MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Agricultural Science and Soil Sciences (ISSN: 2350-2274) Vol. 11(6) pp. 077-087, November, 2023
Available online http://meritresearchjournals.org/asss/index.htm

DOI: 10.5281/zenodo.10325783

Original Research Article

A Critical Review of the Impact of Climate Change on Food Security in Nigeria: A Vulnerability Assessment

Hassaini Iliyasu[1], Samson Olayemi Sennuga[1*], Joseph Bamidele[2], Bankole Osho-Lagunju[1] and Rukayat Orire Abdulahi[1]

[1]Department of Agricultural Extension and Rural Sociology, Faculty of Agriculture, University of Abuja, FCT, P.M.B. 117, Abuja, Nigeria

[2]Faculty of Business and Law, University of Northampton, Waterside Campus, University Drive, Northampton NN1 5PH, United Kingdom

***Corresponding Author's E-mail: dr.yemisennuga@yahoo.co.uk**

Abstract

This review explores the profound ramifications of climate change on food security in Nigeria through a comprehensive vulnerability assessment. As a nation heavily reliant on agriculture, Nigeria faces escalating challenges exacerbated by shifting climatic patterns. This study employs a multi-faceted approach to analyze the intricate interplay between climate change and food security, considering both current and projected impacts. Utilizing a combination of quantitative and qualitative methods, the research evaluates the vulnerability of key agricultural regions, examining variations in temperature, precipitation, and extreme weather events. The findings underscore a heightened susceptibility of crop yields and livestock production to climatic anomalies, presenting a clear threat to the nation's food supply chain. Moreover, the study delves into the socio-economic dimensions of vulnerability, scrutinizing the adaptive capacity of local communities and the efficacy of existing policies. Identifying vulnerable populations and regions is crucial for targeted interventions and policy formulation. The study however, discusses potential adaptation strategies, emphasizing the importance of sustainable agricultural practices, climate-resilient crop varieties, and community-based initiatives.

Keywords: Assessment, Climate change, Food, Security, Vulnerability

INTRODUCTION

In many parts of the world, the reality of climate change and the rising incidence of its harmful effects pose serious challenges to human life. The negative effects of climate change have sparked widespread worries, initiatives to lessen their effects, and calls for legislation to stop the human activities that cause it. Changes in the climate's normal characteristics that last for a long time—typically decades or more are referred to as climate change (Ebikiba *et al.,* 2023). The term "climate" in this context refers to the region's average long-term weather patterns. It includes the cumulative representation of atmospheric components across time, including variations in solar radiation, temperature, relative humidity, and precipitation. Climate change is defined as a sustained departure from the mean or normal climate characteristics. According to the IPCC (2014), the human-induced greenhouse effect is the main cause of the current climate change. The concentration of greenhouse gases and aerosols, both of which have an effect on the climate, is constantly rising as a result of human activity. The greenhouse effect produced by these greenhouse gases causes later global warming.

Climate change's enduring effect, global warming, results from the trapping of heat radiated from the Earth toward space by particular greenhouse gases, including nitrous oxide (N2O), carbon dioxide (CO2), methane (CH4), and chlorofluorocarbons (CFCs). Both plants and animals profit from these naturally occurring greenhouse gases' contribution to keeping the Earth's atmosphere at a temperature conducive to life (Sennuga *et al.*, 2023). However, due to rising emissions of these gases brought on by human activity, particularly in industry and agriculture, the greenhouse effect—also known as global warming—has become more pronounced. The amount of

carbon dioxide in the atmosphere has dramatically increased as a result of human activities like the combustion of fossil fuels like coal and oil. Land clearing for agriculture and some industrial operations have also, albeit to a lesser level, added to the greenhouse effect. According to Oyinloye et al. (2018), the production of artificial substances like CFCs, which have industrial origins, has also contributed to the ozone layer's destruction, further accelerating global warming (Barnabas *et al*., 2023).

The greenhouse effect is exacerbated by changes in the natural composition of greenhouse gases, warming the Earth. Increased evaporation and regional differences in precipitation are brought on by this warmer climate. The greenhouse effect also warms the oceans, which results in glaciers and ice sheets partially melting and ultimately causes sea levels to rise (Idu *et al*., 2023). High levels of atmospheric carbon dioxide have been demonstrated to affect crop yields in both good and negative ways, according to research. Under these circumstances, some crops thrive while others do not. One of the effects of climate change is the occurrence of climate-related events such floods, droughts, and extreme temperatures (Taub et al., 2018). These occurrences have led to crop losses and long-term food security issues, particularly in developing nations, which have an impact on farmers' lives. The challenges that climate change poses to human security have sparked global worries, according to (Ufot, 2019), and led to programs and actions aimed at regulating human activities that contribute to global warming. For instance, the Kyoto Protocol aimed to control global industrial processes' emissions of greenhouse gases.

The effects of climate change have been felt in many parts of Nigeria, which is not immune to them. According to research, climate change increasingly poses a serious danger to Nigeria's agricultural productivity. The increased aridity of the Sahel and Sudan savannah belts has adversely affected agricultural activity in those regions, according to research (Zwedie, 2014). Previously well-drained agricultural plains have seen flooding. Agricultural activities and food systems in Nigeria are negatively impacted by additional effects of climate change, including excessive precipitation, erratic rainfall patterns, rising temperatures, and changes in relative humidity. Due to the disruption of the seasonal cycles of food distribution and production, there are now shortages of food, rising food prices, and restricted access to food. In this essay, the impact of climate change on human and food security in Nigeria is examined.

According to the available data, climate change has sparked food crises across the globe and exacerbated security issues in some areas as a result of disputes over scarce agricultural resources. One nation where these intricate climate change crises are developing without strong mitigating measures in place is Nigeria. In its "The State of Food Security and Nutrition in the World" reports published in 2017, 2018, and 2019, the Food and Agricultural Organization (FAO) listed conflict, national economies, and climate change as the three main global causes of food insecurity. According to academics, Nigeria is a nation where these three factors are acknowledged as having a major negative impact on food security. According to some research, climate change is a major factor in the conflict in some areas of Nigeria, making local people poorer and aggravating problems with food security. The goal of this study is to determine how much Nigeria's food and human security have been impacted by climate change.

AIM AND OBJECTIVES

The aim of this study is to analyze the impact of climate change on food and human security in Nigeria. The specific objectives of the study are as follows to:

i. assess the current food security situation in Nigeria.
ii. identify the specific effects of climate change of food security in Nigeria; and
iii. identify the effects of climate change of human security in Nigeria

This section of the study examines the results of earlier academic investigations into the relationship between food and human security and climate change. The majority of these empirical studies used statistical methods and drew their conclusions from simulation models with an emphasis on the relationship between fluctuating climatic conditions and the efficiency of food production. literatures that concentrate on vulnerability assessment are also important.

Climate Change: Concept and Evidence in Nigeria

There is no common understanding of what "climate change" means. As a result, the notion has many definitions that are connected. It is merely a discernible average variation over time in the worldwide meteorological conditions. Ifeanacho and Okudu (2020) state that anthropogenic activities on the environment and natural events both contribute to climate change. Ifeanacho and Okudu (2020) among other writers have observed variances in a number of climate change indicators in sub-Saharan Africa. (Enete, 2014; Federal Ministry of Environment, 2014) indicated that temperatures in Nigeria have grown significantly above average since the 1980s, with relatively higher numbers in 1973, 1987, and 1998. Nigeria is not exempt from this global phenomenon. According to the analysis, the country's diverse biological zones experienced temperature increases of roughly 0.2 to 0.3°C per decade. Even before the 1980s, records of variation in climate change indicators existed in Nigeria. Ifeanacho

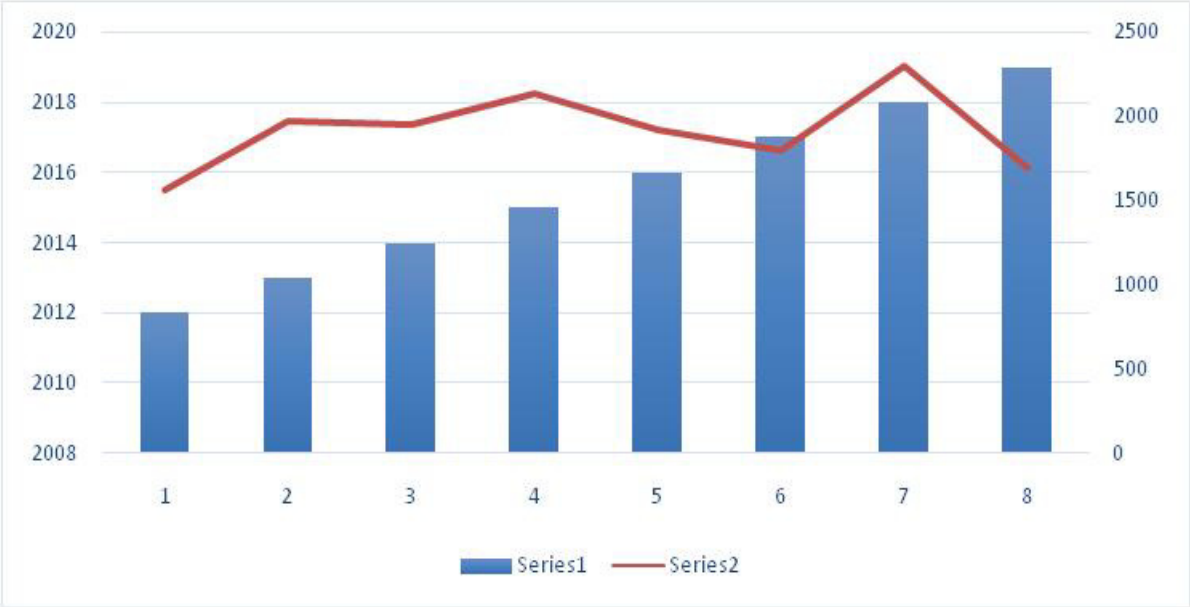

Figure 1. Annual mean rainfall in Nigeria from 2012-2019 according to climatological record

and Okudu (2020) found evidence of rising surface air temperatures since 1920 for Kano, Calabar, and Lagos based on available meteorological data on surface air temperature.

From 1975 to 2010, the average temperature, relative humidity, and rainfall in Nigeria are depicted in data from the Nigerian Meteorological Agency (Figure 1). The three graphs depict the three indications of climate change's variability. Ifeanacho and Okudu (2020) linked the impact of climate change and its related global warming to a substantial rise in temperature between 1971 and 2005. The effects of climate change vary depending on the location in Nigeria. With the loss of wetlands and a rapid decline in the amount of surface water, flora, and fauna resources on land, the Northern region's desertification has been accelerated by a combination of rising temperatures and less rainfall (Federal Ministry of Environment, 2014; Ebele and Emodi, 2016; Abdulkadir et al., 2017; Akande et al., 2017). Numerous towns have been uprooted due to the Southern region's sea level rise, increasing precipitation, coastal erosion, and flooding (Federal Ministry of Environment, 2014; Matemilola, 2019). However, flooding has emerged as a defining characteristic of the two areas. According to the Federal Government of Nigeria (2013), floods are the most frequent and recurrent calamity in the nation. In the past three decades, rainfall durations and intensities have grown, resulting in major runoffs and flooding in numerous locations (Enete, 2014). In Jigawa State in Northern Nigeria, a flood in 2010 had an impact on 2 million people (Elisha et al., 2017). In Southern Nigeria, settlements in Lagos and certain locations in the Niger Delta were drowned, according to Anabaraonye et al.'s, 2019 study.

Climate Change and Agriculture

The influence of climate change on agriculture will be one of the key determining elements influencing the future food security of humanity on earth, according to some of the past experiences mentioned above. Not only is agriculture vulnerable to climate change, but it is also one of the main contributors to it. The obstacles facing the expansion of the agricultural industry as a whole include comprehending how the weather varies over time and changing management strategies to produce better harvests. Agriculture's climate sensitivity is unknown because rainfall, temperature, crops and cropping systems, soils, and management techniques vary according to area. Compared to the expected changes in temperature and precipitation, the inter-annual variability in temperature and precipitation were significantly larger. If the expected climate change increases climate variability, agricultural losses could rise. Due to the complicated effects of global warming, different crops react differently. Because 75% of the world's population resides in the tropics and two thirds of them make agriculture their primary source of income, the tropics are more dependent on it than other regions (Elum, Modise, and Nhamo, 2017). Any impact on tropical agriculture will disrupt their way of life due to low levels of technology, a vast variety of pests, illnesses, and weeds, land degradation, unequal land distribution, and rapid

population expansion. The six major crops that make up over 70% of animal feed and are farmed on 40% of the world's arable land are rice, wheat, maize, sorghum, soybean, and barley (FAO, 2014). Together, they account for 55% of non-meat calories. Therefore, any impact on these crops would have a negative impact on food security.

Climate Change and Food Security in Nigeria

Since agriculture is Nigeria's most significant economic sector, the government has been working to support its growth. In addition to the technical and financial support of UN organizations, they include the Fadama Projects, Agricultural Development Projects, River Basin Development Authorities, Livestock Development Project, and Aquaculture Development Project. However, farmers in the nation rely significantly on natural systems that are extremely susceptible to climate fluctuations because they have few financial resources (Adeyemi *et al*., 2023). Smallholder farming methods itself have a detrimental effect on these ecological systems, which makes the issue worse. Reduction in the size of productive lands, a general decline in productivity, unaffordable prices, and food insecurity are the results of this. The country has a total size of 923,768 sq km, a variety of topographies and climates, and abundant natural resources. It includes roughly nine different ecological zones, including Lowland, Montane, Freshwater Swamp, Mangrove Forest, and Coastal Vegetation. These ecological zones include Sahel, Sudan Guinea, and Derived Savannah. These ecological systems are suffering from the nation's growing population. Deforestation, desertification, soil degradation, erosion, flooding, general habitat loss, and resource depletion are a some of the country's urgent environmental issues (Ayo et al., 2014). Sand desert is spreading southward in the northern part of the country at a rate of 0.6 km per year, while in the southern part, the rainforest environment, which made up approximately 10% of the country's land mass in 1934, has now dwindled to only 5% (Sennuga et al., 202b). The fact that they all have an impact on the nation's food security makes them all the more worrisome. In particular, it has been noted that the country's overall agricultural potential is in peril because of the "increasing heat" and water stress brought on by the heat, which has caused a drop in vegetation.

Climate Change is Profoundly Modifying the Conditions under which Agricultural Activities are Conducted

Both direct and indirect effects of climate change are seen in agricultural production systems. Direct effects include the effects on certain agricultural production systems brought on by a change in physical attributes like temperature levels and rainfall distribution. The productivity is impacted by indirect effects when pests, pathogens, invasive species, pollinators, and other species are altered. These unintended consequences may be quite important. Given the large number of interacting characteristics and links, many of which are yet unknown, they are significantly more challenging to assess and project (Sennuga et al., 2023c).

The projected impacts of climate change on major crop yields based on two decades of research, and are now extensively established. Positive effects are less frequent than negative ones worldwide. The yields of wheat and maize have already been significantly impacted by climate change in several places, as well as internationally, according to observations of the effects of climate trends on crop production (Ajah *et al*., 2023). According to findings from significant agricultural model inter-comparison projects, there is consensus regarding the direction of yield changes in many important agricultural regions at both low and high latitudes, with strong negative impacts especially at higher levels of warming and at low latitudes, despite uncertainties regarding how models represent the representation of combined carbon dioxide fertilization, ozone stress, and high temperature effects. In low-latitude nations, food output will likely be continuously and negatively impacted by climate change in the future, while northern latitudes may experience either positive or negative consequences. This is according to the IPCC. Even though some high-latitude regions might experience a change in their climatic suitability for growing crops, these areas' soil and water conditions may limit long-term gains in agricultural output. In a recent multi-model study, the highest warming scenario used by the IPCC was found to have a mean global effect of minus 17% by 2050 on the yields of four crop groups, including coarse grains, oil seeds, wheat, and rice, which account for roughly 70% of the world's harvested crop area (Muringai et al., 2020).

The most extreme radiative forcing scenario and the assumption of limited CO_2 fertilization effects in 2050 were combined in the hypothesis for this multi-model assessment, but the harmful effects of elevated ozone concentrations, biotic stresses from a variety of pests and diseases, as well as the likelihood of increased occurrence of extreme events, were left out. The likelihood of more damaging effects rises after 2050. Overall, the results show that crop yield variability will rise due to climate change in many places. Major cereal crops have been the subject of more research than other possible implications.

The effects of climate change on ecosystem functioning, such as the balance between crops, weeds, and pests, as well as the effects on pollinators, are typically not taken into consideration by the models used to create estimates of crop yields. Following climate change, pests and illnesses are expected to spread to

previously immune areas, posing a greater risk of harm due to a lack of biological and institutional capacity to manage and control them. The direct beneficial benefits of climate change may be somewhat offset by these changes. According to Idumah et al. (2016), climatic conditions in high-latitude locations will improve for crops but at the expense of weeds and pests.

Climate change affects livestock production in multiple ways, both decrement and tangentially. The health and productivity of animals, as well as the yields of forages and feed crops, are the most significant effects. During severe drought occurrences in the recent past, 20 to 60 percent reductions in animal populations were seen in a number of sub-Saharan African nations. Climate change may cause a 10 to 25% decline in dairy yields in South Africa. Significant decreases in forage production can be brought on by rising temperatures and decreased precipitation, as was the case in 2003 when France experienced a 60% deficit of green fodder.

Climate change and climate variability are impacting forests as well as their ability to provide the vast array of commodities and environmental services that an estimated 1.6 billion people rely on entirely or in part for their ability to survive and be resilient. Evidence suggests that climate change is a factor in a number of environmental issues including decreased tree productivity and dieback due to drought and temperature stress, increased wind and water erosion, increased storm damage, increased frequency of forest fires, pest and disease outbreaks, landslides and avalanches, changes in the ranges of forest plants and animals, inundation and flood damage, saltwater intrusion and sea level rise, and damage from coastal storms. According to FOA, (2015), this may imperil the contribution that forests make to the resilience of agricultural systems, such as the regulation of water and temperature at the landscape level and the supply of habitat for significant species like pollinators.

Climate change affects capture fisheries and the development of aquaculture in marine and freshwater environments. Impacts occur as a result of both gradual atmospheric warming and associated physical (sea and inland water surface temperature, ocean circulation, waves and storm systems) and chemical changes (salinity content, oxygen concentration and acidification) of the aquatic environment. Increased occurrence of coral reef bleaching has been observed, threatening habitats of one out of four marine species. Different fish species are already moving poleward, which hastened the "tropicalization" of systems at mid- and high latitudes. It is predicted that there will be a significant shift of the world's potential marine fish harvest, with a loss of up to 40% in the tropics and an increase of 30–70% in high-latitude regions. It has been noted that invasive species from lower-latitude regions have been moving into the Mediterranean in recent years at a rate of one new introduction every four weeks. The amount and variety of riverine fish species are particularly susceptible to changes in water flow quantity and timing, and notably to drops in water levels during dry seasons. Human efforts to keep water in reservoirs and irrigation channels may increase pressures on river flows (FOA, 2015).

Climate Change and Human Security in Nigeria

The subtle character of climate change gives the phenomenon the impression that it does not pose a serious threat to human security. Evidence suggests that peaceful human habitation in many places of the world has been negatively impacted by climate change. According to the United Nations, human security "is a people-centered notion of security that seeks to integrate the various determinants of well-being such as economic, food, health, environment, personal, community, and political security (Kelechi and Vincent, 2022). Creating a world where people can live in security and dignity, free from poverty, despair, and the fear of want, requires building human security." Human security was divided by the United Nations into acute risks from unexpected interruptions like natural catastrophes and chronic threats like sickness, famine, and violence. Human security must be taken into consideration in order to attain the traditional concepts of national security and international security. In the same manner that international security complements national security, human security does the same (Sennuga *et al.*, 2023)

Human security thus provides a more fundamental, in-depth, and all-encompassing approach to security discourse, which is fundamental to the idea of security both at the national and international levels. The General Assembly resolution 66/290 of the United Nations declares that "human security is an approach to assist member states in identifying and addressing widespread and cross-cutting challenges to the survival, livelihood, and dignity of their people." The resolution states that this strategy calls "for people-centered, comprehensive, context-specific, and prevention-oriented responses that strengthen the protection and empowerment of all people." A more thorough human security approach can help evaluate how climate change will affect domestic and global security. Nigeria's human security faces a new challenge from climate change.

According to Idumah et al. (2016), the phenomena has caused violent conflicts through its different incarnations, which has disrupted public safety and stability. Noting that climate change's unpredictable effects have reduced agricultural productivity prospects and increased the aridity of pasture areas in some parts of northern Nigeria, pastoralists have been forced to migrate south, where they are competing with southern farmers for limited resources. A further point made by Enete (2014) was that

"climate change is undermining human security by reducing access to important natural resources and undermining the capacity of states to act in ways that could promote human security." A decrease in agricultural output and population displacement are results of flood, drought, and desertification. Insurgency and violent conflicts have been connected to this syndrome in some places of Nigeria. There are connections between farmer-herder disputes and climate change in some parts of Nigeria, according to (Idumah et al., 2016).

Pastoralists have been migrating south as a result of continued environmental degradation in regions of northern Nigeria that has led to the loss of grazing fields. The main effects of this migration pattern are the ongoing violent battles between farmers in the host towns and herders. Conflict patterns have disrupted agricultural operations, resulted in significant human casualties, and destroyed farm villages and communities. Armed trafficking has increased globally as a result of the conflict pattern. In order to commit crimes like kidnapping, armed robbery, and rape, some herders have turned to using their newly acquired weapons, which has made the country's security situation worse. In Nigeria, agricultural activities are governed by rainfall. With isolated vegetable and grain cultivation, the Sahel and Sudan savannah belts are mostly used for grazing (Kelechi and Vincent, 2022).

The main food-producing regions in Nigeria are located in the Guinea savannah. Root crops, tuber crops, cereals, and vegetables are all widely grown in the area. In the Guinea savannah, crops such yams, potatoes, cassava, guinea corn, zea maize, and millet are grown in great quantities before being distributed to other regions of the nation. The production of root and tuber crops is likewise heavily concentrated in the rain forest zone, but only cash crops like cashew, cocoa, rubber, and cashew are grown there. The harmful effects of climate change on these vegetative regions of Nigeria are diverse. Numerous pastoralists have been compelled to relocate to the guinea savannah and rain forest regions due to the region's ongoing drought in the Sudan and Sahel savannah regions. This has led to more strain being placed on the lands in these locations. Cattle frequently eat up fallow land that was intended for crop production. In their pursuit of water and grazing areas, the herders and their herds frequently ruin farmlands, which puts them at odds with the local farmers. Conflicts between farmers and herders have frequently occurred in Nigeria's central belt and in some areas of the south. According to research by Murgai et al. (2020), community disputes in Nigeria between 1991 and 2005 accounted for around 31.1% of all violent acts committed against private property. This conclusion is consistent with many others studies.

Assessing The Vulnerability of Farmers, Fishermen and Herdsmen to Climate Change

Climate change vulnerability to farmers in Nigeria

Both moderate climate change (such as temperature and precipitation) and extreme climate change (such as drought and flood) are a concern for Nigerian farmers. Because sensitivity is influenced by exposure, exposure to increased frequencies and intensities of climate risk has a significant impact on outcome (such as yield, income, and health). The ability to adapt is also correlated with exposure. increasing adaptive capacity, for instance, leads in lower sensitivity (biophysical vulnerability) and lower potential harm from increasing exposure (i.e., socioeconomic vulnerability). As a result, total vulnerability is also a function of sensitivity and adaptive capability (Medugu et al., 2014). Both moderate climate change (such as temperature and precipitation) and extreme climate change (such as drought and flood) are a concern for Nigerian farmers. Because sensitivity is influenced by exposure, exposure to increased frequencies and intensities of climate risk has a significant impact on outcome (such as yield, income, and health). The ability to adapt is also correlated with exposure. increasing adaptive capacity, for instance, leads in lower sensitivity (biophysical vulnerability) and lower potential harm from increasing exposure (i.e., socioeconomic vulnerability). As a result, total vulnerability is also a function of sensitivity and adaptive capability (Medugu et al., 2014).

Climate change vulnerability to fishermen

The average global temperature rises, precipitation patterns alter, extreme weather events get worse, and the sea level rises. As a result, there are environmental changes that have a direct impact on fishery productivity and have a big impact on food security along many different paths. Temperature, rainfall, and hydrology all have an impact on fish migration, growth, and reproduction (Medugu and Leal, 2014). As a result, modifications to these characteristics will alter patterns of species availability and abundance. Changes in precipitation have affected seasonal flooding patterns and driven inland fish production in some locations, as has recently happened in some parts of Nigeria. Drier dry seasons may endanger supplies of both wild and cultivated fish. Extreme weather conditions, however, have the potential to worsen Nigeria's fish productivity by reducing aquaculture stock and destroying infrastructure for fishing and aquaculture. People that depend on fishing as their main source of income, such as rural riverine and coastal populations, are likely to be the ones most affected by changes in fishery production. The

consequences of climate change on fisheries will harm those least able to adapt because these people are frequently poorer and more marginal than those who own land and have other primary sources of income (Medugu, and Leal 2014). The effects of anticipated climate change on fishery production have been studied by the International Panel on Climate Change (IPCC). Overall, it is concluded that the sector is exposed to the effects of climate change and has the potential to be significantly influenced by them (Oyinloye et al., 2018).

Climate Change Conflict Between Farmers and Herdsmen

The relationship between climate change and conflict in Nigeria is extremely strong, and research indicates that while natural resource scarcity is the immediate cause of the Fulani-herdsmen and farmer conflict in northern Nigeria, the remote cause is climate change, which has worsened the conflict between the two as farmers migrate from the arid zone savannah of northern Nigeria to Guinea. However, because climate change is a current problem and a gradual process in temperature, the Nigerian government should mobilize more resources, especially in the north, where more than 70% of the country's food crop is grown. This can be done by encouraging measures for climate change mitigation and adaptation. Heat waves, less rain, drought, and desertification are currently being experienced in the north, and they have an impact on climate conflict, as was recently seen in the states of Benue, Nasarawa, and Plateau in Nigeria.

Mitigation and Adaptation Strategies for the Agricultural Sector

Countermeasures Against Climate Change

It is well recognized that the increase in greenhouse gases and aerosols in the atmosphere, as well as changes in land cover and solar radiation, have all contributed to the disturbance of the energy balance for the entire world's climate system. Particularly, the findings of scientific investigations have revealed that it is highly likely that human activities are to blame for global warming (IPCC, 2007). The mitigation strategy, which lowers the scale and rate of climate change by reducing and absorbing greenhouse gas emissions, and the adaptation strategy, which acknowledges the inevitable nature of global warming, comprehends its effects, and seeks to reduce potential harm, are the two main countermeasures that the agricultural sector can consider in response to the risks and challenges of climate change, represented by global warming (Elisha et al., 2016).

Once climate change has begun, the atmosphere, hydrosphere, cryosphere, biosphere, lithosphere, and other elements of the climate system are initially impacted by it by being exposed to it and making an effort to voluntarily adapt to that stimulus. However, if the effects of climate change are significant, the climate system will not be able to handle them through voluntary adaptation alone, then it is necessary to try planned adaptation that necessitates special measures. It is claimed that there is a residual influence of climate change if it continues to have an effect on the climate system even after the anticipated adaptation has taken place. Given that systems find it challenging to adapt to climate change, efforts have concentrated on minimizing the severity of climate change through mitigating actions like reducing greenhouse gas emissions and absorbing them. Mitigation that lowers greenhouse gas emissions helps to prevent, lessen, and delay a variety of climate change effects. According to Chang Gil (2015), as adaptation and mitigation of climate change are intimately tied to one another, mitigation can be seen as a part of long-term adaption efforts. Therefore, adjusting to climate change is a necessary preventative strategy rather than a discretionary one. Improvements in animal excretion treatment technologies in the livestock sector, as well as carbon fixing for farmland soil, are some of the mitigation measures for the agricultural sector. These measures aim to reduce major greenhouse gases like methane (CH4) and nitrous oxide (N2O) by improving cultivation methods through improved irrigation and fertilization control for the arable sector.8 This study focuses on adaptation plans that are based on analyses of the implications of climate change in connection to countermeasures against climate change for the agriculture sector.

Strategies for Climate Change Mitigation

The first-best option to correctly evaluate the external impacts of global warming and impose the economic penalty to the specific greenhouse gas emitters is practically hard to put into practice. Given this context, a practical strategy using a policy mix is addressed as the second-best option for creating pertinent policy programs and creating acceptable portfolios to approach. The measures for reducing greenhouse gas emissions are divided into economical means, regulatory means, voluntary agreement, R&D and popularization, information providing, and public awareness promotion, taking into account the current circumstances in a realistic manner. According to Elisha et al. (2017), "economic means" refers to regulations that make use of market processes, such as fees, carbon taxes (or taxes on greenhouse gases), emission trading plans, and subsidies. An ideal economic way to accomplish effective resource distribution using fiscal incentives is to

implement a greenhouse gas charge, a plan to apply a fee corresponding to the input price for the unit emission of greenhouse gas to the individual greenhouse gas emitters. This plan must be put into action, and each emitter's greenhouse gas emissions must be tracked and taxed in accordance with their actual emissions.

Carbon tax and greenhouse gas tax are two types of taxes used to lower greenhouse gas emissions. A carbon tax is a system that levies fees based on how much carbon is present in the fossil fuels being utilized. In actuality, carbon taxes have been implemented as a product fee due to the ease of assessment and collection. The difference between greenhouse gas taxes and carbon taxes is that the former are based on the quantity of gas emissions, whereas the latter are based on the quantity of fossil fuels used in the generation of the gas emissions. Although a carbon tax and a greenhouse gas tax both have the ability to keep the input of fossil fuels at efficient levels, the former is more practical because it bases its taxes on the input of fossil fuels. A carbon tax merely requires the taxation office to monitor the shipping or distribution stage of fossil fuels for taxation, as opposed to a greenhouse gas tax, which also mandates that the taxation office track the precise amount of greenhouse gas emissions. The cost of greenhouse gases can be considered in end users' decisions because tax is included in the price of fossil fuels. As a result, the administrative expense associated with implementing a carbon price is minimal. A plan known as an emission trading system allows for the trading of emission credits on the market and establishes emission credits based on overall greenhouse gas emissions. (2015) Chang Gil Kim. The pricing function and market demand work together to determine the supply and demand for emission credits.

If a specific source of greenhouse gases can emit greenhouse gases for less money, the source can reduce its emissions, receive as many emission credits as the lowered amount, and sell the emission credits on the market for emission trading at a profit. Subsidy is a mechanism whereby the government grants greenhouse gas emitters the right to emit greenhouse gases up to a specific level and pays them with subsidies if they give up a specific amount of the right granted to them. (Vincent and Kelechi, 2022). Reliable data and information about the social marginal cost of greenhouse gas emissions and the social benefits of greenhouse gas reduction should be gathered in order to ensure the proper operation of economic tools based on the market function. To ensure that emitters can comply and reach the acceptable level of greenhouse gas emissions, the government may utilize a variety of policies and legal procedures known as "direct regulation" to regulate emission requirements. A policy measure known as an emission standard is one that is easier for the government to establish and implement than other policy measures because it sets total greenhouse gas emission caps for each source and guarantees emitters' compliance.

Emission caps, chemical fertilizer spraying standards, manure and liquid fertilizer spraying standards, and breeding density limitations are a few examples of regulatory measures that apply to the agricultural sector. A non-regulatory policy mechanism called voluntary agreement allows businesses (such as restaurants or farms) and the government to voluntarily agree on greenhouse gas reduction goals, action plans, and the level of support needed to reach those goals. agreements made voluntarily for greenhouse gas practices in the form of product fees. The difference between greenhouse gas taxes and carbon taxes is that the former are based on the quantity of gas emissions, whereas the latter are based on the quantity of fossil fuels used in the generation of the gas emissions. Although a carbon tax and a greenhouse gas tax both have the ability to keep the input of fossil fuels at efficient levels, the former is more practical because it bases its taxes on the input of fossil fuels. A carbon tax merely requires the taxation office to monitor the shipping or distribution stage of fossil fuels for taxation, as opposed to a greenhouse gas tax, which also mandates that the taxation office track the precise amount of greenhouse gas emissions. The cost of greenhouse gases as an input can influence how end users make decisions because tax is incorporated into the price of fossil fuels (Anabaraonye et al., 2019).

As a result, the administrative expense associated with implementing a carbon price is minimal. A plan known as an emission trading system allows for the trading of emission credits on the market and establishes emission credits based on overall greenhouse gas emissions. The pricing function and market demand work together to determine the supply and demand for emission credits. If a specific source of greenhouse gases can emit greenhouse gases for less money, the source can reduce its emissions, receive as many emission credits as the lowered amount, and sell the emission credits on the market for emission trading at a profit. Subsidy is a mechanism whereby the government grants greenhouse gas emitters the right to emit greenhouse gases up to a specific level and pays them with subsidies if they give up a specific amount of the right granted to them. The government must have a correct grasp of a variety of information, including the level of technology, cost, and reduction potential of the subsidized, in order for the subsidy system to work well.

Reliable data and information about the social marginal cost of greenhouse gas emissions and the social benefits of greenhouse gas reduction should be gathered in order to ensure the proper operation of economic tools based on the market function. To ensure that emitters can comply and reach the acceptable level of greenhouse gas emissions, the government may utilize a variety of policies and legal procedures known as "direct regulation" to regulate emission requirements. A

policy measure known as an emission standard is one that is easier for the government to establish and implement than other policy measures because it sets total greenhouse gas emission caps for each source and guarantees emitters' compliance. According to Anabaraonye et al. (2019), some regulatory measures that apply to the agricultural industry include emission caps, manure and liquid fertilizer spraying standards, chemical fertilizer spraying standards, and breeding density limitations.

A non-regulatory policy mechanism called voluntary agreement allows businesses (such as restaurants or farms) and the government to voluntarily agree on greenhouse gas reduction goals, action plans, and the level of support needed to reach those goals. Good Farming Practices (GFP) and the voluntary creation of resource-recycling villages by locals are two voluntary agreements for greenhouse gas reduction in the agricultural sector. There is no disciplinary action against noncompliance with the target under the voluntary agreement model because greenhouse gas reduction targets are established by voluntary agreements. As a result, it might not be a useful policy tool for reaching the country's greenhouse gas reduction goal. In addition, technology for reducing and capturing GHGs are being developed and made more widely known. Information is also being made available and public awareness of greenhouse gas monitoring is being raised. Regarding economic effectiveness, environmental effectiveness, policy adaption, and practicability, each policy measure for reducing greenhouse gas emissions has benefits and drawbacks. Therefore, rather than choosing and promoting just one policy program, it is preferred to develop a portfolio of mixed policies based on a thorough assessment of the specific circumstances of each policy before putting it into effect. It is difficult to select a workable policy mix, so it is important to perform a preliminary evaluation using policy simulation and benchmark international situations where relatively successful policies are already in place.

Strategies for Climate Change Adaptation

Basic Framework for Adaptation

Different definitions exist for the idea of adaptation to climate change. The IPCC defines adaptation as "adjustment in natural and human systems in response to actual or expected climatic stimuli and their effects." According to the UNFCCC, adaptation is the "regulating process of ecological and socioeconomic systems to reduce possible damages from actual and expected climate change, that is, actions taken to help communities and ecosystems cope with changing climate conditions." In order to mitigate the effects of climate change, adaptation is crucial since it helps to lower the risks associated with it and offers possibilities to use it for good. According to Kelechi and Vincent 2022, adaptation involves both steps taken to actively reduce climate-related damages and improve future adaptive capability as well as steps done to indirectly reduce those damages.

Economic strength, technology, information, infra-structure, institutions, and equity—commonly referred to as the components of adaptable capacity—should all be met before adaptation is put into practice. Occasionally, modification can be carried out for nothing or at a moderate cost. However, the majority of the time, the deployment of effective adaptation techniques comes at a cost. The application of relevant technologies is also a requirement for adaption implementation. The recognition of the need for adaptation measures and the selection of the best adaptation measures through an evaluation of the alternatives are also essential for the successful execution of adaptation measures. Adaptive capacity, also known as adaptive capability, is the capacity of a given system to self-regulate, mitigate potential harms, take advantage of opportunities in response to climate change, or deal with its effects (Kelechi and Vincent, 2022).

In order to lessen the frequency and severity of the negative effects of climate change, it refers to the capacity to successfully plan and implement adaptation and to react to growing risks and demands. Although the aforementioned elements can be combined to create adaptable capacity, the relative weight of each element depends on the situation in which adaptation is used and the type of disaster. Each element is closely related to the others rather than independent or exclusive of one another. Accessibility to wealth, information, and technology in the system, the relative distribution of education and healthcare, and social flexibility are all factors that affect adaptive ability. Vulnerability, on the other hand, refers to the risks associated with climate change without adaptation, including the severity of the negative effects of climate change, including climate variability and extreme weather events, as well as the severity of not being able to deal with the negative effects (Ogbo et al., 2013). As a result, vulnerability can be viewed as a function of the system's sensitivity and capacity for adaptation as well as the extent and rate of climatic change to which it is exposed. The degree to which a climate disturbance affects the system in this case is referred to as the system's sensitivity. It is specifically the system's capacity for self-adaptation to changes. The ability of a system, region, or civilization to adjust to the effects of climate change is known as adaptive capacity, and increasing adaptive capacity is a significant way to deal with climate change uncertainty.

The development of adaptation programs for climate change must be preceded by an evaluation of vulnerability, which necessitates an evaluation of the effects of the current climate. The impact assessment

makes it possible to determine which component of each system is vulnerable. Considerable estimation of climate change, identification of the vulnerable parties, calculation of socioeconomic exposure to climate change, and adaptation to the anticipated changes in the climate are all factors in the assessment of vulnerability. Those decreasing the vulnerability of systems that are severely impacted by climate change (improving reservoir storage capacity, growing crops that can withstand high temperatures, preparing for floods, etc.) are one category of adaptations to climate change. those that alter how vulnerable a system is to the effects of climate change (using investments in risk mitigation and early warning systems), as well as those that boost the social and ecological systems' resilience (resource preservation). The ability of a community or biological system to organize or adjust itself to stresses and changes by absorbing the changes and/or impediments is referred to as resilience in adaptation to climate change. It can be viewed as the capability of a system to tolerate changes and stressors while preserving its structural integrity and functional capabilities.

According to the intention, adaptation is divided into autonomous and planned adaptation, pre-adaptation and post-adaptation, short-term and mid-long-term adaptation, and adaptation for each rural household unit, community unit, and country according to the spatial range. Additionally, it can be separated into pre- and post-adaptation depending on when it was applied, as well as short-term and mid- to long-term adaptation depending on when it was applied. According to the application's scope, it can also be loosely divided into adaptations at the national, regional, sectoral, and projectal levels. The private sector, which includes agriculturalists and concerned businesses, and the public sector, which includes the national and municipal governments, are the main groups in charge of putting adaptation measures into action. While the public sector seeks to maximize public value, the private sector aims to maximize private profit.

CONCLUSIONS

As seen above, climate change causes heat waves, droughts, and floods to occur more frequently all around the world. They have a terrible impact on farmers' ability to make a living. In Nigeria, where agriculture plays a larger role in the economy, this is especially true. It's interesting to note that opposite-natured weather extremes, such as cold and hot spells, floods and droughts, are sometimes observed in the same year over the same region or in separate locations, and they're predicted to become more frequent in the decades to come. Heavy crop and human losses are probably in store. Growing greenhouse gases and human-induced aerosols are linked to the entire climate change, and the imbalance between them could cause unpredictability even in year-to-year monsoon behavior. Therefore, there should be a determined effort from developed and developing countries to make industrialization environment friendly by reducing greenhouse gases pumping into the atmosphere. In the same fashion, awareness programs on climate change and its effects on various sectors viz., agriculture, health, infrastructure, water, forestry, fisheries, land and ocean biodiversity and sea level and the role played by human interventions in climate change need to be taken up on priority basis. Changes in lifestyle are also necessary during this phase to prevent greenhouse gasses and CFCs from harming the Earth's atmosphere continuously. In order to help planners in such reoccurring events for limiting the negative consequences, the effects of extreme weather events on crops are to be documented on a regional scale 26. In order to reduce risk in the agricultural sector, it is also necessary to educate farmers about the predicted effects of climate change and make them aware of potential solutions for mitigation and adaptation.

REFERENCES

Abdulkadir A, Maryam LA, Muhammad TA (2017). Climate change and its implications on human existence in Nigeria: a review. Bay J. Pure. Appl. Sci. 10(2): 152-158.

Adeyemi SO, Sennuga S. O., Bamidele, J., Omole, A. O., Alabuja, F. O., Osho-Lagunju, B. &Iheonu, M. E. (2023). A Critical Review of Rural Agricultural Development Innovative Programmes in Nigeria, J. *Plant Biol. Soil Health J.* 1(1), 10-17

Adger W, Arnell N, Tompkins E (2005). 'Successful adaptation to climate change across scales', Global Environmental Change,15, (2), 77–86.

Ajah J, Unamba FC, Sennuga SO, Bamidele J, Onjewu SS, Omole AO (2023). Socio-Economic Factors Affecting the Adoption of Farm Chemicals by Small-Scale Rice Farmers in Abuja, *J. Agric. Sci. Pract.* 8(4), 70-79.

Akande A, Costa CA, Mateu J, Henriques R (2017). Geospatial Analysis of Extreme Weather Events in Nigeria (1985– 2015) Using Self-Organizing Maps. Advances in Meteorology.

Anabaraonye B, Okafor JC, Ikuelogbon JO (2019). Educating farmers and fishermen in rural areas in Nigeria on climate change mitigation and adaptation for global sustainability. Intl. J. Sci. Eng. Res. 10(4):1391-1398.

Ayo JA, Omosebi MO, Sulieman A (2014); Environmental Science Review Article Effect of climate change on food security in Nigeria Sec. J. Environ. Sci. Computer Science and Engineering & Technology 3(4), 1763-1778.

Barnabas TM, Pam HD, Ajah J, Fadiji TO, Sennuga SO, Osho-Lagunju B, Iheonu ME, Alabuja FO (2023). Gender Participation of Orange Fleshed Sweet Potato Production activities in FCT Abuja, Nigeria, *J. Plant Biol. Soil Health,* 1(1), 01-10.

Ebele NE, Emodi NV (2016). Climate change and its impact in Nigerian economy. J. Sci. Res. Rep. 10(6): 1-13

Ebukiba ES, Owolabi FN, Sennuga SO, Omole AO, Bamidele J, Osho-Lagunju B, Alabuja FO, Iheonu ME (2023). Profitability and Resource-Use Efficiency of Poultry Egg Production in Kuje Area Council, Federal Capital Territory, Nigeria, *Direct Res. J. Agric. Food Sci.* 11(7), 172-179

Elisha I, Sawa BA, Ejeh UL (2017). Evidence of climate change and adaptation strategies among grain farmers in Sokoto State, Nigeria. J. Environ. Sci. Toxicol. Fd. Tech. 11(3). 1-7.

Elum ZA, Modise DM, Nhamo G (2017). Climate change mitigation: the potential of agriculture as a renewable energy source in Nigeria. Environ. Sci. Poll. Res. 24: 3260–3273

Enete IC (2014). Impacts of climate change on agricultural production in Enugu State, Nigeria. J. Ear. Sci. Clim. Chan. 5(9), 234.

FAO (2014). The state of food insecurity in the world.

FAO, IFAD, UNICEF, WFP and WHO (2017). "The state of food security and nutrition in the world 2017", Building Resilience for Peace and Food Security, FAO, Rome.

FAO, IFAD, UNICEF, WFP and WHO (2018), "The state of food security and nutrition in the world 2018", Building Climate Resilience for Food Security and Nutrition, FAO, Rome.

FAO, IFAD, UNICEF, WFP and WHO (2019), "The state of food security and nutrition in the world 2019", Safeguarding against Economic Slowdowns and Downturns, FAO, Rome.

Federal Ministry of Environment (2014). United Nations Climate Change Nigeria. National Communication (NC)

FOA (2015). Climate change and food security: risks and responses.

Idris NM, Rafee MM (2014). Assessing the vulnerability of farmers, fishermen and herdsmen to climate change: a case study from Nigeria. Int. J. Global Warming, 6, (1),

Idu EE, Ola IA, Sennuga SO, Bamidele J, Alabuja FO, Osho-Lagunju B, Preyor TJ, Omolen AO (2023). Evaluation of Factors Influencing the Use of Information and Communication Technologies (ICTs) Among Smallholder Rice Farmers in Kuje Area council, Abuja, Nigeria, *Int. J. Res. Innov. Soc. Sci.* 7(6), 1025-1036

Idumah FO, Mangodo C, Ighadaro UB, Owombo PT (2016), "Climate change and food production in Nigeria: implication for food security in Nigeria", J. Agric. Sci. 8(2), 74-83

Ifeanacho MO, Okudu HO (2020). Climate Change and Nutrition Security in Nigeria Appl. Sci. Environ. Manage. 24 (11) 1853-1860

Ifeanacho MO, Okudu HO (2020). Climate Change and Nutrition Security in Nigeria. Journal of Applied Science Environment Manage, 24 (11) 1853-1860

IPCC (2014). Climate change 2014: synthesis report.

Kelechi JA, Vincent OA (2022). The impact of climate change on food and human security in Nig. Int. J. Climate Change Strategies and Management 14 (2), 2022

Matemilola S (2019). Mainstreaming climate change into the EIA process in Nigeria: Perspectives from projects in the Niger Delta Region. Clim. 7(2), 29.

Medugu IN, Majid MR, Leal FW (2014). 'Assessing the vulnerability of farmers, fishermen and herdsmen to climate change: a case study from Nigeria', Int. J. Global Warming, 6, (1),1–14.

Muringai RT, Naidoo D, Mafongoya P, Lottering S (2020). "The impacts of climate change on the livelihood and food security of Small-Scale fishers in Lake Kariba, Zimbabwe", J. Asian and Afr. Stud. 55 (2),298-313

Ogbo A, Ebele N, Ukpere W (2013). "Risk management and challenges of climate change in Nigeria", J. Human Ecol. 41 (3), 221-235.

Onwutuebe CJ (2019). Patriarchy and Women Vulnerability to Adverse Climate Change in Nigeria

Oyinloye OD, Akinola OO, Akande YO, Akinyele AA, Mosimabale MM (2018), "Food insecurity in Africa", J. Humanit. Soc. Sci. 23(9), 68-75.

Sennuga SO, Bamidele J, Omole AO, Onjewu SS, Osho-Lagunju B (2023). Examining the Adoption of Improved Cassava Processing Technologies Among Women in Abaji Area Council, Abuja: Implications for Sustainable Farming Practices, *Merit Res. J. Agric. Sci. Soil Sci.* 11(6), 077-086

Sennuga SO, Ojewole GO, Bamidele J, Alabuja FO, Abdulahi RO, Iheonu ME, Chinwuba MA (2023). Women Participation in Household Food Security in OgbomosoSouth Local Government Area, Oyo State, Nigeria. *J. Agric. & Edu. Res.* 1(1), 1-11.

Sennuga SO, Salaudeen MA, Bamidele J., Alabuja, F. O., Osho-Lagunju, B., Preyor, T. J. &Iheonu, M. E. (2023). Application of Internet Communications in Agricultural Extension Delivery System Among Farmers in Abuja, Nigeria, *Pollution and Community Health Effects* 1(1); DOI: 10.59657/pche.brs.23.002

Sennuga, S. O., Ujoyi, S. A., Bamidele, J., Onjewu, S. S., Lai-Solarin, W. I., Omole, A. A. (2023). Exploring the Role of Smartphone Apps for Livestock Farmers Data Management Extension and Informed Decision Making in Nigeria. *Int. J. Probiotics and Dietetics*, 3(2), 46-53.

Taub DR, Miller B, Allen H (2018), "Effects of elevated CO2 on the protein concentration of food crops: a meta-analysis", Global Change Biology, 14(3), 565-575

The Impact of Climate Change on the Agricultural Sector: Implications of the Agro-Industry for Low Carbon, Green Growth Strategy and Roadmap for the East Asian Region Prepared by Dr. Chang-Gil Kim Korea Rural Economic Institute

Ufot EO (2019). "Food security, poverty and investment dimensions", Perspectives on Food Security,46(2)32-38.

Zwedie A (2014). "Impact of climate change on food security: a literature review in Sub-Saharan Africa", J. Earth Sci. Climate Change, 5 (8), 225.