory evaluation of Potato - Based Drinks

SAMPLES	OFSPD	IPD	SPD
COLOUR	6.67 ± 1.58^{a}	6.10 ± 2.40^{a}	6.13 ± 1.71^{a}
TASTE	5.50 ± 1.22^{a}	5.27 ± 1.91^{a}	5.43 ± 1.27^{a}
MOUTH FEEL	5.87 ± 1.50^{a}	5.67 ± 2.03^{a}	5.30 ± 1.47^{a}
FLAVOUR	6.23 ± 1.38^{a}	5.50 ± 2.17^{a}	5.93 ± 1.34^{a}
GENERAL ACCEPTABILITY	6.07 ± 1.28^{a}	5.70 ± 1.93^{a}	6.10 ± 1.32^{a}

Means of triplicate determinations ± S.D. Means with different superscripts on the same row are significantly different at $p\leq0.05$

Orange Flesh Sweet Potato Drink = OFSPD, Irish Potato Drink = IPD, Sweet Potato Drink = SDP

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Evaluation of Pineapple (*Ananas comosus*) Peels as Phytogenic Feed Additives in the Diet of Juveniles *Clarias gariepinus*

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Abstract

The study investigated the potential of Pineapple Peel (PPL) on morphometric characteristics and intestinal morphology of Clarias gariepinus fingerlings. The experimental diet of composed control (0%), PPL_2 (0.5%), PPL_3 (1.0%), PPL_4 (2%), PPL_5 (3%), and Oxytetracycline (OXYL 30 mg/kg). Two hundred and twenty C. gariepinus fingerlings (4.80±0.02g) were randomly assigned to six treatment diets in a completely randomized design for 56 days. Clarias gariepinus fingerlings were replicated twice with 20 fish per replicate and were fed twice daily at 3% body biomass. Phytochemical screening of pineapple peel and core, morphometric characteristics and intestinal morphology were measured using standard procedures. Data were analyzed using descriptive statistics and ANOVA at P=0.05. The result of the phytochemical screening of pineapple peel and core revealed the presence of saponins, tannins, triterpenes and steroids, phenols, and flavonoids and proteins and amino acid. The result of the morphometric characteristic revealed that there was a general increase in the values of total length, standard length, dorsal width, and head length of C. gariepinus fingerlings as the week of the feeding trial increases and the treated groups perform better than the control group. The results of intestinal morphology showed a better performance in the treated groups compared to the control, there were significantly different (P<0.05) among the dietary groups. The results suggest that inclusion of pineapple peel and core in the diet of C. gariepinus fingerlings could be a promising dietary phytogenic feed additives that would positively enhance physiology and productivity of C. gariepinus in aquaculture.

Keyword: *Clarias gariepinus, pineapple meal, Haemaotology, Oxyl-tetracycline.*

Introduction: Fisheries and aquaculture products are globally important sources of much needed, high quality, aquatic animal proteins, and providers of employment, income, and foreign exchange. About 950 million people worldwide, depend on fisheries and aquaculture, directly or indirectly for their livelihoods. Globally, the consumption of fish and fishery products as a protein source has increased considerably over the years constituting about 20% of total protein (FAO, 2006). Fisheries are also globally important source of employment for about 200 million people who depend directly upon ocean fishing for their livelihoods (FAO, 2006). With the population of Nigeria on the rise, there is a corresponding demand for fish consumption. Thus, there is a need for a suitable method to enhance fish growth and health to meet the increasing demand for food (Olusola and Olaifa, 2018). Asides application of synthetic growth promoter, medicinal plants could be used as alternatives to synthetic which could enhance growth and health of fish. Natural alternatives such as the inclusion of plant materials in fish feed formulation do not only have antimicrobial potential but also have been found to have other properties such as digestive stimulant, anti-inflammatory, antioxidant and anti-carcinogenic (Olusola *et al*., 2013; Olusola and Olaifa, 2018),

Pineapple is a perennial plant of the family Bromeliaceae and its edible fruit. Pineapple is native to tropical and subtropical America and has been introduced elsewhere. The fruit has become a characteristic ingredient in the meat, vegetable, fish, and rice dishes of what is loosely termed Pan-Asian cuisine. The fruit is eaten fresh where available and in canned form worldwide. The plant has 30 to 40 stiff succulent leaves closely spaced in a rosette on a thick fleshy stem. The originally separate light purple flowers, together with their bracts, each attached to a central axis core, become fleshy and fuse to form the pineapple fruit, which ripens five to six months after flowering begins. Fruits of commercial varieties range from 1 to 2 kg (2 to 4 pounds) in weight. But there is little or no record of the utilization of pineapple peels on the physiology of *C. gariepinus*. This study was evaluated to assess the efficacy of pineapple peels on morphometric characteristics and intestinal morphology of *Clarias gariepinus* fingerlings.

Materials and Methods: Collection, identification and preparation of plant material: Pineapple was bought in Okitipupa and Ijebu Imushin and was identified at the Department of Biological Sciences (Botany Programme), Olusegun Agagu University of Science and Technology, Okitipupa were a voucher specimen for future references. The pineapple was manually cut to obtained the peel. Thereafter, the peel obtained were chopped into small pieces and was air dried for six weeks, ground into fine particles and was stored in an airtight container until required.

Experimental system, procedure and feeding trials: The experiment was carried out in twelve plastic experimental tanks (50 x 34 x 27cm) for 8 weeks in the Fisheries and Aquaculture Laboratory of Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State. The water level was maintained at volume of 40 litres throughout the experimental period. Water in each tank was replaced every three (3) days throughout the period of the experiment to maintain relatively uniform physiochemical parameters, and also to prevent fouling of the result from feed residues. The source of water was from Olusegun Agagu University of Science and Technology, Okitipupa (OAUSTECH) borehole. The fish was acclimated for seven days in plastic tanks before the experiment. after acclimatization, the fish were weighed and randomly distributed into 12 experimental tanks. Each treatment has two replicates, 20 *C. gariepinus* fingerlings per replicate with mean initial weight of 4.80g and uniform – sized fish was selected from 280 fingerlings. The experiment last for 56 days during which the fish was fed at 3% body weight daily. The diet per day was divided into two; 1.5% given in the morning by 8:00 – 9:00 am and 1.5% in the evening by 5:00 pm. Measurement of the weight changes was performed every two weeks and the fish feed were adjusted to the new body weight

Formulation and preparation of experimental diet : Six experimental diets were formulated at 40% crude protein, 7% moisture, 12% crude fibre, 18% ash, 8% ether extract, and 15% nitrogen-free extract diets using Pearson's square method to determine individual ingredient contribution at g/100g diet. Each ingredient such as fish meal, soybean, cashew nut, maize, barley malt, vitamin mineral premix, starch, vegetable oil, Di - calcium phosphate was weighed using sensitive weighing balance. Pineapple peel and cores were incorporated at different inclusion levels of 0%, 0.5%, 1%, 2%, 3% and oxytetracycline (30 mg/kg) was used as positive control. The dry ingredients were mixed thoroughly using manual method. Pineapple peel were added as feed additives in the study as a partial replacement for vitamin – mineral premix. Each diet was treated separately, water was added and the resulting dough was extruded/pelleted through a 2 mm fabricated pelleting machine to form a noodles like strand which was manually broken into suitable sizes for the *C. gariepinus* fingerlings. The pelleted diets were sundried for four days and stored in air – tight nylon at a room temperature to prevent mycotoxin formation until required.

Morphometric Indices of *C. gariepinus* fingerlings

Total Length (TL), Standard Length (SL), Head Length (HL), Dorsal Width (DW) and Height (H) were measured as shown in plate 1.

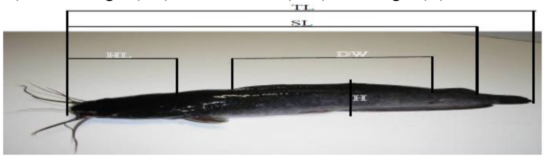

Plate 1: Morphometric characteristics of *C. gariepinus juveniles*

Phytochemical screening of pineapple peel: The pineapple peel was analyzed for phenols, glucosinolates, flavonoids, saponins, tannins, triterpenes and steroids and protein and amino acids as described Olusola *et al.*, (2019) and Fakoya *et al.*, (2019)

Statistical analysis: Morphometric indices and intestinal morphology resulting from the experiment were subjected to one-way analysis of variance (ANOVA) using SPSS (Statistical Package for Social 2006 version 20.0). Duncan multiple range test was used to compare differences among individual mean at p= 0.05

Results : Phytochemical screening of pineapple peel: The result of phytochemical screening of pineapple peel revealed the presence of saponins, phenols, flavonoids, glucosinolates, tannins, triterpenes and steroids, and proteins and amino acids which occurred in different concentrations. Saponins and tannins were observed in low quantity while proteins and amino acids, phenols, flavonoids, glucose and tripenenes and steroids were observed in moderate quantity. The different phytochemical component present in each plants were recorded and their level of metabolites concentrations was recorded as detected in low amount (+) and detected in moderate amount (++) and not detected (-).

Table 2: Result of Phytochemical Parameters present in Pineapple peel

Phytochemical	*Anonas comosus*
Protein and Amino acid	++
Saponins	+
Phenols	++
Tannins	+
Flavonoids	++
Glucosinolates	++
Tripenenes and steroids	++

Morphometric indices of *Clarias gariepinus* fed with the experimental diet for 56 days

There was general increase in the values of total length, standard length, dorsal width, and head length *of C. gariepinus*. There was fluctuation in the total length, standard length and dorsal length of the fish among the dietary groups

Table 3: Morphometric indices of *Clarias gariepinus* fed with the experimental diet for 56 days

Parameters	Week 2	Week 4	Week 6	Week 8
Dorsal width				
Control	4.65±0.25[a]	4.85±0.15[a]	5.35±1.15[a]	5.52±0.50[a]
PPL 2 (0.5%)	5.57±0.15[a]	6.40±0.71[a]	5.75±0.65[a]	4.12±0.10[a]
PPL 3 (1.0%)	4.45±0.35[a]	5.51±0.50[a]	5.70±0.50[a]	5.71±0.51[a]
PPL 4 (2.0%)	5.55±0.15[a]	6.51±0.05[a]	4.85±0.15[a]	4.91±0.31[a]
PPL 5 (3.0%)	4.25±0.20[a]	4.25±0.45[a]	5.47±0.31[a]	5.47±0.33[a]
OXYL 6 (30mg/kg diet)	5.01±0.20[a]	5.75±0.65[a]	5.49±0.32[a]	5.49±0.30[a]
Standard length				
Control	9.30±0.80[a]	7.30±0.20[a]	7.25±0.45[bc]	8.80±0.71[b]
PPL 2 (0.5%)	8.55±0.95[ab]	6.25±0.25[a]	10.25±0.30[c]	8.45±0.55[b]
PPL 3 (1.0%)	8.55±0.95[b]	8.0±1.10[a]	7.90±1.10[bc]	8.40±0.51[a]
PPL 4 (2.0%)	8.55±0.95[ab]	9.25±0.75[a]	6.00±0.31[bc]	8.95±0.05[b]
PPL 5 (3.0%)	9.00±0.50[b]	8.25±0.20[a]	7.75±0.75[a]	8.95±0.05[ab]
OXYL 6 (30mg/kg diet)	9.00±0.51[a]	6.45±0.05[a]	8.80±0.70[ab]	8.95±0.05[b]
Head length				
Control	1.45 ±0.05[a]	1.55 ±0.50[a]	4.5 ±0.25[ab]	2.25 ±0.25[a]
PPL 2 (0.5%)	1.55 ±0.15[a]	1.50 ±0.00[a]	1.85 ±0.50[ab]	1.40 ±0.10[a]
PPL 3 (1.0%)	1.45 ±0.05[a]	1.69 ±0.05a	1.25 ±0.05[a]	2.00±0.50[a]
PPL 4 (2.0%)	0.15 ±0.20[a]	1.85 ±0.50[a]	1.55 ±0.45[ab]	1.70 ±0.01[a]
PPL 5 (3.0%)	1.65 ±0.50[a]	1.95 ±0.05[a]	1.60 ±0.01[ab]	1.95 ±0.05[a]
OXYL 6 (30mg/kg diet)	1.55 ±0.50[a]	1.95 ±0.05[a]	2.60 ±0.50[b]	1.15 ±0.15[a]
Total length				
Control	8.0 ±0.20[ab]	8.50 ±0.50[a]	9.00 ±1.00[a]	11.50 ±1.05[a]
PPL 2 (0.5%)	8.6 ±0.40[ab]	8.10 ±0.90[a]	7.65 ±1.25[a]	9.20±0.90[a]
PPL 3 (1.0%)	8.45 ±0.55[b]	10.60 ±0.60[a]	9.31±1.11[a]	10.80±0.75[a]
PPL 4 (2.0%)	7.71±0.60[a]	9.91±0.60[a]	9.30±1.10a	9.75±0.75[a]
PPL 5 (3.0%)	7.65±0.45[ab]	9.90±0.40[a]	10.50±0.25[a]	10.32±0.30[a]
OXYL 6 (30mg/kg diet)	7.60±0.40[ab]	10.61±0.20[a]	10.50±0.25[a]	12.45±0.95[a]

PPCM=Pineapple peel and core meal, OXYL = Oxytetracycline, mean value (n = 2) in each row with similar superscripts are not significantly different (P>0.05)

Intestinal morphology *C. gariepinus* fed with pineapple peel meal: The result of the experiment shows that there was a significant difference (P>0.05) in the villi width, villi height, cryptal width, cryptal depth and area of absorption while there was no significant difference (P<0.05) muscular thickness among the dietary groups. The treated groups show a significant increase in intestinal morphology in the *C. gariepinus* than the control diet (Table 4).

Table 4: Intestinal morphology *C. gariepinus* fed with pineapple peel and core meal for 56 days

	Villi height (µm)	Villi width (µm)	Cryptal Depth (µm)	Cryptal width (µm)	Muscular thickness (µm)	Area of Absorption (µm)
Control	1083.00±18.37[b]	116.61±1.55[a]	327.33±5.54[a]	117.53±2.59[a]	216.36±5.67[a]	126315.86±32.36[a]
PPL 2 (0.5%)	1116.60±2.65[bcd]	149.12±3.21[c]	417.474±4.04[b]	136.36±3.79[b]	223.43±2.44[a]	165592.22±31.29[b]
PPL 3 (1.0%)	1096.25±5.63[bc]	193.16±13.50[d]	416.44±13.60[b]	204.07±7.80[c]	218.97±3.69[a]	211600.35±137.25[c]
PPL 4 (2.0%)	1156.96±25.06[d]	144.03±1.49[c]	341.36±40.33[a]	147.15±2.08[b]	211.90±5.21[a]	166319.91±45.21[b]
PPL 5 (3.0%)	970.80±24.70[a]	118.85±2.65[ab]	307.67±3.42[a]	121.56±3.16[a]	214.51±1.18[a]	115511.52±54.43[a]
OXYL 6 (30mg/kg diet)	1138.66±1.80[cd]	137.19±2.93[bc]	312.49±3.52[a]	143.33±1.54[b]	215.32±2.70[a]	156222.03±34.90[b]

PPCM=Pineapple peel and core meal, OXYL = Oxytetracycline, mean value (n = 2) in each row with similar superscripts are not significantly different (P>0.05)

Discussion: The phytochemical analysis revealed the presence of glucosinolates, steroids, phenols, saponins, tannins and flavonoids. This result was similar to the report of Gunwantrao *et al.*, (2016) who reported the presence of tannins and flavonoids in the pineapple peel. Tannins are likely to be responsible for the free radical scavenger activities because of their phenolic compound which in turns are good primary antioxidants (Belewu and Belewu, 2007). The plant has antimicrobial activity were the most prominent activities both associated to presence of flavonoids (Borges *et a*l., 2008).

The results of morphometric indices revealed that the standard length, dorsal width, head length, and total length increases as the period of culture increase. The treated groups show a better performance compared to the control and there were significant differences ($p<0.05$) among the dietary groups. The reason better performance in the treated groups compared to the control might be as aa result of growth promoting constituents such as tannin, flavonoids and phenols present in the pineapple peels. The results of this present findings accord with the report of Mugroho *et al*., (2019) and Amulejoye *et al*., (2024) who also reported better performance in total length, standard length, dorsal width, head length and height in the treated group compared to the control diet of stripped catfish and African catfish respectively.

The result of the experiment showed better area of absorption, villi height, villi width, cryptal width and depth in the treated groups compared to the control, there were significant differences ($p<0.05$) among the dietary groups. The report was in agreement with the work of Bello *et al.,* (2012) who reported the same in the *Clarias gariepinus* juveniles fed onion bulb and walnut leaves supplemented diets compared to the control.

Conclusion: Pineapple peels inclusion in the diet of *Clarias gariepinus* could be used as fish feed ingredients and as a potential tool for growth promoter and gut health. It is therefore concluded that pineapple meal-based diet will enhance productivity in fish farming.

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Sexual Dimorphism and Phenotypic Correlations among Physiological Parameters of Adult Scavenging Muscovy Duck.

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Abstract

The objective of this study was to determine the effect of sex and phenotypic correlations on physiological parameters. Data on various physiological parameters collected from a total of 100 adult Muscovy ducks (27 males and 73 females) were used to determine the effect of sex on the physiological parameters. The effect of sex on the variables was significantly (p<0.05) different on heartbeat and respiratory rate, however, it was not significantly (p>0.05) different on body temperature and rectal temperature. The body temperature, rectal temperature, heartbeat and respiratory rate for female were 40.26℃, 41.11℃, 137.70bpm and 33.18bpm respectively, while the corresponding values for male were 40.69℃, 41.24℃, 148.67bpm and 35.19bpm respectively. The correlation coefficients were both positive and negative for both sexes and ranged between -0.001 and 0.0278 for female, -0.004 and 0.400 for male. Understanding sex-related variations in these parameters is essential for optimizing management practices, assessing health status, and promoting the welfare and productivity of Muscovy duck populations in scavenging systems.

***Keywords**: Muscovy duck, sex, body temperature, rectal temperature, heartbeat, respiratory rate.*

Description Of Problem: Muscovy ducks (Cairina moschata) hold a unique position among domesticated waterfowl, revered for their distinct characteristics and versatile roles in various ecosystems and human societies. Muscovy ducks play a crucial role in waste management, pest control, and nutrient recycling. Their scavenging behavior allows them to forage for insects, weeds, and organic debris, contributing to the ecosystem's balance and agricultural sustainability (5). However, despite their ecological significance, Muscovy ducks face various challenges, including disease susceptibility, environmental stressors, and physiological constraints, which can impact their overall health status. Sexual dimorphism, refers to the phenotypic differences between males and females of the same species beyond disparities in reproductive organs (2). These differences can manifest in a wide array of physical, behavioral, and physiological traits, often serving specific roles in mating strategies, competition, parental care, and overall fitness within a given species. Physiological parameters are important parameters in predicting body temperature, heartbeat, respiratory rate and rectal temperature. These parameters help assess the overall health, development and functioning of the birds.

Some of the key physiological responses in Muscovy duck include, regulating their body temperature through behaviors such as fluffing feathers to trap air for insulation or panting to dissipate heat, they have efficient respiratory systems to support their high metabolic rate during flight, they have specialized digestive systems adapted for their omnivorous diet including a muscular gizzard to grind food and have a four- chambered heart that pumps oxygenated blood efficiently throughout the body, supporting their high metabolic demands (8). Physiological parameters in Muscovy ducks are influenced by various biological, environmental, and management factors. Age, sex, genetics, and reproductive status can affect metabolic, endocrine, and cardiovascular parameters by influencing metabolic rates, hormonal profiles, and cardiovascular function (1).
According to (4), genetic factors play a significant role in determining physiological characteristics such as growth rate, body size, metabolism, disease resistance, and reproductive traits. Breeding practices and genetic selection can influence the genetic diversity and variability of Muscovy duck populations. Physiological parameters often change with age as ducks mature and develop. Growth rates, metabolic rates, hormone levels, immune function, and reproductive performance may vary throughout different life stages, from ducklings to adults. Biological sex can impact various physiological parameters, including hormone levels, reproductive anatomy and function, secondary sexual characteristics, and behavior. Males and females may exhibit differences in growth rates, body composition, and susceptibility to certain diseases (4). Dietary factors are critical for maintaining optimal physiological function and health in Muscovy ducks. Nutrient intake affects growth, metabolism, immune function, reproductive performance, feather quality, and overall well-being. Imbalances or deficiencies in essential nutrients (e.g., protein, vitamins, minerals) can lead to physiological abnormalities and health problems (3). Therefore, the objective of this study is to determine the impacts of sex and the phenotypic correlation on the physiological parameters in adult Muscovy duck

Materials and Methods: Animals and Experimental Design: The experiment was carried out at Okitipupa local government, Olusegun Agagu University of Science and Technology. A total of 100 scavenging Muscovy Duck (27 drake and 73 hen) across Okitipupa local government were used for this study for a period of two months. The birds are provided with shelter in the night and in the morning, they are given household waste by the farmers before scavenging around and return in the night. Traits measured were rectal temperature, body temperature and heart rate. Measurements were made immediately after weighing the birds. Heartbeat was determined with the aid of a stethoscope (3M™ Littmann® Classic III™, USA) and a stop watch (model 870A, Century clock-timer) by counting the number of beats in 30s and multiplied by two. The stethoscope was placed on the left side of the breast of an inverted bird after feathers were separated in order to expose as much skin as possible. Rectal temperature was measured using a digital clinical thermometer (±0.1°C accuracy; model MC-246 Omron) inserted 3cm into the rectum and left until a constant reading followed by a repeated beeping tone was reached (3). The thermometer was wiped using fresh clean cotton wool moistened with methylated alcohol between subsequent measurements in order to prevent possible cross infection among birds. Body temperature was measured using a digital clinical thermometer inserted under the wings of the duck and was left until a constant reading follows with a beeping tone. To ensure accuracy, each measurement was taken twice and the mean was used in subsequent analysis.

Statistical Analysis: Data collected on physiological parameters and hematology were subjected to T- test using (6), where significant differences occurred in the means, the means were separated using Duncan Multiple Range Test. Pearson correlation was used to determine the correlations among the physiological parameters.

Results and Discussion: Table 1 shows the effect of sex on physiological of adult Muscovy duck. The body temperature, rectal temperature, heartbeat and respiratory rate for female were 40.26ºC, 41.11ºC, 137.70bpm and 33.18bpm respectively, while the corresponding values for male were 40.69ºC, 41.24ºC, 148.67bpm and 35.19bpm respectively. The effect of sex on the variable was not significantly (p>0.05) different in body temperature and rt. However, it was significantly (p<0.05) different in of heartbeat and respiratory rate, this is in line with (7). Respiratory rate and heartbeat of 35.19 and 148.67 respectively were observed in male while the lower value of 33.18 and 137.70 were observed in female.

Table 1: Effect of sex in physiological parameters

Variables	Male	Female
Body weight (kg)	$2.97^{a} \pm 0.05$	$1.50^{b} \pm 0.02$
Body temperature (ºC)	40.69 ± 0.17	40.26 ± 0.11
Rectal temperature (ºC)	41.24 ± 0.08	41.11 ± 0.06
Heartbeat (bpm)	$148.67^{a} \pm 1.88$	$137.70^{b} \pm 0.99$
Respiratory rate (bpm)	$35.19^{a} \pm 0.65$	$33.18^{b} \pm 0.28$

a,b means with different superscript in the same row are significantly different (p<0.05

Table 2: Phenotypic correlation among physiological parameter of Male and Female

	Bwt	*bt*	*Rt*	*hb*	*rr*
Body weight		0.057^{ns}	-0.039^{ns}	-0.001^{ns}	0.029^{ns}
Body temperature	-0.405^{*}		0.004^{ns}	0.115^{ns}	0.028^{ns}
Rectal temperature	-0.219^{ns}	-0.044^{ns}		0.068^{ns}	0.179^{ns}
Heartbeat	0.268^{ns}	0.066^{ns}	-0.272^{ns}		0.278^{ns}
Respiratory rate	-0.059^{ns}	0.400^{*}	0.015^{ns}	-0.127^{ns}	

(*p<0.05; **p<0.001; ***p<0.0001); The upper diagonal is for female while the lower diagonal is for male.

The phenotypic correlation among the physiological parameters of male and female Muscovy duck. The upper diagonal is for female while the lower diagonal is for male. In female, the correlation coefficients ranged between -0.001 and 0.0278, low, positive and not significant (p>0.05). while in male the coefficients ranged between -0.004 and 0.400. Medium, positive and significant correlation was observed between body temperature and respiratory rate (0.400), however no significant different and low correlations were observed among other paired traits, but positive among body temperature and heartbeat, and rectal temperature and respiratory rate, while others are negatively related.

Conclusion and Application : It could be concluded that, some parameters were statistically significant (p<0.05) while some were not significant (p>0.05) for the duration of the study. The lack of statistical significance might be attributed to factors such as sample size, individual variations, or other confounding variables that were not accounted for in this particular study

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Sexual Dimorphism and Phenotypic Correlations among Hematological Parameters of Adult Scavenging Muscovy Duck in Okitipupa.

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Abstract

The objective of this study was to determine the effect of sex and phenotypic correlations on hematological parameters. Data was collected on various hematological parameters from a total of randomly selected 10 adult Muscovy ducks which was used to determine the effect of sex on the hematological parameters. The effect of sex on the variables was not significantly (p>0.05) different. The packed cell volume, hemoglobin, red blood cell, white blood cell, platelet, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, neutrophils, lymphocyte, monocyte, posi and paso for male were 41.50%, 13.85g/L, 4.80m/L, 13.45uL, 34.95mcL, 86.45fi, 28.90pg/dL, 33.35g/dL, 69.00%, 29.00%, 2.00%, 0% and 0% respectively, while the corresponding for female were 40.50%, 13.50g/L, 4.60m/L, 13.20uL, 38.95mcL, 88.05fi, 34.35pg/dL, 33.30g/dL, 69.50%, 29.00%, 1.00%, 0.50% and 0% respectively. The correlation coefficients were both positive and negative and ranged between -0.021 to 0.999. Understanding sex-related variations in these parameters is essential for optimizing management practices, assessing health status, and promoting the welfare and productivity of Muscovy duck populations in scavenging systems.

***Keywords**: Muscovy duck, sex, packed cell volume, hemoglobin, red blood cell, white blood cell, platelet, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration.*

Description of Problem: Muscovy ducks (Cairina moschata) hold a unique position among domesticated waterfowl, revered for their distinct characteristics and versatile roles in various ecosystems and human societies. Muscovy ducks play a crucial role in waste management, pest control, and nutrient recycling. Their scavenging behavior allows them to forage for insects, weeds, and organic debris, contributing to the ecosystem's balance and agricultural sustainability (9). However, despite their ecological significance, Muscovy ducks face various challenges, including disease susceptibility, environmental stressors, and physiological constraints, which can impact their overall health status**.** Sexual dimorphism, refers to the phenotypic differences between males and females of the same species beyond disparities in reproductive organs (6). These differences can manifest in a wide array of physical, behavioral, and physiological traits, often serving specific roles in mating strategies, competition, parental care, and overall fitness within a given species.

Hematology is a branch of medical science that focuses on the study of blood and its components, encompassing a wide range of analyses related to blood cells, plasma, and clotting factors (8). It plays a pivotal role in understanding the physiological processes of blood formation, circulation, and function, as well as in diagnosing and managing various hematological disorders and systemic diseases. In the context of animal production and health, hematology holds significant importance due to its invaluable contributions to monitoring the health status of animals, diagnosing diseases, evaluating treatment responses, and optimizing management practices (7). It is important to comprehend sexual dimorphism in hematology for a number of reasons. First, it sheds light on the physiological distinctions between Muscovy duck males and females, which can help us better understand the biology of their reproduction, immune system, and general health. Hematological parameters such as red blood cell indices, white blood cell counts, and platelet parameters serve as vital indicators of health, helping to diagnose diseases, monitor treatment responses, and assess overall physiological status. Other hematological parameters include packed cell volume, hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, neutrophils, lymphocyte, monocyte, posi and paso. Environmental factors such as temperature, humidity, altitude, and seasonality can also impact hematological parameters in Muscovy ducks by influencing hydration status, metabolic demands, and stress responses (3). Scavenging environments like Okitipupa local government may expose Muscovy ducks to diverse environmental stressors, including pathogens, toxins, and dietary fluctuations, which can affect their hematological parameters and overall health. Therefore, the objective of this study is to determine the impacts of sex and the phenotypic correlation on the hematological parameters in adult Muscovy duck.

Materials and Methods: Animals and Experimental Design**:** The experiment was carried out at Okitipupa local government, Olusegun Agagu University of Science and Technology. Blood sampling was drawn from the brachial wing vein, which is located between the bicep and triceps at the underside of the wing by using 6 mL syringe from randomly selected ten (10) Muscovy ducks for hematology studies. Ethylene Diamine Tetra Acetic Acid (EDTA) was used as anti-coagulant. Blood profiles were measured to determine the health status of livestock and blood parameters measured were hemoglobin levels, the number of red blood cells and white blood cells, packed cell volume/ hematocrit, and differentiation of white blood cells and calculation of types of white blood cells using the techniques of Pampori and Iqbal. A counting chamber was used to count the RBC and WBC. The percentage of hemoglobin was measured by using 0.1N HCl and distilled water that converted the hemoglobin into acid hematin**.**

Statistical Analysis: Data collected on physiological parameters and hematology were subjected to T- test using (10), where significant differences occurred in the means, the means were separated using Duncan Multiple Range Test. Pearson correlation was used to determine the correlations among the hematological parameters.

Results and Discussion: Table 1 shows the effect of sex on hematology of adult Muscovy duck. The packed cell volume, hemoglobin, red blood cell, white blood cell, platelet, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, neutrophils, lymphocyte, monocyte, posi and paso for male were 41.50%, 13.85g/L, 4.80m/L, 13.45uL, 34.95mcL, 86.45fi, 28.90pg/dL, 33.35g/dL, 69.00%, 29.00%, 2.00%, 0% and 0% respectively, while the corresponding for female were 40.50%, 13.50g/L, 4.60m/L, 13.20uL, 38.95mcL, 88.05fi, 34.35pg/dL, 33.30g/dL, 69.50%, 29.00%, 1.00%, 0.50% and 0% respectively. Sex had no significant effect ($p>0.05$) on all the hematological parameters considered. However, numerically, higher values were reported in male for PCV, HB, RBC, WBC, MCHC and Mono while higher values were observed in female for plate, MCV, MCH, Neut and posi (5).

Table 1: Effect of sex on hematological parameters

Variables	*Male*	*Female*	*Overall Mean*
PCV	41.50 ± 0.50	40.50 ± 1.50	41.0 ± 0.70
HB	13.85 ± 0.15	13.50 ± 0.50	13.67 ± 0.23
RBC	4.80 ± 0.10	4.60 ± 0.10	4.70 ± 0.08
WBC	13.45 ± 0.65	13.20 ± 0.20	13.32 ± 0.28
PLATE	34.95 ± 4.45	38.95 ± 0.55	36.95 ± 2.16
MCV	86.45 ± 0.75	88.05 ± 1.35	87.25 ± 0.78
MCH	28.90 ± 0.30	34.35 ± 4.55	31.62 ± 2.43
MCHC	33.35 ± 0.05	33.30 ± 0.00	33.32 ± 0.02
Neut	69.00 ± 1.00	69.50 ± 0.50	69.25 ± 0.47
Lymp	29.00 ± 1.00	29.00 ± 1.00	29.00 ± 0.57
Mono	2.00 ± 0.00	1.00 ± 1.00	1.50 ± 0.50
Posi	0.00 ± 0.00	0.50 ± 0.50	0.25 ± 0.25
Paso	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

PCV – Packed Cell Volume; HB - Hemoglobin RBC – Red Blood Cell; WBC – White Blood Cell; plate - platelet; MCV – Mean Corpuscular Volume; MCH – Mean Corpuscular Hemoglobin; MCHC – Mean Corpuscular Hemoglobin Concentration; Neut-Neutrophils; Lymph- Lymphocyte; Mono-monocyte

Table 4: Phenotypic correlation among hematological parameter of Male and Female

	PCV	**HB**	**RBC**	**WBC**	**PLATE**	**MCV**	**MCH**	**MCHC**
PCV								
HB	0.999**							
RBC	0.866^{ns}	0.865^{ns}						
WBC	-0.410^{ns}	-0.378^{ns}	-0.426^{ns}					
PLATE	-0.549^{ns}	-0.536^{ns}	-0.848^{ns}	0.671^{ns}				
MCV	0.256^{ns}	0.255^{ns}	-0.261^{ns}	0.013^{ns}	0.570^{ns}			
MCH	-0.938^{ns}	-0.949^{ns}	-0.862^{ns}	0.101^{ns}	0.465^{ns}	-0.136^{ns}		
MCHC	0.000^{ns}	0.035^{ns}	0.000^{ns}	0.900^{ns}	0.377^{ns}	-0.021^{ns}	-0.331^{ns}	

(*p<0.05; ** ns- not significant); PCV – Packed Cell Volume; HB - Hemoglobin RBC – Red Blood Cell; WBC – White Blood Cell; plate - platelet; MCV – Mean Corpuscular Volume; MCH – Mean Corpuscular Hemoglobin; MCHC – Mean Corpuscular Hemoglobin Concentration; Neut-Neutrophils; Lymph- Lymphocyte; Mono-monocyt

Table 2 shows the phenotypic correlation among the hematological parameters of Muscovy duck. The correlation ranged from -0.021 to 0.999. Very high significant correlation (0.999) was observed between PCV and HB, while correlations among other parameters are not significant. The correlation between PCV and Hb (0.999) was positive and have significant effect which indicate that PCV is contained within red blood cell and an increase in RBC count or size typically increases both PCV and Hb (1). The strong positive correlation between HB and RBC (0.865) suggests that as hemoglobin levels increase, the number of red blood cells also tends to increase. This differs with the findings of (2) who reported negative correlation among hematological parameters. Similarly, the negative correlations with WBC and RBC (-0.426) indicate that as WBC count increases, RBC count decreases. The negative correlation suggests that changes in one parameter may be related to changes in the other (9). The positive correlation between Platelet and WBC (0.671) suggests that there may be some relationship between the number of white blood cells and platelet count. The result of this study in agreement with the findings of (4) who reported high positive correlation among WBC, MCV, MCH and MCHC. This suggests that as platelet count increases, there may be an increase in white blood cell count, mean corpuscular volume, mean corpuscular hemoglobin level and mean corpuscular hemoglobin concentration

Conclusion and Application : It could be concluded that, the effect of sex on the variables was not significantly ($p>0.05$) different. The lack of statistical significance might be attributed to factors such as sample size, individual variations, or other confounding variables that were not accounted for in this particular study

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Profitability analysis of four-week-old broiler production enterprise in Okitipupa Township, Ondo State

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Abstract

The study investigates the profitability of four-week-old broiler enterprise in Okitipupa, Ondo state. The study was conducted in Adeomoh farm enterprise. Data for the study was collected through participatory approach. Five cycles of 4-week-old broiler was used for the study. Data were collected on input and output variables. Data collected were analyzed with the aid of budgetary analysis. Results revealed that the mean total revenue was ₦ 319,120, the mean total variable cost was ₦ 184,920, while the mean fixed cost was ₦ 3,840. The mean total cost was ₦ 188,760, while the mean gross margin was ₦ 134,200. The mean net profit was ₦130,360 while the net profit margin was 35.56% . This implies that the enterprise is profitable. Therefore, youths and unemployed Nigerians can seek livelihood in four-week-old broiler production enterprise

Keywords: Profitability, analysis, broiler production, enterprise.

Introduction: Livestock production constitutes a critical and basic part of the agricultural economy of Nigeria, where poultry is an important enterprise. Poultry is a noteworthy subsector in the livestock industry, which contains chickens, turkeys, ducks, quails, peafowl, guinea fowls etc. However chicken alone constitutes as much as 95% of all poultry kept on the planet (Ameh *et al*., 2016). The industry has been described as the fastest means of solving the problem of protein deficiency in Nigeria. It in addition a means of engagement through small and medium enterprises (Ameh *et al*., 2016). Broiler production is the poultry enterprise with the fasted return to investment (Ettah *et al*., 2021). Specifically, investment in broiler enterprises is attractive because production cost per unit is low relative to other types of livestock (Omolayo, 2018). The rate of growth and return to investment is high and this make the enterprise an economically viable (Ike, P. C. and Ugwumba, 2011). Most profitability studies addressed layers birds, while the few studies on broiler addressed table sized broilers, hence, the study.

Research Methodology: Area of Study: The study was conducted in Ade-Omoh farms, Okitipupa, Okitipupa Local Government Area of Ondo State. The farms produces broilers, layers and turkey.

Data Collection: Data for the study were collected through the direct participation of the researchers in raising 4-week old broiler in the farm. Direct interview of the farm manager was also adopted to fortify the information gathered during the on-the-sight observation. Data were collected on input and output variables. Procedures were established to ensure data accuracy, reliability, and confidentiality. For accuracy, data collection form was designed, clearly defining the variables and providing instructions for data entry. Regular checks and validation processes were conducted to minimize errors. To ensure reliability, data were collected for five production circles under the same management and operational activities

Method of data analysis: Budgetary technique were used to analyze the data collected. Budgetary technique is an analytical method used to determine the residue of income or revenue over and above cost of production. The total budgetary component is expressed as:

$\Pi = TR - TC$

Where:

Π = Net revenue or profit

TR = Total revenue

TC = Total Cost.

$TR = pq$

Where:

p = price per unit of chicks

q = quantity of output/chicks

$TC = TFC + TVC$

Where:

TFC = Total fixed cost

TVC = Total variable cost

Profitability analysis of four-week-old broiler

Table 1 presents a comprehensive view of the financial performance of four-week-old broiler production across five production cycles in Okitipupa Township, Ondo State. The mean total revenue generated from broiler production was while the mean total variable and fixed costs were ₦ 184,920 and ₦ 3,840, respectively. The mean total cost of production was ₦ 188,760 while the mean gross margin was ₦ 134,200. The mean net revenue was 130, 360 while the mean net profit margin was 35.56%, respectively. The result implies that a very small scale four-weak-old broiler production enterprise is profitable.

Table 1: Costs and return analysis of 4 weeks broiler production (pooled)

Items	C 1	C 2	C 3	C 4	C 5	Pooled
Total Revenue	352,800	153,000	505,800	304,000	280,000	319,120.00
Variable cost	210,000	123,900	197,450	162,750	230,500	184,920.00
Fixed cost	6,400	3,200	3200	3200	3200	3,840.00
Total cost	216,400	127,100	200,650	165,950	233,700	188,760.00
Gross Margin	142,800	29,100	308,350	141,250	49,500	134,200.00
Net Revenue	136,400	25,900	305,150	138,050	46,300	130,360.00
Net profit margin	38.7%	16.9%	60.3%	45.4%	16.5%	35.56%

Source: Data obtained from Adeomoh Farm through self-participation.

Note: C=Circle.

Conclusion: The study concluded that four-week-old broiler production enterprise is a profitable enterprise, with high return on investment.

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Physical Properties of Bitumen Laden Soils: Implication for Soil Nutrient Conservation

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Abstract

Bitumen as a product of organic mineralization and decomposition if properly handled, can contribute to soil nutrient storage and availability for plant use and soil conservation. The study was carried out at Ode-Irele in the Ondo State of Nigeria. This study evaluates the implication of bitumen's physical properties on soil nutrient content. Composite samples of bitumen sample and soil were evaluated for physical characteristics – gravel, sand, clay, and silt. The data collected were subjected to a t-test of unpaired samples. Results of the study showed that sand particles in bitumen sample were significantly higher than in exploratory soil (P<0.05). Soil clay in seepage and control were significantly higher than bitumen sample and exploratory soil. The higher amount of silt and clay in exploratory and seepage soils respectively over bitumen sample coupled with the higher value of sand in bitumen sample over the surrounding seepage and exploratory soils has proved that the physical characteristics of exploratory and seepage soils could be beneficial to the soil in terms of contribution to soil nutrients and conservation from leaching.

Keywords: Bitumen, Conservation, Nutrients, Physical propeties, Soil

Introduction: Bitumen composition as described by Mining Technology Newsletter (2021) is a mixture of sand, crude bitumen, water, and clay. The bitumen content ranges between one to 20%, with the remainder being 83% silica sand, 4% water, and 3% fluvial clay. According to Larter and Head (2014), bitumen is "a dense and extremely viscous form of unconventional petroleum that can also occur in some petroleum deposits as bituminous sands or oil sands, where in combination with sand, clay and water". Tomori *et al*. (2016) revealed high quartz, low kaolinite, low feldspar, and low gibbsite of bitumen. He said these characteristic bitumen contents might indicate moderate to a high degree of weathering; higher contents of silica and alumina. He further added that a higher range of alkalis and calcium in the surface layer might suggest an aeolian addition and relative enrichment of minerals during weathering and nutrient cycling by vegetation.

Soils are composed of sand, silt, clay, and organic matter, with the latter two having a net negative charge. Thus, the clay and organic matter that are negatively charged soil particles will attract and hold positively charged particles. In the same vein, the clay and organic matter will repel other negatively charged particles. In this way, the cations on the soil's exchange sites serve as a source of resupply for those in soil water removed (Solly *et al*., 2020) by plant roots or lost through leaching. Therefore, the amount of cations supplied to the soil is dependent on the higher C.E.C. of a soil. With the bitumen content mentioned above to contain silica sand, water and clay, there is no doubt that bitumen on one part is a product of weathering. If this is so, then has the mineral components in the form of silica sand, silt and clay, which are features that can contribute to increased soil nutrient status, been drastically transformed that bitumen cannot have a beneficial organic contribution to the soil. Then, there is the need to evaluate bitumen components to determine how they enhance soil nutrient content.

The following hypotheses were tested to evaluate the physical properties of bitumen on soil nutrient content and conservation:
1) Ho: There is no significant difference in the physical properties of bitumen and exploratory soil
2) Ho: There is no significant difference in the physical properties of bitumen and seepage soil
3) Ho: There is no significant difference in the physical properties of bitumen and control soil

Materials and Methods: The study was carried out at Ode-Irele in the southern fringe of Ondo State of Nigeria longitude $04^{0}47^{1}$E to $05^{0}10^{1}$E and latitude $06^{0}16^{1}$N to $06^{0}40^{1}$N (Ogunsusi and Adeleke, 2017). Bitumen sample and composite samples of soil were collected in bitumen seepage and exploratory sites and on the control site. The soil samples were evaluated for physical characteristics – gravel, sand, clay, and silt. Soil particle-size analysis followed the Bouycous hydrometer method by Bouycous (1951). The data collected were subjected to descriptive statistics and t-test of unpaired samples.

Results and Discussion: The physical properties of bitumen sample and associated exploratory surface soil are as presented in Table 1. The result showed that sand, 957.5±7.8g/kg, in bitumen sample was significantly higher than 892.00±0.00g/kg in exploratory soil. On the other hand, silt, 94.00±0.00g/kg of exploratory soil, was significantly higher than 27.00±9.90g/kg of bitumen sample. The result of the physical properties of bitumen sample and associated seepage surface soil showed that sand, 957.5±7.8g/kg, in the bitumen sample was significantly higher than 882.00±14.14g/kg in exploratory soil. However, soil clay, 54.00±0.00g/kg, was significantly higher in seepage soil than 9.20±11.03g/kg in bitumen sample. For the physical properties of bitumen sample and associated control surface soil, the result showed that clay, 54.00±5.66g/kg in control, was significantly higher than 9.20±11.03g/kg in bitumen sample.

The significantly higher concentration of sand in bitumen sample over that of exploratory and seepage soils is only attributable to sand being a component and the major part of bitumen (Olutaiwo *et al*., 2018). The higher value of silt in exploratory soil over bitumen sample is also attributable to possible removal of the silt from bitumen which has come to settle down during exploration. Foght *et al*. (2017) asserted that bitumen occupies the void spaces with embedded fine silt and clay minerals in oil sand ores. This implies that soil of the exploratory site is more fertile than the bitumen sample. Why clay was higher in seepage and control soils than bitumen sample is attributable to the non-expansivity of the clay particles in the bitumen sample. The non-expansivity of the clay particles in bitumen indicates a more strong adhesive force between the bitumen and clay particles, making the clay possibly get firmly attached to the bitumen (Liu *et al*., 2004). The higher value of clay in seepage soil over bitumen sample is also attributable to the possible removal of the clay from bitumen into the surrounding soil. This study thus proved that the % composition of silt and clay in bitumen is not up to the sand. For this reason, the embedded fine silt and clay particles in the bitumen sample have possibly been loosened during seepage and exploratory activities. The embrittlement of the bitumen sample would then have made more of the embedded fine silt and clay particles in the bitumen to be released unto the surrounding soil. The significantly higher concentration of clay in control soil over bitumen sample further points to the dissolution of the kaolinite clay in control, possibly by anthropogenic activities, which could have resulted in the vast amount of clay recorded in the control site over the bitumen sample (Christopher *et al*., 2017). Then the higher amount of sand in the bitumen sample over seepage and exploratory soils indicates that the soils in the seepage and exploratory soils are richer in soil nutrients than the bitumen sample. Therefore, the soils of bitumen exploratory and seepage sites (Table 1) can supply nutrients for plant use, which partly owes the significantly higher amount of silt, clay and C.E.C in these soils.

Table 1. Physical Properties of Bituminous Tar and Associated Exploratory, Seepage and control Surface Soil

Variable	Mean (g/kg)		t– value	df	P	S. D.	
	Bitumen Sample	**Exploratory Soil**				**Bitumen Sample**	**Exploratory Soil**
Sand	957.50*	892.00*	11.91*	2*	0.01*	7.78*	0.00*
Silt	27.00*	94.00*	9.57*	2*	0.01*	9.90*	0.00*
Clay	9.20	14.00	0.62	2	0.60	11.03	0.00
Gravel	115.65	132.85	0.50	2	0.67	14.92	46.74
	Bitumen Sample	**Seepage Soil**	**t – value**	**df**	**P**	**Bitumen Sample**	**Soil**
Sand	957.50*	882.00*	6.62*	2*	0.02*	7.78*	14.14*
Silt	27.00	74.00	2.22	2	0.16	9.90	28.28
Clay	9.20*	54.00*	5.74*	2*	0.03*	11.03*	0.00*
Gravel	115.65	96.85	0.34	2	0.77	14.92	77.99
	Bitumen Sample	**Control**	**t – value**	**df**	**P**	**Bitumen Sample**	**Control**
Sand	957.50	892.00	3.16	2	0.09	7.78	28.28
Silt	27.00	54.00	3.55	2	0.07	9.90	4.24
Clay	9.20*	54.00*	5.11*	2*	0.04*	11.03*	5.66*
Gravel	115.65	127.10	1.01	2	0.42	14.92	5.80

N.B.: Marked mean values are significant at P < 0.05

1) Exploratory soil has higher silt content, while seepage soil has higher amount of clay than bitumen sample.
2) Seepage and control soils have more clay content than exploratory soil, holding and supplying more nutrients for plants than exploratory soil.
3) The higher value of silt in bitumen exploratory soil over bitumen sample and control points to the silt being highly enriched in exploratory soil and possible leaching from bitumen.
4) The higher amount of sand in the bitumen sample over seepage and exploratory soils indicates that the soils in the seepage and exploratory soils are richer in soil nutrients than the bitumen.

This study has thus proved that bitumen's physical characteristics could benefit the soil in terms of contribution to soil nutrients and conservation.

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Evidence of the Impact of Land Use on Some Soil Physiochemical Properties in A Tropical Alfisol, Southwest Nigeria.

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Abstract

This study looks into how land use in four different land use areas—School Farm, Watershed, Developed Area, and Palm Plantation—affects the physical and chemical characteristics of soil. Both surface (0–30 cm) and subsurface (30–60 cm) soil depths are included in the investigation. The results show that there are notable differences in soil texture in various land use areas, which have an effect on things like soil water-holding ability and nutrient retention. Interestingly, there is a notable depth-dependent variation in the clay composition, with certain places showing a transition towards higher clay content in deeper soil layers. The study finds differences in organic carbon, organic matter, pH levels, nitrogen, phosphorus, and potassium content at varying depths in terms of chemical characteristics. At different depths, these changes have an impact on soil fertility and nutrient availability.This study emphasizes how crucial it is to comprehend soil profiles when making decisions about land management, particularly when it comes to sustainable agriculture and maintaining the health of the soil. The intricacies of soil composition and nutrient distribution require customized land management techniques. In the locations under investigation, this study offers insightful information for planning land use and sustainable farming methods.

Keywords: land use, pH, organic carbon, soil fertility, chemical properties, land management, School farm, Watershed, Developed area, and Palm plantation.

Introduction: One of the primary features of land is land use, which refers to human-driven activities on land (Lambin et al., 2003). The types of land used may have an impact on both the producer's status and the overall output from the land. Producer needs, environmental factors (soil, climate, rainfall, altitude, etc.), socioeconomic status (landlord, tiller, or peasant), political factors (tenure, land policy, and ownership), and cultural practices (beliefs, norms, and bylaws on the land) specific to the area could all influence the types of land use (Defries et al., 2004; Duguma et al., 2010). These considerations could influence the owner's decision on the sort of land use on their land. The field's soil quality is one of the variables that could affect the user's choice. By examining the qualities of the soil and contrasting them with the criteria, the condition of the soil can be determined. Natural and socioeconomic elements, as well as how humans have used them across time and space, determine a region's land use and land cover (LULC) (Oyinloye and Kufoniyi, 2011). The ability to manage soil effectively in order to preserve its quality requires knowledge of how soil reacts to various uses and agricultural methods over time. Various land use systems have been observed to have an impact on the physical, chemical, and biological aspects of soil (Agoume and Birang, 2009). Because maintaining healthy soil is essential to sustainable agriculture and a practical way to increase crop output, it forms the cornerstone of sustainable agricultural development (Liu et al., 2010). According to Bore and Bedadi (2015), soil resources have also made a significant contribution to the production of food and fiber as well as the preservation of the local, regional, and global environmental quality. It is thought that the kind of land use and the rate at which a particular land use type expands are influenced by rapid urbanized development (Lambin et al., 2001)

Materials and Methods: **The study sites:** Ondo State's Okitipupa local government area is home to Olusegun Agagu University of Science and Technology (OAUSTECH). In Nigeria's tropical rainforest zone, OAUSTECH is located between longitudes 4.759oE and 4.772oE and latitudes 6.45oN and 6.464oN. The total area covered by OAUSTECH is 178.79 hectares (ha). It is situated on the tertiary sandy strata of the Okitipupa geological formation. The average annual temperature is 27°C, and there is an average of 1900 mm of precipitation, with a total of frequently above 2000 mm of rainfall.

Terrain Analysis: A general understanding of the topography was produced with the use of the site's perimeter and topographic maps, in addition to other data. An assessment was made of the topography's predominant slope.

The base map displayed the approximate locations of these features, and the Geographic Positioning System (GPS) was utilized to capture the precise coordinates of these features (Adeyolanu et al, 2017).

Soil Survey, Mapping and Analysis: With the use of topo-sheets, satellite photos, and cadastral maps, preliminary traverses of the whole research area were completed. Following permanent features such as roads, cart tracks, canals, streams, tanks, etc., the field borders and survey numbers listed on the cadastral sheet were located on the ground. Any modifications observed were then included in the cadastral map. Where listed resources are not available, the reference transects were established by conducting a reconnaissance assessment of the location. There were five transects created, all with different lengths. Dutch Soil Auger used the global positioning system (GPS) to find the locations of each sampling point. For every sampling point, the physical properties of the soils were inspected and suitably documented between 0 and 30 cm and between 30 and 60 cm of depth. After removing coarse debris and roots, the auger samples were composited individually by bulking samples taken from the same plot and depth, air drying at room temperature, and sieving through a 2 mm sieve and taken to laboratory received the composite soil samples, and they were examined for total, particle, and mineral-associated soil organic carbon in addition to other physio-chemical soil parameters.

Data Analysis: ANOVA (analysis of variance) and Duncan To ascertain were used to analyse and test the significant variations between different plots and soil depths under various management approaches at a 95% confidence level.

Results: Table 1 display the results of the laboratory soil test for the physical and chemical characteristics of soil samples collected from each of the four land uses, while Tables 2 and 4 exhibit the results of the analysis of variance comparison across depth for each land use. The amount of sand, silt, and clay in the soil as well as its textural classifications are examples of its physical attributes. The PH, OC, OM, N, P, K, Na, Ca, Mg, EN+, and EAI3+ are among the chemical characteristics.

Table 1: physical properties of the soil samples

Sampling location	%Sand	%Silt	%Clay	Classes
School farm	35.00±8.48^{a}	20.00±0.00^{a}	45.00±8.49^{b}	Clay loam
Watershed	65.00±0.00^{c}	12.00±0.00^{b}	23.00±0.00^{a}	Sandy clay loam
Develop area	51.00±2.83^{b}	20.00±0.00^{a}	29.00±2.83^{ab}	Sandy clay loam
Palm plantation	54.00±2.83^{bc}	18.50±2.12^{a}	33.50±7.78^{ab}	Sandy clay loam

*Mean with same superscript along the columns are not significantly different at p>0.05

Discussion: Land Use Effect on Physical Properties of the soil sample: The percentages of sand, silt, and clay in the soil varied significantly throughout the four land use zones, according to the soil analysis results. These differences demonstrate the significant influence of land use on soil texture, an essential component of soil fertility and quality (Smith et al., 2018). According to Jones and Smith (2017), the watershed had the most percentage of sand (65.00%), suggesting a primarily sandy nature. The lowest amount of sand, however, was found at 35.00% on School Farm, indicating a finer soil texture (Brown and Johnson, 2019). The specific land management techniques and erosional causes within the Watershed area are responsible for this variation in sand content. School farm and Developed area showed the highest results in terms of silt concentration, both at 20.00%. These results point to a greater concentration of fine particles in these regions (Jackson, 2016). Watershed, on the other hand, had the least amount of silt (12.00%). Variations in soil erosion dynamics and land use practices can be the cause of this variance in silt concentration (Williams and Davis, 2020).

Remarkably, School Farm also had the largest percentage of clay (45.00%), indicating a texture of clay-loam (Smith and White, 2018). Watershed, on the other hand, had the least amount of clay (23.00%). This substantial variation highlights how land use practices affect the composition of the soil (Roberts and Green, 2019). The four sampling locations' observed differences in soil texture serve as an indicator of the effects of land use practices. Clay-loam soils are found in School Farm, whereas sandy-clay-loam soils are found in Watershed, developed area, and palm plantation soils (Miller & Brown, 2017). These differences affect the soil's ability to store water, retain nutrients, and function as a whole (Johnson et al., 2021).

Conclusion and Recommendation: The thorough examination of soil properties at various depths and land use areas has provided important new information about the intricate link between soil properties and land management techniques. These findings highlight the significant impacts that land use patterns have on soil characteristics, including texture, nutrient concentration, and general soil quality. This study emphasizes how important it is to manage land sustainably and how decisions affecting soil health and environmental sustainability must take into account the particularities of various land use areas and depths.

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Serum Indices of Broiler Chickens Offered Bitter Leaf (*Vernonia Amygdalina*) Extracts in Drinking Water

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Abstract

This study investigated the influence of bitter leaf extract in drinking water to the health of broiler chickens through the assessment of haematological and serum parameters. Ninety (90) Cobb 500 day- old broiler chicks were randomly assigned to three (3) treatments (0ml, 50ml and 100ml per litre of drinking water) of constituted bitter leaf extract. The treatments were replicated three (3) times with ten (10) birds per replicate under a completely randomized design (CRD) experiment. The study commenced at the finisher phase and lasted 4 weeks. Serum result showed that globulin significantly decreased while albumin significantly ($P<0.05$) increased with bitter leaf dosage. Furthermore, 100ml\L broilers had the lowest ($P<0.05$) serum urea and creatinine. 50ml/L had the highest AST and ALP value and 100ml/L had the highest value. From the above, it can be concluded that oral dosage of bitter leaf through water can be used for broilers at the rate of 50ml/L without any negative effect.

Key words: Blood; bitter leaf extract; feed additive; phytogenics.

Description of Problem: The poultry birds remain a relatively affordable source of animal protein especially broiler chickens (1). Broiler chickens reach the table size within six weeks; at times left till seven weeks or more for those that have preference for relatively tough meat (2). Consumption of broiler chickens is gradually becoming part of daily diets, now that much awareness had been created on their rearing for family consumption and income. However, high cost of feed and other rearing inputs like medications tend to make chicken unaffordable for consumption. This experience prompted the majority of the poultry farmers to have deployed various indigenous knowledge into prevention and treatment of poultry diseases (3). This involve the use of herbs, generally referred to as phytogenics. The phytogenics are of plant origin incorporated into either feed or water of the birds to enhance productivity, nutrient absorption and elimination of pathogens in the gut of the birds (4). The use of these plant parts had been found effective as antioxidants with therapeutic and prophylactic properties (5). Hence, birds performance were enhanced with ease of preventing common poultry diseases like coccidiosis (6), Newcastle disease (4) and worm infestation (7). Bitter leaf has the potential of enhancing performance and health of poultry chickens. It has been proven that bitter leaf (*Vernonia amygdalina*) contain significant quantities of lipids, carbohydrates, proteins having high essential amino acid scores, fibre, iron, phosphorus, copper, calcium potassium, cobalt and manganese, appreciable amounts of biologically active compounds like ascorbic acid, saponins, alkaloids, steroids terpenes, flavonoids, coumarins, ligans, phenolic acids, edotides, xanthones, anthraquinone and sesquiterpenes and caroteinoids (5). Extracts from bitter leaf can be used as tonics to treat variety of ailments and maladies, including emesis, nausea, diabetes, anorexia, diarrhea, dysentery and other gastrointestinal tract issues (8). Bitter leaf (*Vernonia amygdalina*) is one of the medicinal shrubs common in Nigeria. It is also an edible vegetable used mostly to cook soup. While the bitter leaf plant is useful to man, it has a lot of antioxidants and therapeutic properties that are of importance to animals, especially poultry (9). The reports of 9 and 3 have highlighted the positive influence of bitter leaf extract on the growth and health performance of poultry. Phytogenic like bitter leaf extract is a feed additive added to broiler drinking water to improve health, reduce morbidity and enhance production efficiency. These suggest that bitter leaf may contribute to the wellbeing of broiler chicken. However, the specific impact of bitter leaf extract in the drinking water of broiler chickens remains relatively unexplored.

Objective This investigation assessed the impact of bitter leaf extract in drinking water to the health of broiler chickens through serum indices.

Materials and Methods: Animals and Experimental Design: The study was carried out at the Poultry Unit of the Teaching and Research Farm, Olusegun Agagu University of Science and Technology (OAUSTECH) Okitipupa, Nigeria. The OAUSTECH is located within the rainforest zone, Latitude 5° 28' N and longitude 4° 46' E at an elevation of about 200 m above sea level. Fresh bitter leaf (*Vernonia amygdalina*) was harvested from the Teaching and Research Farm, Olusegun Agagu University of Science and Technology (OAUSTECH) Okitipupa. Ondo State, Nigeria. The broiler chicks were obtained from Zartech farm, Ibadan, Oyo State. The birds were housed in deep litter system where they received uniform care and management. The experiment lasted for eight weeks. Light were provided 24 hours daily, while feed and clean cool drinking water were given *ad libitum* throughout the experimental period. An open sided wall house were used and experimental birds were managed on deep litter system. Prior to the arrival of the birds, the pens were subjected to thorough washing with disinfectant (Izal® solution), followed by scrubbing, cleaning, removal of debris and cobwebs. The outer wall of the pens were properly covered with transparent nylon in order to avoid heat loss. Fresh wood shavings were spread to a depth of 5 cm in order to help in conserving heat, particularly during the brooding stage. Charcoal stoves were used as sources of heat during the brooding stage. Other appliances such as drinkers and feeders were also provided. The birds were vaccinated and fed starter diet (Metabolizable energy of 2750kcal/kg and 20% Crude Protein) for four weeks with plain drinking water.

Preparation of Bitter Leaf extract: Two hundred grammes (200gms) of freshly harvested bitter leaves were washed thoroughly without squeezing with clean water to remove dirt (sand and dust). The washed leaves were put in a bowl containing two litres of clean water and then squeezed to have the leaves extract. The extract was constituted into one litre of water at different volume of the extract to form the treatments.
Ninety (90) Cobb 500 day- old broiler chicks were randomly assigned to three (3) treatments (0ml, 50ml and 100ml per litre of drinking water) of constituted bitter leaf extract. The treatments were of 30 birds each. The treatments were replicated three (3) times with ten (10) birds per replicate under a completely randomized design (CRD) experiment. The study commenced at the finisher phase. At the finisher phase, the birds were fed *ad libitum* with finisher diet (Metabolizable energy of 2750kcal/kg and 19% Crude Protein) and exposed to the experimental drinking water without restriction for 4 weeks.

Chemical Analyses: At the end of the fourth week of the finisher phase study, two birds per replicate were randomly selected for the collection of blood samples. The collected samples were allowed to coagulate to produce serum for blood chemistry measurements (10). The samples were immediately transported to the laboratory for analysis. The samples were first centrifuged and decanted. Sigma kits were thereafter used to determine protein, globulins and albumins. Serum aspartic aminotransferase (AST), alkaline phosphatase (ALP) and alkaline aminotransferase (ALT) were determined using the procedure of (11).

Statistical Analysis: *All experimental data were analysed using One-way Analysis of Variance while means were separated by Duncan Multiple Range Test at 95 % level of significance (SAS Inst. Inc., Cary, NC).*

Results and Discussion: ***Effect of treatments on serum indices of broiler chickens:*** *Table 1 showed the serum indices of broiler chickens offered bitter leaf extract in drinking water. All the indices except total protein and glucose were significantly (P<0.05) affected by the bitter leaf extract in drinking water. The birds under 100ml/litre of drinking water had the highest albumin value and was significantly (P<0.05) different from those under 50ml/litre of drinking water and 0ml/litre of drinking water that were not significantly (P>0.05) different from one another. The globulin values for birds under 100ml/litre of drinking water and 0ml/litre of drinking water were significantly (P<0.05) different with those under 50ml/litre of drinking water not significantly (P>0.05) different from those under 100ml/litre of drinking water and 0ml/litre of drinking water. The Aspartate transaminase (AST) value for the birds under 50ml/litre of drinking water was significantly (P<0.05) different from those birds under 100ml/litre of drinking water and 0ml/litre of drinking water that were not significantly (P>0.05) different from one another. The Alanine transaminase (ALT) values were significantly (P<0.05) different among the three treatments with values 12.00, 7.00 and 9.00μ/L for 100, 50 and 0 ml/litre of drinking water respectively. The birds under 100ml/litre of drinking water had the least Alkaline phosphatase (ALP) and significantly (P<0.05) differed from treatments 50ml/litre of drinking water and 0ml/litre of drinking water that were not significantly (P>0.05) different from one another. The values for Chloride, Urea and Creatinine showed similar trends among the treatments. Birds under 100ml/litre of drinking water had the least values for the three serum indices of Chloride, Urea and Creatinine that were significantly (P<0.05) different from values under 50 and 0ml/litre of drinking water that were not significantly (P>0.05) different from one another. The serum values are essential in the assessment of clinical and health status of broiler chickens. Blood urea, nitrogen and creatinine are the final product of protein metabolism, and they are often regarded as indicator of renal functions (12). In the study, the low level of urea and creatinine in the highest bitter leaf inclusion, suggest that bitter leaf did not affect renal function or reduced skeletal muscle breakdown. Furthermore, creatinine, an indicator of skeletal muscle breakdown can increase in the blood serum due to heat stress (13). Thus, it also indicate that it can help alleviate broiler heat stress even in tropical environment. The activities of ALT and AST reflect the integrity of hepatocytes and are often used as indicators of liver injuries/infarction. This is because, when liver damages occur, there is leakage of some of these organ specific enzymes beyond the concentration expected in the blood. Although these enzymes are available in the blood at a level, undue increases could suggest a liver damage especially with ALT enzyme (14). Although 50ml/L had the highest AST and ALP value and 100ml/L had the highest ALT value, they were all within the range for normal broiler chicken, which suggest no negative effect of treatment.*

Table 2**: Serum indices of broiler chickens offered bitter leaf extract in drinking water**

Parameters	Level of bitter leaf extract		
	0ml\L	50ml\L	100ml\L
Total Protein (g/L)	80.00±5.00	77.00±2.00	78.00±3.00
Albumin (g/L)	34.00±2.00[a]	34.00±1.00 [a]	38.00±2.00 [b]
Globulin (g/L)	46.00±2.00 [b]	43.00±1.00 [ab]	40.00±2.00 [a]
Aspartate transaminase (AST) (μ\L)	7.00±1.00 [a]	10.00±1.00 [b]	7.00±1.00 [a]
Alanine transaminase (ALT) (μ\L)	9.00±1.00 [b]	7.00±1.00 [a]	12.00±1.00 [c]

Alkaline phosphatase (ALP) (µ\L)	19.80 ± 0.20^{b}	21.30 ± 1.30^{b}	17.60 ± 1.10^{a}
Glucose (mmol\L)	5.90 ± 1.05	7.00 ± 1.00	6.00 ± 0.20
Chloride (mmol\L)	93.00 ± 1.00^{b}	94.00 ± 2.00^{b}	89.00 ± 2.00^{a}
Urea (mmol\L)	3.70 ± 0.10^{b}	3.90 ± 0.15^{b}	2.70 ± 0.05^{a}
Creatinine (mmol\L)	70.10 ± 9.45^{b}	71.30 ± 0.70^{b}	50.10 ± 0.60^{a}

Mean±Standard Deviation
[abc] Means with different superscripts along the rows are significantly different (P<0.05)

Conclusion and Application : *The study has demonstrated that::Application of bitter leaf extract in broiler chicken water up to 50ml/L did not compromise the health of broiler chicken. Bitter leaf extract has the potential of being used as alternative to antibiotics in the rearing of broiler chickens.*

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Exploring Fungal Diversity: A Comprehensive Study of Fungi Species in Ondo Agro-Ecological Zone

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Abstract

This study investigates the prevalence and diversity of fungi species in soil samples collected from all the local government areas in Ondo State, South West Nigeria. The research aims to provide valuable insights into the distribution of fungi species in these regions and generate data for developing strategies to manage soil resources and conserve fungal diversity. Soil samples from three different locations in five selected farmlands in each local government were processed on a Potato Dextrose Agar (PDA) for isolate and identification done under laboratory condition. The relative abundance of various fungi, including Rhizopus spp, Trichoderma spp, Aspergillus spp, Fusarium spp, yeast, and Rhizopus spp, were determined across the selected local government areas. This research findings potentially reveal not only the abundance of pathogenic fungi but also the relative availability of beneficial microorganism contributing to the development of new methods for improving soil fertility. Among the fungi species reported, Aspergillus species recorded the highest prevalence across the state with 64.5%, Fusarium spp 16%, Trichoderma spp 14.5%, yeast 3%, and Rhizopus spp 2% respectively. The presence of Trichoderma can further be exploited as biocontrol agent to managed the prevalence of other pathogenic organism for agricultural sustainability.

Key Words: *Aspergillus spp, Trichoderma spp, Fusarium spp, Rhizopus spp, Yeast.*

Introduction: Fungi are a diverse group of eukaryotic organisms that play a crucial role in the biosphere's functioning. They are ubiquitous in nature and can be found in various habitats, including soil, water, air, and living organisms. Fungi are essential decomposers of organic matter, contributing to the nutrient cycle and soil health (Avery *et al.,* 2019). They also form mutualistic relationships with plants, enhancing nutrient uptake and promoting plant growth. Moreover, fungi produce a wide range of secondary metabolites, including antibiotics, enzymes, and food additives, with significant applications in medicine and biotechnology (Makun *et al.,* 2011). Ondo State, located in Southwestern Nigeria, has a diverse range of climates and soil types, making it an ideal place to investigate the prevalence and diversity of fungi species in soil. The soil types, are influenced by various factors such as geological formations, agricultural activities, and environmental contamination. The geoelectric properties and localized geology have been identified as indicators affecting cocoa yield in southwestern Nigeria, including Ondo State Osotuyi *et al.,* (2021). Additionally, the measurement of natural radioactivity and radiological hazard evaluation in soil samples collected from Owo, Ondo State, provides insights into the composition and properties of the soil in the region (Aladeniyi *et al.,* 2019). The relationship between fungi diversity, prevalence, distribution, and type of soil is a complex interplay influenced by various environmental factors. The occurrence and diversity of root-associated fungi are influenced by soil environmental conditions and the presence of preferred plant hosts (Burke *et al.,* 2009). The observed diversity of soil fungi largely depends on the method used and the numbers of isolates obtained (Gams, 2006). Soil fungal community composition and diversity change with different plot types, indicating a relationship between soil fungi and the surrounding environment (Long *et al.,* 2021). The distribution and abundance of keratinophilic fungi are well studied in relation to the presence of organic materials in soil and different soil factors (Shadzi *et al.,* 2002). This study aims to isolate and identify fungi species from soil samples collected from selected local government areas in Ondo State, determine their abundance and distribution, and generate data on the occurrence of fungi species in the region. The study's findings could potentially contribute to the development of new methods for improving soil fertility, controlling pests and diseases, and raising awareness of the importance of soil fungi for environmental conservation and agricultural sustainability.

Materials & Methods: Description of the Study Area: Ondo state is a south-western Nigerian state situated in the Derived savannah agroecologicalzone. The rainfall pattern is a bimodal distribution averaging between 1000 and1300 mm per year and the temperature varies from 26 to 38 °C (Aruwa *et al.,* 2017). Soil samples were collected from all the local governments in Ondo State Southwestern Nigeria, namely Ondo East, Ondo West, Idanre, Igbokoda, Irele, Igbotu, Okitipupa, Odigbo, Ile-Oluji, Akure South, Akure North, Ifedore, Akoko North East (Ikare), Akoko North West (Oke- Agbe), Akoko South west, Akoko South East, Ose, and Owo Local Governments Areas. Food crops, such as maize and cassava are grown mostly by subsistent farmers in the state. Soil from (5) five selected agricultural farms in each local government area were collected and mixed thoroughly for equal representation of the environment and tagged according to the location, thereby taken to the Soil lab of the Olusegun Agagu University of Science and Technology, Okitipupa, Ondo Nigeria for further isolation procedures.

Isolation of Fungi Isolates.*:* All collected samples were processed within 24-48 hours after collection for the isolation of fungi species. The soil samples were sieved to remove large particles and mixed with sterile distilled water to make a suspension. (Hanson 2008). One-gram sieved soil sample from each location was mixed separately in ninety (90) mL of distilled water in a 150mL conical flask. The flask was shaken on an orbital shaker for 15 minutes at 240 rpm. then, serial diluted into make various concentration of 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7} ml. 0.1mL suspensions of 10^{-4} dilutions were transferred to potato dextrose agar (PDA) spread evenly, and incubated at 28 ± 2°C for 3–7 days. Based on colony morphology, five-day old cultures of each plate were viewed under the light microscope for colony differentiation and identification, fungal count recorded range from $1.00 \times 104 \pm 0.02$ sfu/g to $6.33 \times 104 \pm 0.11$ sfu/g.Data were collected on number of colony formation and subjected to analysis of variance using the Minitab Statistical packages and means separated using Tukey's Test at 5% probability.

Results and Discussion: The most prevalent fungi species across the North Senatorial District is *Aspergillus* Species with no significant difference in Akoko South West, South East and North West respectively (Fig 1), although this area recorded the highest mean value and differs significantly in Akoko North East, while Owo and Ose local Government area are not significantly different in respect to the fungi population. However, Ose Local government area recorded the highest significant means value for *Yeast* species, while Fusarium species do not differ significantly across the district area. The beneficial rhizosphere *Trichoderma* was significantly recorded in Akoko South west.

According to figure 2 below, the result corresponds with the findings and prevalence of *Aspergillus* species across all the local government in the central district when compare to figure 1, while *Trichoderma* species do not differ significantly across all the local government in this zone. However, unlike figure 1 Ondo East and Idanre local government recorded the highest means value for Fusarium species but do not differ significantly in their means value.

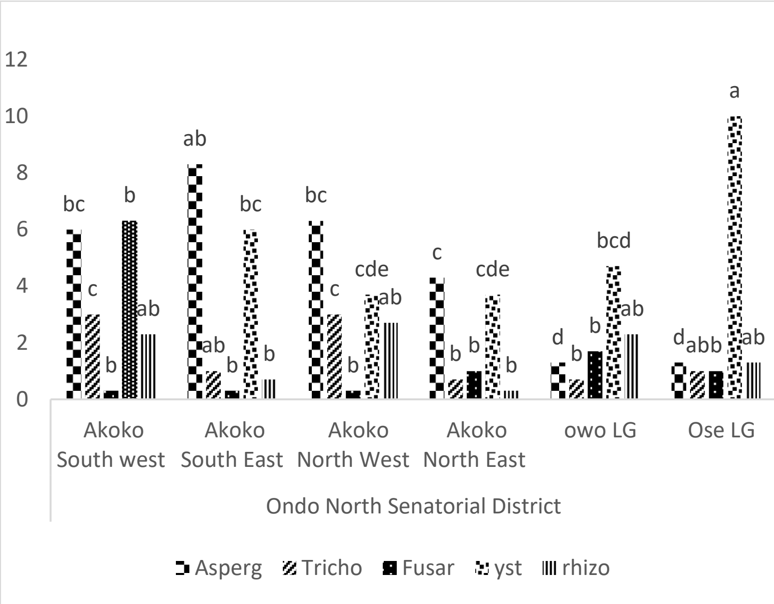

Figure 1: Fungi diversity across Ondo North Senatorial District, means with the same letter are not significantly different.

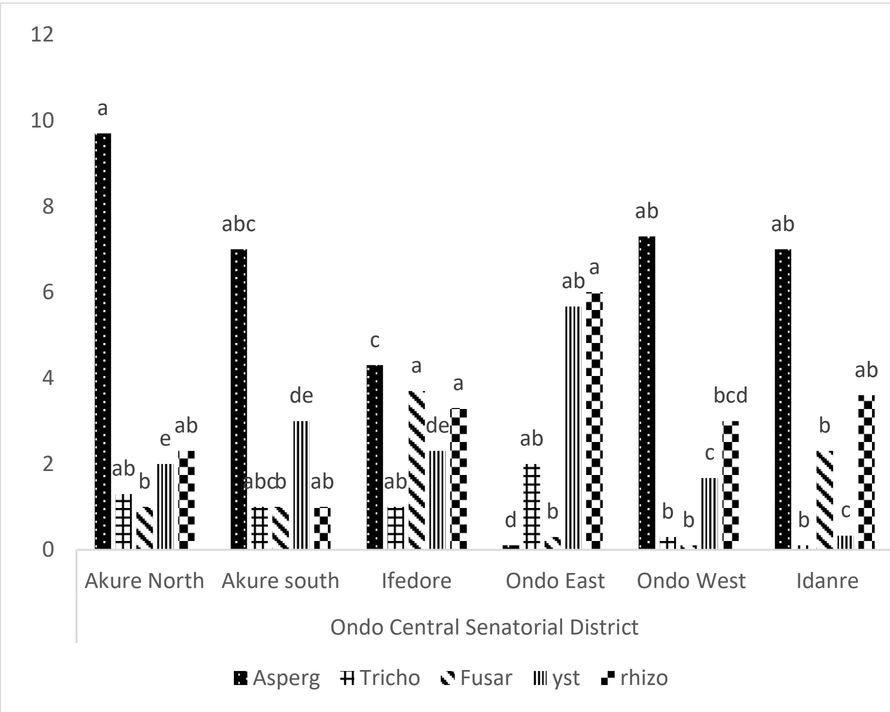

Figure 2: Fungi diversity across Ondo Central Senatorial District, means with the same letter are not significantly different.

The result from figure 3 below correlate with other finding reported in Figure 1 & 2 respectively, all the local government in the South Senatorial district recorded *Aspergillus* species as the most dominant fungi species with significant differences followed by *Yeast* species, while *Trichoderma* species was equally represented across all the local government with no significant difference.

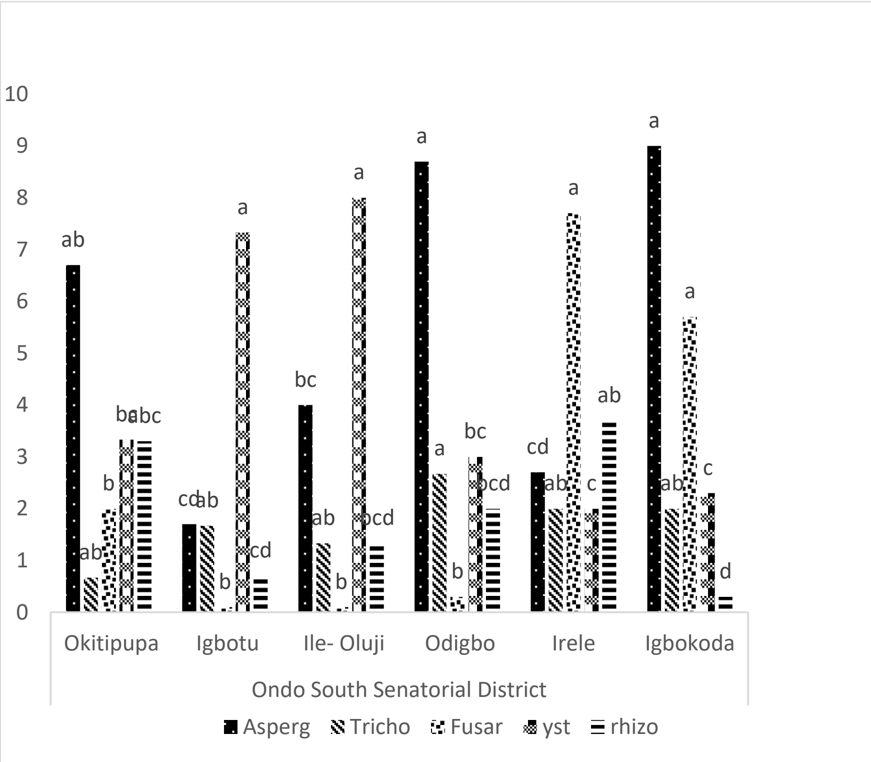

Figure 3: Fungi diversity across Ondo South Senatorial District, means with the same letter are not significantly different.

The relationship between fungi diversity, prevalence, distribution, and type of soil is a complex and multifaceted phenomenon that is influenced by various factors. Soil properties such as pH, nutrients, geographical distance, and soil type play crucial roles in shaping the composition and diversity of soil fungal in that communities (Yokoya *et al.,* 2021: Chen *et al.,* 2022). The result of this study shows that Ondo South, Central and North Senatorial district contain 23.5%, 29.5%, 31.5% of *Aspergillus* species respectively. The abundance of *Aspergillus* species in all the 18 local government in Ondo State shows that there is a correlation between the area and certain weather, climatic and agricultural characteristics. According to Ekpakpale *et al.,* (2021), who studied the fungal diversity in maize, cassava-based flour (pupuru), and rice in Ondo state, reported 26 species fungal family where *Aspergillus* specie accounted for 80.9% of the fungal isolated.

The prevalence of *Aspergillus* species in Ondo State is in correlation with the type of crops commonly found in this area, it is worthy of note that Ondo state is among the state with the highest cultivation of Maize ad cassava as a staple crop commonly cultivated among the people of the state. This crop type is the primary host of *Aspergillus* species, as reported by Reflinaldon *et al.,* (2014), the occurrence and diversity of pathogenic fungi are influenced by geographical location, soil types, altitude, habitat, soil temperature, environmental conditions, type of crop, and cultivation practices. However, the predominant population of *Aspergillus* species in Ondo State accounted for the high aflatoxin content which have been reported in food and animal feeds respectively. *Aspergillus* flavus is a common type of fungi in the *Aspergillus* family that produces toxin which has been reported to be carcinogenic and detrimental to both human and animal health. (Ayeni *et al.,* 2020). The rhizosphere beneficial microorganisms were significantly presence across the state which can be explore as biocontrol agent to manage crop disease, increase plant growth and lower incidence and severity of diseases

Conclusion and Recommendation: This study provides snapshot data on the fungal diversity and can be concluded that different areas, is prone to different diseases susceptibility, in relation to the abundance of fungi found therein. However, it is recommended that further study should be carried out to identify the toxigenic and atoxigenic strain of *Aspergillus* fungi and evaluate the biocontrol potential of all available *Trichoderma* species to develop a biocontrol strategy for progressive productibility.

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Assessment of Black Seed *(Nigella sativa)* Oil on Growth Performances And Morphometric Indices of *Clarias gariepinus* Juveniles

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Abstract

This study was conducted to assess the effectiveness of *Nigella sativa* on growth performance, morphometric parameter of *Clarias gariepinus* juveniles. Experimental diet was composed of Control (0.0%), T2 (0.4%), T3 (0.8%), T4 (1.2%), T5 (1.6%) and T6 (2.0%). A total of two hundred and fourty (240) *Clarias gariepinus* with average mean weight of (2.79 ± 0.02g) were replicated twice with 20 fish per replicate. The fish were fed twice daily at 3% body weight of 40% crude protein for 8 weeks, also biweekly body weight and morphometric indices of each treatment were recorded for 8 weeks. At the end of 8 weeks, biological evaluation and morphometric parameters were measured. Data obtained were analysed using Statistics and ANOVA at P= 0.05, treatment T3 had the highest value in percentage weight gain (149.83) and specific growth rate (0.71). For the survival rate and production performance index, treatment T5 had the highest value (92.50 and 6.78 respectively) than the control and other treated groups. The result suggests that black seed oil enhance growth performance and morphometric indices of *Clarias gariepinus* juveniles.

Keyword: *Clarias gariepinus*; Growth ; Morphometric; *Nigella sativa*;

INTRODUCTION

Aquaculture has become an increasingly important industry globally due to the growing demand for fish protein and the depletion of wild fish stocks. The African catfish, *Clarias gariepinus*, is a popular aquaculture species due to its fast growth rate and adaptability to different water conditions. Fish growth is affected by various factors, including genetics, environment, and nutrition. In order, to make up for this, several researches are put in place to bridge the gap. Black seed (*Nigella sativa*) is a medicinal plant belonging to the family: Ranunculaceae and it has been known as far back as 1400 years ago (Botnick *et al*., 2012). Due to its numerous therapeutic properties, black seed is widely cultivated and used in different regions of the world (Polat *et al*., 2011). Several researchers have reported the positive effects of dietary black seed on the growth performance, biochemical and immuno-haematological parameters of *Carrasius auratus* (Alishahi *et al*., 2012), *Oreochromis niloticus* (Elkamel *et al.,* 2012), *Lates calcarifer* (Abdelwahab *et al*., 2012), *Oncorhynchus mykiss* (Awad *et al*., 2015), *Sparus aurata* (Khatun *et al*., 2015) and *Anabas testudineus* (Khatun *et al*., 2015). However, the effects of black seed oil on growth response of *C. gariepinus* juveniles have not been well elucidated.Therefore, the present study aims to evaluate the effects of black seed oil on the growth performance of *C. gariepinus* juveniles.

Materials and Methods: **Collection, Acclimatization of Experimental Fish and Design** : Seeds of *Nigella sativa* was purchased from Okitipupa, Ondo State, Nigeria and the oil was extracted under low heat for at least two hours until it becomes brownish. It was later poured into clean bottles and stored in a cool dry place until ready for use. Two hundred and fourty (240) juveniles of *C. gariepinus* of average weight 2.79 ± 0.02g were obtained from a fish farm in Akure, transported in a plastic jerry can and acclimatized for a week in twelve 45 litres bowl at the Fisheries and Aquaculture laboratory, during which they were fed with commercial diets (coppens) of 40% crude protein twice daily at 3% body weight. Six experimental diets were formulated at 40% crude protein diets and black seed oil were added lat different inclusion levels of 0%, 0.4%, 0.8%, 1.2%, 1.6% and 2.0% respectively as a partial replacement for palm oil. Each diet was treated separately and pelleted through a 2mm pelleting machine were sundried to a constant temperature and then, stored in air – tight nylon at a room temperature.

Measurement of Growth parameters : The weights of treated and untreated (control) test media were recorded at the commencement and termination of the experiment (after 56 days). Weight changes in the fish were measured at 14days intervals of the experiments to reduce the introduction of handling stress in the animals. The following biological evaluation were measured:

1. Weight gain = Final Body Weight – Initial Body Weight.

2. Percentage weight gain = (Final Body Weight – Initial Body Weight) × 100

Initial Body Weight

3. Specific Growth Rate (SGR) = 100 (loge FBW – loge IBW) / Time

4. Feed Conversion Ratio (FCR) = Dry weight of the feed / Fish weight gain

5. Nitrogen Metabolism (NM) = 100 (number of fish stocked - Mortality) / Number of Fish Stocked

6. Survival Rate (SR) = Initial number of fish stocked – Mortality x 100

Initial number of fish stocked

7. Nitrogen metabolism = $\frac{(0.549)(a+b)h}{2}$

Where; a = Initial mean weight of fish; b = Final mean weight of fish; h = Experimental periods in days (Nwamna, 2003).

Table 1: Gross composition of experimental diet (g/100g) fed to *C. gariepinus* Juveniles

Ingredient	Control	C2	C3	C4	C5	C6
Fish meal	13.06	13.06	13.06	13.06	13.06	13.06
Soybean	26.12	26.12	26.12	26.12	26.12	26.12
Groundnut cake	26.12	26.12	26.12	26.12	26.12	26.12
White maize	8.23	8.23	8.23	8.23	8.23	8.23
Yellow maize	8.23	8.23	8.23	8.23	8.23	8.23
Guinea corn	8.23	8.23	8.23	8.23	8.23	8.23
Lysine	1.00	1.00	1.00	1.00	1.00	1.00
Vit-min. Premix	2.00	2.00	2.00	2.00	2.00	2.00
Salt	2.00	2.00	2.00	2.00	2.00	2.00
DCP	2.00	2.00	2.00	2.00	2.00	2.00
Methionine	1.00	1.00	1.00	1.00	1.00	1.00
Palm oil	2.00	1.60	1.20	0.80	0.40	0.00
Black seed oil	0.00	0.40	0.80	1.20	1.60	2.00
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00

Table 2: Growth performance and nutrient utilization of *Clarias gariepinus* juveniles fed different inclusion levels of black seed oil for 56days.

	Control	T2	T3	T4	T5	T6
IBW	2.79±0.02[a]	2.79±0.01[a]	2.79±0.02[a]	2.79±0.02[a]	2.79±0.01[a]	2.79±0.02[a]
FBW	6.80±0.13[a]	6.90±1.04[a]	6.97±0.16[a]	6.00±0.56[a]	6.89±0.11[a]	6.34±0.67[a]
WG	4.01±0.13[a]	4.11±0.04[a]	4.18±0.16[a]	3.21±0.56[a]	4.10±0.11[a]	3.54±0.67[a]
PWG	143.73±4.66[a]	147.31±37.28[a]	149.83±5.74[a]	115.06±20.08[a]	146.90±3.95[a]	127.07±23.84[a]

SGR	0.70±0.02ᵃ	0.70±0.12ᵃ	0.71±0.02ᵃ	0.59±0.07ᵃ	0.70±0.01ᵃ	0.63±0.08ᵃ
SR	72.50±2.50ᵃᵇ	77.50±7.50ᵇ	80.00±0.00ᵇ	85.00±5.00ᵇ	92.50±2.50ᵇ	55.00±10.00ᵃ
FCR	0.13±0.01ᵃ	0.16±0.04ᵃ	0.13±0.01ᵃ	0.15±0.03ᵃ	0.14±0.01ᵃ	0.14±0.03ᵃ
NM	222.13±76.71ᵃ	148.96±15.99ᵃ	150.03±2.45ᵃ	135.12±8.61ᵃ	148.80±1.69ᵃ	140.27±10.22ᵃ
PPI	5.19±0.01ᵃ	5.83±1.99ᵃ	5.97±0.23ᵃ	4.93±1.13ᵃ	6.78±0.37ᵃ	3.60±1.29ᵃ

Key: IBW= Initial body weight, FBW = Final body weight, WG = Weight gain, PWG = Percentage weight gain, SGR = Specific growth rate, FCR = Feed conversion rate, SR = Survival rate, NM = Nitrogen metabolism, PPI = Production performance index, mean followed by the same letter is not significantly different (p>0.05)

Table 3: Total length of *Clarias gariepinus* juveniles fed different inclusion levels of black seed oil for 56days.

	Week 2	Week 4	Week 6	Week 8
Control	7.50±0.38ᵇ	8.47±0.06ᵃᵇ	10.12±0.52ᵃᵇ	10.65±0.45ᵃ
T2	7.33±0.40ᵇ	10.05±0.08ᶜ	10.40±0.30ᵇ	12.47±0.50ᵃ
T3	7.00±0.27ᵃᵇ	8.34±0.57ᵃᵇ	9.93±0.13ᵃᵇ	10.69±0.22ᵃ
T4	6.85±0.35ᵃᵇ	7.72±0.50ᵃ	9.52±0.12ᵃᵇ	10.79±0.78ᵃ
T5	7.10±0.83ᵃᵇ	9.19±0.15ᵇᶜ	9.17±0.27ᵃ	11.20±0.07ᵃ
T6	5.58±0.15ᵃ	8.14±0.47ᵃᵇ	9.45±0.15ᵃᵇ	10.75±1.02ᵃ

Mean followed by the same letter is not significantly different (p>0.05)

Table 4: Standard length of *Clarias gariepinus* juveniles fed different inclusion levels of black seed oil for 56days.

	Week 2	Week 4	Week 6	Week 8
Control	6.34±0.14^{ab}	7.14±0.49^{a}	8.79±0.45^{bc}	9.40±0.40^{a}
T2	6.43±0.20^{ab}	8.70±0.15^{c}	9.18±0.15^{c}	10.94±0.36^{a}
T3	6.32±0.42^{ab}	7.44±0.17^{ab}	8.72±0.15^{bc}	9.63±0.27^{a}
T4	6.40±0.02^{ab}	6.89±0.04^{a}	8.24±0.04^{ab}	9.65±0.75^{a}
T5	6.52±0.05^{b}	8.35±0.25^{bc}	7.85±0.25^{a}	10.10±0.20^{a}
T6	5.35±0.40^{a}	7.37±0.08^{a}	8.45±0.08^{abc}	9.64±1.07^{a}

Mean followed by the same letter is not significantly different (p>0.05)

Table 5: Dorsal width of *Clarias gariepinus* juveniles fed different inclusion levels of black seed oil for 56days.

	Week 2	Week 4	Week 6	Week 8
Control	0.99±0.09^{ab}	1.52±0.15^{ab}	1.69±0.02^{a}	1.60±0.37^{a}
T2	1.08±0.15^{b}	2.15±0.15^{c}	1.74±0.17^{a}	1.97±0.20^{a}
T3	0.95±0.12^{ab}	1.24±0.37^{a}	1.65±0.05^{a}	1.85±0.05^{a}
T4	1.12±0.02^{b}	0.99±0.09^{a}	1.58±0.35^{a}	1.85±0.15^{a}
T5	1.24±0.07^{b}	1.57±0.14^{ab}	1.24±0.17^{a}	1.82±0.09^{a}
T6	0.65±0.08^{a}	1.15±0.25^{a}	1.78±0.09^{a}	1.70±0.17^{a}

Mean followed by the same letter is not significantly different (p>0.05)

Table 7: Head length of *Clarias gariepinus* juveniles fed different inclusion levels of black seed oil for 56days.

	Week 2	Week 4	Week 6	Week 8
Control	1.54±0.29^{ab}	1.57±0.00^{a}	2.14±0.14^{a}	2.47±0.07^{a}
T2	1.22±0.35^{c}	2.43±0.20^{a}	1.88±0.05^{a}	2.79±0.19^{a}
T3	0.88±0.05^{ab}	1.83±0.27^{a}	1.44±0.34^{a}	2.67±0.14^{a}
T4	1.14±0.37^{a}	1.47±0.07^{a}	1.74±0.03^{a}	2.48±0.05^{a}
T5	1.22±0.12^{bc}	2.08±0.05^{a}	1.77±0.14^{a}	2.35±0.05^{a}
T6	0.55±0.02^{ab}	1.69±0.09^{a}	1.70±0.47^{a}	2.22±0.42^{a}

Mean followed by the same letter is not significantly different (p>0.05)

Table 7: Height of *Clarias gariepinus* juveniles fed different inclusion levels of black seed oil for 56days.

	Week 2	Week 4	Week 6	Week 8
Control	0.54±0.04^{a}	0.82±0.09^{ab}	1.25±0.12^{a}	1.32±0.15^{a}
T2	0.50±0.10^{a}	1.33 ±0.10^{c}	1.17±0.00^{a}	1.64±0.07^{a}
T3	0.60±0.13^{a}	0.80±0.13^{a}	1.20±0.03^{a}	1.34±0.14^{a}
T4	0.65±0.15^{a}	0.75±0.05^{a}	1.18±0.05^{a}	1.64±0.04^{a}
T5	0.67±0.07^{a}	1.14±0.04^{bc}	1.14±0.04^{a}	1.55±0.08^{a}

T6	0.47±0.00[a]	0.90±0.10[ab]	1.57±0.14[b]	1.28±0.15[a]

Mean followed by the same letter is not significantly different (p>0.05)

Result and Discussion: There were no significant differences (p>0.05) in Growth performance and nutrient utilization of the experimental fish in all the dietary treatments though there were marginal variation in the values except for the Survival Rate in which there was significant difference (p<0.05) as shown in Table 2 above. Morphometric indices evaluation was carried out after 56 days of the feeding trial by using three fish samples from each treatment and it was done according to the method described by Fischer et al., (1981). The data included the total length (TL), standard length (SL), dorsal width (DW), head length (HL) and height (H). The result showed that standard length, total length, dorsal width, head length and height increased in all the treatments from the 2nd week to the 8th week, which shows that as the week of feeding trials increases the weight-recorded increases. This report was in accordance with the report of Olusola et al. (2021) who reported an increase in morphometric characteristics of C. gariepinus juvenile fed nutmeg seeds.

Conclusion and Recommendation: In conclusion, the inclusion of black seed oil can be incorporated in the diets of C. gariepinus juveniles as feed additives to improve physiological functions of the fish which may increase productivity in fish farming. Harnessing the benefits of this oil, fish farmers can improve the growth rates, overall health of their stocks and reduce the reliance on synthetic additives and antibiotics, thus promoting environmentally friendly and health-conscious aquaculture practices.

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Greenhouse gas emissions from livestock production in Nigeria: exploring options for its mitigation

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Abstract

The growing impact of greenhouse gas emissions from livestock production on climate change and global warming is becoming worrisome. Food production to meet the needs of the augmenting human population is a major driver of the greenhouse gas emissions from livestock production. This sub-sector contributes substantially to the recent rise in global warming and climate variability. Ruminants play a critical role in emission of methane, a potent greenhouse gas. The Tier 1 methods of the Intergovernmental Panel on Climate Change (2006) was used as the basis for the estimation of the emissions. The results showed that 96.15% of methane emission inventory produced by livestock was by ruminants with cattle alone accounting for 74.06%. While the non-ruminants accounted for ca. 3.85%. with this background, it could be suggestive that, livestock producers should concentrate efforts on production efficiency that produces lesser methane emissions emanating from enteric fermentation. This system had been successfully demonstrated with intensive animal production. Meanwhile in Nigeria, only non-ruminants have resulted in improved yield under intensive system while the ruminants are best managed under extensive and semi-intensive systems. In conclusion, selection of mitigation strategies for reducing greenhouse gas emissions should therefore be consistent with country specific objectives taking cognisance of the nutritional and cultural practices that aligns with the traditions of the livestock producers.

Keywords: *greenhouse gas, livestock production, climate change, mitigation strategies*

Introduction: Livestock production represents a universal practice across culture and contributes significantly to agriculture greenhouse gases (GHGs) emissions (Smith *et al.,* 2014). The primary GHGs particularly generated from livestock production are methane (CH4) and nitrous oxide (N2O) (IPCC, 2013). Methane emission especially occurs during enteric fermentation in ruminant particularly cattle while N2O is mostly emitted from manure management in swine. For instance, enteric fermentation represents 36 % of total agriculture emissions while livestock manure management accounted for about 60 % of global N2O emission (Syakila and Kroeze, 2011; Smith *et al.,* 2014). Apparently, livestock production accounted for a greater environmental burden, accounting for about half of agricultural GHG emissions (Jan Kramer et al., 1999; Garett, 2009) and 18 % of global GHG emission. In the case of Nigeria, emission estimates were 123.11 Mt CO e in 1990 and 492.44 Mt CO2e in 2014 (CAIT, 2017). By implication, these values indicated 25 % rise in national emissions while the actual national contribution to global GHG emission was 1.01 %, making Nigeria to be ranked ninth among the top 25 emitting nations of the world (CAIT, 2018; USAID, 2019). The recent upsurge in GHG emissions has raised concerns among several researchers across the world. One of the major drivers of this upsurge is the rise in global demand for animal protein particularly meat and milk, to meet the increasing human population (FAO, 2011; UN, 2017). This has consequently increased the number of animals, acreage of land cleared for feed grains, pasture and grassland, severe manure management challenges and an almost 'dangerous climate change' scenario. In effect, these livestock species occupy space, feed and excrete feaces. The many interactions with the environment generate GHGs through enteric fermentation occurring during digestion in ruminants although this also happens in swine but to a lesser extent during manure management. The environmental challenges of climate change imposed by GHGs emissions from livestock are enormous. This study sought to provide update on livestock GHG emission and rekindle available mitigation strategies

Livestock population, estimation of greenhouse gas emission and trend*: The Nigeria livestock population has continued to increase from the 60's to date. Over the last two decades, the Nigeria livestock population has increased substantially to over 325 million species (FAOSTAT, 2021). This implies that more resources are needed to sustain the growth of the livestock industry under stringent environmental challenges including greenhouse gases emissions. Estimation of GHGs emissions have become a global trend due to the increasing consequences particularly on the environment and food production and security. Up to date, Nigeria does not have reliable country specific emission data on livestock species but relies on FAO default values for estimation (FRN, 2018). Based on IPCC (1996) methods, emission can be estimated by multiplying the individual animal population with the default emission factor of the respective animal type for the specific activity. The activity data is the intensity or quantity of activity that led to emissions of GHGs while emission factor represents the rate at which a particular GHG is emitted. The Tier 1 emission equation as provided by IPCC (1996) is:*

Emission (Gg) = LP. Ef Ef =(GE of feed . Ym '365days) / 55.65

LP= Livestock population; EF = Emission Factor; Ym = Methane conversion rate; GE = Gross energy of feed; 55.65 = Energy content of methane (MJ/KgCH4); Gg = Giga gram (the unit of measurement)

The estimated GHG emission from each species of livestock is shown in Table 1. By livestock species, cattle contributed the greater proportion (74.06 %) followed by goat (13.25 %), sheep (8.84 %), pigs (2.51 %) and lastly poultry (1.34 %). Ruminants contributed with 96.15 % and this is because the bulk of CH emissions occur during enteric fermentation. The trend in GHGs emissions in between the preIndustrial period and 2018 is shown in Figure 1. In 1961, less than 250 Gg of CH4 emissions were recorded and continue to increase by almost the same magnitude. In between 2010 and 2012, there was an upsurge of over 100 Gg CH4 emission compared to the previous years. The surge may imply that, livestock production either increased or production efficiency reduced for those periods. Similar trend was **observed for CH emission from manure management, although the magnitude of emission was very low. However, for N2O emission from manure management, the emission intensity seems to be constant despite the growth in livestock population. Overall, there was steady increase in both the magnitude and intensity of emission and this may be due to increase in livestock number arising from the need to meet the demand for meat, milk and egg for the rapidly increasing human population. This rising trend especially in CH4 emission is worrisome as it has unleashed several changes in the climatic condition, threatening human survival and food production.**

Species	Livestock population (Million)	Emission by livestock species CH4 emission from enteric fermentation (emission/head/yr)	N2O emission from manure production (emission/head/yr)	Total GHG emission (Gg)	% contribution
Cattle	20,905,254	995.472	14.215	1009.687	74.06
Goat	88,037,053	180.710	13.703	194.413	13.25
Sheep	50,284,350	152.905	12.514	165.419	8.84
Swine	9,509,551	15.286	45.682	60.968	2.51
Poultry	200,446,756	-	38.28	38.28	1.34
Total	369,182,964	1,344.373	124.394	1,468.767	100.0

Emission factors are obtained from FAOSTAT (2024)

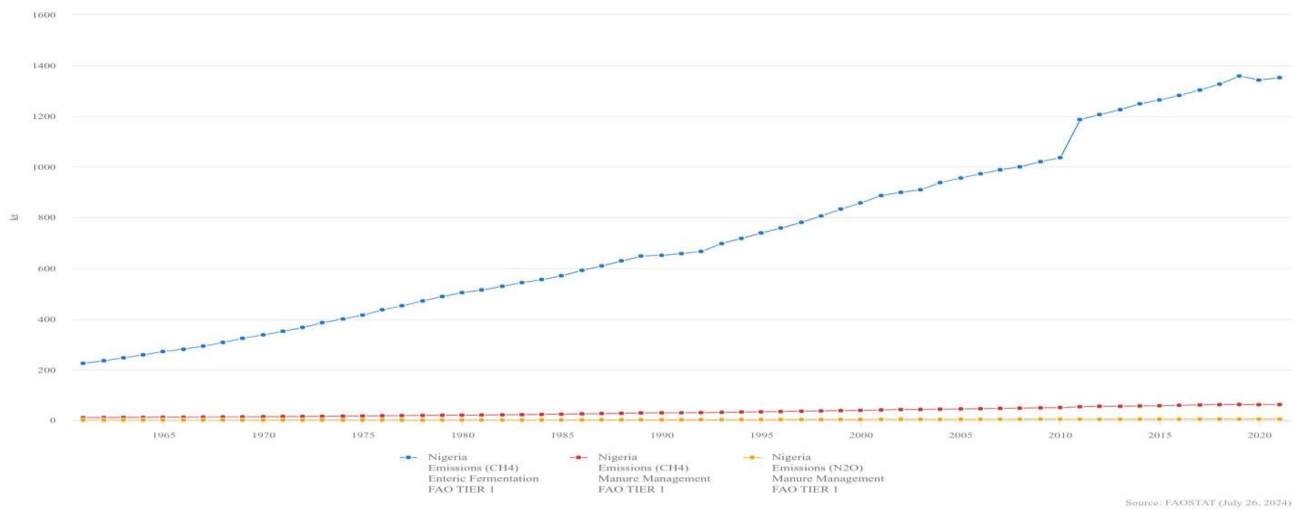

Figure 1: Trend in greenhouse gases emission between 1961 and 2022

Source: FAOSTAT (2024)

Mitigation options for methane emission from livestock: *The intricacy in defining absolute mitigation options for livestock greenhouse gas emissions may be due to differences in livestock species, production systems and climatic variations. This limits the capacity for a strategy to fully encompass all emission reduction potentials; hence combination of several selected options would produce a better outcome (Llonch* ***et al.,*** *2017). Some of the GHG emission strategies are summarized into three broad headings as follow;*

Nutrition: *Nutritional techniques exist for the improvement of rumen efficiency. This includes diet manipulation, use of direct inhibitors, feed additives, propionate enhancers, methane oxidisers, probiotics, defaunation and hormones (Zeoula* ***et al.,*** *2018). Diet composition has significant effect on rumen microbial ecosystem and so any manipulation in the diet by means of forage, concentrate and their components will result in change in the microbial community and may decrease or inhibit activity* *of methanogenic bacteria. Dietary manipulation can be achieved by increasing the quantity of green fodder thereby decreasing methane production by 5.7 % (Singhal and Madhu Mohini, 2002). Efficiency in ruminant production systems can also be enhanced through the use of concentrate feeds, allowing animals emit less GHG per unit of product (Pelletier* ***et al.,*** *2010). Some methane inhibitors tested in vivo for reduced emission include Bromo-chloromethane (BCM), 2-bromoethenesulfonate (BES), chloroform and cyclodextrin and were found to reduce methane production by up to 50% in cattle and small ruminants (Knight* ***et al.,*** *2011). Also, reduction in methane emission by 15 to 32 % has been achieved through increasing the level of concentrate in the diet of animals (Singhal and Madhu Mohini, 2002). Diet supplementation has also recorded substantial progress. The diet for all animal species should be balanced for amino acids to avoid a depression in feed intake and a decrease in animal productivity. Manufactured amino acids are routinely used to balance the diet*

Livestock management*: Global analyses have clearly shown that greenhouse gas (GHG) emissions particularly of CH4 and N2O are inversely related to animal productivity (Gerber* ***et al.,*** *2011). Increase in animal productivity can be achieved through improvements in animal genetics, feeding, reproduction, health, and overall management of the animal operation. In many parts of the world, reduction in animal numbers was the single most influential mitigation strategy that significantly reduced the C footprint (Capper* ***et al.,*** *2009). For instance, in The Netherlands, Sheep population has reduced from 57.9 million in 1990 to 45.2 million in 2000, while dairy and beef cattle population have increased slightly (Bannink* ***et al.,*** *2011). The net outcome was a decline in ruminant CH emission from 1.45 to 1.314 Tg/year from 1990 to 2000 (Sejian* ***et al.*** *2011).*

Livestock farmers' education, review of product consumption and economic development*: Education opportunities for livestock producers especially the Fulani cattle herders in Nigeria may be one component of efforts to promote the use of emissions - reducing practices. Such programs could be one avenue for implementing the emissions- reduction initiative. Lowering consumption of meat and milk in areas having high standards of living will support short term response to the GHG mitigation.*

Conclusion and Recommendation: *Livestock production especially ruminants contribute significantly to GHGs emissions. Based on the above points, it appears that nutrition and prioritizing sheep and goat against cattle are the two possible options that could mitigate methane production by livestock in Nigeria aside raising of non-ruminants.*

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CAIT, 2018*. Climate Analysis Indicators Tool. Emissions from other fuel combustion include emissions from stationary and mobile sources such as commercial/institutional, residential, or agricultural/forestry/fishing/fish farms. Other fuel combustion also includes biomass combustion.*

Impacts of egg position and duration of storage on external qualities of Isa brown eggs

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Abstract

The objective of this study was to determine the impacts of egg position and duration of storage on external quality characteristics of Isa brown eggs. A total of 360 table eggs laid by ISA brown layers were collected within 24 hours of lay and used for this study. Eggs from the first treatment (T1) were stored normal placement at room temperature of 28.7^{0}C and relative humidity of 75.9%; eggs from the second treatment (T2) were stored upside down placement at room temperature of 28.7^{0}C and relative humidity of 75.9% and eggs from the third treatment (T3) were stored horizontal placement at room temperature of 28.7^{0}C and relative humidity of 75.9%. Eggs in all the treatments were preserved for 7, 14, 21 and 28 days respectively in plastic crates on the laboratory bench. The results revealed that external traits (egg weight, egg length, egg width, shell weight and shell thickness) of eggs were not affected by the duration of storage until after 21 days. The same deterioration effects were felt in all the positions of eggs during egg storage while storage conditions had significant effect after 14 days of storage. It can be deduced that egg stored in plastic crate on the table of any position of eggs will keep egg quality intact until 14 days.

Keywords: *Egg position, storage duration, egg quality, Isa brown.*

Introduction: Eggs have been one of the most acceptable and affordable human food and are being referred to as nature's sources of protein foods, offering nutrients of great biological value as vitamins, minerals and fatty acids required for growth and maintenance of body tissues (Belitz *et al.,* 2009). However, during egg storage, some components of eggs may alter and tend to deteriorate in quality (Scot and Silversides, 2001). The main factors that affect the quality of eggs immediately after lay are temperature, relative humidity conditions and storage time. An intense deterioration begins after 72 h of lay, the dense layer tends to become liquid, and consequently albumen loses its quality (Adeogun and Amole, 2004). Therefore, less time is required between laying and preservation methods, besides suitable transportation to the retail market. From farm to consumer's table, egg is subjected to physicochemical changes that affect the yolk and albumen qualities which may modify flavour, freshness and palatability. As the storage time increases, the external and internal qualities are affected because of carbon dioxide that is being transferred through egg shell (Oyeleye *et al.,* 2022). It has been reported that cold storage can preserve eggs for 6 to 9 months, with increased shelf life and subcooled storage of −1.5 °C (Belitz *et al.,* 2009). Packing eggs under modified atmosphere preserves their internal quality up to 28 days (Gomez-de- Travecedo *et al.,* 2014).

Egg qualities are those characteristics that affect acceptability by consumers; it is therefore important that attention is paid to the preservation and marketing of eggs to maintain their quality. One of the most important qualities of egg is the egg weight. It is the first quality that is considered by the consumer. Other external quality characteristics including cleanliness, freshness, shell appearance and shell weight are important in consumer's acceptability of eggs (Adeogun and Amole, 2004; Dudusola, 2010; Gerber, 2012; Scott and Silversides, 2001). The egg is a complex structure distinguished by having four different parts: the eggshell, shell membrane, albumen, and yolk. On the other hand, processors take into account easy eggshell removal and separation of the yolk from the albumen, as well as egg functional properties. When eggs are for human consumption, it is important that they are suitable for this purpose (Williams, 1992). Conventionally eggs are stored in either paper crate or plastic crate with the tapper end down and the broad end up. However, there is dearth of information in storing eggs upside down and horizontally. Therefore, the objective of this study was to determine the effects of egg position and duration of storage on the external qualities of table eggs of Isa brown layers.

Materials and Methods: Experimental Site: This experiment was carried out at Food Processing Laboratory, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State. Okitipupa lies between latitude 6.25° and 6.46° N and Longitude 4.35° and 4.50° E within the tropical rainforest zone of Nigeria.

Experimental Materials: 360 table egg laid by ISA brown layers collected within 24 hours of laying, were bought from Aduro's Farm in Okitipupa, Ondo State for this study. Fifteen (15) eggs were randomly selected immediately and subjected to analysis to determine the egg qualities.

Evaluation of Egg Quality : The eggs were weighed on an electronic weighing balance to determine their weight in grams. Egg length and egg width were measured with a Vernier caliper in centimeters. Egg shape index calculated as the ratio of egg width to egg length (%) by method of Anderson *et al.,* (2004). After the eggs are broken, eggshells are washed with water and dried in order to clean the remaining albumen. Following Anderson's procedure, shell weight (with membrane) is measured using a laboratory scale Owa Labor (VEB Wägetechnik Rapido, Germany) and the percentage proportion of the shell in the egg determined. Shell thickness (with membrane) was measured at the sharp poles, blunt poles, and equatorial parts of each egg using digital Vernier caliper (Wagetechnik, Germany). Shell thickness was obtained from the average values of these three parts.
Eggshell thickness was measured with Vernier caliper, Egg shape indexes estimated using the equation:

$$\frac{\text{Egg width}}{\text{Egg length}} \times 100$$

Eggshell weight was measured using electronic balance (Mexler – Teledo PB 3002 with sensitivity of 0.01 g) after air-dried for 72 hours in egg trays. Eggshell ratio (%) according to Olawunmi and Ogunlade (2004) was gotten by using the equation:

$$\frac{\text{Eggshell weight}}{\text{Egg weight}} \times 100$$

Statistical Analysis: The data collected on egg quality were subjected to two-way analysis of variance (SPSS/24 PC Statistics 24.0 IBM) to determine the effects of egg position and storage duration on egg quality. Significant means were separated using Duncan Multiple Range Test (Duncan, 1955).
Results and Discussion: Table 1 reveals the effect of duration of storage on the external traits of table eggs. At T1(Normal placement in a plastic crate on the lab bench at room temperature), significant differences ($P<0.05$) were observed in egg weight ($50.98^{b}\pm3.82$) and shell weight ($6.69^{b}\pm0.69$) at 28 days of preservation. Shell thickness ($0.49^{c}\pm0.13$) showed significant difference at 14 days of preservation. Egg width and egg length showed no statistical significance through day 0 to day 28. At T2 (Upside down placement in a plastic crate on the lab bench at room temperature), there was no significant difference in shell weight, egg width and egg length from day 0 to day 28 while egg weight ($57.70^{b}\pm3.88$) was significant at 28 days ($P<0.05$). The weight of the eggs decreased with age. Shell thickness ($0.47^{c}\pm0.07$) was significant after 14 days of preservation($P<0.05$). Table 2 reveals the effect of egg position on external traits of table eggs. At day 7, the significant effects of egg position were not well felt. There were slight differences across all the parameters. At 14 days, no significant difference in egg weight, egg length, shell thickness except in T1 in the egg width ($P<0.05$). At 21 days, there was no significant difference in all the parameters except in the shell thickness ($P<0.05$). At 28 days, T1 differed significantly in egg length, egg width and shell weight ($P<0.05$).

There have been reports of decreased egg weight as storage time increased (Khan *et al.,* 2013). Khan *et al.* (2013) and Gomez-de-Travecedo *et al.,* (2014) have reported that the rate of loss tends to vary depending on the storage time. Egg weight was adversely affected at day 28 by the duration of storage which occurred in the plastic crates on the table. This was as a result of water that evaporated through the egg shell which led to the shrinkage of the egg resulting in egg weight decrease. The external qualities affected by the medium of storage was in contrary to the study of Khan *et al.,* (2004); Jones (2006) and Chatterjee *et al.,* (2009). Shell ratio was not affected at the room temperature across all the durations of storage. The same deterioration effects were felt in all position of the eggs which began to have effect after 21 days.

Table 1. Effect of duration of storage on external parameters.

Treatment	*Age*	*Egg weight*	*Egg length*	*Egg width*	*Shell weight*	*Shell thickness*
T1	0	$62.07^{a}\pm4.73$	$55.43^{a}\pm3.96$	$43.65^{a}\pm2.79$	$8.11^{a}\pm0.80$	$\mathbf{0.72^{ab}\pm0.17}$
	7	$60.81^{a}\pm4.79$	$54.02^{a}\pm4.38$	$42.51^{a}\pm4.38$	$7.85^{a}\pm0.64$	$\mathbf{0.83^{a}\pm0.36}$
	14	$59.71^{a}\pm6.05$	$55.39^{a}\pm3.98$	$40.67^{a}\pm7.02$	$7.67^{a}\pm0.81$	$\mathbf{0.49^{c}\pm0.13}$
	21	$57.92^{a}\pm4.91$	$54.81^{a}\pm1.76$	$43.94^{a}\pm1.40$	$7.70^{a}\pm0.61$	$\mathbf{0.56^{bc}\pm0.12}$
	28	$50.98^{b}\pm3.82$	$52.45^{a}\pm2.85$	$40.88^{a}\pm3.27$	$6.69^{b}\pm0.69$	$\mathbf{0.46^{c}\pm0.06}$
T2	7	$62.24^{a}\pm2.25$	$57.27^{a}\pm5.34$	$44.25^{a}\pm2.26$	$8.16^{a}\pm0.57$	$\mathbf{0.77^{a}\pm0.13}$
	14	$61.69^{ab}\pm5.36$	$56.98^{a}\pm2.48$	$44.15^{a}\pm2.55$	$8.38^{a}\pm0.91$	$\mathbf{0.47^{c}\pm0.07}$
	21	$60.98^{ab}\pm6.33$	$56.73^{a}\pm3.22$	$44.27^{a}\pm1.37$	$7.90^{a}\pm0.82$	$\mathbf{0.51^{bc}\pm0.06}$
	28	$57.70^{b}\pm3.88$	$56.72^{a}\pm3.99$	$43.87^{a}\pm1.17$	$7.91^{a}\pm0.46$	$\mathbf{0.54^{b}\pm0.06}$
T3	7	$62.97^{a}\pm2.55$	$54.69^{ab}\pm4.16$	$43.64^{b}\pm8.14$	$8.06^{a}\pm0.55$	$\mathbf{0.58^{a}\pm0.10}$
	14	$61.58^{a}\pm3.39$	$56.77^{a}\pm2.44$	$44.17^{ab}\pm2.91$	$8.25^{a}\pm0.55$	$\mathbf{0.49^{a}\pm0.06}$
	21	$61.55^{a}\pm2.55$	$56.29^{ab}\pm2.48$	$44.76^{a}\pm6.97$	$8.06^{a}\pm0.47$	$\mathbf{0.57^{b}\pm0.08}$
	28	$\mathbf{56.23^{b}\pm4.49}$	$\mathbf{54.03^{b}\pm4.41}$	$\mathbf{44.22^{ab}\pm0.88}$	$\mathbf{7.98^{a}\pm0.69}$	$\mathbf{0.44^{b}\pm0.05}$

Note: Means with different superscript in a row are significantly different (P<0.05).

Table 2: Effect of egg position on external parameters

Duration	*Treatment*	*Egg weight*	*Egg length*	*Egg width*	*Shell weight*	*Shell thickness*
	T1	$60.81^{b}\pm3.61$	$54.02^{a}\pm4.38$	$42.51^{a}\pm4.38$	$7.85^{a}\pm0.64$	$0.83^{a}\pm0.36$
	T2	$62.24^{ab}\pm4.79$	$57.27^{a}\pm5.34$	$44.25^{a}\pm2.26$	$8.16^{a}\pm0.57$	$0.77^{a}\pm0.13$
7	T3	$62.97^{ab}\pm2.25$	$54.69^{a}\pm4.16$	$43.68^{a}\pm1.97$	$8.06^{a}\pm0.55$	$0.58^{ab}\pm0.11$
	T1	$59.71^{a}\pm6.05$	$55.39^{a}\pm3.99$	$40.67^{b}\pm7.02$	$7.68^{c}\pm0.81$	$0.49^{a}\pm0.13$
	T2	$61.69^{a}\pm5.36$	$56.98^{a}\pm2.48$	$44.15^{a}\pm2.55$	$8.38^{a}\pm0.91$	$0.47^{a}\pm0.07$
14	T3	$61.58^{a}\pm3.39$	$56.77^{a}\pm2.44$	$44.17^{a}\pm1,13$	$8.25^{ab}\pm0.55$	$0.49^{a}\pm0.06$
	T1	$50.92^{a}\pm4.91$	$54.81^{a}\pm1.76$	$43.94^{a}\pm1.40$	$7.70^{a}\pm0.61$	$0.56^{ab}\pm0.12$
	T2	$60.98^{a}\pm6.33$	$56.73^{a}\pm3.22$	$44.27^{a}\pm1.37$	$7.90^{a}\pm0.82$	$0.51^{bc}\pm0.06$
21	T3	$61.55^{a}\pm2.55$	$56.29^{a}\pm2.48$	$44.76^{a}\pm0.75$	$8.06^{a}\pm0.47$	$0.58^{a}\pm0.08$
	T1	$50.98b^{a}\pm3.82$	$52.45^{b}\pm2.85$	$40.88^{b}\pm3.27$	$6.69^{b}\pm0.69$	$0.46^{bc}\pm0.06$
	T2	$57.70^{a}\pm3.88$	$56.72^{a}\pm3.99$	$43.87^{a}\pm1.17$	$7.91^{a}\pm0.46$	$0.54^{a}\pm0.06$
28	T3	$56.23^{a}\pm4.49$	$54.03^{ab}\pm4.41$	$44.22^{a}\pm1.01$	$7.98^{a}\pm0.69$	$0.44^{c}\pm0.05$

Note: Means with different superscript in a row are significantly different (p<0.05).

Conclusion: It can be deduced that egg stored in any position will keep the quality intact till 14 days. It is not advisable to store eggs beyond duration of 14 days in any medium of storage.

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Actions of *Vernonia amygdalina* (Bitter Leaf) Extracts on a Gastroenteritis Bacteria in a Coastal Agricultural Environment in Southwestern Nigeria

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Abstract

The main target of this research is to investigate the activities of extracts of *Vernonia amygdalina* on *Salmonella enteritidis* causing gastroenteritis, isolated from a coastal agricultural environment where livestock manure mainly cow dung is used for soil improvement in crop production. The plant materials were obtained by using extraction medium of ethanol, water and chloroform. The susceptibility of the test bacteria was determined using the agar-well technique where the diameter of the zones of inhibition was measured in millimeters (mm). The minimum inhibitory concentration was determined using the agar-dilution method for each of the extracts. Microsoft office excel 2010 version was used to compute the charts for the zones of inhibition (mm) and Statistical Package for Social Science (SPSS) version 25 was used to determine range mean and $p<0.05$ based on a one-way ANOVA test was used to determine statistically significant difference between the results obtained from the three extracts. The three extracts of *Vernonia amygdalina* all showed antimicrobial properties inhibiting the growth of the test bacteria. Ethanolic extract was observed to be more potent and show larger inhibition when compared to the other two extracts. The ethanolic extract showed the largest zone of inhibition among the three extracts with the value of 21±1.00 mm at 125 mg/ml. The potency of the aqueous extract was lower than that of the ethanolic extract with values for zones of inhibition ranging from 11±0.56 mm to 17±1.00 at 25 mg/ml and 125mg/ml respectively. The least potent of the three extracts was the chloroform extract that inhibited the growth of the test organism at higher concentrations of 100 mg/ml and 125 mg/ml with zones of inhibition of 9±2.0 mm and 10±1.5 mm respectively. The minimum inhibitory concentration was higher for the chloroform extract due to its low potency, it was observed to be 100 mg/ml which is higher than the two other extracts that were found to be 25 mg/ml. phytochemical analysis was carried out on the extracts and bioactive components found present are flavonoids, alkaloids, reducing sugars, saponins, tannins, anthraquinones, steroids, terpernoids, cardiac glycosides and these were contributory factors to the antimicrobial properties of the extracts The extracts from *Vernonia amygdalina* was generally observed to inhibit the growth of *Salmonella enteritidis,* this implies that the extracts of the plant have antibacterial properties. Further research is recommended to understand more on the structure of the components of the bioactive substances in *Vernonia amygdalina* and their principles of action as a lead way to the formulation of potent antibacterial agents and drugs.
Keywords: Gastroenteritis, Bacteria, *Vernonia amygdalina, inhibition,* Bitter leaf extract, Salmonella *enteritidis,* susceptibility

Introduction: Herbs and plants are abundant in nature which form the main source of traditional medicines used for relief in some infectious diseases and are still widely used all over the world (Ajose, 2017). Medicinal plants have a long history of use and their use is spread across both developing and developed countries kavitha (2016). According to the report of the World Health Organization (WHO), 80 per cent of the world's populations rely mainly on traditional therapies which involve the use of plant extracts or their active substances (WHO, 1993). Plants generally contain certain bioactive substances that make them relevant over the years in traditional medical practices and these extracts are modified in drug industries for pharmaceutical use (adebanjo et al. 1983). From the advent of drug development, it is evident that many drugs have been derived from medicinal plants (yuan et al. 2016). Plant-derived compounds have been precursors to drug formulation, many are used as drugs, either in their original or semi-synthetic forms and have been proven to be effective. In recent times, Antimicrobial drug resistance has received increased attention from several international bodies and is more generally recognized as a threat to global health (Davies and Davies, 2010, Fanta and Gemechu, 2017). Overtime, much concern in the treatment of infectious diseases caused by many of the bacterial pathogens associated with epidemics of human disease is their evolution into multidrug-resistant (MDR) forms subsequent to antibiotic use, which render therapy more precarious, costly and sometimes unsuccessful causing fatality in many cases (Ventola, 2015). These increasing concerns of the MDR bacteria pathogens are now a great concern to both the clinicians and pharmaceutical industries and this has made it significant to search for newer drugs that are highly effective, affordable, acceptable and available (Martino et al., 2002; Akinjogunla et al., 2011). This have also increased the demand for drugs from plants in recent times, as many plants or herbs are scientifically proven to contain bioactive compounds that can be precursor to novel drugs coupled with the global campaign for consumption of plant based substances as food supplement compared to synthetic substance usage (Vadhana, 2015). It is stated by Ashraf et al. (2015) that some medicinal plants in which their activities are either not yet confirmed scientifically or need further exploitation after confirmation even though they are traditionally used by the local communities. Some plants known to be used primitively to alleviate symptoms of illnesses have been screened to have medicinal importance, some of which include Azadirachta indica (Dogonyaro), V. amygdalina (Bitter leaf), Allium sativum (Garlic), O. gratissimum (Scent leaf), and Zingiber officinale (Ginger). These plants have been reportedly used in the treatment of ailments such as stomach disorder, fever symptoms and cough traditionally (Evbuomwan et al. 2017). This study will conduct its research using Vernonia amygdalina. According to study of Anibijuwon et al. (2012), Vernonia amygdalina is considered to be readily availabile and useful to homes, but it is still categorized as an underutilized crop. The main bioactive constitutions in bitter leaf according to Abere et al. (2018) was identified as Sesquiterpene Lactones in which its subunits are made up of Vernoniosides A1, Vernoniosides 2, Vernoniosides B1, Vernoniosides B2, Vernodalin, Vernolepin, Vernomygdin, Vernodalol and Vernodalinol. Constituents of Sesquiterpene Lactones are said to be responsible for the bitter taste of *Vernonia amygdalina* and observed to possess antimicrobial and antitumor activities. *Vernonia amygdalina* (Bitter Leaf) is one of the medicinal plants used in the treatment of many diseases (Ogundare, 2011 and Abere, 2018). The plant is a shrub usually about five-meter high, the leaves are simple and entire (5x15 cm) finely glandular below and displaying few lateral nerves. Anibijuwon (2012), explained that the plant leaves are used in the preparation of soup in food in many homes, especially in the southern part of Nigeria and east African countries like Ethiopia and Kenya. The plant is also used in the treatment malaria, helminth infection, gastrointestinal disorder and fever.

The presence of microorganisms like *Escherichia coli, Shigella* spp, *Salmonella* and other enteric bacteria in agricultural environment are boosted by the use of manure from animal dung (Black et al. 2021). Manure is used to improve soil conditions in order to make plant nutrients readily available, this became necessary to support intensification of agriculture to meet the rising global population (Chaudhari, 2021). "The use of animal manure for soil amendment intensifies the spread of Antimicrobial Resistance Genes (ARGs) as they are prominent in the animal gut due to the overuse of antibiotics in farming or intensive use of in-feed antibiotics" [Zhao et al. 2018 and Zeng et al. 2018]. "When Crops are produced under these conditions they have potentials to contain organisms found within the soil micro-biome, creating a potentials route for pathogens finding their way into the food chain causing various illnesses" [Grarchi-Sanchez]. "Manure application can inadvertently spread zoonotic diseases to humans" (Tran et al. 2020). Bacteria pathogen found within manure associated with bacterial outbreaks include, but are not limited to *Campylobacter, Salmonella* and strains of pathogenic *E.coli* such as O157:H7" [Swanenburg et al. 2001 and Zhong et al. 2020]. "*Salmonella* is a facultative anaerobe with many serotypes capable of causing gastroenteritis in humans" [Black et al. 2021]. "The infective dose of Salmonella is debated in many literatures, but generally it is agreed that the dose required is higher than that of *Campylobacter and E.coli"* [Hara-Kudo et al. 2011]. "An increase in the occurrences of antimicrobial resistant strains of *Salmonella"* has been reported by [Williamson et al. 2017]. "Crops exposed to *salmonella* contaminated soils may be enablers of bacterial population growth and maintenance as well as a vehicle for transmission to human populations" [Black et al. 2021]. Guo et al. (2002) Reported that "*Salmonella* levels remained constant within the soil over an initial 14-day period with little decline over a 45-day period". Ge et al. (2012) Reported that normal techniques of washing with water may not remove or reduce the risk of infection in humans of salmonella on some food crops. The prevalence, antimicrobial resistance and infectious nature reported to have been exhibited by *salmonella spp*. (Black et al. 2021) forms the thrust of this research work. This work investigates the activities of *Vernonia amygdalina* on *Salmonella enteritidis* that have been reported to be a cause of infectious gastroenteritis in humans.

Materials and Methods: **Collection and Identification of Plant Materials:** Leaves of *Vernonia amygdalina* were collected in an agrarian community of Itebu-Manuwa, Ilushin area of Ogun waterside LG in Ogun state. Leaves were also collected in Igbotako in Okitipupa LG and Igbokoda in Ilaje LG areas of Ondo state, all within the coastal region of the southwestern part of Nigeria. The cow dung samples from which the bacteria were isolated were collected during the period between the month of January and Feburary 2024. The plant is cultivated on farms, gardens and backyards in the areas and it is used in preparation of soup for food and also used as medicine. The leaves were identified by Olusegun Koko an Agricultural officer at the Planning Research and Statistics Department of the Ogun state Ministry of Agriculture. Five (5) kg of *Vernonia amygdalina* leaves were collected from each of the four locations making a total of twenty (20) kg and air dried for one week and grinded into powder using a blender and stored in a bottle container till when needed.

Preparation of Crude Extract and Plant Extract : The method adopted by [18] was used to prepare crude extract of *Vernonia amygdalina*. Fifty gm of powdered plant material was soaked in 250 ml of each of distilled water, Chloroform and ethanol for 24 hours. A sieve was used to filter the extract to remove debris and passed through filter paper. The filtrate obtained was evaporated in a water bath at 40°C to get the crude extract. The extracts for ethanol and aqueous was stored at 4°C until required for phytochemical and antimicrobial test. The plant extract was later prepared by putting one gm each of the crude extracts of ethanol, aqueous and chloroform extract into 5ml of ethanol, distilled water and chloroform respectively and diluted to give a concentrations of 125 mg/ml, 100 mg/ml, 75 mg/ml, 50 mg/ml and 25 mg/ml.

Sterilization Techniques : Glassware used was sterilized in a hot air oven at 170°C for 2 hours after proper washing and drying. Aluminum foil was used before sterilization to wrap each of the material. Distilled water was autoclaved at 121°C for 15 mins, Cork borer and glass rods were flamed using Bunsen burner after been dipped into 70% alcohol. Constant swabbing of the work bench during the experiment was carried out.

Phytochemical Analysis of Plant Extracts: Phytochemical parameters tested in Vernonia amygdalina using standard methods were glycosides, steroids, flavonoids, tannins, alkaloids, proteins, saponins, quinines and sugars. Test for glycosides: 25 ml of dilute sulfuric acid (H_2SO_4) was added to 5ml of plant extract in a 100 ml volume flask, boiled for 15 minutes cooled and further neutralized with sodium hydroxide (NaOH). Fehling solution A and B (5 ml) was added to the neutralized solution where a brick red precipitate of reducing sugars indicates the presence of glycosides. Test for steroids: 1 g of the plant extract was dissolved in a few drops of acetic acid, warmed and cooled under the tap water. Sulfuric acid (H_2SO_4) was added along the sides of the test tube. Appearance of green coloration indicates the presence of steroids.

Test for tannins: The plant extracts were mixed with basic lead acetate solution. The absence of Formation of white precipitate indicated the absence of tannins. Test for alkaloids: Plant extracts were shaken with few drops of 2N HCL. An aqueous layer was formed which was decanted, one or two drops of Mayer's reagent was added and the observation of the formation of white precipitate indicated the presence of alkaloids. Test for flavonoids: Few magnesium turnings and concentrated hydrochloric were added to the plant extract in alcohol and then boiled for 15 minutes. Appearance of red coloration indicates the presence of flavonoid. Test for saponin: The plant extract was shaken vigorously with water and formation of foamy leather indicates the presence of saponin. Test for quinines: Indication of blue green or red color on addition of sodium hydroxide to the extract indicates the presence of quinine.

Test Microorganism: The test microorganism used was *Salmonella enteritidis* which was isolated from the manure applied for soil improvement on the farms in the study area. The availability of large numbers of cattle herds in the area makes farmers have access to enough cow dungs that is used on farmlands. The bacteria strains were grown in nutrient agar plates at 37°C.

Antibacterial Susceptible Testing tf the Extracts with Organism: The test organisms were inoculated in nutrient broth and incubated for 24 hours at 37°C and the cultures were diluted to 0.5 McFarland turbidity standards after the incubation. 0.2milliliters of the culture was diluted using normal saline. Inoculation of culture was done using glass rod into solidified nutrient agar by using the spreading technique. The agar well technique was used to determine the ability of the extract to inhibit the growth of the test organisms.The inoculated nutrient agar plates were allowed to dry and wells are bored on the surface of the inoculated agar plates using sterilized 6 mm cork borer 0.3 ml of each of the extracts at different concentrations were filled into the well using a sterilized Pasteur pipette. To prevent overlapping of the zones of inhibition, the wells were adequately spaced. Incubation of the plates was done at 37°C for 24 hours. The experiment was performed in triplicate and the zones of inhibitions obtained were recorded as mean ± standard error.

Determination Of Minimum Inhibitory Concentration: Minimum inhibitory concentration of the extracts was determined by agar dilution method, the dilutions of the extracts were prepared in 1% dimethyl sulfoxide, which is clear of antimicrobial activity against the test organism. Two portions of extracts were prepared and 2 ml of aliquots of the various concentrations of the different extracts were added to 18ml pre-sterilized Mueller Hinton agar at 50°C to produce a final 20 mg/ml which was then poured into pre-labeled sterile Petri dishes on a level surface. Petri dishes containing only the growth media prepared in the same way were also made available so as to compare the growth of the test organism with that including the extract. The lowest concentration of each of the extracts which inhibited the growth of the test organism is taken as its minimum inhibitory concentration.

Data Presentation And Analysis: The data were analyzed using statistical Package for Social Science (SPSS) version 25. Mean values of the results were obtained and data were interpreted based on the standard interpretive results of zones of inhibition diameter in millimeters (mm) of extracts at the different concentrations on the test organisms. $P<0.05$ based on one-way ANOVA was used to indicate statistically significant differences in the results obtained for the three different extracts and results were presented in tables and charts.

Results: Phytochemical analysis of the different extract shows the presence of flavonoids, tannins, glycosides, reducing sugars, terpenoids, saponins, anthraquinones, alkaloids and Steriods. The results are presented in Table 1. These phytochemicals were present in all three extracts, except for the absence of tannins in both ethanolic and aqueous extracts and the absence of anthraquinones and alkaloids in the chloroform extract. The results for Zones of inhibition obtained for each extracts are presented in Fig. 1 Results showed that the ethanolic extract (BLE) showed zones of inhibitions at all concentrations.

Discussion: The activities of *Vernonia amygdalina* on *Salmonella enteritidis* was observed to be dependent on the medium used for extraction and the concentration of the extract. Ethanolic abstract was observed to show zones of inhibitions at all concentrations and therefore exhibit more antibacterial activities when compared to aqueous and chloroform extract this could be as a result of the fact that ethanol extracted more bioactive substances present in the plant a similar result was obtained in the work of [Evbuomwan et al. 2017]. This may also be due to the higher volatility of the ethanol which tends to extracts more bioactive compounds from the samples than water this was also reported by [Anibijuwon, 2012].The results showed the highest zone of inhibition at the highest concentration of 125mg/ml. The values of these zones of inhibition ranged from 15±1.0mm at 25mg/ml and 21±1.0mm at 125mg/ml. the minimum inhibitory concentration obtained from the result for the ethanolic extract was found to be 25mg/ml. when the results obtained were subjected to ANOVA test it was found that there was significant difference between the results when compared to the other two extracts with $p<0.05$. This finding was similar to the work of [Ogundare, 2011] who recorded antimicrobial susceptibility of some microorganisms to ethanolic extracts of *Vernonia amygdalina*. The antibacterial property exhibited by the ethanolic extract can be linked to the different secondary metabolites or phytochemicals present and they have been described by [Fanta et al. 2017] to have antimicrobial properties.

Fig 1. Map showing the study area

Table 1. Phytochemical analysis of ethanol, aqueous and chloroform extract of *Vernonia amygdalina*

Phytochemicals	*Solvents*		
	Ethanol	**Aqueous**	**Chloroform**
Flavonoids	+	+	+
Tannins	-	-	+
Glycosides	+	+	+
Reducing Sugars	+	+	+
Terpenoids	+	+	+
Saponins	+	+	-
Anthraquinones	+	+	-
Alkaloids	+	+	-
Steroids	+	+	+

Key: + = present; - = absent

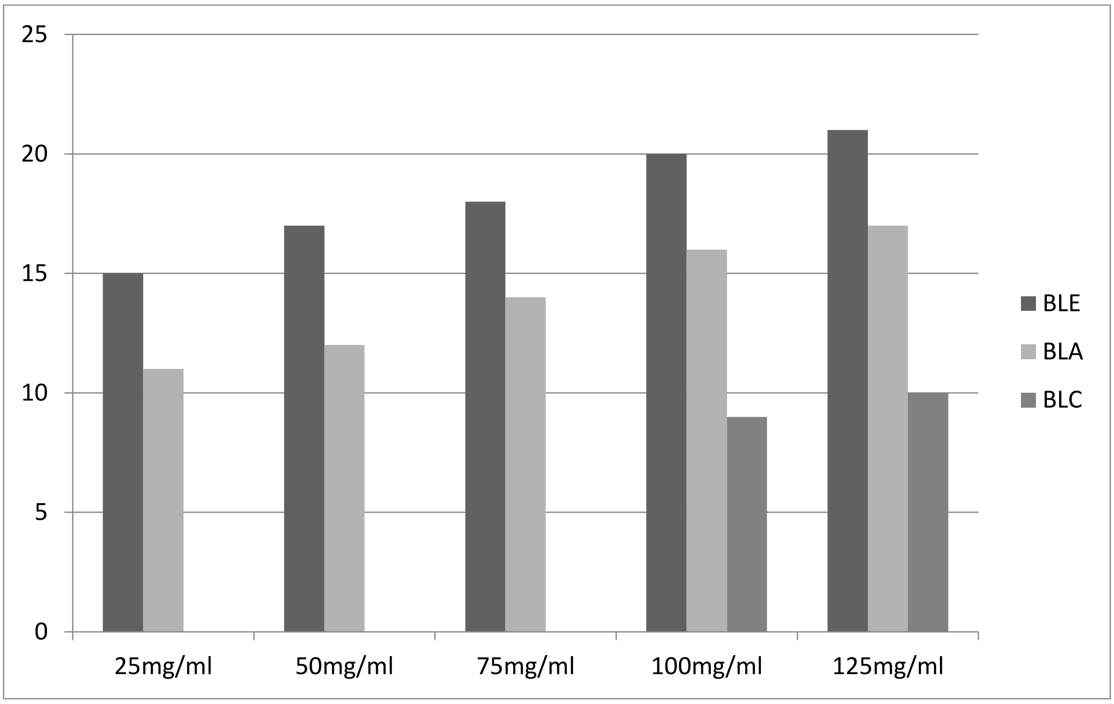

Fig. 2. Antibacterial activity of the three extracts (zones of inhibition are measured in millimeters)

The aqueous extract (BLA) was found to also exhibit antibacterial properties but the zones of inhibitions observed was less in diameter when compared to that of the ethanolic extract. The zones of inhibitions increases as concentration increases, the lowest zone of inhibition was recorded at 25 mg/ml concentration with the value of 11±0.56 mm and the highest zone of inhibition was recorded at the highest test concentration of 125 mg/ml with the value of 17±1.00 mm in diameter. The minimum inhibitory concentration found for the aqueous extract is 25 mg/ml similar to the concentration of the ethanolic extract. Using ANOVA test at $p<0.05$ the result showed significant difference in the zones of inhibition obtained when compared to the other two extracts. The chloroform extract (BLC) is the less effective of the three tested extracts this may be connected to low availability of bioactive substance in the extract when compared to the other two extracts. The result showed that the test bacteria were not susceptible to the extract at 25, 50 and 75 mg/ml but was susceptible at higher concentrations of 100 and 125 mg/ml, the zones of inhibition ranged between 9±2.0 mm and 10±1.5 mm at these concentrations respectively. The results obtained showed significant difference when compared with the results of the two other extracts at $p<0.05$. The minimum inhibitory concentration of the chloroform extract was found to be 100mg/ml higher than that of the two other extracts. generally the result showed that the values obtained for each of the three extracts of Ethanol, water and chloroform using ANOVA test, were statistically significantly different at $p<0.05$.

Conclusion: The results obtained in this research work indicated that the leaves of *Vernonia amygdalina* contain antimicrobial properties that can inhibit the growth of *Salmonella enteritidis*. The three extracts showed varying activities on the test bacteria with the ethanolic extracts being more potent than the other two therefore, the plant extracts should be further explored to develop antibacterial drugs. The extracts from the leaves of *Vernonia amygdalina* should be tested in-vivo after the bioactive components in the plant have been isolated.

Recommendation:Further study of the structural components and principle of action of these bioactive should be explored for subsequent processing into chemotherapeutic agents.

Competing Interests: Authors have declared that no competing interests exist.

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Evaluation of Extension Services Delivery among Rural Populace on The Adoption Ofimproved Wheat Production Technologies In Bebeji Local Government Area of Kano State Nigeria

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Abstract

The research was aimed at Evaluation of Extension Services delivery among Rural populace on the Adoption of Improved Wheat production Technologies in Bebeji Local Government area of Kano State Nigeria This study was carried out in five communities of Bebeji LGA of Kano State, Nigeria which were; Maizaure, Madiya, Tarau, Madaki and Yalwa as participation communities. Multistage random sampling was used to choose 189 respondents. Face-to-face interviews wheat producers generated primary data, which was obtained using structured questionnaires. The socio-economic profile of the sampled respondents was determined using descriptive methods. The data obtained from objective I, II and III was analyzed using descriptive statistics such as (frequency distribution, percentage mean) while objective IV was achieved using Kendall's coefficients. The outcome of the research appeared that most of the respondents were male and of active working group and the average age of the sample respondents was approximately 47 years while the average family size was 8. The findings of the study showed that 66.1% were married and literacy level was very low and sample respondents has 10 years of wheat farming experience. The result further revealed that 87% (46.1) of respondents in the study area access technical service while 56% (29.6) access facilitation services and 46% (24.3) access advisory services for the adoption of improved wheat production technologies. The result showed that a larger proportion of respondents do not enhanced improved wheat production technologies with an adoption rate of 70% which implies that rate of adoption is low in the study area. The results inadequate fund (X = 2.61), decrease in income (X = 3.64) and poor credit facilities (X = 5.33) were ranked first, second and third most severe constraints face by respondents in adoption of improved wheat production. It was recommended that credit facilities should be provided for the wheat producers in the study area to enable then expand the adoption of improved wheat production technologies

***Keywords**: Evaluation, Adoption, Wheat, Extension service, Rural, populace.*

Background of The Study: Wheat has been uneven compared to the demand over the years. The country's best output was in 2015 when the country produced 795,613 tones. Thereafter the out fell and picked up in 2019. It fell again in 2020. (Adeju et al, 2024). Despite the fluctuation in output, Nigeria's export of Wheat has improved significantly. Although, there was no continuous increase in export, data seen by DAILY TIMES of Thursday 13th 0ctober 2023, shows that the country recorded the highest export of Sesame in 2023. Ethopia is the highest producer of Wheat in Africa. Its output in 2023 was 7.500.000MT. Ethopia alone accounts for 50.6 percent of the total output of the top six African countries put together. Nigeria's output makes up 27.6 percent of the total output. By implication, Nigeria is the third –largest producer of wheat in Africa. We are currently doing 600,000 tones for Nigeria and out of the 70 percent of the Wheat seeds produced are exported abroad. Currently, there are 14 Wheat- growing state in Nigeria, Adamawa, Bauchi, Borno, Gombe, Jigawa, Kaduna, Kano, Katsina, Kebbi, Plateau, Sokoto, Taraba, Yobe, and .Jigawa has the highest number of production and total production in the country followed by Kano state.(Balachi 2023). The crop is commonly used for its high quality oils 8- 14% (Yusuf and Zainab, 2023). It is useful for Kidney cells function and for preventing aging. It is also rich in proteins; owing to its desirable amino acids status. Its nutritional value is similar to that of sesame (FAO, 2023). The oil was then used in cooking, and it's still one of the healthiest oil varieties in the world .It is of high nutritive value and is used for many purposes. The oil content is around 39% to 50%. The oil is used for cooking, preparation of salad as well as for the production of margarine, soap, pharmaceuticals, paints and lubricants. The residues are used as animal feed (Ubale *et.al,* 2023). Wheat is a herbaceous annual plant cultivated for its edible seed and flavor some values and it is also the oil seed crops cultivated globally (Karma and James, 2024). Wheat is found in tropical and subtropical areas of Asia, Africa and South America, it is grown for the oil in its edible seed. Wheat seed contain chemicals that might help reduce swelling, increase wound healing, and slow how fast sugar is absorbed from food (Ndana et al, 2024).

The purpose of this study is to evaluate extension service delivery among rural populace on the adoption of improved wheat production technologies in bebeji local area of Kano State Nigeria, the specific objectives are to:; describe the socio-economic characteristics of respondents in the study area,determine the of extension service delivery on adoption of improved Wheat production technologies in the study area. Examine the rate of adoption of improved wheat production technologies among the wheat farmer; ascertain the challenges faced by the respondents in the study area

Material and Methods:**Selection of the study area and sample**: The research was carried out in five (5) different communities in Bebeji Local Government area of Kano State. Both descriptive and analytical techniques were used for the study. The communities are: Maizaure, Tarau, Madiya, Madaki and Yalwa as participation communities in adoption of improved wheat production technologies.

Sampling Procedure and Sample Size

Multi-stage sampling technique was used for the study. The first stage involved random selection of Agricultural zones I in the State. At the second stage, one (1) Local Government Area (LGA) was randomly selected, this is due to the abundance of wheat production of farming activities in Bebeji local government area of agricultural zone I. The third stage involved random selection of five (5) communities from the Local Government Areas (LGA). At the fourth stage, 15% of the respondents were randomly selected from the sampling frame of each community. In all, a total of 289 respondents were selected from the LGA as the sample size for the study.

Table 1: Sample distribution of the respondents in the study area

Communities	Sample frame	Sample size (15%)
Maizaure	303	30.3
Tarau	232	23.2
Madiya	207	20.7
Madaki	130	13.0
Yalwa	128	12.8
Total	1000	100

Sources: Field survey, 2024

Method of Data collection and Analytical Techniques : Primary data was used for the study, the data were collected by researchers and trained enumerators using structured questionnaire complimented with interview schedule. The data obtained from objective I, II and III was analyzed using descriptive statistics such as (frequency distribution, percentage mean) while objective IV was analyzed using Kendall's coefficient

Results and Discussions: **Socio-economic Characteristics of Respondents** Table 2 revealed that 70.4% of the respondents were male while 29.6% were female. This shows that male dominate wheat production in the study area. This was due to the fact that male control decision in term of income in wheat production than the female counterpart in the study area, which allows males respondents to have total control on the income. This finding agreed with Adamu and Fatima (2023) who reported that male are dominance in wheat production in North central Nigeria. Table 2 also indicated that 58.7% of the respondents had age range of between 31- 40, while, 23.3% of the respondents had age range of between 41-50 years. The mean age of the respondents was 47 years, implying an active and productive age in wheat production. Audu and James (2023). Table 2 further revealed that majority (66.1%) of the respondents were married while 25.4% were single. This implies that since majority were married, it therefore suggests higher engagement and commitment to wheat production and adoption towards their sustainable livelihood. They also tend to have access to more family labour in wheat farming. Table 2 also revealed that 47.1% of the respondents had non formal education while 4.2% had tertiary education. This result revealed a lower preponderance of the educated respondents have negative effects on production and adoption of improved wheat technologies as while as strategies on wheat farming. The implication of this is that education provides a platform for adoption of new technologies strategies in agricultural enterprises and easy access to information. This agreed with Yusuf (2024) who observed that literacy had it owns merits and contribution towards the process of modernization of agricultural revolution. Further to Table 2, 73.5% of the respondents had household size of between 6-8 persons while 10.1% had household size of between 9-11 persons. This implies that the availability of family labor reduce labor cost, thereby enable respondents to adopt improved agricultural technologies in the study area. Table 2, also revealed that 72% of the respondents had wheat production farming experience of 1-10 years, implies that higher experience in farming activities encourage respondents to adopt new agricultural technologies, the study is in line with Ezekiel and Kunle (2023) who suggest that high experience in farming activities lead to adoption of an innovation.

Table 2: Socio-economic Characteristic of the Respondents (n=189)

Variables	Frequency	Percentages
Gender		
Male	133	70.4
Female	56	29.6
Age		
21-30	19	10.1
31-40	111	58.7
41-50	44	23.3
51- 60	15	7.9
Mean	47.2	
Marital status		
Married	125	66.1
Single	48	25.4

Widow	16	8.5
Educational attainment		
Non formal education	89	47.1
Quranic education	49	25.9
Adult education	28	14.8
Secondary	15	7.9
Tertiary	8	4.2
Household size		
3-5	24	12.7
6-8	139	73.5
9-11	19	10.1
>11	7	3.7
Year of experience		
1-10	136	72
11-20	35	18.5
21-30	18	9.5

Sources: Field survey, 2024

Determine the of extension service delivery on adoption of improved Wheat production technologies in the study area.

Table 3, shows that the respondents in the study area access extension services for the adoption of wheat production technologies such services are technical, facilitation and advisory services, the result further revealed that 87% (46.1) of respondents in the study area access technical service while 56% (29.6) access facilitation services and 46% (24.3) access advisory services for the adoption of improved wheat production technologies in the area, access to extension service delivery will encourage end users to involved and adopt agricultural technologies, this results is in line with Adepoju and Samuel (2023), who revealed that extension services encourage rural citizens to adopt agricultural innovation

Table 3; Showing extension services accessible by the respondents

Type of service	Accessibility	Frequency	Percentage (%)
Technical service	Yes	87	46.1
Facilitation service	Yes	56	29.6
Adversary service	Yes	46	24.3
Total		189	100

Source: Field Survey, 2024

Table 4. The result showed that a larger proportion of respondents do not enhanced improved wheat production technologies with an adoption rate of 70% which implies that rate of adoption is low in the study area, this result is in line with Khadijat *et.al* 2024 while the adopters are 30% response adoption rate, which affirms that low rate of adoption of Agricultural technologies may be as a result of lack of access to credit facilities.

Table 4: Examine the rate of adoption of improved wheat production technologies among the wheat farmer

	Wheat producers = (n = 189)		
Type of technology	Adopters/Non adopters		Adoption rate (%)
Local production	Non adopters	132	70
Improved production	Adopters	57	30

Source: Field survey 2024.

Constraints faced by respondents: Table 5, showed that seven constraints were identified as constraints faced by wheat producers. The results inadequate fund (X = 2.61), decrease in income (X = 3.64) and poor credit facilities (X = 5.33) are ranked first, second and third most severe constraints face by respondents in adoption of improved wheat production, decrease in quality and quantity of wheat production (X = 6.22) ranked 4th as the most serious constraints faced by wheat producers. This was followed by poor transportation (X = 6.42) which ranked 5th. Rabi *et al.* (2024) reported that inadequate fund, poor credit facilities and poor transportation means where the major constraints identify in the study on soya bean adoption technologies step by step in Kano State Nigeria. More so, Land tenue (X = 7.11) were ranked last. This agreed with Magaji *et al.* (2023), who reported that land tenue problem is one of the major constraints faced by wheat producers in Kebbi State, Nigeria.

Table 4: Constraints faced by respondents

Variables	**Bebeji (n=189) Mean ($\bar{x}$)**	**Ranking**
Decrease in income	3.64	2nd
Inadequate fund	2.61	1st
Poor credit facilities	5.33	3rd
Decrease In quality & quantity of wheat production	6.22	4th
Inadequate extension contact	6.73	6th

Poor transportation means	6.42	5th
Land tenue problem	7.11	7th

Conclusion and Reccommendations: Based on the findings of these research it can be concluded majority of wheat producers were in their active age and married. The literacy level of wheat producers in the study area was low. Moreover, majority of the wheat producers had moderate household size with large years of experience in wheat production. Further findings revealed that majority of 87% of the wheat producers access technical service for extension service delivery The findings agree that larger proportion of respondents do not enhanced improved wheat production technologies with an adoption rate of 70% which implies that rate of adoption is low in the study area. Findings furthered showed that inadequate fund (X = 2.61) as well as decrease income (X = 3.64) and poor credit facilities (X = 5.33) were ranked 1st 2nd and 3rd most constraints faced by wheat producers in the study area. It was recommended that credit facilities should be provided for the wheat producers in the study area to enable then expand the adoption of improved wheat production technologies.

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A Review of Using Rabbit Production to Improve Food Security and Animal Productivity in Nigeria

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Synopsis

In Nigeria, where there is a growing population and a growing desire for foods high in protein, rabbit farming offers a promising way to improve the supply of animal products. The potential of rabbit farming as a long-term solution to issues with food security, better public health, and economic empowerment in Nigeria is examined in this paper. The study highlights the advantages of rabbit farming in terms of nutrition, economic prospects, and environmental sustainability. It also emphasizes how crucial it is to use this alternative livestock option to satisfy the changing dietary needs of Nigeria's rapidly expanding population. Among other benefits, rabbit farming reduces greenhouse gas emissions, provides a healthy supply of meat, and may be a solution to the problem of food security. Notwithstanding the previously indicated promise, there are a number of obstacles that Nigerian rabbit farmers must overcome, such as poor infrastructure, scarce availability to high-quality breeding stock, and a lack of technical expertise among farmers. In order to address these issues, government organizations, agricultural extension services, and commercial players must work together to support policies and make coordinated efforts to increase market connections, improve input accessibility, and offer training. In conclusion, it is hoped that by implementing the aforementioned suggestions, Nigeria would be able to fully utilize its rabbit production capacity, meet the country's demand for food that is high in protein, encourage rural development, support sustainable agriculture, and provide food security.

Key words: *Nigerian sustainable agriculture, food security, animal productivity, and rabbit production.*

Overview Alternative livestock solutions must be investigated in Nigeria due to the country's growing population, rising demand for animal products, and unstable security situation (Oseni and Anigo, 2019). The raising of rabbits is one such substitute. One possible source of animal products that could close the gap between the supply and demand of animal protein caused by Nigeria's expanding human population is the cultivation of rabbits (Oni and Oluremi, 2020). Rabbit farming appears to be a viable industry despite the lack of infrastructure, knowledge, and access to excellent breeding stock in the nation. It offers a number of advantages, such as high reproductive rates, effective feed conversion ratios, and the production of high-quality meat (Yusuf and Sani, 2021). Some of the characteristics that make rabbit farming appealing and appropriate in Nigeria's rural and urban settings are small body size, the ability to use low-quality feeds, and ease of management (Owolabi and Idowu, 2017). This paper explores the potential of rabbit farming as a way to increase the availability of animal products in order to promote rural development, enhance public health, and guarantee food security in Nigeria.

Rabbit farming: An Ecological Approach Modern food production systems have significant challenges with food losses and wastes, but one way to mitigate some of these issues is through waste management (Karwowska et al., 2021). Reusing food wastes and byproducts as animal feed has been more popular recently since it helps to maintain natural resources, mitigate issues with food security, and combat global warming (Zamaratskaia et al., 2023).
Malnutrition and hunger are significant worldwide issues that need to be given careful consideration (Owolabi and Idowu, 2017). Food security entails having access to nutritious food and safe food, whereas food access is directly tied to a steady supply of food (Zamaratskaia et al., 2023). Sustainable food production and consumption has to be prioritized in order to solve **Nigeria's serious food security issue.**
A sustainable answer to the problems of providing Nigerians with the protein they require is rabbit farming. In contrast to conventional livestock like cattle and poultry, rabbits require less space, feed, and very little initial expenditure. They are simple to handle and adjust nicely to being raised in the home. They can therefore be used in both urban and rural environments (Owen and Amakiri, 2010). Their quick turnover and higher production rates provide for a steady supply of meat for consumers, which in turn provides producers with a steady stream of income (Niles, 2009). For Nigeria's expanding population, rabbits have the promise of providing high-quality animal protein at a reasonable cost in an environmentally friendly manner. It can utilize forages more effectively than cattle, sheep, and goats and be raised on inexpensive diets made of forages and kitchen scraps. They don't face much competition from humans for food either. A doe can have up to 40 offspring annually with proper care, compared to 0.8 for cows and 1.4 for ewes (Kitayi et al., 2016).
Benefits to Nutrition : Nigerians have traditionally consumed rabbit meat. However, due to societal and religious taboos, which restricted rabbit production to backyard or family usage, there is very little taste for rabbit meat, particularly in the northern half of the country (Ayeni et al., 2023). Rabbit meat has excellent nutritional qualities. It is perfect for hypertension people since it is low in fat (9%) cholesterol, sodium, and calories (8%), high in protein (56%), low in phosphorus (28%), iron (13%), zinc (16%), riboflavin (14%), thiamin 6%, 35% B12, and niacin 48%. It is advised that children, pregnant women, teenagers, and the elderly consume meat because it also satisfies the dietary needs of a population that is health-conscious (Oni and Oluremi, 2020).
There is a greater need for functional foods as people become more conscious of the connection between diet and health (Plasek and Temesi, 2019). Due to this trend in dietary preferences toward leaner meats, rabbit meat is well-positioned to fill this void and enhance public health outcomes. As a result, industrialized nations frequently promote a wide range of inventive rabbit meat products, including smoked, canned, frozen, cured, sauce-picked, dried, roasted, and sausages (Składanowska-Baryza and Stanisz, 2019). Because of its leanness and ideal fatty acid profile, rabbit meat can be regarded as a nutritious food, making it a good choice for the elderly (Zamaratskaia et al., 2023). Patients with hypertension can benefit from the meat's high potassium and low sodium content (Hermida et al., 2006). Additionally, consumers of rabbit meat are at a lower risk of cardiovascular disease (CVD) due to the meat's bioactive peptides (WGAP), ubiquinone-related chemicals, angiotensin-I-converting enzyme (ACE) inhibitory properties, and comparatively high anserine content (Chen et al., 2022). Additionally, the

reduced levels of cholesterol, saturated fat, and hemoglobin in rabbit meat help to decrease the development of atherosclerosis, hypertension, and CVD (Chen et al., 2021). Accordingly, switching to rabbit meat from beef, hog, and chicken may lower the risk of CVD (Bernstein et al., 2010).

Financial Empowerment : Nigeria's economic development continues to be anchored in agriculture, especially in terms of mitigating rural poverty (Ayeni et al., 2023). One of the main factors influencing rural livelihood is the rearing of livestock (Pica-Ciamarra et al., 2015). It increases crop diversification and lowers the likelihood that crops may suffer financial losses as a result of pests, illnesses, or bad weather (Ayeni et al., 2023; Pica-Ciamarra et al., 2015). A bigger segment of the global impoverished population are subsistence farmers. Thus, it is argued that growing agriculture is a vital and effective worldwide approach to reducing poverty (Ogutu and Qaim, 2019). A major source of income in many third-world nations is rabbit farming. Many African rural households see an improvement in their economics as a result (Akinsola et al., 2021; Mutsami and Karl, 2020).Raising rabbits is a feasible way to generate cash because it requires few upfront costs and little upkeep. Additionally, farmers can diversify their sources of income and reduce the risks associated with volatile market conditions by incorporating rabbit farming into already-existing agricultural systems (Oseni and Anigo, 2019).

Due to their quick investment turnover, rabbits can be sold for more money than other animal species like cattle, sheep, and goats in areas where there is a taste for rabbit meat. Children can thus use rabbit farming to pay for their school fees as well as to purchase books, uniforms, shoes, bicycles, and many other items. However, rabbits are not easily sold in many locations because of taboos and a lack of awareness raising in rabbit faming (Niles, 2009). These locations might be beneficial for a creative businessperson looking to expand into new markets for rabbit-related goods. implying that in the near future, concerns about food security and poverty reduction may cause rabbit farming to become a commercial enterprise.

Sustainability of the Environment: : Because rabbits are raised without cereals, rabbit farming is considered sustainable. In addition to its rapid growth rates, high fecundity, high feed conversion rates, and early maturity, its capacity to flourish well on fodder is helpful in developing countries due to rising food prices and rising demand for grains (Ayeni et al., 2023). When given the right care, rabbits can yield over 40 kits year as opposed to a cow's calf and a sheep or goat's two youngsters. Furthermore, rabbits are odorless, noiseless, and adaptable to a wide range of habitats, in contrast to ruminants (Anthony and Madu, 2015). The environment may suffer as a result of the growing need for animal protein. Rabbits are a more environmentally friendly food source than other meat animals. Its life cycle is brief, and it can convert feed quite well. Consequently, one tactic to lower resource use and greenhouse gas emissions could be to partially substitute rabbit meat for conventional meats like beef and pork (Gidenne et al., 2017). According to Cesari et al. (2018), the feed efficiency of rabbits in respect to environmental issues revealed opportunities to mitigate the impacts on the environment. Raising rabbits is becoming a more environmentally friendly choice for animal production as environmental concerns grow. In comparison to traditional livestock, rabbits require less space, water, and feed, leaving a smaller ecological footprint.

Opportunities and Difficulties: : Among other benefits, rabbit farming reduces greenhouse gas emissions, provides a healthy supply of meat, and may be a solution to the problem of food security. Notwithstanding the previously indicated promise, there are a number of obstacles that Nigerian rabbit farmers must overcome, such as poor infrastructure, scarce availability to high-quality breeding stock, and a lack of technical expertise among farmers. Government organizations, agricultural extension services, and corporate stakeholders must work together to address these issues by improving input accessibility, fostering market linkages, and offering training. Sani and Yusuf, 2021). In conclusion, the production of rabbits exhibits great potential as a way to expand the supply of animal products for Nigeria's expanding population. Nigeria has the potential to improve food security by utilizing the advantages of rabbit farming, such as sustainability, nutritional value, and economic empowerment, in addition to animal meat.

Suggestion: : In order to fully realize the potential of rabbit farming, regulatory support and concerted efforts are needed to address current issues and establish a supportive environment for the practice's widespread adoption and integration into the agricultural landscape. To ensure adequate productivity and food security in the nation, coordinated efforts including government agencies, private players, and agricultural extension services should be made to offer training, enhance input accessibility, and foster market linkages.

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Economic Analysis of Climate Change Effects in Nigeria, Sub Sahaaran Africa.

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Abstract

This reviewed research work examined the economic analysis of climate change effects in Nigeria, a sub Saharan Africa Country. As far back as 2012, the country was already suffering from variability in the climate and high-intensity rainfall events in the central and southern regions, which led to perennial flood disasters with total losses and damages of about USD 16.9 billion (EUR 16.9 billion). Currently, floods (river and urban) and other climate-change-related disasters in the country are also leading to an increase in disease incidence, mostly vector-borne diseases such as malaria, which caused 200,000 deaths in 2021, 32% of total global malaria deaths, and affected a total of 60 million Nigerians. There is also an increasing risk of waterborne diseases such as cholera. Economic analysis of climate change is an umbrella term for a range of investigations into the economic costs around the effects of climate change, and for preventing or softening those effects. This study reviewed different functions and models for the climate change analysis, such as Benefit –Cost Analysis, Computable general equilibrium models, Damage Function and Cost-effectiveness analysis. The Climate change effects on various climatic factors, human life, value of a statistical life, Value of Mortality Risk and environment were also delved into. A policy effectiveness depends on its ability to exploit possibilities for reducing (energy-related) CO2 emissions across the economy. It is therefore recommended that for every and any greenhouse emission, since there is cost implication, the society producing much should be charged accordingly by the Government. This will reduce the emission drastically.

Keywords: Climate, Change, Economic, Effects, Analysis, Models, Enviroment

Introduction: Nigeria is the most populous African country as estimated by the World Bank in 2021 and one of the top ten most vulnerable to climate change, which is exposing tens of millions of people to climate and disaster risks. Climate change in Nigeria is most visible in the form of drought, flooding, sea level rise and erosion, resulting in damaging outcomes such as lower crop yields, food insecurity, deepening poverty, forced displacement and conflicts, to name a few (Hemen et al., 2022). In 2016, Verisk Maplecroft ranked Nigeria as the 7th most vulnerable country in the world (Van Der Ploeg et al ,2020) Similarly, in 2021, Nigeria's vulnerability to climate disasters and its adaptive capacities ranked 161 out of 182 countries assessed by the Notre Dame Global Adaptation Initiative (ND-GAIN) (IPCC, 2022). Nigeria is particularly exposed to climate impacts because of its large population, extensive coastline, limited resources to adequately finance climate from both the public and private sector entities and an adaptation knowledge gap.

As far back as 2012, the country was already suffering from variability in the climate and high-intensity rainfall events in the central and southern regions, which led to perennial flood disasters with total losses and damages of about USD 16.9 billion (EUR 16.9 billion) Currently, floods (river and urban) and other climate-change-related disasters in the country are also leading to an increase in disease incidence, mostly vector-borne diseases such as malaria, which caused 200,000 deaths in 2021, 32% of total global malaria deaths, and affected a total of 60 million Nigerians (Wiebe, Keith D , 2016) There is also an increasing risk of waterborne diseases such as cholera. In other parts of the country, a combination of droughts, saltwater intrusion and sea level rise has adversely affected crop yields and urban infrastructure, leading to rising food prices, cost of development and other linked effects. Crop yields are particularly sensitive to changes and climate variations as they are affected by multiple factors and agriculture is largely rain-fed; only 1% of farmland is irrigated across the country with over 70% engaging in subsistence agriculture, which accounts for nearly 23% of GDP (FAO, 2022) Econometric analyses estimate that Nigeria stands to lose between USD 100 billion (EUR 100 billion) and USD 460 billion (EUR 460 billion) if it fails to adequately adapt to climate change by 2050 (Hemen et al., 2022)

Economic Analysis of Climate Change: An **economic analysis of climate change is a concept of** using economic tools and models to calculate the magnitude and distribution of damages caused by climate change. It can also give guidance for the best policies for mitigation and adaptation to climate change from an economic perspective. Many effects of climate change are linked to market transactions and therefore directly affect metrics like GDP or inflation (Borenstein, 2024) However, there are also non-market impacts which are harder to translate into economic costs. These include the impacts of climate change on human health, biomes and ecosystem services. Economic analysis of climate change is challenging as climate change is a long-term problem. Furthermore, there is still a lot of uncertainty about the exact impacts of climate change and the associated damages to be expected. Future policy responses and socioeconomic development are also uncertain. Economic analysis also looks at the economics of climate change mitigation and the cost of climate adaptation. Mitigation costs will vary according to how and when emissions are cut. Early, well-planned action will minimize the costs (Hemens et al. 2022) Cost estimates for mitigation for specific regions depend on the quantity of emissions allowed for that region in future, as well as the timing of interventions .Economists estimate the cost of climate change mitigation at between 1% and 2% of GDP (Adelekan, 2022)

Value of a Statistical Life: The estimate of willingness to pay for small reductions in mortality risks are often referred to as the "value of a statistical life." This is because these values are typically reported in units that match the aggregate dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year, such that would expect one fewer death among the group during that year on average.

Value of Mortality Risk: The Value of Mortality Risk (VMR) and the Value of Statistical Life (VSL) are indeed related. The underlying theoretical concept is the same, and the estimated values for either metric would be based on the same published literature. The difference lies in the choice of units used to aggregate and report the risk changes. The VSL is typically reported in units of dollars per statistical death per year. The VMR would be reported in units such as dollars per micro-risk per person per year, where a "micro-risk" represents a one in a million chance of dying. EPA is proposing using VMR because it should help to reduce the misunderstandings that are sometimes caused by the VSL terminology.

There are many economic models and frameworks.: Various economic tools are employed to understand the economic aspects around impacts of climate change, climate change mitigation and adaptation. Several sets of tools or approaches exist. Econometric models (statistical models) are used to integrate the broad impacts of climate change with other economic drivers, to quantify the economic costs and assess the value of climate-related policies, often for a specific sector or region. Structural economic models look at market and non-market impacts affecting the whole economy through its inputs and outputs. Process models simulate physical, chemical and biological processes under climate change, and the economic effects (Weibe et al 2017)

Benefit-Cost Analysis: Benefit-cost analysis is an analytical tool used to evaluate public policy options. The tradeoffs between climate change impacts, adaptation, and mitigation are made explicit. For this kind of analysis, integrated assessment models (IAMs) are useful. Those models link main features of society and economy with the biosphere and atmosphere into one modelling framework. The total economic impacts from climate change are difficult to estimate. In general, they increase the global surface temperature. For environmental policies, benefits are determined by what individual would be willing to pay for risk reductions or for other improvements from pollution prevention. Costs are determined by the currency value of the resources directed to pollution reduction. If the total benefits exceed the total costs, then the policy is said to "pass a benefit-cost test." Of course in most cases where the total benefits exceed total costs, it will not be true that the benefits exceed the costs for each and every person affected by the policy; rather, some individuals will gain and others will lose. However, if the total benefits are greater than the costs, then it is in principle possible for those who gain to compensate those who lose so that everyone could be better off with the policy. This is what it means for a policy to pass a benefit-cost test. The primary purpose of benefit cost analysis is to provide policy makers and others with detailed information on a wide variety of consequences of environmental policies. Benefit-cost analysis is only one of many inputs into policy evaluation. Other factors include environmental justice considerations; ethical concerns; enforceability; legal consistency; and technological and institutional feasibility. (Verisk Maplecroft, 2016)

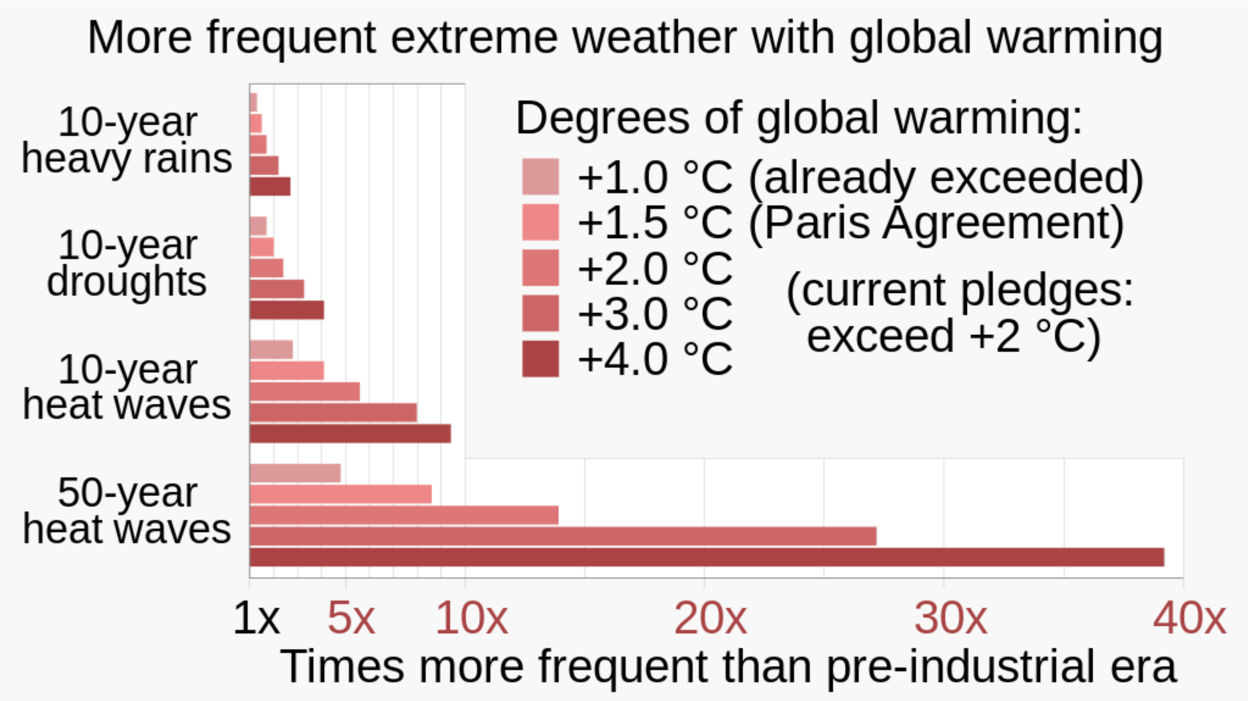
Computable general equilibrium models : Computable general equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. CGE models are also referred to as AGE (applied general equilibrium) models. A CGE model consists of equations describing model variables and a database (usually very detailed) consistent with these model equations. The equations tend to be neoclassical in spirit, often assuming cost-minimizing behaviour by producers, average-cost pricing, and household demands based on optimizing behaviour. CGE models are useful whenever we wish to estimate the effect of changes in one part of the economy upon the rest. They have been used widely to analyse trade policy. More recently, CGE has been a popular way to estimate the economic effects of measures to reduce greenhouse gas emissions (Verisk Maplecroft, 2016)

Statistical (econometric) methods: **Econometric model**: A more recent modelling approach uses empirical, statistical methods to investigate how the economy is affected by weather variation (Weibe et al., 2017 This approach can causatively identify effects of temperature, rainfall and other climate variables on agriculture, energy demand, industry and other economic activity. Panel data are used giving weather variation over time and spatial areas such as ground station observations or (interpolated) gridded data. These are typically aggregated for economic analysis such as.to investigate effects on national economies. These studies examine temperature and rainfall, and events such as droughts and windstorms. They show that for example, hot years are linked to lower income growth in poor countries, and low rainfall is linked to reduced incomes in Africa (Verisk Maplecroft, 2016). Other econometric studies show that there are negative impacts of hotter temperatures on agricultural output, and on labour productivity in factories, call centres and in outdoor industries such as mining and forestry. The analyses are used to estimate the costs of climate change in the future.

Damage functions: Damage functions play an important role in estimating the costs associated with potential damages caused by climate-related hazards. They quantify the relationship between the intensity of the hazard, other factors such as the vulnerability of the system, and the resulting damages. For example, damage functions have been developed for sea level rise, agricultural productivity, or heat effects on labour productivity. In a Cost benefit analysis, CBA framework, damages are monetized to facilitate comparison with the benefits of proposed actions or policies. Sensitivity analysis is conducted to assess the robustness of the results to changes in assumptions and parameters, including those of the damage function.

Cost-effectiveness analysis: Cost-Effectiveness Analysis (CEA) is preferable to CBA when the benefits of impacts, adaptation and mitigation are difficult to estimate in monetary terms. A CEA can be used to compare different cost policy options for achieving a well-defined goal. This goal (i.e. the benefit) is usually expressed as the amount of GHG emissions reduction in the analysis of mitigation measures. For adaptation measures, there is no single common goal or metric for the economic benefits. Adaptation involves responding to different types of risks in different sectors and local contexts. For example, the goal might be the reduction of land area in hectares at risk to sea level rise.[58]

CEA involves the costing of each option, and providing a cost per unit of effectiveness. For example, cost per tonne of GHG reduced ($/tCO2). This allows the ranking of policy options. This ranking can help decision-maker to understand which are the most cost-effective options, i.e. those that deliver high benefits for low costs. CEA can be used for minimising net costs for achieving pre-defined policy targets, such as meeting an emissions reduction target for a given sector.[42]: CEA, like CBA, is a type of decision analysis method. Many of these methods work well when different stakeholders work together on a problem to understand and manage risks (Adelekan,et al 2022)



Climate Change Effects

Changes in temperature: Global warming affects all parts of Earth's climate system. Global surface temperatures have risen by 1.1 °C (2.0 °F). Scientists say they will rise further in the future (Federal Ministry of Enviroment, 2021). The changes in climate are not uniform across the Earth. In particular, most land areas have warmed faster than most ocean areas. Also, heat wave seasons have grown in length. Heatwaves over land have become more frequent and more intense in almost all world regions since the 1950s, due to climate change. Heat waves are more likely to occur simultaneously with droughts. Marine heatwaves are twice as likely as they were in 1980. Climate change will lead to more very hot days and fewer very cold days. Heat stress is related to temperature (Bruce et al., 2016) It also increases if humidity is higher. The wet-bulb temperature measures both temperature and humidity. Humans cannot adapt to a wet-bulb temperature above 35 °C (95 °F). This heat stress can kill people.

Rain: Warming increases global average precipitation. Precipitation is when water vapour condenses out of clouds, such as rain and snow (Borenstein, Seth 2024). Higher temperatures increase evaporation and surface drying. As the air warms it can hold more water. For every degree Celsius it can hold 7% more water vapour. Scientists have observed changes in the amount, intensity, frequency, and type of precipitation. Overall, climate change is causing longer hot dry spells, broken by more intense rainfall.[57] Climate change has increased contrasts in rainfall amounts between wet and dry seasons. Wet seasons are getting wetter and dry seasons are getting drier. In the northern high latitudes, warming has also caused an increase in the amount of snow and rain (Bruce et al., 2016

Extreme storms: Storms become wetter under climate change. These include tropical cyclones and extratropical cyclones. Both the maximum and mean rainfall rates increase. This more extreme rainfall is also true for thunderstorms in some regions.[58] Furthermore, tropical cyclones and storm tracks are moving towards the poles. There has probably been an increase in the number of tropical cyclones that intensify rapidly (Bruce et al ,2016). Meteorological and seismological data indicate a widespread increase in wind-driven global ocean wave energy in recent decades that has been attributed to an increase in storm intensity over the oceans due to climate change. Atmospheric turbulence dangerous for aviation (hard to predict or that cannot be avoided by flying higher) probably increases due to climate change (Federal Ministry of Environment, 2021)

Floods: Due to an increase in heavy rainfall events, floods are likely to become more severe when they do occur. The interactions between rainfall and flooding are complex. There are some regions in which flooding is expected to become rarer. This depends on several factors. These include changes in rain and snowmelt, but also soil moisture (Federal Ministry of Environment, 2021) Climate change leaves soils drier in some areas, so they may absorb rainfall more quickly. This leads to less flooding. Dry soils can also become harder. In this case heavy rainfall runs off into rivers and lakes. This increases risks of flooding (Adelekan et al., 2022)

Droughts: Climate change affects many factors associated with droughts. These include how much rain falls and how fast the rain evaporates again. Warming over land increases the severity and frequency of droughts around much of the world (World Bank 2022). In some tropical and subtropical regions of the world, there will probably be less rain due to global warming. This will make them more prone to drought. Droughts are set to worsen in many regions of the world. Higher temperatures increase evaporation. This dries the soil and increases plant stress. Agriculture suffers as a result. This means even regions where overall rainfall is expected to remain relatively stable will experience these impacts.[55]: Several impacts make their impacts worse. These are increased water demand, population growth and urban expansion in many areas.

Wildfires: Climate change promotes the type of weather that makes wildfires more likely. In some areas, an increase of wildfires has been attributed directly to climate change. Evidence from Earth's past also shows more fire in warmer periods (World Bank, 2022). Climate change increases evapotranspiration. This can cause vegetation and soils to dry out. When a fire starts in an area with very dry vegetation, it can spread rapidly. Higher temperatures can also lengthen the fire season. This is the time of year in which severe wildfires are most likely, particularly in regions where snow is disappearing. Weather conditions are raising the risks of wildfires. But the total area burnt by wildfires has decreased. This is mostly because savanna has been converted to cropland, so there are fewer trees to burn. The carbon released from wildfires adds to carbon dioxide in Earth's atmosphere and therefore contributes to the greenhouse effect. Climate models do not yet fully reflect this climate change feedback.[31]

Oceans: Climate change causes a drop in the ocean's pH value (called ocean acidification): There are many effects of climate change on oceans. One of the most important is an increase in ocean temperatures. More frequent marine heatwaves are linked to this. The rising temperature contributes to a rise in sea levels due to the expansion of water as it warms and the melting of ice sheets on land. Other effects on oceans include sea ice decline, reducing pH values and oxygen levels, as well as increased ocean stratification. All this can lead to changes of ocean currents The various layers of the oceans have different temperatures. For example, the water is colder towards the bottom of the ocean. This temperature stratification will increase as the ocean surface warms due to rising air temperatures. Connected to this is a decline in mixing of the ocean layers, so that warm water stabilises near the surface. A reduction of cold, deep water circulation follows. The reduced vertical mixing makes it harder for the ocean to absorb heat. So a larger share of future warming goes into the atmosphere and land. One result is an increase in the amount of energy available for tropical cyclones and other storms. Another result is a decrease in nutrients for fish in the upper ocean layers. These changes also reduce the ocean's capacity to store carbon. At the same time, contrasts in salinity are increasing. Salty areas are becoming saltier and fresher areas less salty.(IPCC, 2022). Warmer water cannot contain the same amount of oxygen as cold water. As a result, oxygen from the oceans moves to the atmosphere. Increased thermal stratification may reduce the supply of oxygen from surface waters to deeper waters. This lowers the water's oxygen content even more. The ocean has already lost oxygen throughout its water column. Oxygen minimum zones are increasing in size worldwide (Federal Ministry of Environment,. 2021)

Wildlife and nature : Recent warming has had a big effect on natural biological systems. Species worldwide are moving poleward to colder areas. On land, species may move to higher elevations. Marine species find colder water at greater depths Climate change had the third biggest impact on nature out of various factors in the five decades up to 2020. Only change in land use and sea use and direct exploitation of organisms had a bigger impact (World bank 2022 The impacts of climate change on nature are likely to become bigger in the next few decades. The stresses caused by climate change, combine with other stresses on ecological systems such as land conversion, land degradation, harvesting, and pollution. They threaten substantial damage to unique ecosystems. They can even result in their complete loss and the extinction of species. This can disrupt key interactions between species within ecosystems. This is because species from one location do not leave the warming habitat at the same rate. The result is rapid changes in the way the ecosystem functions. These changes of land and ocean ecosystems have direct effects on human well-being (Kotz et al 2024). For instance, ocean ecosystems help with coastal protection and provide food. Freshwater and land ecosystems can provide water for human consumption. Furthermore, these ecosystems can store carbon. This helps to stabilize the climate system.[120]

Health, food security and water security: Humans have a climate niche. This is a certain range of temperatures in which they flourish. Outside that niche, conditions are less favourable. This leads to negative effects on health, food security and more.

Health.: The effects of climate change on human health are profound because they increase heat-related illnesses and deaths, respiratory diseases, and the spread of infectious diseases. There is widespread agreement among researchers, health professionals and organizations that climate change is the biggest global health threat of the 21st century (World Bank, & WHO, 2020). When people are exposed to higher temperatures for longer time periods they might experience heat illness and heat-related death (WHO, 2022) Certain diseases that are carried and spread by living hosts such as mosquitoes and ticks (known as vectors) may become more common.. Contracting waterborne diseases such as diarrhea will also be more likely. Scientific studies have linked mental health to several climate-related exposures. This especially manifests in the form of anxiety over the quality of life for future generations.[161]

Food security: Climate change will affect agriculture and food production around the world. The reasons include the effects of elevated CO_2 in the atmosphere. Higher temperatures and altered precipitation and transpiration regimes are also factors. Increased frequency of extreme events and modified weed, pest, and pathogen pressure are other factors.[167] Droughts result in crop failures and the loss of pasture for livestock. Loss and poor growth of livestock cause milk yield and meat production to decrease WHO, 2022) The rate of soil erosion is 10–20 times higher than the rate of soil accumulation in agricultural areas that use no-till farming. In areas with tilling it is 100 times higher. Climate change worsens this type of land degradation and desertification (World Bank, & WHO, 2020). Climate change is projected to negatively affect all four pillars of food security. It will affect how much food is available. It will also affect how easy food is to access through prices, food quality, and how stable the food system is. Climate change is already affecting the productivity of wheat and other staples (Federal Ministry of Environment. 2021)

Water security: Water resources can be affected by climate change in various ways. The total amount of freshwater available can change, for instance due to dry spells or droughts. Heavy rainfall and flooding can have an impact on water quality. They can transport pollutants into water bodies through increased surface runoff. In coastal regions, more salt may find its way into water resources due to higher sea levels and more intense storms. Higher temperatures also directly degrade water quality. This is because warm water contains less oxygen. (Federal Ministry of Environment. 2021). Changes in the water cycle threaten existing and future water infrastructure. It will be harder to plan investments for water infrastructure. This is because there are significant uncertainties about future variability of the water cycle

Conclusion and Policy Recommendation: Economic analysis of climate change is an umbrella term for a range of investigations into the economic costs around the effects of climate change, and for preventing or softening those effects. This study reviewed different functions and models for the climate change analysis, such as Benefit –Cost Analysis, Computable general equilibrium models, Damage Function and Cost-effectiveness analysis. The Climate change effects on various climatic factors, human life and environment were also delved into. A policy effectiveness depends on its ability to exploit possibilities for reducing (energy-related) CO2 emissions across the economy. It is therefore recommended that for every and any greenhouse emission, since there is cost implication, the society producing much should be charged accordingly by the Government. This will reduce the emission drastically.

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Effect of Different Levels of Maca (*Lepidium meyenii* L.) Root Powder as Feed Additive on the Performance of *Clarias gariepinus* (Burchell, 1822) Hatchlings

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Abstract

A feeding trial was conducted at the National Biotechnology Research and Development Agency, Billiri, Gombe State to evaluate the effect of different levels of maca root powder as feed additive on the performance of Clarias gariepinus hatchlings. Maca root powder in form of feed additive was incorporated into Coppens fish feeds (0.2 – 0.5mm) with 49% crude protein at 0.0g/100g (L_0)), 0.25g/100g (L_1), 0.5g/100g (L_2,) 0.75g/100g (L_3) and 1.0g/100g (L_4) inclusion levels, diet without maca root powder served as the control (L_0), in triplicates. Diets were fed to hatchlings (n = 1,500, 0.25±0.0g) for a period of 28 days in 15 plastic hatchery tanks (n = 100). Hatchlings were fed at a fixed feeding rate of 10% body weight 6 times daily between the hours of 07:00 and 23:00 at regular interval. Data obtained were analyzed using One - way ANOVA at P = 0.05. Mean weight gain (1.69±0.83 g/fish), daily weight gain (0.060±0.09 g/day) and specific growth rate (2.97±0.13 %/day) were significantly ($p < 0.05$) higher in hatchlings fed diet L_3, while diet L_0 had the least mean weight gain (1.55±0.07 g/fish), daily weight gain (0.055±0.09 g/day) and specific growth rate (2.83±0.11 %/day). Feed conversion ratio was best (least) in L_3 (0.414±0.09), while it was poor (highest) in L_0 (0.451±0.03). Survival rate was significantly ($p < 0.05$) higher in L_3 (93.6±1.06 %), while it was least in L_0 (88.1±1.13 %). Incorporating maca root powder as feed additive into feed of Clarias gariepinus hatchlings promotes growth and survival.

Keywords: Clarias gariepinus, Feed Additive, Hatchlings, Maca Root Powder, Performance.

Introduction: The hatchlings stages are considered as the critical period in the life cycles of fish in aquaculture (Onyia *et al.*, 2016). Favourable outcome in aquaculture is determined mainly on the availability of suitable feed or food that are readily eaten with efficiency of digestion and provision of the needed nutrients for growth, good health and survival of the hatchlings (Mehrabi *et al.*, 2018). However, the culturing of fish at the hatchlings stages has been a great challenge for many fish breeders (Onyia *et al.*, 2016). The knowledge of the special nutritional requirements of fish hatchlings can really promotes the functioning and standard of the aquaculture species. The choice of feed with minute particles always result to the leaching of nutrient due to very high ratio surface to area volume (Onyia *et al.*, 2016). Primarily live food organisms especially zooplanktons, are mostly used as the starter food for the hatchlings of many fish species that are not suitable to be reared on formulated feed (Sogbesan, 2023). The increasing cost of Artemia and starter formulated feed for fish hatchlings is a constraint to fish breeders particularly in the tropical countries such as Nigeria (Ali *et al.,* 2023). This has necessitated the need for alternative starter food and or feed like special starter fish feed incorporated with growth promoters as natural feed additives which positively affect the body weight gain without any negative effect on public health and consumer (Ali *et al.*, 2022). Then, there is generally demand for using natural sources of herbal as feeding additives; it is among of this herbal was maca root powder (Mahdy *et al.*, 2023). Maca is a vegetable root native to Peru in South America (Gül *et al.*, 2022). While its scientific name is *Lepidium meyenii* and also known in Hausa language as "sauyar maca" or "albasar tamoji" while Yoruba language it known as "Isu baka" (Garba *et al.*, 2022). Maca is rich in crude protein, crude lipid, essential acids, and a pharmacological compound (Mahdy *et al.*, 2023). A dry maca contains 10.2% crude proteins, 59% carbohydrates, 2.2% crude lipids, 8.5% crude fibre, 40.1% free fatty acids (linoleic, palmitic, and oleic acids) and 52.7% saturated fatty acids and unsaturated fatty acids (Mahdy *et al.*, 2023). This study was designed to determine the effect of different levels of maca (*Lepidium meyenii)* root powder as feed additive on the performance of *Clarias gariepinus* hatchlings.

MATERIALS AND METHODS

Study Area

The study was carried out at the Aquaculture section of the National Biotechnology Research and Development Agency, Billiri Local Government Area (LGA), Gombe State. Billiri LGA lies within Latitude 9°50' and 11°09''N and Longitude 9.833°and 11.150°E. It covers an area of 737km² and is 50 km away from Gombe the capital city. The hatchlings for the experiment were bred at the hatchery room of Lay – Joy fish farm Billiri. The hatchlings were 4 days old at the commencement of the feeding trial.

Experimental Diets

Coppens fish feed (0.2 – 0.5 mm) were used as the basal diet for this study and was obtained from feed suppliers at Gombe, while the maca root powder was purchased from Bon - Amour Pharmacy Limited Lagos, Nigeria, imported from Piping Rock Health Products, Ronkonkoma, New - York, USA. Experimental diets were prepared by incorporating maca root powder as feed additive at four graded levels; 0.25 g, 0.50 g, 0.75 g and 1.0 g / 100 g feed, into Coppens fish feeds (0.2 – 0.5 mm), while diet without maca root powder i.e., 0.0 g / 100 g feed served as the control diet and were coded as L_0 (0.0 g), L_1 (0.25 g), L_2 (0.5 g), L_3 (0.75 g) and L_4 (1.0 g) respectively. The maca root powder was included at the measured quantity for each diet and were diluted into 5 mL of warm water (35 ^{0}C) to form a solution. The solution was sprayed onto the Coppens fish feed (0.2 – 0.5 mm), fish oil was added to all the experimental diets with maca root powder to reserve the maca root powder additive. The Coppens fish feed (0.2 – 0.5 mm) with the maca root powder additive was prepared in 100 g each time.

Experimental Design

Each of the treatment diets were fed to *Clarias gariepinus* hatchlings (n = 1,500; 0.25±0.0 g) in triplicate making a total of 15 plastic hatchery tanks (semi flow - through system) i.e. (n = 100 per tank). Water quality parameters such as; Temperature, pH, Dissolved Oxygen (DO) and Ammonia (NH_3) were monitored weekly. Hatchlings were fed 6 times daily between the hours of 07:00 and 23:00 at regular interval for a period of 28 days at a fixed feeding rate of 10% body weight as recommended by Ukwe *et al.* (2018). The initial body weight of each set of hatchlings was measured using a digital weighing balance before stocking and subsequently bulk weighing of hatchlings in each tank was done after every 7 days, the growth performance parameters were computed and analyzed according to the following equations as described by Stickey *et al.* (2006) as follows;

$Mean\ weight\ gain, MWG\ =\ final\ weight\ (g) -\ initial\ weight\ (g)$

$Daily\ weight\ gain, DWG\ =\ \{final\ weight\ (g) -\ initial\ weight\ (g)\}/experimental\ days$

$Specific\ Growth\ Rate, SGR = \{(log\ \ final\ weight\ (g) - log\ initial\ weight\ (g)\}/\ culture\ period\} \times 100$

$Feed\ Conversion\ Ratio, FCR\ (g/g)\ =\ feed\ intake\ (g)/weight\ gain\ (g)$

$Survival\ rate = \{(final\ no. of fish - initial\ no. of fish)/initial\ no. of\ fish\}\ \times\ 100$

Statistical Analysis

The data obtained were subjected to one - way analysis of variance (ANOVA) using the GraphPad instant package for windows 2010 of statistical analysis system (SAS, 2010). Mean separation was done (at P = 0.05) using Fisher's least significance difference (LSD) to separate the means in cases of significant difference.

RESULTS AND DISCUSSION

The proximate composition of the Coppens fish feeds (0.2 – 0.5 mm) fed to the Clarias gariepinus hatchlings is presented in Table 1. All the diets contained 49% crude protein, 12% crude lipid, 6.0% crude fibre, 8.0% ash, 1.5% calcium, 8.0% moisture and 1.5% phosphorus.

Table 1: Proximate Composition of Coppens Hatchlings Feeds (0.2 – 0.5 mm) Used for the Study

Nutrients	Percentage (%)
Crude protein	49
Crude lipid	12
Crude fibre	6.0
Ash	8.0
Calcium	1.5
Moisture	8.0
Phosphorus	1.5

Results from the growth performance parameters and survival rates of the *Clarias gariepinus* hatchlings fed maca root powder as feed additive at different levels of inclusion (Table 2). The significantly ($p<0.05$) highest growth performance parameters' values in terms of mean weight gain (1.69±0.83 g / fish), daily weight gain (0.060±0.09 g / day) and specific growth rate (2.97±0.13% / day) were recorded from the fry fed maca root powder incorporated diet at 0.75 g / 100 g feed (L_3). Similarly, the significantly ($p<0.05$) least (best) feed conversion ratio value; (0.414±0.09) was recorded from the Hatchlings fed diet L_3. The highest survival rate value; (93.6±1.06%) was recorded from the hatchlings fed diet L_3. There was a significant difference ($p<0.05$) in terms of the survival rate values recorded from the hatchlings fed diets with maca root powder as feed additive compared with the control diet. During the experimental period, the water quality parameters monitored such as the Water temperature, pH, Dissolved Oxygen (DO) and Ammonia (NH_3) were within the recommended ranged for the culture of *Clarias gariepinus*.

Table 2: Performance of *Clarias gariepinus* Hatchlings Fed Different Levels of Maca Root Powder as Feed Additive

Parameters	L_0	L_1	L_2	L_3	L_4
Mean initial weight (g/fry)	0.25±0.0^a	0.25±0.0^a	0.25±0.0^a	0.25±0.0^a	0.25±0.0^a
Mean final weight (g/fry)	1.80±0.17^a	1.86±0.13^b	1.87±0.39^b	1.94±0.15^c	1.89±0.11^b
Mean weight gain (g/fry)	1.55±0.07^a	1.61±0.03^b	1.62±0.87^b	1.69±0.83^c	1.64±0.18^b
Daily weight gain (g/day)	0.055±0.09^a	0.057±0.03^b	0.058±0.02^b	0.060±0.09^b	0.059±0.01^b
Specific growth rate (%/day)	2.83±0.11^a	2.89±0.17^b	2.90±0.13^b	2.97±0.13^c	2.92±0.18^b
Feed conversion ratio (g/fry)	0.451±0.03^c	0.434±0.08^b	0.432±0.04^b	0.414±0.09^a	0.426±0.06^b
Survival rate (%)	88.1±1.13^a	91.3±1.18^b	91.5±1.22^b	93.6±1.06^c	91.6±1.03^b

Mean values in each row with similar superscripts are not significantly different ($p>0.05$).

Keys:

L_0 - Maca root powder (0.0 g / 100 g)
L_1 - Maca root powder (0.25 g / 100 g)
L_2 - Maca root powder (0.5 g / 100 g)
L_3 - Maca root powder (0.75 g / 100 g)
L_4 - Maca root powder (1.0 g / 100 g)

Growth performance parameters values such as the mean weight gain, daily weigh gain and specific growth rate were highest in the hatchlings fed diet L_3 which was in agreement with the findings of Mahdy et al. (2023) which reported a similar result but for weaning lambs fed maca root powder as feed additive and the findings of Garba et al. (2022) for red Sokoto bucks fed 0.75 g / 100 g feed inclusion levels of maca root powder as feed additive. The least (best) feed conversion ratio value which was recorded from the hatchlings fed diet L_3 containing maca root powder at 0.75 g / 100 g feed inclusion level was in agreement with the findings of Mahdy et al. (2023) which reported similar result for weaning lambs fed maca root powder as feed additive and Garba et al. (2022) for red Sokoto bucks fed 0.75 g / 100 g feed inclusion levels of maca root powder as feed additive The highest values of the mean weight gain, daily weight gain, specific growth rate and the least (best) FCR recorded from the hatchlings fed diet L_3 containing maca root powder at 0.75 g / 100 g feed, indicated that the maca root powder has more beneficial effect when added to the diet at 0.75 g / 100 g feed, however, below or above that level does not have any negative effect on the metabolism of the fish. The significantly ($p<0.05$) higher survival rate values recorded from all the hatchlings fed diets with maca root powder as feed additive used in this study indicated that diets with maca root powder were well tolerated by the hatchlings, the water quality parameters were not affected by the incorporation of maca root powder as feed additive into the diet of the *Clarias gariepinus* hatchlings.

Conclusion: It could be concluded that the incorporation of maca root powder as feed additive at 0.75 g / 100 g feed inclusion level into the diet of *Clarias gariepinus* hatchlings has a far - reaching effect on the mean weight gain, daily weight gain, specific growth rate, feed conversion ratio and the survival rates without any defect. Considerable changes in the performance of *Clarias gariepinus* hatchlings fed maca root powder as feed additive are the changeable framework observed from this study.

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A Review on Applications of Artificial Intelligence Devices in Aquaculture

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ABSTRACT

Lately, there has been extensive discourse within the University communities and broader society regarding the possible uses of artificial intelligence (AI). Researchers have been exploring and experimenting with novel applications of AI in both research endeavors and other academic pursuits. This study reviews current applications of AI devices in aquaculture. AI, a branch of computer science and technology, focuses on creating intelligent machines capable of tasks typically requiring human intelligence, such as visual perception, speech recognition, decision-making, and language translation. The potential applications of AI are extensive and boundless. Its applications span various sectors, from agriculture to full-scale industrial automation. Numerous studies have also explored machine learning applications in smart aquaculture. AI in Aquaculture enables farmers to remotely oversee and manage their farming sites. This includes alerting farmers to any blockages, depletion of food stocks, or other critical issues that require immediate attention such as overseeing water quality, optimizing processes, handling feeding and nutrition, size and weight measurement, grading, species classification, identifying and averting diseases, and conducting predicting analyses. These AI solutions play a role in elevating the quality and precision aquaculture. This review offers an overview of importance of AI's application in aquaculture, synthesizing findings from 100 articles collected over nearly a decade. It delves into methodologies, results, and emerging technologies crucial for advancing smart aquaculture. The aim is to provide valuable insights for readers interested in this field.

Keywords: Review; Applications; Artificial Intelligence; Devices; Smart Aquaculture.

Introduction:Capture fisheries sector performance in many developing countries (including Nigeria) reaches below expectation with low supply - is evident in the fact that most African countries began importing fish after they were exporting fish (Agossou, 2021). Again, fish farmers in developing countries use manual measurements to know the condition of the various parameters of the water. Manual measurements are time consuming and give inappropriate results as parameters for measuring water quality change continuously (Saha, 2018).

As a critical aspect of fisheries, aquaculture provides a source of high-quality protein for humans worldwide and has become one of the fastest growing industries in global food production (Zhoa *et al*., 2021). Yet, 88% of this rapidly growing aquatic production is consumed by human beings (Yang *et al*., 2020). With the continuous growth of the world population, global aquaculture production will have to increase more than double fold to meet the demand for fish for human consumption in the next decade. Along with this trend, the pressure of global fisheries will also continue to increase (O'Neill, *et al*., 2020).

Conventional aquaculture presents numerous environmental challenges and is constrained by production limitations and labor demands (Thi *et al.,* 2021). Hence, the concept of aquaculture aims to promote sustainable development within the industry, increase production, and prioritize environmental friendliness. However, Aquaculture is a rapidly growing sector where much technological development is still needed to improve the farming practices. Thus, it is crucial to develop the conventional farming method to increase production. Modern technologies are being brought into aquaculture to overcome this and other challenges. Therefore, increasing fish production with the aid of artificial intelligence (AI) in aquaculture will lead to an increase in the economy of the countries. Fish farming can contribute to increasing the national income of countries wishing to develop the economy. Robots equipped with computer vision systems and Artificial Intelligence (AI) algorithms can automate various labor-intensive tasks in aquaculture, such as fish sorting, feeding, and harvesting. This reduces manual labor requirements and improves operational efficiency (McIntosh *et al.,* 2020). Presently, around 50 billion electronic devices operate using the Internet of Things (IoT) and a significant proportion of them are Artificial Intelligence (AI) devices (Chrispin *et al.,* 2020).

Artificial Intelligence (AI) refers to the simulation or approximation of human intelligence in machines (Gordon 2023). More to that, Artificial intelligence (AI) refers to the field of computer science and technology that focuses on the development of intelligent machines capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. According to Russel and Norvig (2016), Artificial intelligence involves the study and creation of algorithms and models that enable machines to learn from data, reason, perceive their environment, and make decisions or predictions.

Applications of Artificial Intelligence (Ai) in Aquaculture: The utilization of artificially intelligent devices has expanded beyond fisheries to encompass the aquaculture sector. Every aspect of fish containment can now be monitored, with necessary actions taken autonomously, eliminating the need for human oversight. A significant benefit of Artificial Intelligence lies in its ability to learn from experience, facilitating substantial growth in the aquaculture sector, particularly as culture system conditions evolve in response to the environment. Artificial intelligence plays a crucial role not just in managing aquaculture farms but also in open sea fishing, utilizing satellite data to track global fishing activity. Over the past decade, worldwide fish consumption has quadrupled, leading to growing demand and declining productivity in the aquaculture sector. Artificial intelligence technology has the potential to be instrumental in achieving increased production levels while reducing the need for manpower (Chrispin *et al*., 2020). Artificial intelligence devices offer the capability to create a more stable environment for aquaculture stock. These tools harness both historical and real-time data to develop predictive models for various aspects of aquaculture, including fish growth rates, water quality fluctuations, and market demand. This empowers farmers to make informed decisions regarding stocking densities, harvest timing, and overall production planning (Akbari *et al.,* 2020). The advancement of Artificial Intelligence has facilitated the gradual evolution of aquaculture towards a more intensive and intelligent approach worldwide. As a results, the breeding environment has shifted progressively towards sustainable aquaculture systems, significantly enhancing the efficiency of aquaculture operations (FAO, 2018). Utilizing Artificial Intelligence in Aquaculture enables farmers to remotely oversee and manage their farming sites. This includes alerting farmers to any blockages, depletion of food stocks, or other critical issues that require immediate attention. Artificial Intelligence (AI) brings numerous advantages to aquaculture, simplifying activities like overseeing water quality, optimizing processes, handling feeding and nutrition, identifying and averting diseases, and conducting predicting analyses. These AI solutions play a role in elevating the quality and precision in aquaculture. The potential utilization of Artificial Intelligence is extensive and boundless.

Artificial Intelligence in Feeding and Nutrition Management: Artificial intelligence has the potential to optimize feeding and nutrition management in aquaculture. Through machine learning analysis of data regarding fish growth, behavior, and feeding habits, tailored feeding strategies can be developed. This approach aims to decrease feed wastage, enhance fish well-being, boost growth rates and reduce environmental impact (Pérez-Sánchez *et al.,* 2019). However, feeding represents the biggest cost to fish farmers, so optimization in this area always means better profitability. In an aquaculture system, approximately 60% of the total investment is allocated to feed expenses. Incorrect feeding practices, whether too little or too much, can lead to various containment issues. Underfeeding can reduce muscle conversion and, in extreme cases like with shrimps, may even result in cannibalism and aggression. Conversely, overfeeding causes feed wastage and deteriorates water quality. Monitoring appetite levels facilitates precise feeding schedules. Artificial Intelligence (AI), utilizing vibration-based sensors and acoustic signals, distinguishes between hungry and satiated fish. Indonesian aquaculture intelligence firm, has developed an AI feed dispenser (Plate I a and b) that accurately dispenses feed according to appetite levels (Georgopoulou *et al*., 2021). It uses various sensors to detect the appetite of the animal and also infrared imaging has been used to track fish and study feeding behaviour (Pautsina *et al*., 2015; Zhou *et al*., 2017; Georgopoulou *et al*., 2021). While Observe Technologies' company specializing in AI and data processing systems designed to measures and monitor the feeding behavior of aquatic biota. It offers objective and empirical guidance on quantity of feed required by farmers. In Singapore and Japan, 'UMITRON Cell', an aquaculture technology firm, has developed a smart fish feeder controlled by a remote (Plate II). This innovative system represents the world's first real-time ocean-based fish appetite detection system (Chahat, 2022). It operates as a data-driven decision-making device, aiding farmers in optimizing their feeding schedules. These AI-powered feeding devices significantly reduce feeding cost and uphold water quality standards.

Artificial Intelligence in Water Quality Management: The rising global consumption of fish highlights a growing trend in community fish consumption, necessitating an increase in fish production to meet demand (Wamba *et al*., 2021). However, the ability to meet consumer needs through increased fish production is hindered by various factors, such as declining water quality caused by nitrogen waste from leftover feeds, feces, and excretions on the gills, which decompose and degrade water quality in aquaculture systems (Putra *et al*., 2019). It's crucial to identify optimal environmental conditions to enhance fish growth performance and maximize production (Ekasari *et al*., 2015). Therefore, managing water quality in aquaculture system is essential for the well-being and productivity of fish. To address this challenge, various strategies, alone or in combination, can be employed for instance, Robot fish integrated with sensors (Plate III) have the capability to gather and assess various water quality metrics such as turbidity, temperature, dissolved oxygen (DO_2) levels, pH levels and even monitor the heart rates of fishes. These data are conveniently accessible via a smartphone linked to the drone. However, researchers have introduced the concept of a 'shoal'- a collective of robotic fish (Plate IV) designed to detect pollution in the vicinity aquaculture sites. These autonomous robots swim independently, collecting valuable data on water quality (Matondang *et al*., 2022), and facilitates the natural purification of water from waste products and enhances seafood productivity (Matondang *et al*., 2022).

Artificial Intelligence in Disease Detection and Prevention : Disease outbreaks is one of the primary constraints facing aquaculture. Artificial Intelligence (AI) systems have the capability to anticipate and detect these outbreaks by comparing programmed data with real-time data collected from the site. Machine learning algorithms can analyze data from diverse sources including water quality sensors, fish health imaging, and genetic data to recognize disease patterns and indicators. This facilitates prompt interventions and preventive actions, mitigating the impact of diseases on aquaculture operations (Luo *et al.,* 2020). For example, salmon louse epidemic posed a significant threat to the salmon industry, with the direct cost of managing these ectoparasites estimated at a minimum of $600 million annually in Norway (Chrispin *et al.,* 2020). The presence of lice hampers the expansion of salmon production, as farmers must demonstrate control over lice infestations to expand their operations. To address this persistent issue, BioSort iFarm sensor (Plate VIII) analyze and forecast lice spread in the culture facilities. This enables farmers to take proactive measures to protect their salmon populations from infection. AquaCloud, a predictive analytics platform, automatically gathers data and alerts farmers to potential salmon louse outbreaks. A Convolutional Neural Network (CNN) comprising three layers, each with a *Relu* and *max-pooling*, along with a flattened layer and a fully connected layer, is employed for fish disease classification (Agossou and Toshiro, 2021). These applications empower farmers to preempt disease outbreaks. Periodically, farmers and developers upload images of shrimp diseases and parasites into the app. The program utilizes these images to learn about diseases and stores the information for future reference.

Furthermore, the initial investment costs for such robotic cages may be substantial, the technology proves to be cost-effective in the long term. Aquapods (Plate V) cultivate fish in open sea environments, with robots capable of inspecting and, if necessary, repairing nets, providing a safer and more efficient approach to fish farming and operational management. Detecting diseased fish or damaged cage nets is crucial. For instance, identifying diseased fish typically involves observing fish exhibiting weak swimming behavior near the surface or necessitates divers entering the cage for inspection. Therefore, employing machine learning and computer vision connected to submerged cameras holds significant value. This system can identify fish diseases and continuously and accurately manage fish cage operations, including fish weight and size, thus representing a promising future model for offshore cage culture. Looking ahead, machine learning and computer vision applications should become more accessible in smart aquaculture, deployed not only in hatcheries and land-based farms but also in offshore aquaculture systems. Specifically, computer vision and machine learning can be applied to offshore areas such as cages to detect fish diseases and ensure the safety of fish cages, as depicted in Plate VI.

Artificial Intelligences in Fish Seed Screening/Sorting : The identification and selection of healthy fish or fish seed are crucial aspects of fish farming, often requiring laborious efforts and the employment of numerous workers for screening or sorting purposes. For instance, Manual Microsoft Azure's machine learning studio (Plate VII) is used for identification and removal of abnormal-shaped fish seed from rearing cages, though, labor intensive (Chrispin *et al.,* 2020; Chahat, 2021; Abedin *et al.,* 2022). Additionally, a novel aquaculture system developed by a startup called BioSort (Cermaq), the iFarm (Plate VIII) designed to enable farmers to individually identify up to 150,000 fish in a pen has been introduced with the stocking of salmon for the first time. These artificial intelligence and machine learning used to recognize each fish in a net pen, facilitating targeted health interventions if necessary and maintaining health records for each individual fish (Karl, 2020).

Lutz (2023) highlighted the increasing relevance of Artificial Intelligence in aquaculture research and production, with both startups and established companies developing new AI-based applications for the industry. The system measures factors such as weight and growth rate for each fish, while lice are counted on the entire fish. Any wounds or signs of illness are documented in the fish's health record. The system has the capability to sort fish so that treatment is tailored to each individual's needs, minimizing stress on the fish by eliminating the need for handling or sorting. Housing up to 150,000 salmon per pen, the system maintains fish at lower depths in the water column than conventional net pens, utilizing a net roof. As fish rise to the surface to refill their airbladders, they pass through a portal where a sensor swiftly scans and records data on each specific fish, utilizing recognition data based on individual fish markings and structure. According to Karl (2020), the iFarm contributes to improving the health and welfare of the fish.

Artificial Intelligence in Gender Identification: Sex determination in fish using manual methods, as per current guidelines, relies on human observation. Therefore, the methods of determining sex in fish exhibit considerable diversity and flexibility, distinct from those observed in other higher vertebrates (Desjardins and Fernald, 2009). However, discerning differences in coloration between male and female fish can be challenging for human observers due to minor sexual dimorphism in body color in certain species (Hutter *et al.,* 2012). Conventional guidelines for sex determination in fish through human perception involve observing sex-related variations in features such as color, shape, behavior, and genital papilla (McMillan *et al.,* 2015). For instance, female Zebrafish typically exhibit a round shape and a protruding abdomen compared to males, although not all females display a clearly distended abdomen (Hutter *et al.,* 2010; McMillan *et al.,* 2015). Additionally, relying on coloration for sex determination in Zebrafish is challenging due to individual variation in color, and sometimes, males and females may have similar body coloration (McMillan *et al.,* 2015). Nonetheless, precise sex determination of adult fish can be achieved through microscopic examination by dissecting gonad tissue, a procedure that necessitates euthanizing the animals (Abozaid *et al.,* 2011; Hosseini *et al.,* 2019). These guidelines for sex recognition have been found to be subjective, labor-intensive, inadequately reliable, requiring specialized biological expertise, and potentially traumatic for the fish.

At present, ultrasound diagnostics represent the most effective approach for early sex determination in fish (Memiş *et al.,* 2016; Webb *et al.,* 2017; Chebanov and Galich, 2018; Barulin, 2019), capable of identifying sex from an early developmental stage. However, this method requires expensive equipment and highly qualified fish farmers. Additionally, the BioSort iFarm sensor (Plate VIII) also employed for sex identification (Karl, 2020). Species identification will also improve in accuracy. It can be challenging at times when video footage is absent or of low quality due to conditions within the counting machines (Hafsteinn Einarsson *et al.,* 2023).

Artificial Intelligence in Harvesting System : The final stage in completing the breeding cycle for fish farms involves an intelligent harvesting system. Through this system, the breeding stock is transported to market either with or without water. Currently, trawling stands out as the most efficient method of fishing. In intelligent fish farming systems, sonar, underwater cameras, and net positioning instruments are utilized to achieve precision fishing (Fernandes-Salvador, 2022). The involvement of unmanned vehicles and ships in the transportation of aquatic products will significantly enhance fishery production efficiency. This contributes to the goals of improving efficiency, conserving energy, and reducing the labor intensity of fishermen. A sea cucumber catching robot utilizes Doppler-GPS integrated navigation, computer vision, and mechanical servo-drive technology to automatically harvest sea cucumbers. The navigation system of the sea cucumber catching robot is responsible for collecting underwater robot position information, planning navigation routes, and controlling robot movement. Meanwhile, the machine vision system is tasked with capturing sea cucumber images, preprocessing them, identifying sea cucumbers, and calculating their relative coordinates (Qiao *et al.,* 2017).

The actuator has the capability to regulate the pressure pump and manipulator for harvesting sea cucumbers. Intelligent equipment and robots represent the pivotal elements in freeing up labor in aquaculture and achieving automated production. They rely on modern information technologies such as comprehensive perception, intelligent processing, intelligent navigation, and automatic control technology, coupled with advancements in traditional aquaculture equipment, to realize unmanned production, environmental monitoring, optimization control, and precise operations. Robots, unmanned vehicles, unmanned boats, and robotic fish are poised to play significant roles in intelligent fish farming (Fernandes-Salvador, 2022). Additionally, Matt (2017) discussed an underwater drone known as the PowerRay (Plate IX), designed to assist in locating and attracting fish. This drone can descend to depths of 30 meters (98 feet) underwater, equipped with an optional "Fishfinder" sonar attachment capable of detecting fish up to an additional 40 meters (131 feet) away. Its WiFi system transmits video, images, and additional data on underwater terrain and temperature to the surface, allowing users to view them via a dedicated iOS or Android app on their smartphone. Moreover, it features an "internal fish luring light" designed to attract fish with a welcoming blue hue, along with an optional remote-controlled bait drop system for precise bait placement. Nick (2017) also mentioned an optional accessory set, the PowerVision VR Goggles, providing a first-person perspective and enabling users to control the drone via head tilts.

Artificial Intelligence in Fish Processing : The demand for processed fish remains consistently high. Fish processing facilities have advanced to a stage where automated robots perform tasks with greater accuracy and efficiency, resulting in significantly increased production rates (Abedin *et al.,* 2022). Tasks such as cutting, filleting, and cleaning can be executed by programmed Artificial Intelligence (AI) robots, ensuring precise sizing, shaping, and hygiene standards. Quality control and grading are facilitated by AI programs equipped with visual image sensors and cameras. Following grading, processed foods can be packed and transported by AI robots, eliminating labor costs and the need for human supervision. 'Marel,' an Icelandic company specializing in fish processing machinery, has developed AI-based robots (shown in plates X and XI) capable of performing various tasks within a production facility, from cleaning and filleting to grading and packaging (Fernandes-Salvador, 2022).

Artificial Intelligence in Aquaculture Practices during the Coronavirus Disease, 2019 (COVID-19) Pandemic As a consequence of the COVID-19 pandemic, global aquaculture output experienced its first decline in 60 years (FAO, 2021). While aquatic species are not susceptible to COVID-19 infection, but pandemic disrupted or slowed down most aquaculture activities worldwide. Many farmers were compelled to temporarily suspend fish production or significantly reduce their aquaculture operations during the pandemic (Waiho *et al.*, 2020). The impact of travel restrictions and border closures due to COVID-19 made it challenging for the aquaculture industry worldwide to secure migrant labor. Additionally, social distancing measures were implemented for employees, resulting in many workers involved in the production, harvesting, processing, and marketing of aquatic food being required to either stay at home or work remotely. These factors contributed to a slowdown, with aquaculture production being temporarily halted in many farms, thereby affecting production and subsequent supplies (Bennett *et al.*, 2020; Sunny *et al.*, 2021). Consequently, the implementation of AI in fish farming aims to utilize intelligent machines to replace manual labor and optimize the deployment of fishery resources in a data-driven manner, ultimately achieving efficient, environmentally friendly, and intelligent aquaculture practices.

Table 1. Some Artificial Intelligent devices, descriptions and applications in aquaculture

Device	Description	Purpose	References
Back-propagation neural network (BPNN) for an intelligent feeding system.	Neural network and algorithms based on data on temperature, dissolved Oxygen, fish weight, and stocking density inputs. The corresponding feed intake is obtained using this model.	Feed-intake prediction and minimizing feed loss	Chen *et al*. (2021)
Autoregressive back propagation neural network (ARBPNN) model for dissolved oxygen prediction.	Utilizes data on past dissolved Oxygen and other parameters (for example, temperature, pH, radiations) to make near term predictions of dissolved Oxygen profile.	Intensive aquaculture management of species such as sea cucumbers.	Li *et al*. (2020)
Hybrid deep neural network model.	Records number of fish specimens as input data to intelligently measure production dynamics. Accurate assessment of biomass is necessary for aquaculture economics. Fish count is helpful is optimizing feed quantity, deciding brood stock number in a tank and determining optimal harvest time in addition to other benefits.	Provide an essential reference for feeding and breeding operations.	Putra *et al*. (2019)
IoT based fish farming system.	Processes quantitative data on achieving trade-off between water pumping duration and flow rate through optimizing water volume. Uses sensors, algorithms and simulation.	Reduced energy consumption and pumping duration in the tank for healthy fish production with optimal resource utilization.	Chebanov and Galich, (2018)

Benefits and Limitations: The adoption of Artificial Intelligence (AI) in aquaculture brings several benefits, including increased productivity, reduced environmental impact, and enhanced resource management. However, limitations such as data availability, algorithm complexity, and cost of implementation pose challenges to widespread adoption and require further research and development.

Summary: Artificial Intelligence offers significant potential to revolutionize the aquaculture industry by addressing key challenges and improving various aspects of production. Applications of AI in aquaculture include feed management optimization, disease detection and diagnosis, water quality monitoring, and robotics and automation among others. These technologies have the potential to enhance productivity, reduce environmental impact, and improve overall resource management. However, the limitations related to data availability, algorithm complexity, and implementation costs require further research and development.

Conclusion : In conclusion, the advancements in technologies and the rapid development of electronic devices, sensors, and internet communication have given birth to the concept of 'smart aquaculture' which is quickly expanding in the business and presents automated farming techniques, high-precision useful data collection, data analysis and many other advantages using advanced technologies. Cutting edge technologies such as: Artificial Intelligence (AI), Internet of Things (IoT), Computer Vision (CV), Machine Learning (ML), and Cloud Computing (CC) have become highly adaptive solutions to different use cases ranging from smart cities to smart aqua farming industries, providing us with the ability to construct advanced solutions that make life easier. The enhancement in such technologies gives rise to new possibilities of building a brand-new farming approach. As an advanced stage of aquaculture development, intelligent fish farm will apply intelligent machines to replace manual labour and optimize the deployment of fishery resources in a data-driven way to achieve efficient, blue and smart aquaculture. Even though Artificial Intelligence is developed, complete automation is not available yet. Scientists are working on technology that can work without human interference in the process. The applications of machine learning and computer vision in aquaculture have been contributing to the development of the aquaculture industry in an automatically trend, and improving farming productivity. Investing in Artificial Intelligence plus automation can significantly produce more sea food to feed the growing population while reducing the cost and environmental foot print. However, further research, collaboration, and investment are necessary to overcome limitations and ensure the successful implementation of AI in aquaculture operations.

Recommendations: Increase data collection and sharing: Collaboration between aquaculture stakeholders and researchers should focus on collecting and sharing comprehensive datasets to train AI algorithms effectively.; Develop user-friendly AI tools: Efforts should be made to simplify AI technologies and develop user-friendly interfaces that enable aquaculture operators to easily adopt and utilize AI applications. ;Enhance cybersecurity measures: Given the increasing reliance on AI systems, it is crucial to invest in robust cybersecurity measures to protect sensitive aquaculture data from potential breaches and cyber-attacks.; Promote interdisciplinary collaboration: Encouraging collaboration between AI experts, aquaculture researchers, and industry professionals will facilitate the development of innovative AI solutions tailored to specific aquaculture challenges.; Conduct cost-benefit analyses: Further research should focus on evaluating the economic viability and cost-effectiveness of implementing AI technologies in different aquaculture settings to assess their true value.

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Chrispin C.L., Jothiswaran, V.V., Velumani, T., Agnes, D., Angela, S. and Jayaraman, R (2022). Application of Artificial Intelligence in Fisheries and Aquaculture. Research Today 2(6): 499- 502 Corresponding Author Keywords Open Access.

Economic Analysis of Cowpea Production in Ankpa Local Government Area of Kogi State, Nigeria: Prospect for Food Security.

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Abstract

This study examined the production of cowpea in Ankpa Local Government Area of Kogi State, Nigeria, with the following objectives: (1) to estimate the costs and returns of cowpea production, (2) to determine the impact of socio-economic variables on the income of cowpea farmers, and (3) to identify the constraints faced by cowpea producers. A multi-stage sampling procedure was employed to select 60 cowpea farmers who were administered a well-structured questionnaire. The primary data collected were analyzed using descriptive statistics, farm budgeting techniques, and multiple linear regression. The findings revealed that cowpea production in the study area was profitable, with a net farm income of N143,007.63/ha and a return on Naira invested of N1.60K. However, cowpea farmers in the area faced several challenges, including high input costs, limited access to credit, inadequate extension services, pest and disease infestation, continuous farmers'/herders' clashes, and poor market facilities. Based on the findings, it is recommended that cowpea farmers be encouraged to use herbicides/pesticides to boost their output. Additionally, forming cooperative groups can enable farmers to access loans and production inputs, thereby improving their productivity and profitability.

Keywords: Economic Analysis, Cowpea, Production and Food Security.

Introduction: Cowpea (Vigna unguiculata (L.) Walp) is an annual legume crop cultivated for its seeds or foliage, exhibiting diverse growth habits including erect, climbing, prostrate, and creeping varieties. Prostrate cultivars typically reach a height of approximately 80 cm, while climbing varieties can grow up to 2 m, supported by well-developed root systems (Heuzé et al., 2015). Cowpea pods contain 6-13 kidney-shaped seeds, which become more spherical and compact within the pod (Sheahan, 2012). As one of the oldest human food sources, cowpea has been utilized as a crop plant since the Neolithic era (Directorate of Plant Production and Agricultural Resource Centre, 2011). Its primary production regions include Africa (Egypt, Nigeria, and West African countries), South America (Colombia, Brazil), North America (USA, Mexico), Asia (China, Pakistan, Japan), and Southeast Europe (Spain, Greece, Italy, Portugal, Cyprus) (Antova et al., 2014). Notably, West Africa accounts for 80% of global cowpea production, with Nigeria being the leading producer, followed by Brazil and other West African nations (Gerei et al., 2018). Nigeria dominates global cowpea production, accounting for approximately 45% of the world's total output and over 55% of Africa's production (Alene et al., 2015). Despite efforts to breed resistant varieties, no single cowpea variety is completely immune to the various insect pests that attack the crop (Dzemo et al., 2010). While some varieties exhibit resistance to specific insect pests, they often lack comprehensive protection against the range of pests that affect cowpea (Pulakkatu-Thodi et al., 2014; Abudulai et al., 2017). Breeding programs have focused on developing cowpea varieties with desirable agronomic traits, grain quality, and tolerance to abiotic and biotic stresses, but have largely overlooked the development of varieties with weed-suppressing capabilities (Ehlers et al., 2012; Hall et al., 2013).

Substantial genetic diversity exists for growth habit characteristics in cowpea, offering excellent opportunities for developing varieties with enhanced weed suppressive ability, as demonstrated in soybean (Glycine max (L.) Merr.) (Ehelers and Hall, 1997). Ewansiha and Tofa (2016) reported that the IT98K-573-2-1 cowpea variety exhibited significantly higher yield potentials, with seed and fodder weights reaching 1155.3 kg/ha and 6006.4 kg/ha, respectively, surpassing other tested varieties (IT97K-499-35, IT98K-205, IT89KD-288, and IT99K-241-2). Similarly, Kirkhouse (2017) observed notable variations in cowpea yield and growth habits. Cowpea has been aptly referred to as "the poor man's meat" due to its high protein content in seeds and leaves (Hamid et al., 2016). The seeds provide a rich source of proteins, calories, minerals, and vitamins (Gonçalves et al., 2016). Notably, cowpea seeds contain 23-25% protein, 50-67% carbohydrates, 8-9% moisture, and remarkably low-fat content (3.99%) (Rangel et al., 2021), making them a valuable nutritional resource. Maruca vitrata, a legume pod borer, is a devastating pest of cowpea and other leguminous crops, widely distributed across tropical and subtropical regions, causing significant damage (Baoua et al., 2011). In Africa and Southeast Asia, it is a major concern, with the larval stage inflicting damage on flower buds, flowers, and young pods, resulting in up to 80% yield losses (Dannon, 2011). To combat this pest, Lambda-cyhalothrin 2.5EC (Kombat 2.5EC), a non-systemic, contact, and repellant insecticide, is commonly employed (Saro, 2018). Research has shown that spraying contact or systemic insecticides three times on cowpea enhances grain yield and economic returns (Kotu et al., 2017). Contact insecticide application has been found to improve cowpea growth and yield, which is often limited by insect pests that destroy seed yield and quality (Tony et al., 2014). Consequently, insecticide application remains the primary method for controlling insect pests in cowpea production in most African countries, due to its effective results (Pulakkatu-Thodi et al., 2014; Abudulai et al., 2017). Despite efforts to develop resistant varieties over the past two decades, none are currently available to farmers. Therefore, chemical control using synthetic insecticides remains the most popular option when pest populations exceed the economic injury level (Jackai et al., 2020). Research has demonstrated that applying insecticides twice, at flower budding and early podding stages, can significantly reduce pod pest infestation levels (Ajeigbe and Singh, 2016). This suggests that a two-spray regime, targeting flowering and podding, can yield comparable results to three to five spray regimes, potentially simplifying pest management for cowpea farmers. Moreover, spraying insecticides three times has been shown to increase grain yield and net returns, making this technique attractive to farmers with varying risk attitudes (Kotu et al., 2017). By promoting this approach, cowpea production can be enhanced, contributing to food security and poverty reduction among smallholder farmers. According to the Food and Agriculture Organization (FAO, 2022), food security is achieved when four pillars are met: availability, access, utilization, and stability. However, caution is advised when scaling up insecticide use to mitigate potential negative externalities (Kotu et al., 2017).

Cowpea, is a leguminous crop which offers numerous "Economic Benefits", including: High market demand: Cowpea is a staple food in many regions, ensuring a consistent market demand. Profitable yield: Cowpea production generates significant income for farmers due to its high yield potential. Low production costs: Cowpea requires minimal inputs, reducing production expenses. Drought tolerance: Cowpea's ability to thrive in dry conditions makes it a reliable crop during water-scarce periods. Soil fertility improvement: Cowpea's nitrogen-fixing properties enhance soil fertility, reducing fertilizer costs. Livestock feed: Cowpea haulms (leaves and stems) serve as nutritious fodder for animals. Export opportunities: Cowpea is exported to various countries, generating foreign exchange earnings. Supports food security: Cowpea is an important protein source, contributing to food security and nutrition. Employment creation: Cowpea production and processing provide employment opportunities for rural communities. Value addition: Cowpea can be processed into various products like flour, paste, and snacks, increasing its economic value. Food Security: Cowpea is important for households and communities due to its substantial contributions to food security, nutrition, and revenue production.

By promoting cowpea production and utilization, these economic benefits can be harnessed to improve the livelihoods of farmers and contribute to national economic growth Nwagboso et'al, 2024. Nigeria is the largest producer of cowpea in the world and one of the highest consumers. Despite being the largest producer, the demand for cowpea surpasses its supply due to factors such as the country's large population and low productivity. The data suggest that low input use, low-yield varieties, and low productivity characterize the current level of cowpea production the economic benefits of cowpea vary depending on factors such as location, market conditions, and production levels. Despite the numerous benefits of cowpea, its production in Ankpa Local Government Area (LGA) have received relatively little attention, hindering optimal benefits. Enhancing the production of cowpea could significantly boost farm incomes and improve the livelihoods of farmers and marketers in the LGA. Consequently, conducting an economic analysis of cowpea production is crucial to understanding its impact on the livelihoods of farmers in Ankpa LGA, Kogi State. This analysis will provide valuable insights into the economic viability of cowpea production, identify areas for improvement, and inform strategies to enhance the crop's contribution to local livelihoods.

Objectives of The Study: The overarching objective of this research was to conduct an economic analysis of cowpea production in Ankpa Local Government Area (LGA) of Kogi State. The specific objectives were:; to estimate the costs and returns associated with cowpea production in Ankpa LGA, with a view to determining the economic viability of the enterprise.; to investigate the impact of socio-economic variables (such as age, gender, education, and farming experience) on cowpea output in the study area, in order to identify potential targets for improvement.; to identify and analyze the constraints faced by cowpea farmers in the study area, with a view to informing strategies for addressing these challenges and enhancing the overall productivity and sustainability of cowpea production. By achieving these objectives, this study aimed to contribute to the existing body of knowledge on cowpea production and provide valuable insights for stakeholders seeking to improve the livelihoods of farmers and the local economy in Ankpa LGA.

Methodology: This study was conducted in Ankpa Local Government Area (LGA), situated in the eastern part of Kogi State, Nigeria. Ankpa LGA has a geographical coordinate of 7° 22' 14" N, 7° 37' 31" E, covering an area of 1,200 km² (500 sq mi) with a population of 267,353 according to the 2006 census. The dominant ethnic group in the area is the Igala tribe. The region experiences two main seasons: the dry season and the wet or rainy season, which begins in March and ends in October. The dry season starts in November and lasts until late February, with January being the coldest month due to the influence of the North-East trade wind and Harmattan.
Ankpa LGA has fertile soil, supporting various crops, including annual and perennial crops. The state is also known for producing yam, maize, rice, cassava, cowpea, millet, cashew, groundnut, coffee, cocoa, palm oil, sugar cane, melon, and coconut (Kogi Agricultural Development Project, 2018). The study population consisted of all cowpea farmers in the study area. A multistage sampling technique was employed to select participants. In stage1, three districts (Ankpa, Ojoku, and Enjema) were selected. In stage2, six wards were chosen (Enjema ward I and II, Ojoku ward I and II, Ankpa Township (Ojapata and Ogodo)). In stage3, six villages were selected (Enjema, Ojokwu, Okaba, Ojapata, and Ogodo). Finally, 10 respondents were selected from each village, resulting in a total of 60 respondents for the study. This sampling technique ensured a representative sample of cowpea farmers in Ankpa LGA, allowing for generalizability of the findings to the larger population. Primary data were collected from 60 respondents in the study area through a well-structured questionnaire, supplemented with interview sessions. The data collection took place during the 2023 cropping season.

The data were analyzed using a combination of descriptive statistics, farm budgeting techniques, and inferential statistics. To achieve the first objective, the farm budgeting technique was employed to estimate the costs and returns of cowpea production. The gross margin (GM) was calculated as the difference between gross income and total variable costs. Given the small farm size, all inputs were considered variable inputs, and the determined gross margin was taken as the profit of the venture (NFI = Net farm income). To address the second objective, multiple regression analysis was used to examine the relationship between socio-economic variables and cowpea output. Descriptive statistics, including means, frequencies, and percentages, were employed to achieve the third objective, which involved identifying the constraints faced by cowpea farmers in the study area.

By using a combination of these analytical techniques, this study aimed to provide a comprehensive understanding of the economics of cowpea production in Ankpa LGA.To examine the effect of socioeconomic factors on cowpea output, a multiple regression analysis was employed. The model is specified as follows: $y = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \varepsilon$. Where: y is the dependent variable, representing the output of cowpea in kilograms (kg), X1 is the age of the respondent in years, X2 is a dummy variable for sex (male or female), X3 is a dummy variable for marital status (married or single), X4 is the household size in numbers, X5 is the farming experience in years, X6 is the farm size in hectares, β1 to β6 are the coefficients of the respective independent variables, α is the constant term and ε is the error term. This model aims to investigate the relationships between the socioeconomic variables (age, sex, marital status, household size, farming experience, and farm size) and the output of cowpea production. The coefficients (β1 to β6) represent the change in the dependent variable (cowpea output) associated with a one-unit change in the respective independent variable, while controlling for the other variables in the model.

Results and Discussion: Costs and Returns Analysis: The costs and returns associated with cowpea production in the study area are presented in Table 1. The analysis reveals that: Labour is the most significant variable cost component, accounting for N25,126.50 per hectare, which is consistent with previous findings (Rukwe et al., 2020). The average quantity of inorganic fertilizer used (61.3kg/ha) is below the recommended rate (100kg/ha). Herbicide and pesticide/insecticide costs were N17,955/ha and N7,920/ha, respectively. Transportation and bag costs were N1,200 and N1,964.2, respectively. The average fixed cost was N16,450 per hectare. The total cost of cultivating a hectare of cowpea farm was N88,872.37. The average yield per hectare was 421.6 kg, lower than the average yield of 1000kg reported under improved management practices (Essien et al., 2020). The unit price was N550/kg, resulting in an average gross farm income of N231,880.00 per hectare. The net farm income was N143,007.63 per hectare, with a profitability index of 1.6, indicating a return of 60 kobo for every N1 invested. The gross ratio of 0.4 indicates that total farm costs accounted for 40% of the gross income, suggesting that the cowpea enterprise can survive in the long run. Overall, the results suggest that cowpea production is highly profitable in the study area, with a significant difference between the cost of inputs and returns realized. This supports the findings of Rukwe et al. (2021), who reported a profitability index of 2.3. The study highlights the potential for expanding cowpea production in the area.

Table 1: Costs and Returns of Cowpea Production in The Area.

Variables	Average quantity/ha	Unit price (₦)	Value (₦)
1. **1. Gross Return**			
a) Average yield (kg)	421.6	550	231,880
2. inputs			
i variable costs			
a) seeds (kg)	5.39	620.00	3.341.8
b) fertilizer (kg)	61.3	10,780.67	14,014.87
c) herbicides (ltr)	9.45	1,900	17,955
d) pesticides (ltr)	3.60	2,200.00	7,950
e) labour (Man/day)	23.93	1,050	25,126.5
f) Transportation (₦)		300	2,100
g) Bags (₦)	7	280.6	1,964.2
Total Variable Cost			**72,422.37**
ii Fixed Inputs			
a) Cutlass			2,000
b) Hoe			1,600
c) Sprayer			12,500
d) sickle			350
Total Fixed Cost			**16,450**
3. Total cost (i) + (ii)			**88,872.37**
4. Net Farm Income (NFI)			**143,007.63**
5. Rate of Return			**1.6**
6. Gross Ratio (TC/GR)			**0.4**

Source: Field Survey, 2023

Effect of socioeconomic variables on the output of cowpea farmers: The regression analysis revealed that socioeconomic variables significantly impact cowpea output. The model explained 73% of the variability in the data ($R2 = 0.73$), indicating a strong relationship between the independent variables and the dependent variable (net farm income). The findings showed that: Age positively and significantly ($p < 0.10$) affected output, suggesting older farmers are more likely to adopt new technologies and enhance productivity. Household size had a positive and significant ($p < 0.05$) influence on net farm income, as a larger household provides a larger labor force for production. Farm size strongly and significantly (at 1% probability level) affected net farm income, likely due to limited access to land, with most farmers renting land for cultivation. Experience, age, and educational level did not significantly influence net farm income.These results highlight the importance of considering socioeconomic factors in understanding cowpea production and net farm income.

Table 2: Effect of socio-economic variables on the output of cowpea production

Variables	**Coeff.**	**Std. Error**	**t-value**	**P>(t)**
Constant	2.9643	0.68034	4.36***	0.000
Age	0.2612	0.13644	1.91*	0.058
Years of exp	-0.009	0.02767	-0.33^{ns}	0.743
Sex	-0.013	0.10916	-0.12^{ns}	0.906
Household size	0. 0181	0.00857	2.11**	0.037
Edu level	0. 0138	0.03077	0.45^{ns}	0.654
Farm size	0.6995	0.05354	13.07***	0.000
R-Squared	0.7266			
Adj R-Squared	0.7069			
Prob>F				

Source: Field Survey, 2023

Constraints associated with cowpea production: Table 3 highlights the constraints faced by cowpea farmers in the study area. The results show that: High cost of farm inputs (71.6%): Farmers struggle with the expensive nature of inputs such as seeds, fertilizers, and pesticides. Inadequate access to credit (65%): Farmers lack access to credit facilities, hindering their ability to improve cowpea production. Inadequate extension services (61.7%): Farmers receive insufficient guidance and support from extension agents, limiting their knowledge and skills. Pests and diseases (60%): Cowpea farmers face significant challenges from pests and diseases, affecting yields and productivity. Incessant farmer/herder clashes (no percentage specified): Conflicts between farmers and herders pose a significant constraint to cowpea production. Inadequate market information (no percentage specified): Farmers lack access to reliable market information, making it difficult to maximize profits. These findings align with previous studies (Essien et al., 2020; Tahir et al., 2021) that identified similar constraints faced by cowpea farmers in other regions. Addressing these challenges is crucial to enhancing cowpea production and improving farmers' livelihoods.

Table 3: Constraints to cowpea production in the study area

Constraints	*Frequency (n = 60)	Percentage
High cost of farm input	**43**	**71.6**
Inadequate access to credit	**39**	**65.0**
Inadequate extension	**37**	**61.7**
Pest band disease	**32**	**60.0**
Incessant farmer/herder clashes	**29**	**48.3**
Inadequate market information	**27**	**45.0**

Source: Field Survey, 2023. * = multiple responses

Conclusion and Recommendations: In conclusion, cowpea production is a profitable venture in the study area, with significant factors such as age, household size, and farm size affecting output. To address the constraints faced by cowpea farmers, the following recommendations are made: Cooperative formation: Encourage cowpea farmers to form cooperative groups to access loans and improve their bargaining power. Improved seeds: Encourage farmers to use improved seeds to increase farm output and productivity. Extension services: Improve extension services to provide farmers with innovations and best practices. Input subsidization: Government and NGOs should subsidize farm inputs to encourage farmers to cultivate more and increase production. Credit access: Improve access to credit facilities for cowpea farmers to enhance their productivity and profitability. By implementing these recommendations, cowpea production can be improved, and farmers can maximize their profits, contributing to the overall development of the agricultural sector in the study area.

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Inoculation of *Claroideoglomus etunicatum* improved the tolerance of soybean to excess soil copper under varying watering conditions

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Abstract

The research investigated the effect of inoculation of *Claroideoglomus etunicatum*, an arbuscular mycorrhizal fungus (AMF), on the element nutrition, root colonization and growth of soybean under excess soil copper (Cu) and varied watering conditions. A 3x2x2 factorial setup was used, with soil copper treatments: 0 mg Cu kg^{-1} soil (Cu0), 200 mg Cu kg^{-1} soil (Cu200), and 400 mg Cu kg^{-1} soil (Cu400); AMF: non-inoculated (NMI) and inoculated (AMI); and watering regime: 100 ml/pot/day (W1) and 200 ml/pot/day (W2). Each treatment was replicated five times giving a total of sixty pots with unsterilized soils, maintained in the greenhouse for eight weeks. The data collected was analyzed using a three-way analysis of variance at $P<0.05$. Excess Cu was toxic to soybean in Cu200 and Cu400 soils, with leaf chlorosis observed in NMI plants, but not in AMI. Low watering regime aggravated Cu toxicity, as two NMI plants died in Cu400 soil under W1 treatment, but none in the AMI group. Excess Cu significantly decreased leaf number, shoot lengths and dry weights, but AMF inoculation had a significant protective effect on them. The Cu concentration in root and shoot of plants in polluted soils was significantly reduced by *C. etunicatum*, while shoot phosphorus (P) concentration, root colonization intensity and soil pH were generally increased. In conclusion, inoculation of soybean with *C. etunicatum* increased soybean tolerance to excess soil Cu and low watering conditions by modifying soil pH, regulating Cu uptake and homeostasis, modulating shoot Fe to avoid leaf chlorosis, and boosting root colonization and P nutrition.

Keywords: Cu stress, AMF, watering condition, metal tolerance, element homeostasis.

Introduction:

Inadequate water supply and excessive levels of soil trace elements (TE) are among the several abiotic conditions that can immensely limit plant performance. These two conditions alter the homeostasis of plants, hamper physiological activities and elevate the production of reactive oxygen species (ROS) that are injurious to cells, thereby jointly aggravate plant stress (Kopecká *et al*., 2023). In Nigeria, metal mining and e-waste dumping has led to elevated levels of metals in nearby top-soils, with negative implications for human and environmental health. The elements elevated often include zinc (Zn), lead (Pb), cadmium (Cd), and Copper (Cu) (Obiora *et al*., 2016). Cu is an important TE for several physiological functions, such as respiration, photosynthesis, protein metabolism, as well as being a component of many enzymes, but it can become phytotoxic (Ruscitti, *et al*. 2017) when excessive levels of soil Cu arise due to mining, smelting, waste disposal, agricultural application of Cu-based pesticides, amongst others. Nigeria's Cu deposits occur mostly in the North Central parts of the country (Taofeek and Amos, 2023). Water supply - an important requirement for plant performance - is also a potential challenge for crop production efforts in parts of Northern Nigeria. The changes in precipitation patterns and increasing evaporation rates due to rising temperatures have exacerbated water limitation, scarcity and/or droughts in parts of the globe (Farooq *et al.,* 2017). As Nigeria and the world at large grapples with the consequences of climate change and increasing human population, mitigating the adverse effects of sub-optimal water and soil TE conditions will become more important in the decades ahead. In this regard, the efficient utilization of biofertilizers such as arbuscular mycorrhizal fungi (AMF) for improving crop performance under these kinds of suboptimal conditions is an ecofriendly option to be explored. Soybean is an important crop in Nigeria, and a target for improved country-wide production, including under suboptimal soil conditions (Ibiang *et al*., 2023). This study evaluated the ameliorative effect of AMF inoculation on the element nutrition, root colonization and growth of soybean under watering and excess soil copper stresses.

Materials and methods: **Soil and seeds preparation** *:* The soil utilized for this study was sandy-loam topsoil collected (up to 20cm deep) from the experimental farm of the Department of Genetics and Biotechnology, University of Calabar, Nigeria. The soils were bulked and sieved using a soil sieve (2 mm) to remove stones and other debris and analyzed for pH (6.5), EC (0.91 mS m^{-1}), organic carbon (0.45%), total N (0.15%), available P (0.32 mg kg^{-1}). The soil was not autoclaved before use. Copper salt ($CuSO_4 \cdot 7H_2O$) was artificially applied to the soil at the rate of 0 mg Cu kg^{-1} of soil (Cu0), 200 mg Cu kg^{-1} of soil (Cu200), and 400 mg Cu kg^{-1} of soil (Cu400). Cu0 soils received no copper salt, while the mass of copper salt (g) added to the soils of the other groups was determined as: 0.2 g x (249.68/63.55) per kg of soil for Cu200 treatment; and 0.4 g x (249.68/63.55) per kg of soil for Cu400 treatment. The Cu salt was first dissolved in 500 mL distilled water then applied with mixing to the soil in a bag. All soils after mixing were bulked and kept for 1 week after contamination before dividing into labelled pots (4kg of soil per pot). The soybean (*Glycine Max* (L.) Merr.) were collected from Taraba State Agriculture Development Program (TADP). The seeds were sterilized in 90% ethanol for 5 mins then rinsed twice with distilled water, with any floating seeds discarded before germination on wet tissue papers in Petri dishes for 72 hrs, then transfer to the potted soils.

2.2. Experimental set up

The experiment was set up as a 3x2x2 factorial in a completely randomized design (CRD). Factor one was soil copper treatment with three levels: Cu0, Cu200, and Cu400; factor two was AMF with two levels: no mycorrhizal (NMI) and mycorrhizal inoculation (AMI); and factor three was the watering regimes: 100 ml/pot/day (W1) and 200 ml/pot/day (W2). Each treatment was replicated five (5) times giving a total of sixty (60) pots.

AMF inoculation: The AMF used in this research was *Claroideoglomus etunicatum* (initially supplied by Kyowa Hakko Kirin Co. Ltd. Japan) and reproduced locally in Calabar, using soybean host in autoclaved sandy soil in buckets for two and a half months. After 10 weeks, the shoot was cut off leaving the root in the soil for additional two weeks to stimulate fungal sporulation. Finally, the dead dry root was removed, chopped nicely into tiny bits with a knife and mixed with the soil from which it was gotten to obtain the final inoculum. 10g of the inoculum (containing about 60 spores) were weighed and applied manually in the middle of the soil at about 3cm deep just before pre-germinated seed sowing in the AMI pots, while the NMI pots received no inoculum.

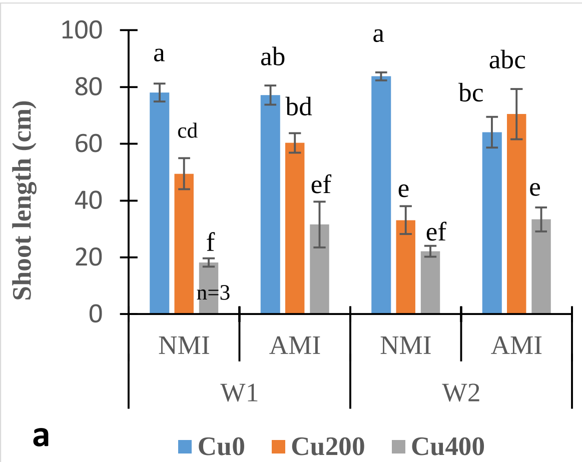
Plant cultivation, harvest and measurement of growth parameters: The plants were maintained in the greenhouse of Department of Genetics and Biotechnology, University of Calabar, Calabar, for a total of eight (8) weeks. Modified Hoagland solution was applied to each pot at the rate of 50 mL/pot/week for six weeks, and 100 mL/pot in the seventh week. After measuring the number and width of the leaves, the plants were harvested by cutting the shoots and measuring shoot lengths and fresh weights, then emptying the soil from the pots to obtain the roots, washing the roots in a bucket of water, then cutting out a portion of the roots for evaluation of root colonization and Cu concentration. 5g of the soil was collected for measurement of soil pH, then the fresh shoots and root were dried in the oven at 80 °C for 48 hr.

AMF colonization: AMF colonization was assessed in the root subsamples of all plants using the trypan blue staining technique as previously described by Rajapakse and Miller (1994) after clearing the roots in 10% KOH solution. 30 root sections of 1 cm lengths were mounted on a slide and observed in a light microscope under ×10 lens for mycorrhizal scoring.

Plant Cu concentration: The concentration of Cu was determined in root and shoot, while Fe, Mn and Zn concentrations were determined only in shoots. The milled dried samples were combusted in an electric muffle furnace at 550 ^{0}C for 6hrs, and the ash was digested in 0.6 mol L^{-1} HCl. Element concentrations in plant extracts were measured using atomic absorption spectrophotometry (AAS) (Shimadu AA-6600AF, Japan). Root-to-shoot Cu translocation ratio (TR) was calculated as element concentration (µg g^{-1}) of shoot divided by that of the root (Stolz and Greger, 2002).

Results: Excess soil Cu was toxic to soybean, especially in Cu400 soils where chlorosis of the leaves was observed in NMI plants but not in AMI. Watering regime aggravated the Cu toxicity in Cu400 soils as two plants died in W1 treatment, under NMI groups, but no mortality was recorded in AMI groups in the scarcely-watered pots. Significant differences were observed in plant lengths and weights (Fig 1) with noticeable protective effect of AMF inoculation. AMF inoculation decreased the shoot Cu concentration (Fig 2) especially in Cu400 soils in W1 series, but the values in Cu0 and Cu200 soils were not significantly different. There was also a significant 3-way interaction between the main treatment effects. Excess soil Cu increased the root Cu concentrations in Cu200 and Cu400 soils, while AMF inoculation decreased the root Cu concentrations compared to NMI plants. The intensity of mycorrhizal colonization (Fig 2) was significantly affected by AMF inoculation and soil Cu, with a decrease due to excess Cu in Cu400 soils and increase due to AMF inoculation across the board.

Discussion: Although it is an essential trace element, injury and death to plants can result from Cu when it is at a high level in soil. According to Kabata-Pendias (2011), the maximum allowable concentration (MAC) of Cu in soils ranges from 60 – 150 mg/kg soil, and toxicity is likely to set in above this range. In this study, excess Cu treatments taken at 200 and 400 mg/kg exceeded the MAC range, and produced obvious signs of toxicity including stunted lengths, reduction in number and width of leaves, as well as chlorosis of the leaves, in line with reported symptoms of Cu phytotoxicity (Kabata-Pendias, 2011). Also, the tested treatments of excess Cu utilized are justified by the report of Adesokan *et al*. (2016) which stated that Cu in soils polluted



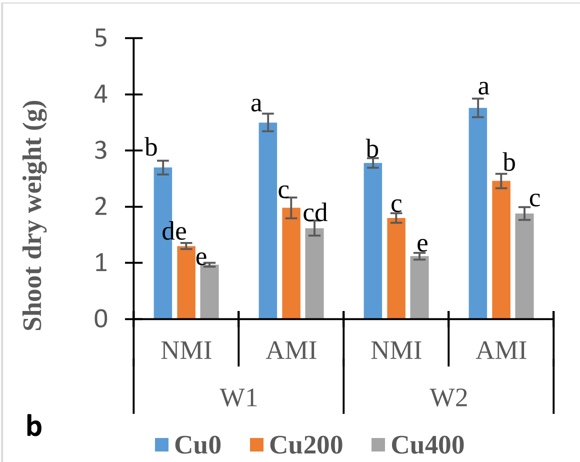


Fig 1. Shoot length (a) and dry weight (b) of soybean plants under varying soil copper and watering conditions. NMI (no mycorrhizal inoculation), AMI (arbuscular mycorrhizal inoculation). Values are Mean ±SEM. [abc]Superscripts indicate differences based on least significant differences (LSD) test.

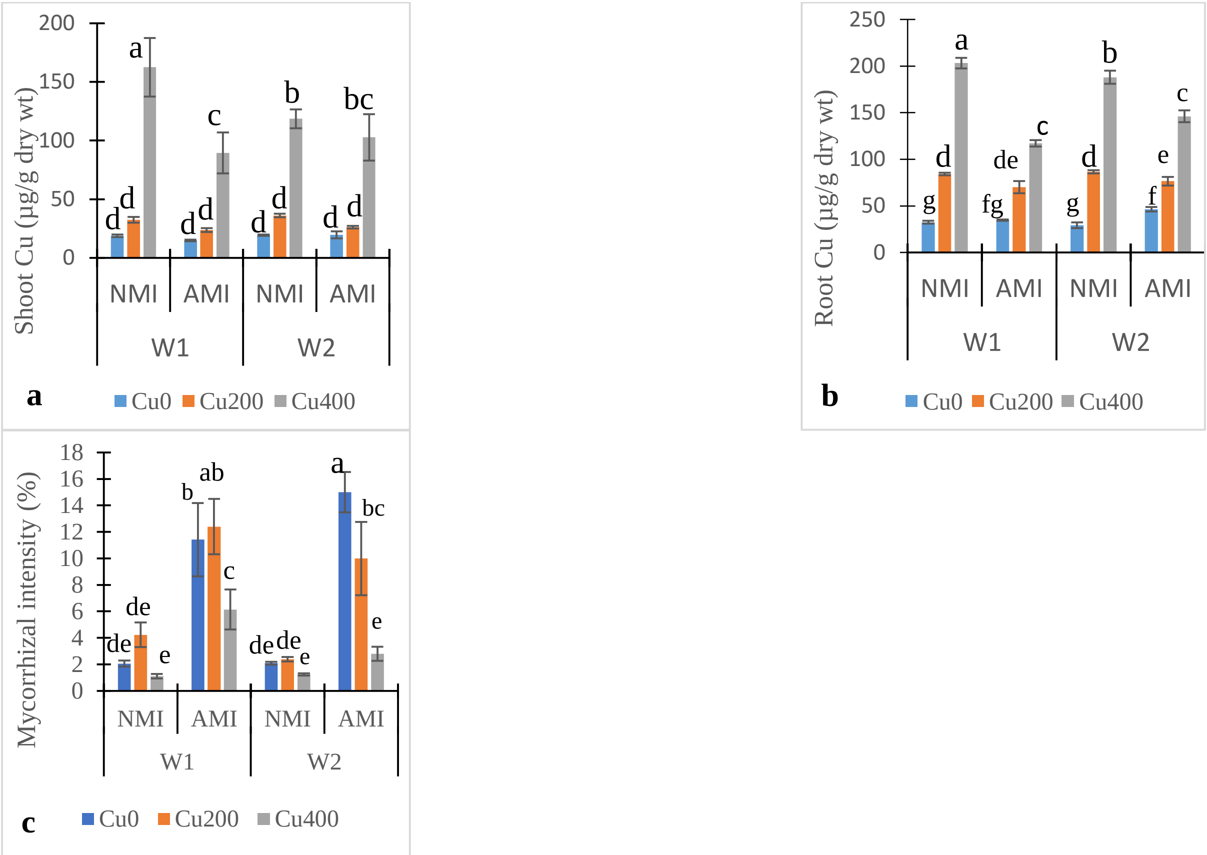


Fig 2. Concentration of copper in Shoot (a), Root (b) and mycorrhizal colonization intensity (c) of soybean under varying soil copper and watering conditions. NMI (no mycorrhizal inoculation), AMI (arbuscular mycorrhizal inoculation). Values are Mean ±SEM. [abc]Superscripts indicate differences based on LSD test.

by e-waste in Nigeria could range from 203 – 3483 mg Cu Kg^{-1} soil. Especially since W1 groups in Cu0 soils didn't suffer any mortality, the death of two plants in Cu400 soils under W1 watering regime indicates that water insufficiency aggravated the Cu toxicity, making the non-inoculated plants more vulnerable. However, the protective role of *C. etunicatum* inoculation is confirmed by the absence of mortality in the AMI plants, and the general amelioration of Cu-induced decreases in the growth indices, under both watering regimes. Therefore, *C. etunicatum* effect was also ameliorative of the potential of water-insufficiency to compound the stress from excess soil Cu. On the other hand, this indicates that the native AM species colonizing the uninoculated plants in NMI groups, did not induce sufficient protection against Cu. This may stem from the native mycorrhiza's own susceptibility to the high levels of soil Cu tested. Since mycorrhizal effects on growth, P uptake and metal tolerance of hosts generally vary among different AMF species (Zhang *et al*., 2015), the tolerance and/or susceptibility of individual AMF to excess heavy metal affects the plant-AMF symbiosis and may diminish their protective effect on hosts exposed to high heavy metal levels. This is supported by the observed greater reduction in root colonization indices in the NMI plants compared to AMI, especially in Cu400 soils. In terms of element nutrition, AMF often protect plants under metal stress by reducing metal uptake and accumulation in host tissues and/or modulating the concentration of other TE in shoots (Smith and Read, 2008; Ibiang *et al*., 2017). The results for Cu concentrations in roots and shoots indicate that *C. etunicatum* primarily decreased the uptake of Cu into the roots, and the accumulation in the shoots, to regulate Cu homeostasis and protect the plants.

Conclusion: Cu soil contamination at 200 mg Cu kg^{-1} soil and above is toxic to soybean and aggravated by limited water supply. Nevertheless, inoculation of *C. etunicatum* in the unsterilized soil improved soybean growth and tolerance to excess copper under such suboptimal watering conditions.

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