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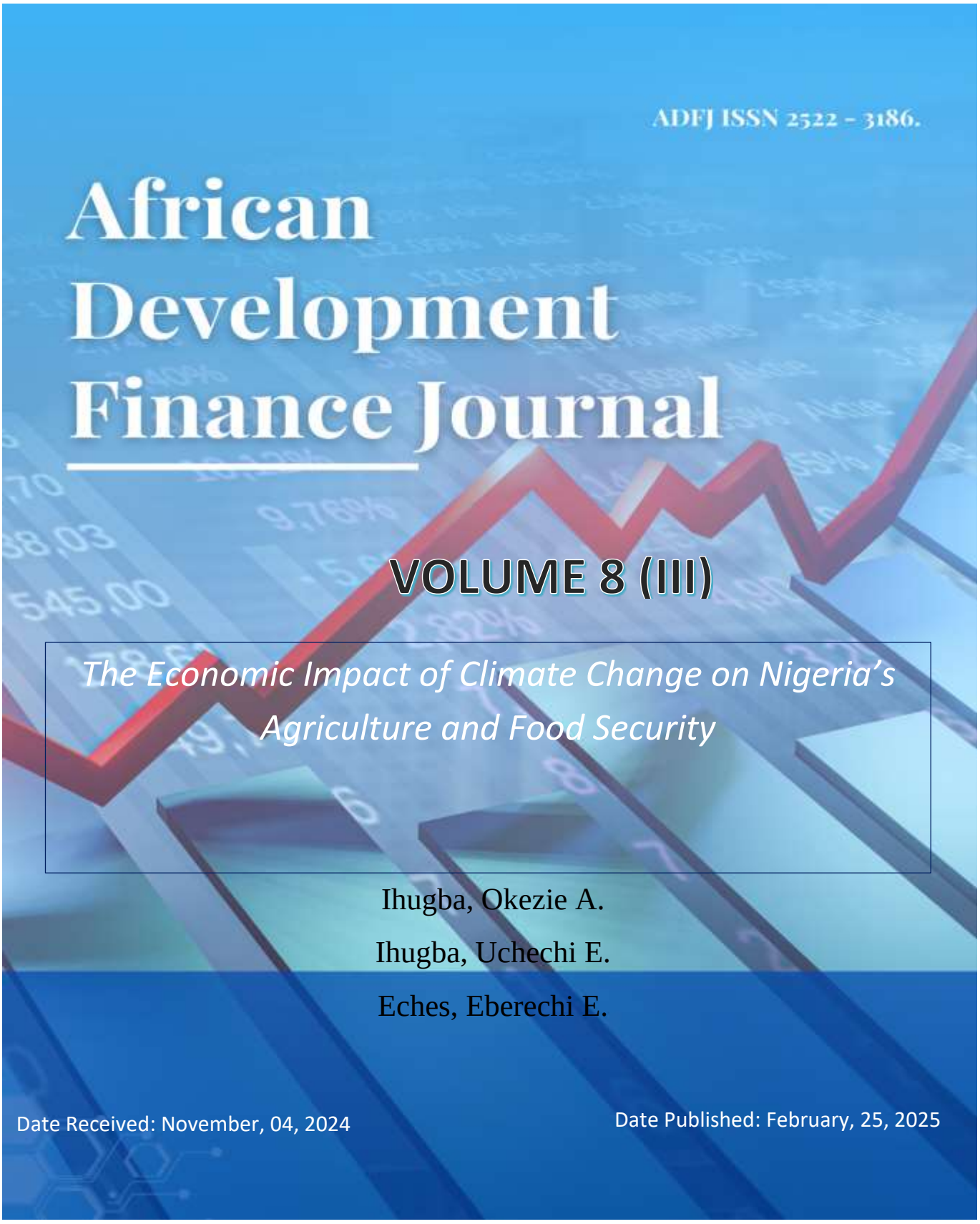
ISSN 2522-3186



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Date Received: November, 04, 2024
Date Published: February, 25, 2025

African Development Finance Journal http://journals.uonbi.ac.ke/index.php/adfj
March Vol 8 No.3, 2025 PP 138-168 ISSN 2522-3186

The Economic Impact of Climate Change on Nigeria's Agriculture and Food Security

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Abstract
Climate change poses a significant threat to Nigeria's agriculture and food security, impacting the nation's economy, environment, and the livelihoods of its population. As the most populous country in Africa, Nigeria relies heavily on rain-fed agriculture, making it particularly vulnerable to changing climate patterns, such as rising temperatures, altered rainfall, and extreme weather events. Inadequate infrastructure, limited access to modern farming methods, and a growing population exacerbate these challenges. This paper provides a comprehensive analysis of the economic impacts of climate change on Nigeria's agricultural sector, focusing on the implications for food security. It evaluates existing policies, identifies gaps, and suggests improvements while applying metrics to measure the effects on food availability, access, utilization, and stability. The findings highlight the urgent need for climate-smart agricultural practices, effective policy interventions, and investment in sustainable technologies to mitigate the adverse effects of climate change. Recommendations include enhancing adaptation and mitigation strategies, strengthening institutional frameworks, and promoting public awareness to build a climate-resilient agricultural sector and ensure long-term food security in Nigeria.

Keywords: *Climate Change, Agriculture, Government Policy, Food Availability, Mitigation*

1. Introduction

Agriculture and food security are only two of the many industries facing serious concerns from climate change. Rising temperatures, altered rainfall patterns, and extreme weather events are some of its repercussions, all of which are impacting food availability and supply. Due to its heavy reliance on rain-fed farmland, Nigeria, the most populous country in Africa, is particularly vulnerable to these effects. Inadequate irrigation systems, poor infrastructure, and restricted access to contemporary farming methods exacerbate these issues (Adamaagashi et al., 2023). Food insecurity results from people not having enough access to food, whereas food security refers to a person's ability to get basic, safe, and nutritious food (United Nations' Committee on World Food Security, as quoted in Ughaelu, 2017; Ikem, 2018). Changes in Nigeria's climate are making the country more vulnerable to environmental calamities, exacerbated by low food production and suffering populations.

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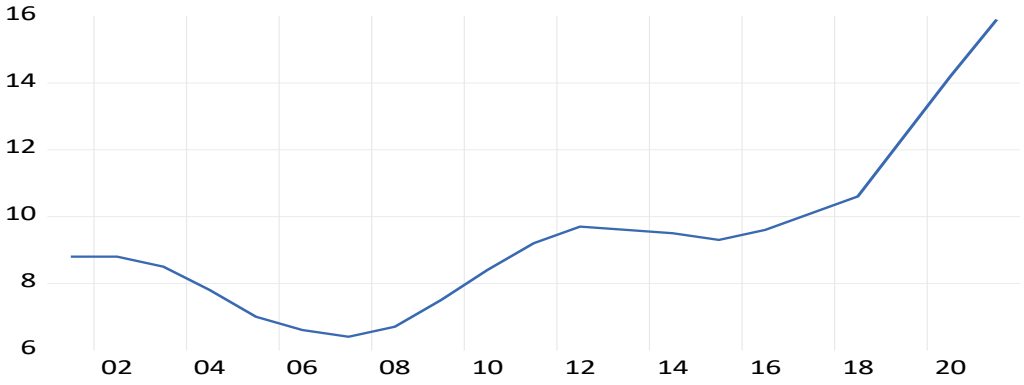
Food security is defined as having access to sufficient, safe, and nutritious food for a healthy and active life. It includes physical and economic access to food that meets dietary needs and preferences. The three pillars of food security are availability, access, and use. Food security is a complex sustainable development issue linked to health, economic development, the environment, and trade. Poverty, insecurity, conflict, natural disasters, climate change, and population growth are the main causes of hunger and malnutrition in Nigeria. According to the World Food Programme (2024), the number of food-insecure Nigerians in January 2024 increased significantly, from 66.2 million in Q1 2023 to 100 million in Q1 2024. The WFP also projects that 26.5 million more people nationwide will experience severe hunger in June through August of 2024, as reported by NSG (2024).

According to the World Bank (2024), the prevalence of undernourishment in Nigeria shows an increasing trend from 2001 to 2021. In 2001, the prevalence was 8.8%, and it decreased to a low of 6.4% in 2007. However, it started increasing again, reaching 10.1% in 2017, and then saw a sharper rise, peaking at 15.9% in 2021. This suggests a growing undernourishment issue in Nigeria over the last two decades, with significant increases in recent years (see Figure 1).

Figure1: Prevalence of Undernourishment (% of population)



Source: World Bank, 2024

One of the central goals of every developing country is to reach high-income status. Agriculture plays a critical role in transforming economies to reach the goal, along with achieving other essential development goals like ensuring food security and improving nutrition. The agricultural sector plays a strategic role in improving food availability and achieving food security. But even with these enormous advantages, agriculture still accounts for 10–12% of global emissions

(Nsabiyeze et al., 2024) and 67% of national emission in 2015. In particular, emissions from the livestock sector in Nigeria increased significantly from 21877 Gg CO2-eq in 2000 to 29375 Gg CO2-eq in 2015 which represented an increase of about 34% (FME, 2021).

Previous studies on the economic impact of climate change on Nigeria's agriculture and food security have examined climate variability and crop yields, economic analysis of agricultural practices, and food security and climate change. Fasona and Omojola (2005) analyzed existing adaptation strategies and their effectiveness in mitigating negative impacts. Apata (2011) analyzed the effectiveness of various policy measures and adaptation strategies in mitigating the impacts of climate change on agriculture. Obayelu (2011), Ani et al. (2021), Oderinde et al. (2022), and Adamaagashi et al. (2023) discussed the effects of climate change on food and human security in Nigeria, while Egbetokun et al. (2018) evaluated the economic implications of specific agricultural practices under changing climatic conditions. These studies provide a comprehensive overview of how climate change is impacting agriculture and food security in Nigeria, identifying challenges and potential strategies for mitigation and adaptation. However, the emphasis on individual crops rather than a comprehensive view of the agricultural sector has limited their comprehensiveness. This is because they prioritize short-term climate variability over long-term climate change impacts, and they are region-specific, not encompassing the entire country.

The paper focuses on existing policies aimed at mitigating the impacts of climate change on agriculture and food security, identifying policy gaps and suggesting improvements while applying comprehensive metrics to measure the impact of climate change on food security. These metrics consider aspects such as food availability, access, utilization, and stability of food supply. This paper also aims to fill the gap in the existing literature by providing a comprehensive analysis and offer recommendation for more effective policy interventions.

1.1 Climate Change Overview

Climate is a long-term measurement of temperature and weather patterns, affecting different areas like deserts, tropical, and temperate climates. Climate change refers to the long-term alteration of temperature and weather patterns, causing unpredictable weather patterns and damaging weather events. In Polar Regions, warming global temperatures have led to ice sheets and glaciers melting,

causing sea levels to rise and damaging coastlines. This contributes to rising sea levels in different parts of the planet. Together with expanding ocean waters due to rising temperatures, the resulting rise in sea level has begun to damage coastlines as a result of increased flooding and erosion (NASA, 2024).

Climate change, global warming, and energy imbalance are the main consequences of human activities, including industrialization, fossil fuel burning, and land use changes. Over the last 100 years, the global average temperature has increased by 0.74°C ± 0.18°C, accelerating and intensifying the water cycle and affecting human activities such as health, water energy exploitation, ecosystems, food security, and industrial supplies (Mahmood, Jia & Zhu, 2019).

Human activity, such as the burning of fossil fuels like natural gas, oil, and coal, is largely responsible for the current climate change. Burning these materials releases greenhouse gases into the Earth's atmosphere (EPA, 2017). These gases trap heat from the sun's rays inside the atmosphere, causing the earth's average temperature to rise. We refer to this increase in the planet's temperature as global warming. The planet's warming has an impact on local and regional climates. Throughout Earth's history, the climate has continually changed. When occurring naturally, this is a slow process that has taken place over hundreds and thousands of years. Human-influenced climate change is happening now at a much faster rate (NGS, 2024).

Nigeria, the largest African economy by GDP, PPP, and population, has a relatively substantial level of greenhouse gas emissions compared to other African countries. According to the 2019 greenhouse factsheet for Nigeria (published by USAID), in 2014, Nigeria's total agricultural greenhouse emissions were 492.44 million metric tons of carbon dioxide equivalent (MtCO2e), accounting for 1.01% of global GHG emissions (Okorie and Lin, 2022).

Data from the World Bank (2024) show that over the past 30 years, Nigeria's emissions per capita have remained relatively stable, with values generally falling within the range of 0.5 to 0.9 metric tons per capita. However, there has been a slight decrease from the early 1990s to the early 2000s, with values decreasing from 0.8 metric tons per capita in the early 1990s to around 0.5 metric tons per capita by 2018. The recent stabilization has seen emissions per capita stabilize around 0.6

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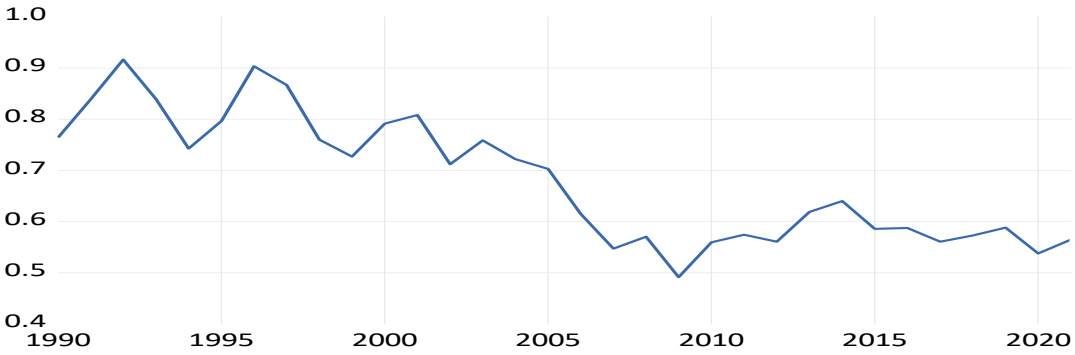
metric tons per capita from 2019 to 2020 (see Figure 2). This suggests that Nigeria's carbon footprint is modest, possibly due to lower levels of industrial activity or energy consumption per capita compared to more developed countries. Factors such as slower economic growth, changes in energy consumption patterns, or increased use of cleaner technologies could account for the stability and slight decline in emissions per capita. The stable emissions per capita amidst a growing population suggest that total national emissions might be rising due to population growth.

Figure 2: Nigeria CO2 Emissions (metric tons per capita) 1990-2022



Source: Worl Bank, 2024

1.2 Specific impacts on Agriculture

In Nigeria, agriculture is a critical sector, with 70% of the population relying on it for sustainable living and accounting for 40% of GDP. Climate change and variability could lead to higher food prices and decreased domestic revenue. By 2080, agricultural productivity could fall by 10% to 25% under a "business as usual" scenario, with rainfed agriculture potentially experiencing a 50% reduction in yield in some states (FME, 2020). These developments threaten the achievement of the Millennium Development Goals (MDGs) and food security. Nigeria's tropical environment has two distinct seasons: rainy and dry, with different lengths depending on the region. The rainy season in southern Nigeria lasts longer, while the northern part experiences high temperatures during the dry season. Additionally, the north experiences longer, hot, dry harmattan winds (Falola et al., 2024). The following are some potential effects on the agricultural sector:

1. Low crop yields due to excessive rain and drought. Crops in the south need rainfall, while those in the north grow more. This affects the natural distribution of crops, leading to stunted growth in northern Nigeria and withering in southern Nigeria during prolonged droughts. This affects the country's food supply and demand.

2. Food scarcity caused by low crop yields due to harsh climate conditions, resulting in inferior quality and quantity of food crops. This leads to poor distribution in other geopolitical zones, such as Nigeria, where crops like tomatoes are abundant. If this falls, other locations will experience reduced supply.
3. Poor feeding conditions, irregular climatic conditions, and flooding reduce livestock production. Poor feeding affects animals' growth and products like beef or milk. Flooding also promotes pest growth, further depreciating the commercial value of farm animals.
4. Some Nigerians, who depend on agriculture for their livelihood in both rural and urban regions, experience a decline in income due to the destruction of farmlands and the impediment to income generation from agriculture and livestock farming.
5. Mosquito breeding in stagnant waters increases the burden of diseases, particularly malaria. This poses a strain on public health and nursing. Additionally, drought-induced wildfires and dust storms can cause respiratory illnesses in some individuals.
6. Nigeria's Kainji Dam, a major hydroelectric power source, is facing challenges due to climate change, causing unpredictable rainfall and drought patterns, reducing water levels, affecting hydroelectric power generation, impacting power distribution, and making industrial activities reliant on constant power supply.
7. Flooding has a significant impact on rural communities, resulting in house collapses and road network obliteration, causing residents to struggle to commute due to their lack of structural strength. Floods in 2019 displaced almost 1.9 million Nigerians, according to the National Emergency Management Agency (Future Learn, 2021).

The many effects of climate change may severely impact the country's crop production, potentially leading to major changes in employment, income, and food production. The labor, employment, and population processes involved would also experience significant effects.

1.3 Agriculture and its Emission

Nigeria's agricultural sector has experienced a significant increase in GDP, from 17.05 billion Naira in 1981 to 47,944.06 billion Naira by 2022. Major spikes in agricultural output occurred between 1992–1993, 2001–2002, 2010–2011, and 2020–2021 (see Figure 3). Agriculture contributed over 40% of Nigeria's GDP between 2011 and 2012 and 25% in 2018, while the oil

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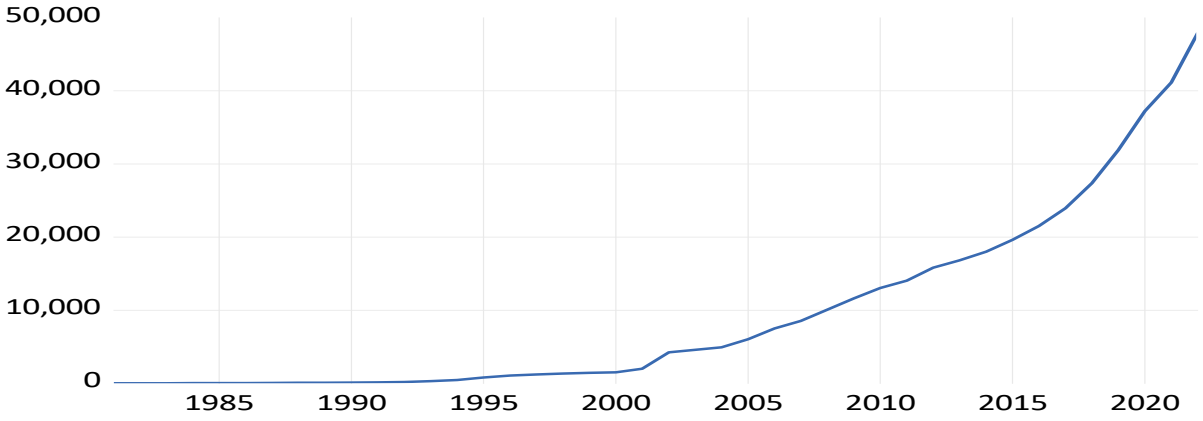
sector contributed 8.6%. In 2019, Nigeria's GDP grew by 2.27 percent, with agriculture accounting for 24%. Policy changes, economic reforms, investments, and favorable weather conditions are responsible for this growth. Agriculture remains a critical sector in Nigeria's economy, supporting food security and rural development. It also provides job opportunities, accounting for nearly 35% of total employment in 2019 and 2020 (Adeite, 2024). Major crops include maize, cassava, guinea corn, yam beans, millet, and rice. Livestock production includes goats, sheep, cattle, and poultry, primarily in the northern region.

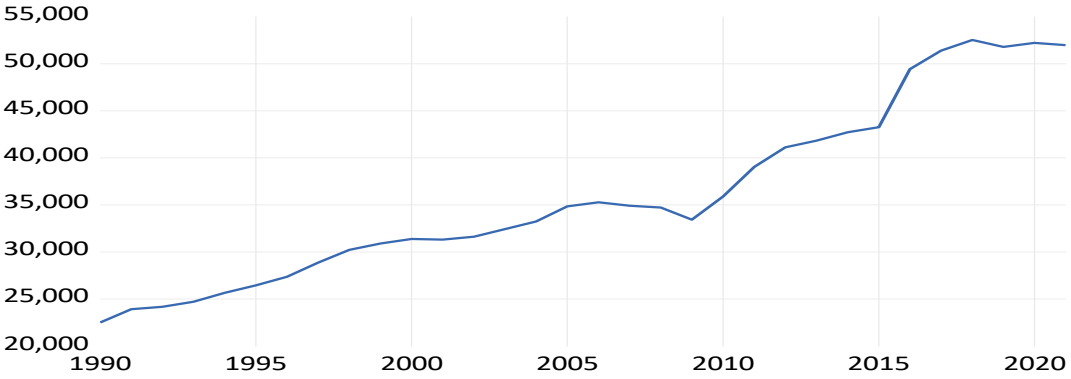
Figure 3: Agriculture GDP, 1981-2022



Source: CBN, 2022

Nigeria has shifted its focus to agriculture to reduce oil reliance, but from 2015 to 2021, the country contributed 2% of global agricultural emissions, including carbon and methane. Methane, a potent greenhouse gas, accounted for 20.3 million metric tons and 2% of global agricultural emissions. Nitrous oxide, on the other hand, accounted for 0.63 million metric tons and 1.6% of global agricultural emissions. In 2021, Nigeria contributed 4.9% of global agricultural emissions and emitted 8.70 million tons of carbon. It produced 8.70 million tons of carbon emissions that year. Methane and nitrogen oxide follow at 3.00 and 0.09 mt, respectively (Oladapo, 2023). The trend of agricultural methane emissions, as shown in Figure 4, has been gradual since 2000, with a peak in 2009 and a slight dip in 2010. The data underscores the environmental impact of agricultural activities and the importance of sustainable practices to reduce greenhouse gas emissions. Therefore, Nigeria's focus on agriculture is crucial to reducing its reliance on oil.

Figure 4: Agricultural Methane Emissions (thousand metric tons of CO2 equivalent)



Source: World Bank, 2024

Nitrous oxide (N2O) is a strong greenhouse gas, that is mainly produced from agricultural activities (e.g. from the use of synthetic and organic fertilizers to grow crops). Data from the World Bank (2022) reveals a significant upward trend in nitrous oxide emissions from Nigeria's agricultural sector from 1990 to 2020, with a steady increase. The annual growth rate fluctuates, but the overall trend is steady. Notable jumps in emissions occur between certain years, such as between 2009 and 2010, between 2018 and 2019 (see Figure 5). This increase could be attributed to increased agricultural activities, changes in farming practices, and possibly a higher use of nitrogen-based fertilizers. Nitrous oxide is a potent greenhouse gas with a higher global warming potential compared to CO2, contributing to climate change and posing environmental challenges. The data suggests the need for policies aimed at reducing agricultural emissions, such as promoting sustainable farming practices, improving fertilizer management, and adopting technologies that minimize nitrous oxide emissions. This data underscores the growing concern about the environmental impact of agricultural practices in Nigeria and the need for effective interventions to manage and mitigate these emissions.

Destructive land use practices like deforestation, negligent fertilizer use, and inappropriate livestock management influence GHG emissions. Agroforestry is one method of proper land use that can boost the sector's potential to act as a carbon sink. Climate-smart technologies may also be included in the government's long-term low-emissions vision for 2050 in order to mitigate climate change.

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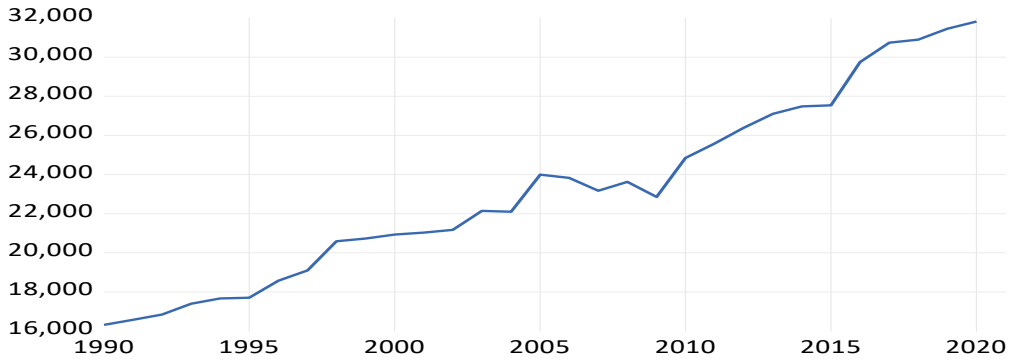
Figure 5: Agricultural Nitrous Oxide Emissions (thousand metric tons of CO2 equivalent)



Source: World Bank, 2024

1.4 Agriculture Production and the Environment

- **Food Production:** Agricultural production is not only fundamental to improving nutrition but is also the main source of income for many. Food production rises annually, compared to a baseline period such as 1990–2020. It includes all crops except fodder crops. The World Bank (2024) calculates the index in international dollars to evaluate changes in crop production over time. The index is critical to ending hunger, as well as economic and social development. Figure 6 shows a steady increase over time, indicating growth in food production through intensive farming practices, increased land use, or technological advancements. However, CO2 emissions do not follow a consistent trend, fluctuating over the years with some peaks and troughs but generally showing a slight increase over the long term. Short-term fluctuations in CO2 emissions do not correspond directly with changes in the crop production index. For example, from 1999 to 2000, CO2 emissions nearly doubled, but the Food Production Index showed only a small increase. From 2008 to 2009, CO2 emissions dropped significantly, while the Food Production Index also decreased, suggesting a potential relationship between reduced agricultural activity and lower emissions. Agricultural practices, climate and environmental policies, and economic factors may all have an impact on the relationship. Food production growth with moderating CO2 emissions is not linear, with some periods of growth while CO2 emissions fluctuate or decrease. Other factors, such as technological advancements, changes in energy sources, or shifts in economic activities, could also influence CO2 emissions independently of food production.

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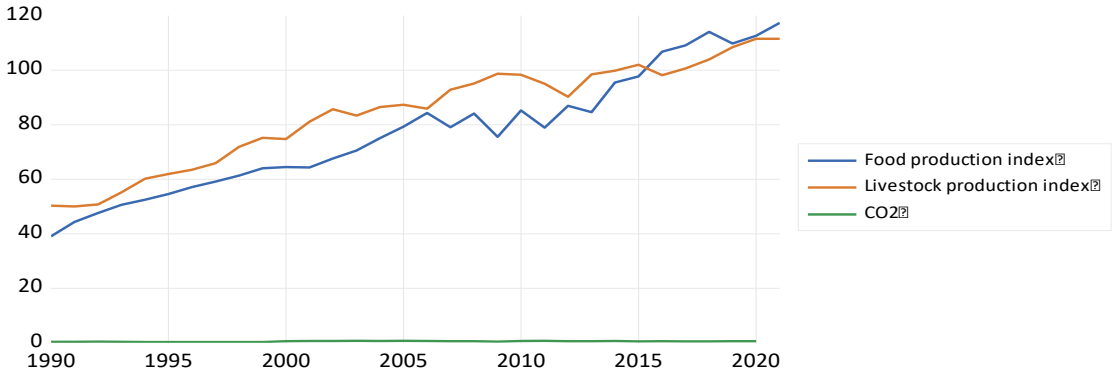
Figure 6: The Correlation between the Food Production Index, the Livestock Production Index, and CO2 Emissions



Source: World Bank, 2024

- **Livestock Production:** Similar to the food production index, the livestock production index in Figure 6 has also shown a steady increase over time, suggesting an increase in livestock farming activities. However, CO2 emissions show fluctuations, with some periods of significant increase or decrease but no clear consistent trend in correlation with the Livestock Production Index. During specific periods (1990–2000), the livestock production index steadily increased from 50.35 to 75.19, while CO2 emissions fluctuated. In 2000, CO2 emissions rose significantly (0.642), despite only a slight increase in the livestock production index (74.71).From 2001 to 2010, the livestock production index continued to grow, reaching values above 110 by 2020. However, CO2 emissions did not show a consistent upward trend, reflecting other factors influencing releases. The overall relationship between CO2 emissions and the Livestock Production Index is not consistent across all years, suggesting that other factors besides livestock production are influencing CO2 emissions. Possible explanations include methane emissions, technological and efficiency improvements, as well as external factors such as economic activities, policies, or global events. In conclusion, the relationship between the crop production index and CO2 emissions over the years appears to be complex, with several influencing factors. While crop production has steadily increased, CO2 emissions have shown variability, possibly reflecting the impact of various environmental, economic, and policy changes over time. The relationship between CO2 emissions and the livestock production index is also complex, with some periods showing a correlation and others not.

- **Supply Chain:** Climate change significantly impacts the agricultural supply chain, particularly in food markets. Extreme weather events like floods, droughts, and storms disrupt the availability, distribution, and pricing of food (IPCC, 2018). Floods can destroy crops, wash away topsoil, and damage infrastructure, hindering transport from farms to markets. Droughts cause water scarcity, reduce crop yields and livestock productivity, and lead to higher prices. Storms can damage crops, uproot trees, and disrupt harvesting activities. Supply chain disruptions include transportation challenges, storage and processing issues, and market access issues. Rural areas are particularly vulnerable, as they often lack resilient infrastructure. Economic and social impacts include price volatility, income losses, and food security, particularly in vulnerable communities (FAO, 2018). Mitigation and adaptation strategies include investing in resilient infrastructure, encouraging crop and livestock diversification, implementing early warning systems, and providing insurance schemes. In conclusion, addressing climate change's impacts on the agricultural supply chain requires a combination of infrastructure improvements, policy interventions, and adaptive strategies. By addressing these challenges, we can ensure food security and economic stability in the face of climate change.

1.5 Government strategy on climate change

The Nigerian government has implemented several policies, strategies, and action plans aimed at mitigating the impact of climate change on the country's agricultural sector. These include the Economic Recovery and Growth Plan (ERGP) 2017–2020, the Transformation Agenda (2011–2020), and Vision 20:2020. Other policies and strategies related to climate change include the National Forestry Action Plan (NFAP) 1996, Nigeria Agricultural Policy (2001), National Gender Policy (2006), National Policy on Drought and Desertification (NPDD) 2007, National Forest Policy (NFP) 2010, National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) 2011, Great Green Wall for the Sahara and Sahel Initiative National Strategic Action Plan (GGWSAP) 2012, National Climate Change Policy and Respond Strategy (NCCPRS) 2012, National Water Policy (2012), Nigeria Erosion and Water Shed Management Project (NEWMAP) 2012, National Agricultural Resilience Framework (NARF) 2013, Nigeria Industrial Revolution Plan (2014), National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015, Agricultural Promotion Policy (APP) 2016 – 2020, National Biodiversity

Strategy and Action Plan (NBSAP) 2016, National Health Policy (2016), National Policy on Environmental (2016), National Gas Policy (2017), and REDD+ Strategy (2019).

Global discourse on climate change has changed since the introduction of the National Climate Change Policy and Response Strategy (NCCPRS) in 2012, leading to the adoption of new initiatives that guide national actions to mitigate the impact and adapt to the problem. In particular, the signature of the 2015 Paris Agreement, which Nigeria ratified in March 2017, represents a significant turning point in the nation's effective response to the issues posed by climate change. This agreement greatly aids the transition to a low-carbon economy. The updated National Policy on Climate Change (2021–2030) aims to establish a new, comprehensive framework to guide the nation's response to the development challenges posed by climate change.

There are two complementary responses to climate change: mitigation and adaptation as mentioned above. Reducing greenhouse gas emissions and limiting the amount of warming our world will experience is known as mitigation. While adaptation refers to the actions people take both now and in the future to adapt to the effects of climate change (IPCC, 2018). Together, these two approaches to climate action—one aimed at reducing the severity and manageability of future climate change, and the other at addressing any that we are unable to prevent—help shield people from its negative effects. As it relates to the agriculture sector, we will describe and go over the implementation framework and programmatic action plan for the agriculture sector, which include short-, medium-, and long-term mitigation and adaptation methods to help develop a climate-resilient nation in the following ways:

Mitigation: Nigeria aims to become a low-carbon economy by reducing its 2015 total GHG net national emissions from agriculture, forestry, energy, industrial processes, and waste. With international financial, technological, and capacity building support, Nigeria can achieve emissions by 45% below business-as-usual levels. Mitigation actions focus on emissions reduction potential, alignment with national development plans, and technological innovation promotion. The Nigerian government implemented the following measures in an effort to mitigate the effects of climate change in the agricultural sector:

- Reduce the loss and damage to forests.

- In rural areas, use less fuel wood and more alternative home fuels.
- Increase soil carbon sequestration in agricultural areas.
- Better management of feed crop production, grazing, and feeding practices can raise livestock productivity.
- Boost the herd's genetic composition.
- Encourage a broad adoption of ecologically sound and climate-smart farming techniques among small-holder farmers, particularly women and young people.
- For crops and livestock systems that are climate resilient, record and encourage the application of relevant indigenous knowledge and best practices.
- Encourage community-based forest management and recovery, as well as afforestation, replanting, and agro-forestry.
- Expand the nation's system of conservation areas and forest reserves.
- Maintain resource rights, land tenure, and forests, as well as ensure that benefit sharing is transparent, inclusive, and gender-neutral.
- Increase both governmental and private investment in the forestry and agriculture industries.

Adaptation: Nigeria's agriculture and food production systems rely on natural resources, including rain-fed agriculture, hunting, and fishing. We expect climate change and non-climate factors like soil degradation and poor technology to significantly impact these systems and food security. Farmers and practitioners need to adopt adaptation strategies like drought-resistant crops, crop diversification, and improved irrigation efficiency. Governments are working to improve national capacity to adapt to climate change's impact on the agriculture sector. Effective climate change-induced agricultural adaptation policies will improve food security, carbon sequestration, biodiversity, soil and water quality, and socio-economic stability. The policies initiated by the government include:

- Encourage productive, gender-sensitive, inclusive, and climate-smart methods for raising cattle, fisheries, and crops.

- Encourage and facilitate efficient research, information creation, and management to link farmers, businesses, policymakers, and researchers in order to help them adapt to changing climatic scenarios in the present and the future.
- Create and implement enhanced agricultural production and risk management technologies.
- Encourage communities and farms to adopt adaptation strategies.
- Revitalize technology transfer, capacity building, and extension services to serve a larger range of farmers, including women and young people.
- Strengthen adaptation strategies based on indigenous knowledge.
- To achieve scale adaptation, create an environment that is supportive of more financial investments and participation from the public and private sectors.
- By using value chain efforts and financial incentives, expand access to financing for adaptation.
- Strengthen institutional and regulatory capacity to adopt and distribute technology solutions for agricultural adaptation.

1.6 Enabling Conditions for policies

Nigeria faces both threats and opportunities from climate change, and its effective management depends on an enabling political, institutional, and legal environment, as well as stakeholder participation. The government has implemented policies, strategies, and plans to address adaptation and mitigation measures for climate-resilient development, ensuring a harmonious approach to climate-resilient development. The following elements contextualize the national response to climate change impacts.

- Legal framework: Nigeria's climate change governance relies on a legal framework that clarifies roles, promotes cooperation, establishes rules, and connects climate change with other areas. This framework should always enhance adaptation capacity and provide effective enforcement as encapsulated in the 1999 Constitution, International Human Rights Laws, and environmental statutes.
- Framework for Institutions and Governance which requires strong country ownership, shared vision, and participatory decision-making. With 36 states and the Federal Capital

Territory, each layer has constitutional responsibilities for managing the environment and climate change.

- Funding, fundraising, and investing: The Nigerian government has introduced Green Bonds as an innovative method to raise climate finance, with guidelines aiming to raise $248 million over the next decade to support national projects and meet sustainable development goals, thereby reducing poverty and promoting growth.
- The Research and Development initiative aims to develop innovative interventions in climate change adaptation, mitigation, finance mobilization, socio-economic issues, security, and gender. The research will improve understanding of the climate system, impacts, adaptation pathways, mitigation options, decision support, and international cooperation. The policy direction is to build research capacity for a deeper understanding and response to climate change impacts.
- Nigeria is embracing technology and innovation to tackle environmental issues, focusing on low carbon, climate-resilient development. Key technologies include solar, wind, energy-efficient light bulbs, landfill methane capture, improved cook stoves, drought-tolerant crop varieties, conservation agriculture, drip irrigation, and water harvesting.
- Institutional strengthening, training, and capacity building: The Paris Agreement emphasizes capacity-building for governments and stakeholders to manage climate risks, including gender and social inclusion skills. The policy aims to increase human and institutional capacities, fostering coordinated efforts among various actors.
- The private sector is crucial for a comprehensive climate change response, promoting green growth and climate-friendly actions. Involving the private sector in climate change adaptation and mitigation planning is strategic and essential for meeting NDC targets and reducing GHG emissions.
- The Research and Development initiative aims to develop innovative interventions in climate change adaptation, mitigation, finance mobilization, socio-economic issues, security, and gender. The research will improve understanding of the climate system, impacts, adaptation pathways, mitigation options, decision support, and international cooperation. The policy direction is to build research capacity for a deeper understanding and response to climate change impacts.

- Climate change impacts differ based on gender, age, and class, with the poor most affected. Women face larger negative impacts due to low participation in decision-making and labor markets. Nigeria has a National Gender Policy and a Federal Ministry of Women Affairs to promote gender equality and involve vulnerable groups in climate change management programs.
- Information availability, involvement, public awareness, and education are all essential.

1.7 Implications on Food Security

Climate change poses a serious threat to food security, thereby putting humanity and vulnerable populations at risk. Because of the unequal distribution of climate change's effects around the world, developing nations are likely to experience negative effects. The complex effects of climate change on Nigeria's food supply networks impact on the following:

1. Climate change impacts Nigerian livestock productivity through heat stress, decreased water availability, and altered pasture quality. Droughts limit the amount of water and fodder available to livestock, while heat stress can lower fertility and output. According to predictions from the Food and Agriculture Organization (FAO), Nigeria's livestock production could decline by 10% to 15% by 2050 due to climate change.
2. Changes in salinity, increasing acidity, and rising sea temperatures have had a negative impact on aquatic life. The past decade has recorded massive fish deaths in the Niger Delta. Climate change has adversely affected commercial fishing. The reduced outcome from fishing activities poses a significant threat to the food security and livelihood of households that depend on marine resources (Ani et al., 2022). According to the FAO, by 2050, fish catches in Nigeria could decline by as much as 30% due to climate change.
3. The National Emergency Management Agency (NEMA) estimates that flooding in Nigeria causes annual economic losses of over $1 billion, with a significant portion affecting transportation infrastructure. Floods and storms can damage roads, bridges, and railways, disrupting the transportation of food products. Climate change impacts the transportation infrastructure, which is essential for moving food from farms to markets.
4. Food prices may rise as a result of infrastructural damage, an increase in the frequency of extreme weather occurrences, and transportation expenses. If supply chain interruptions and infrastructure deterioration cause rising fuel prices, they could also contribute to the

growth of transportation expenses. According to the World Bank, transportation costs in Nigeria can make up as much as 30% of the total cost of food items, leaving them vulnerable to climate fluctuations.

5. Climate change can have an impact on food processing plants by causing extreme weather events and higher temperatures. Higher temperatures can impact the viability of processing operations by increasing the cost of refrigeration and cooling. Storms and floods have the potential to destroy processing infrastructure, delaying output and raising expenses.
6. Nigeria already has large post-harvest losses because of poor infrastructure and storage facilities; climate change makes these losses worse. Elevated temperatures and humidity levels have the potential to hasten food product degradation and pest infestations, thereby shortening their shelf life. According to FAO estimates, post-harvest losses in Nigeria can make up as much as 40% of overall agricultural production, and these losses are predicted to get worse due to climate change.
7. Climate-related disruptions in food production, transportation, and processing have an impact on food supply and access. Food prices may rise as a result of lower agricultural yields and higher transportation expenses, making it more difficult for low-income people to meet their needs. Climate change exacerbates the problem of food insecurity, which affects over 19% of Nigerians, according to the World Food Programme (WFP).
8. Crops can lose nutritional value due to changes in nutrient content caused by temperature and precipitation changes. Furthermore, inadequate nutritional results and a lack of variety in diet might result from a greater reliance on processed foods brought on by supply chain disruptions.

Nigeria is not exempt from the adverse effects of climate change, as the country still practices rain-fed agriculture, making it vulnerable to the adverse effects of climate change. Extreme climatic events such as flooding, heat, and drought have led to soil degradation, resulting in low crop yields. This has made Nigeria one of Africa's largest importers of produce, with farmers still facing historically low yield factors due to drought and pest attacks on crops. Climate change impacts affect food security across its four dimensions: availability, access, utilization, and stability, directly and indirectly (Agbo, 2024).

1.8 Case Studies

- A NASA (2021) study published in Nature Food suggests that climate change could affect maize and wheat production as early as 2030 under a high greenhouse gas emissions scenario. The projections indicate a 24% decline in maize crop yields, and a potential growth of about 17% in wheat. The change in yields is due to projected increases in temperature, shifts in rainfall patterns, and elevated surface carbon dioxide concentrations from human-caused greenhouse gas emissions. These changes would make it more difficult to grow maize in the tropics but could expand wheat's growing range. The research team used two sets of models: climate model simulations from the international Climate Model Intercomparison Project-Phase 6 (CMIP6) and state-of-the-art global crop models part of the Agricultural Model Intercomparison and Improvement Project (AgMIP). They created approximately 240 global climate-crop model simulations for each crop, with most of the results pointing in the same direction. Worldwide, countries nearer the equator grow maize, and as average temperatures rise across these breadbasket regions, North and Central America, West Africa, Central Asia, Brazil, and China may see a decline in their maize yields in the coming years and beyond. Temperature rise may expand the growing area for wheat, a crop that thrives in temperate climates, but these gains may plateau by mid-century.
- Climate change poses a significant threat to food security because it affects biodiversity, ecosystem resilience, and the availability of goods and services such as pollination, natural pest control, food, and medicine. Globally, we expect climate change to reduce cereal production by 1–7% by 2060, thereby putting 5–170 million people at risk of hunger by 2080. Agricultural yields in Africa alone could decline by over 30 percent by 2050, distressing the poor. Rising temperatures also increase asset losses due to weather-related disasters, affecting the lives and food security status of millions in disaster-prone areas (Muluneh, 2021).
- A study by Bako et al. (2016) surveyed peasant farmers in Kaduna State about their perceptions of climate variability and change. The primary perceived problems faced by farmers include poor crop yield (33.3%), increased fertilizer costs (17.3%), and water scarcity (24%). Other issues include pest and disease outbreaks (13.6%) and delayed harvesting (11.7%). The results showed that most communities are aware of climate

variability, with signs including drought, poor rains, changes in rainfall patterns, and temperature increases. Rainfall is a key determinant of crop planting season, while insect pests and diseases are associated with rainy seasons due to higher relative humidity.

- In addition to increased demand for forest resources and population growth, forests are facing substantial strain from climate change. Climate change's new problems, such as planting difficulties, tree mortality, and a decrease in species diversity, are exacerbating the loss of native forests. Desertification in arid and semi-arid regions, along with overexploitation of marginal lands, exacerbates environmental deterioration (FME, 2014).
- There is growing concern, though, that the north-central region might be undergoing a climatic shift towards aridity, which, alongside variable, declining rainfall, adversely affects water resources, agricultural output, and economic performance. A downward trend in rainfall was observed in Plateau, Benue Nassarawa, and Abuja, the FCT (Ideki and Weli, 2019).
- The most exposed region is the Northeast. Estimates indicate that two-thirds of Bauchi, Borno, Gombe, Jigawa, Kano, Kaduna, Katsina, Kebbi, Sokoto, Yobe, and Zamfara states could turn desert or semi-desert in the twenty-first century. Declining precipitation, which impacts the water supply in rain-fed agriculture, is a critical exposure issue in the north, while water loss due to high soil porosity is a key concern in the southeast, where the subject also experiences high exposure, according to the Federal Ministry of Environment (2014).
- Southern Nigeria, known for its high rainfall and irregular rainfall patterns, faces significant challenges from climate change and flooding. The Southwest rainforest zone and Southeast region are particularly vulnerable, with the Niger Delta region being the most vulnerable. The coastal region, particularly Lagos and the Niger Delta, is less than twenty feet above sea level, making it particularly vulnerable (Haider, 2019).
- Rising sea levels due to climate change and precipitation are expected to increase flooding frequency and intensity, leading to erosion and disarticulation of coastal wetlands. Urban areas are also at risk because the built environment prevents rainfall infiltration, leading to more surface runoff and increased flooding risks. Lagos State, the largest urban agglomeration in Sub-Saharan Africa, is already at risk due to coastal inundation, which increases problems with flooding and the intrusion of sea water into freshwater sources and

ecosystems. Other urban environments, such as Warri, are also at risk due to climate change impacts and rapid urban expansion into floodwater storage zones (Odemerho, 2014).

1.9 Adaptation Strategies

Climate-Smart Agriculture (CSA): The goal of Climate-Smart Agriculture (CSA) is to enhance farmer productivity and income, aid in climate adaptation, and reduce greenhouse gas emissions. It's not a universally applicable approach; it requires local contexts for implementation. CSA can increase agricultural productivity in Nigeria by up to 25% and reduce emissions by 15%. Investing in resilient infrastructure, such as climate-resilient roads, bridges, and storage facilities, is crucial for enhancing food supply chains' resilience. Technological innovations like precision agriculture, digital tools, and biotechnology can also enhance food supply chains' resilience. Precision agriculture techniques, such as remote sensing and data analytics, help farmers optimize resource use and improve decision-making. Biotechnology offers opportunities for developing climate-resilient crop varieties with improved yield and nutritional value (TheCable, 2024). The following case studies demonstrate how the agricultural sector and farming communities have benefited from the regional application of the CSA approach.

1. Burundi: The Kagera Transboundary Agro-Ecosystem Management Project, funded by the Global Environment Facility, was implemented from 2010 to 2014 in the Kagera river basin, shared by Burundi, Rwanda, Uganda, and Tanzania. The project used the LADA-WOCAT method to assess agro-environmental practices and governance issues in the region. Maps were developed to show degradation levels and successful interventions, and information was gathered for analysis of vegetation cover, biodiversity, and water quality. Key action areas for improved climate-smart production and Sustainable Land Management were identified, including developing intervention toolsets, identifying micro-watersheds, characterization of the environment, developing a community action plan, implementing the action plan, and endogenous monitoring and evaluation. Overall, local communities oversaw 50 project locations. More than 1,200 FFS members (60 percent of whom were women) received training from the project in sustainable agriculture methods (SLM), including biological pest management, agro-biodiversity promotion,

effective water resource harvesting, and the use of improved seeds. Consequently, the project restored 4,600 hectares of previously damaged watersheds. Additionally, the project gave local communities the tools they needed to manage vegetation covers better and drastically alter their perspective on long-term development initiatives.

2. Burkina Faso and Niger: The Sahel region experienced disastrous droughts in the 1970s and 1980s, resulting in widespread famine. Experts consider the observed major shift in temperature and precipitation patterns as an early impact of climate change in this region. Where two-thirds of the land cover consists of dry lands and deserts, desertification affects millions of the most vulnerable people in Africa. The Great Green Wall Initiative, led by the African Union, aims to plant 11 million trees across 11 countries in the Sahara and Sahel region to combat climate change and desertification. The Action against Desertification programme, launched in 2014, is implemented by FAO and partners with EU funding. The program focuses on capacity development for partner organizations and NGOs, dissemination of sustainable land management practices, income generation, and knowledge exchange. It supports large-scale land restoration in Burkina Faso and Niger, promoting natural regeneration, capacity development, and value chains of non-timber forest products. Policy changes and off-farm employment opportunities contribute to recent progress. The initiative has already seen positive results in 11 Sahelo-Saharan African countries. In Burkina Faso and Niger, FAO helped restore large areas of land by using techniques like enrichment planting, direct sowing, and fencing to promote natural regeneration. They also worked to build people's skills and promote value chains of high-potential non-timber forest products to help the economies of those countries become more diverse. Between 2015 and 2017, the initiative planted over 12,000 hectares of degraded land to begin the restoration process throughout the region. Improved farming practices, land restoration on over 4,200 hectares of degraded land, and benefits to over 4,700 agropastoralist farmers, half of whom are women, have improved water availability and soil fertility in Burkina Faso (Central Plateau). In Niger (southern Niger), farmers have improved food security by regenerating and multiplying trees, crops, and livestock, supporting 3 million people. They prepared 1,050 hectares of degraded land in 2017 and planted 250,000 seedlings. Increased water levels in wells, as well as increased fodder and crop residues, have led to intensive crop-livestock production systems.

3. Zambia: Projections predict a quadrupling of the demand for animal products in southern Africa between 2006 and 2050. Zambia is especially vulnerable to climate change because of its high levels of food insecurity, comparatively poor yields, high rates of deforestation, and localized land degradation. We anticipate shorter growing seasons, more frequent extreme weather events, and higher temperatures in Zambia. The Global Livestock Environmental Assessment Model (GLEAM), a model that simulates the relationship between livestock production and the environment, analyzes variables such as feed consumption, greenhouse gas emissions, land degradation, nutrient and water use, and biodiversity. It was used in two circumstances (drought and baseline) and two timeframes (1999–2011 and 2012–2030). The cattle industry was given better husbandry and health alternatives, as well as better animal feed to boost output and reduce greenhouse gas emissions, in the model. The livestock sector has shown benefits in reducing greenhouse gas emissions. The study found that productivity differences between the drought and baseline scenarios were limited, but the former led to lower production increases. Livestock can help build resilience by buffering climate and vegetation production variability, particularly in drought scenarios. Improved practices could increase GHG emissions by 7–20% due to increased production gains and animal numbers. However, by improving livestock productivity, emission intensity could decrease from 21-36%. Overall, livestock plays a crucial role in reducing greenhouse gas emissions.
4. The Near East and North Africa (NENA): The Near East and North Africa region faces severe water shortages, with 90% of agricultural areas exposed to salinity, soil nutrient depletion, and wind-water erosion. Per capita fresh water availability has decreased by 23% over 40 years, and climate change is causing higher temperatures, droughts, floods, and soil degradation. The FAO's 2013 introduction of the Regional Initiative on Water Scarcity in the Near East and North Africa Region resulted in the production of a regional collaborative strategy on sustainable agricultural water management. This strategy uses creative implementation techniques, streamlined policies, and governance reforms to increase agricultural productivity and food security. It seeks to address problems related to water and agriculture by using evidence-based methods, identifying knowledge gaps, fostering collaboration, and recording solutions. Between 2013 and 2015, the NENA countries produced more water resources and built more storage per person than any other

region. By developing best practices, benchmarking, implementing standards, building capacity, and optimizing the economically viable use of treated wastewater, regional collaboration helped alleviate supply-side scarcity. Other important achievements included creating a groundwater governance framework and giving Transboundary resource benefits priority.

5. Bangladesh: Heavy rains, frequent storms, and rising sea levels in Bangladesh reflect climate change, leading to severe flooding and crop loss. Land for agriculture is scarce, and location-specific adaptation and resilience measures are prioritized to improve food security for vulnerable people. The 2015 FAO study examined a successful climate-smart production system in Bangladesh's lowlands called "floating gardens." Growers use these floating plots, made from local organic material, to grow vegetables and seedlings. The system, which involves preparing rectangular beds and sowing seeds, contributes to resilience and livelihoods in communities. The study examined the construction and use of these systems, which include around 30 vegetable, spice, and seedling crops, with mixed intercropping being the most prevalent system. The study highlights the advantages of floating gardens, including increased cultivable area, fertile land, minimal fertilizer and manure requirements, and the use of biomass as organic fertilizer. Floating gardens can also serve as shelters for poultry and cattle during floods, allowing farmers to cultivate crops and fish simultaneously. Research and development programs can enhance these environmentally friendly gardens, which also contribute to food security and nutrition. They also offer potential for value addition, improved productivity, profitability, and marketing in local, urban, and export markets.
6. Central America: The Dry Corridor is located in Central America’s ecoregion of dry tropical forests that cover the lowlands of the Pacific coastal areas of El Salvador, Guatemala, Honduras, and Nicaragua. The Dry Corridor has a distinct and prolonged dry season, but at the same time, the region experiences excessive rainfall and severe flooding. Climate change accentuates these impacts every year, significantly impacting agricultural production and land degradation, particularly on hillside plots (FAO, 2018). In 2005, FAO supported a participatory process with grain producers in the Dry Corridor to transition from traditional slash-and-burn methods to an integrated climate-smart production system. The project involved 15 plot trials and highlighted the Slash-and-Mulch Agroforestry

System, known as Quesungual farming in Honduras and Kuxur rum in Guatemala. This system uses conservation agriculture principles to grow grains interspersed with native multipurpose nitrogen-fixing trees, providing better soil erosion control on drought-prone hillsides. The trees provide critical services such as shading, soil retention, fertilization, diversification of household production, and protection of crops and soil from rain and wind. This agroforestry system has proven "climate-smart" through improved soil and water conservation, increased productivity, and reduced greenhouse gas emissions. The Quesungual/Kuxur rum farming systems increased maize, beans, sorghum, and coffee yields, reducing labor scarcity. They also reduced preparation time and weed control, crucial factors in farm productivity. The CIAT found that the Quesungual Slash-and-Mulch Agroforestry System has a quarter of the global warming potential of traditional slash-and-burn agriculture methods, based on methane, nitrous oxide emissions, and carbon stocks sequestered in soil and trees.

Climate-smart agriculture is a revolutionary strategy for promoting development and food security in a changing climate. CSA practices can help achieve the Sustainable Development Goals and the Paris Agreement. Climate change impacts all agricultural industries, from Bangladesh's floating gardens to the Dry Corridor of Central America. Good programs and initiatives help communities protect their way of life and put adaptation and mitigation strategies into practice to counteract the effects of climate change. Strong national and local institutions, improved financing choices, policy backing, and field-level practices are all necessary for the implementation of CSA.

2.1 Conclusion

Climate change presents significant challenges to Nigeria's agriculture and food security, threatening the livelihoods of millions and the country's overall economic stability. As temperatures rise, rainfall patterns shift, and extreme weather events become more frequent, the agricultural sector faces declining productivity and increased vulnerability. Nigeria's reliance on rain-fed agriculture exacerbates these challenges, leading to reduced crop yields, food scarcity, and heightened food insecurity.

While the Nigerian government has implemented numerous policies and strategies to mitigate and adapt to climate change, there remain gaps in their execution and effectiveness. The emphasis on short-term solutions rather than long-term resilience-building highlights the need for more comprehensive, region-wide approaches that consider the entirety of Nigeria's diverse agricultural landscape. Additionally, the impact of climate change on livestock, water resources, and overall food supply chains requires urgent attention and innovative solutions.

To safeguard Nigeria's future, it is imperative to strengthen existing policies, increase investment in climate-smart agriculture, and enhance adaptive capacities across the sector. By promoting sustainable agricultural practices, improving infrastructure, and fostering greater collaboration among stakeholders, Nigeria can build a more resilient agricultural sector capable of withstanding the impacts of climate change. Ultimately, addressing these challenges will not only secure food availability and accessibility but also contribute to the broader goal of sustainable economic development.

2.2 Recommendations

1. The government should encourage the adoption of climate-smart agricultural practices, such as the use of drought-resistant crop varieties, improved irrigation techniques, and conservation agriculture. Training programs for farmers should be established to ensure they understand and can implement these practices effectively.
2. Encourage crop and livestock diversification to reduce dependence on a few climate-sensitive crops and livestock. Introducing crops and livestock that are resilient to varying climatic conditions can help mitigate the impacts of climate change.
3. Invest in the development and maintenance of irrigation systems, especially in northern Nigeria, where rain-fed agriculture is most vulnerable. This will help stabilize crop yields despite erratic rainfall patterns.
4. Regularly update agricultural policies to reflect climate change realities, integrate climate resilience into national strategies, and strengthen institutional capacity to better coordinate and implement climate-related strategies at federal, state, and local levels.

5. Implement policies for sustainable land management, such as agroforestry, reforestation, and controlled grazing, to prevent degradation and enhance soil fertility, and develop technologies to minimize post-harvest losses.
6. Increase funding for agricultural research on climate-resilient crops and sustainable practices, collaborate with universities and organizations, and establish robust data collection and monitoring systems for targeted interventions.
7. Expand credit facilities, insurance schemes, and subsidies for farmers to adopt climate-resilient practices and recover from losses, while encouraging private sector investment in renewable energy, climate-smart technologies, and resilient infrastructure.
8. Implement awareness campaigns and expand extension services to educate communities about climate change impacts. Engage local communities in developing climate adaptation plans, ensuring context-specific solutions for different regions.
9. The government should seek international climate finance and technical assistance, participate in global initiatives, and implement Nationally Determined Contributions (NDCs) under the Paris Agreement, focusing on mitigation and adaptation strategies.
10. Strengthen social protection programs to support vulnerable populations affected by food insecurity, and improve national food storage and distribution systems to ensure accessibility during climate-related disruptions.

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