

**CLIMATE CHANGE, FOOD SECURITY, NATIONAL SECURITY and
ENVIRONMENTAL RESOURCES**

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Climate Change, Food Security, National Security and Environmental Resources

Global Issues & Local Perspectives

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It eschews pedantry and lays bare the issues in such clarity that conduces to learning. The book elaborates on contemporaneous climate change, food security, national security and environmental resources issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate change, food security, national security and environmental resources issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate change, food security, national security and environmental resources necessary in policy making process that will stimulate increase in food production and environmental sustainability.

Climate Change, Food Security, National Security and Environmental resources: Global issues and Local Perspectives is organized in four parts. Part One deals with Climate Change with Six Chapters, Part Two is concerned with Food Security with Nine chapters, Part Three deals with National Security with Five Chapters, while Part Four pertains Environmental Resources, has Five Chapters.

Ahmed Makarfi / Eteyen Nyong

April 2024

Chapter 5:

The Nexus between Climate Change and Agricultural Production in Nigeria

¹Ettah, O. I., ²Igiri, Juliana and ³Ettah, Goddy I.

Introduction

My contribution to this book tries to make enormous inroads in understanding climate change and its causes, with the believe that it will help develop a strong understanding of current and potential impacts that will affect people today and in coming decades. This understanding is crucial because it allows decision and policy makers to place climate change in the context of other large challenges facing the nation vis a vis agriculture and the world. There is however a strong, incontrovertible, credible body of evidence, based on multiple lines of research, documenting that climate is changing and that these changes are in large part negatively affecting agricultural production and productivity. Many developing countries are facing the enormous challenges of the changing climate and Nigeria is not left out. Climate change has direct impact on agricultural production, because of the climate-dependent nature of agricultural systems. In fact, many communities in the various ecological zones within the country are already in grief over the brutality of its impacts. This impact is particularly significant in developing countries where agriculture constitutes employment and income sources for the majority of the population. To exacerbate these impacts of climate change in agricultural practices is the fact that adaptation and mitigation interventions are either lacking or are not sufficient to avert calamity in agricultural production.

Climate change: an overview

Climate is generally conceived as the expected weather conditions for specific geographical location, while Climate change on the other hand is a deviation from the normal weather conditions of an area over time, whether due to natural conditions or as a result of man, that results in degradation of an environment (Tarfa, Ayuba, Onyeneke, Idris, Nwajiuba and Igberi,

2019). Studies have shown significant and alarming negative impacts of climate change and adaptation of farmers in different parts of the world. Various research findings indicate that the damaging effects of global temperature is increasing and most damages are predicted to occur in sub-Saharan Africa - the region that already faces average high temperature and low precipitation, frequent droughts and scarcity of both ground and surface water. Climate change is currently ravaging the world and manifests in extreme conditions of flooding, temperature rise (heat waves), rises in sea levels, drought and desertification, wind storms, and the drying up of streams and rivers (Enete and Onyekuru, 2019, IPCC, 2017, Ettah and Chima, 2018 and Elum, Modise and Marr, 2017).

Climate phenomenon is pivotal in redefining development in the twenty-first century. How Nigeria communities and households respond to the impact of climate changes and variability, to which the world has already been committed, will in many instances determine their prospects for growth and sustainability of agricultural production. According to United Nation Framework Convention on Climate Change (UNFCCC) (2017) change in climate is the most serious environmental threat to agricultural development and can only be resolved through the intervention of institutions which have formal and informal mechanisms that shape social and individual expectations, interactions and behavior. These institutions can be classified as public (bureaucratic, administrative units, and elected local government), civic (membership and cooperative organizations) and private sectors (service and business organizations). This is because institutions are the formal and informal organizations through which society structures share decision making and takes collective action. Institutions help to define climate change both as a problem and a context, through such socialized devices as the use of scientific knowledge, culturally defined interpretation of scientific findings and politically tolerable management strategies (Agbachom, Amalu , Uzoikwe, Ettah and Ubi, 2019).

Climate change is of serious concern to Nigeria and Nigerians alike because of its effect on agriculture which is the main source of food production. The role of agriculture to the economy of the country cannot be overemphasized; it is mostly responsible for food for humans and livestock, as well as employing over 70% of the labour force and contributes the largest portion to Gross Domestic Product (GDP) and foreign exchange earnings and also the major source of raw

materials to industries. Despite all the advancement in technology, climate is still the most important factor in agricultural production. It is gradually attaining catastrophic dimension given the associated disaster in the various key socio-economic sectors in recent time. Onoja and Achike (2017) noted that climates' importance is aptly demonstrated in the serious threats of various developmental programmes like the Millennium Development Goals (MDGs), National cum State Economic Empowerment Development Strategies (NEEDS/SEEDS), New Partnership for Africa Development (NEPAD), FADAMA III and actualization of the nation's vision 20:2020, following their failure to address issues of climate changes by successive governments of Nigeria. The management strategy by Nigerian Meteorological Agency (NIMET) through the reduction of the flow of the man-made greenhouse gases into the atmosphere cannot do enough due to the very long-life span of the gases which is estimated to stay for about a century. This is why researchers recommend adaptation and management as the only option for Nigeria to cope with the projected changes and impact over the next century if human existence is to be guarantee here on earth (Enete, 2019). According to Intergovernmental Panel on Climate Change (IPCC, 2017), it is a change in the state of the climate that can be identified by changes in the mean and or the variability of its properties and that persists for an extended period typically decades or longer. This change is made visible especially when focusing on important climatic factors like temperature, rainfall, humidity, wind and sunshine which have shown significant variability. Elum, Modise and Marr, (2017) noted that scientist have also asserted that the time-lagged nature of climate change implies that the currently observed climate change is attributed to greenhouse gas emission of the 19th and 20th centuries and that the effects of current greenhouse gas emission will also lag into the future.

Climate Change in Nigeria

Several reports have been presented which tend to confirm that Nigeria, like many other countries, is experiencing climate change. One study attempted to provide evidence of climate change in Nigeria based on annual series of rainfall of daily amounts by computing annual series of light rainfall, moderate rainfall and heavy rainfall for 4 zones: coastal, Guinea-savanna, midland and sahelian-utilizing daily rainfall data for the period 1980-1990 (Onoja and Ahike, 2019). The study examined evidence of change in structure in terms of pattern of decrease and increase in dry and wet years, the overall trend and the occurrence of

runs of dry and wet years and reported evidence of climate change in northern Nigeria (midland and sahel) and evidence of high frequency of oscillation about stable long-term mean. In the same vein, another study by Eneji, Onnoghen, Acha, and Diwa (2020) established a decadal variation in 2 key climate elements in Nigeria namely rainfall and air temperature. While still another revealed that both rainfall and temperature have been on the increase in the Niger Delta region (Abraham, 2018). Nigerian Environmental Study/Action Team (NEST) quoted the Third and Fourth Assessment Reports of the IPCC as noting that Nigeria ought to be concerned about climate change for a number of reasons one of which is its practice of rain-fed agriculture and fishing from which 2/3 of her population depend on primarily for food are under serious threat of climate change.

The earth's average temperature has gone up 1.4° F over the past century and is expected to rise as much as 11.5° F over the next (IPCC. 2017). That might not seem like a lot, but the average temperature during the last Ice Age was about 4° F lower than it is today, these are also peculiar to Nigeria. Others include warming ocean temperatures associated with stronger and more frequent storms, additional rainfall particularly during severe weather events leading to flooding and other damage, increase in the incidence and severity of wildfires threatening habitats, homes, and lives (Enete, 2018). Live threatening impacts include the following: heat waves contributing to human deaths (example is the one that occurred in January to February of 2024), increasing extreme weather conditions such as, erratic rainfall pattern, rising temperature, sea level rising, delay in the onset of rainfall, early rainfall retreat, flood, prolonged dry season, and increase in ground water salinity are other observed evidences of climate change in Nigeria. Nigeria's is Africa's largest economy, most populous country, and home to a wealth of natural resources, particularly agricultural, oil and natural gas.

According to Kuye and Ettah (2018) the country's wide range of livelihoods, agricultural practices, and commodities are threatened by climate change: the rising sea levels increase vulnerability to flooding and waterborne disease, drought and rising air temperature hinder agricultural production and fishing, reducing food security and negatively impacting health and nutrition. According to the United Nations, Nigeria has the highest rate of deforestation in the world, losing 3.7 percent of its forest every year. It is also home to Africa's largest mangrove

forest, but only six percent is protected. Its multiple ecological zones have given rise to a wide range of livelihoods, agricultural practices, and commodities, all of which are affected by climate change and shocks. Echendu (2020) asserted that rising sea levels threatens southern cities such as Lagos and coastal areas, increasing vulnerability to flooding and waterborne disease. Drought and reduced rainfall, combined with rising air temperatures, inhibit the country's hydropower systems, and hinder agricultural production and fishing, reducing food security and negatively impacting health and nutrition. Climate therefore remains an outstanding predominant natural factor influencing food crop production.

Historical meteorological data show rising temperatures and declining rainfall in Nigeria's key farming zones. Temperatures have increased across various agro-ecological zones over the past three decades, while rainfall has declined by 2–8% in northern Nigeria and become more variable in the south (Ettah and Chiemela, 2018). Climate models predict these trends will continue through the 21st century. Reduced agricultural productivity threatens the viability of smallholder farming in Nigeria. With poorer harvests, small farms are compelled to lay off workers, rely on family labor, or exit farming. Modeling studies estimate climate change could eliminate 40–45% of unskilled agricultural jobs in northern Nigeria by 2050 (Elum *et. al.*, 2017).

Rainfall, a very essential element of climate has numerous implications for agricultural production of a place. This is because its nature (time of commencement in a given period, amount, duration, intensity and distribution) to a very large extent determines the type of and level of agricultural practices and production of a place (Eneji *et. al.*, 2020). Much of the water for agricultural production comes from rainfall. Where rainfall is well distributed and in adequate amount, growth and productivity of crops like yam, cocoyam, cassava, plantain, corn, rice and tree crops like rubber, kola-nut, oil palm, citrus, among others which are major staples of Nigerian is guaranteed. The most important element of climate is rainfall, the amount that falls, how it falls example steadily over several days or suddenly in torrential downpours, hence its effectiveness i.e. how much of it is available for use by plants. Currently, it has been observed, and even available records have shown that the nature of rainfall has not been encouraging and there has been a deviation from the natural pattern of rainfall. An encouraging nature of rainfall in terms of commencement at the right time, moderate or adequate in amount, duration and intensity, no doubt,

is desired and generally accepted as the best nature of rainfall for any desired level of agricultural production. Consequent upon this, best nature of rainfall is the utmost desire of places substantially involved in agricultural production.

Ojoyi and Mwenge (2018) noted that a change in the type, distribution and coverage of vegetation may occur given a change in the climate. Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO₂. A gradual increase in warmth in a region will lead to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Conversely, cold will cause plant bio-cycles to lag. Larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances. While some quantities of these gases are a naturally occurring and critical part of earth's temperature control system, the atmospheric concentration of CO₂ did not rise above 300 parts per million (ppm) between the advent of human civilization roughly 10,000 years ago and 1900. Today it is at about 400 ppm, a level not reached in more than 400,000 years (Weber, 2020).

Climate Change and Flooding

Nigeria Erosion and Watershed Management Project (NEWMAP) reported that in 2022 alone in Nigeria, flooding arising from climate change killed at least 662 people, injured 3,174, displaced about 2.5 million, and destroyed 200,000 houses of individuals. The project further held that erosion is affecting over 6,000 square kilometres of land in the country, with about 3,400 square kilometres highly exposed and gully erosion doing an estimated \$100 million worth of damage each year. Currently, about 178 local government areas (LGAs) in 32 of 36 states in Nigeria and the Federal Capital Territory fall within the highly probable flood risk areas, according to the Nigeria Hydrological Services Agency (NIHSA). NIHSA further stated that another 224 of the country's 744 LGAs fall within moderately probable flood risk areas, and 372 falls within probable flood risk areas. Nigeria's more than 830 kilometres of coastline are increasingly threatened by floods, erosion, water and air pollution. Communities in the Niger Delta states bordering the Atlantic Ocean have lost or fear losing their homes and farmlands due to the eroding bedrock shielding the shoreline (Matemilola, Adedeji, Elegbede and Kies, 2019). This is why the

country began working with the World Bank through NEWMAP to rehabilitate degraded lands and reduce erosion and climate vulnerability in 23 states, with four work streams as follows:

i. investing in erosion and watershed management infrastructure to reduce land degradation. On this intervention, the project more than doubled the land under sustainable management, completed nearly five dozen participatory surface water management plans and reduced gully erosion considerably.

ii. developing information services to strengthen erosion and watershed monitoring and disaster risk management. The project drafted environmental impact assessment guidelines and launched over a hundred automated hydrology and meteorology and flood early warning systems in the region.

iii. strengthening Nigeria's strategic framework for climate action to promote low carbon development. The country issued green bonds to spark private investment in climate smart projects, such as distributing fuel-efficient cooking stoves and developing solar-based electricity generators for rural health centers and

iv. supporting project management at federal and state levels with financial, social and environmental safeguards and oversight, outreach, and project monitoring and evaluation. On this, the project tested the use of remote sensing, geographic information system techniques, and 360-degree cameras and drones for remote supervision and grievance resolution. Overall, NEWMAP showed Nigeria's acceptance of climate change effects, appetite for action and results.

Climate Change and Agricultural Production

Climate change poses a major threat to Nigeria agricultural production in the 21st Century (IPCC, 2022). Farmers (who constitute the bulk of the poor in Nigeria), face prospects of tragic crop and animal failures, reduced production and productivity, culminating to increased hunger, malnutrition and diseases. For food security concerns that are central to economic and sustainable development agendas, to be attended to, it is desirable to also address climate change and agriculture (Agbachom *et. al.*, 2018). Abraham (2018) noted that competition for resources among farmers and pastoralist is a direct consequence of climate change problems which has caused

clashes between ethnic groups living next to Fulani herdsmen. Constant conflict over land and water resources between herdsmen and farmers will have negative effects on food production and animal yield (food security). Climate change phenomena like rising temperatures, changing rainfall patterns, and more frequent extreme weather events will likely reduce crop yields, farm profits, and agricultural employment. Higher temperatures, reduced rainfall, and increased climate extremes can lower crop yields by disrupting growth cycles, increasing water stress, and enabling pests (Matemilola *et. al.*, 2019).

Deforestation and overgrazing have led to increased carbon emissions into the atmosphere and also affects the local weather and climate systems in the concerned regions through moisture fluxes and energy change. With agriculture central to rural income and employment generation, climate change may substantially alter the quantity and quality of agricultural jobs available, reduced farm productivity and profitability and could undermine livelihood viability, particularly for marginal and smallholder farmers (Eneji *et. al.*, 2017). This raises concerns over potential declines in agricultural employment, increased rural–urban migration, and exacerbated poverty levels. According to Ettah and Chima (2017) in Nigeria, the agricultural sector is a cornerstone of the economy, significantly contributing to the GDP growth and providing livelihoods to a substantial portion of the population, mainly smallholder farmers in rural areas. However, this sector faces complex challenges, including limited access to modern farming techniques, inadequate infrastructure, and the substantial impact of climate change, which affects agricultural production (Tarfa, Ayuba, Onyeneke, Idris, Nwajiuba and Igberi, 2019).

Climate Change and Agricultural Sector Employment: Climate change is expected to have a significant impact on agricultural sector employment in Nigeria, which employs over 70% of the population as stated earlier. The sector is highly vulnerable to climate change, as it is heavily dependent on weather conditions and climate-sensitive resources, such as water and land (Echendu, 2020). One of the channels through which climate change is expected to impact agricultural sector employment in Nigeria is through changes in crop and animal yields. Enete and Onyekuru (2018) averred that climate change is expected to lead to more extreme weather events in Nigeria, such as droughts and floods, which can damage crops and reduce yields. These yield

changes may necessitate alterations in labor demand within the sector, potentially leading to job losses or shifts in employment patterns.

Changes in climate patterns might exacerbate resource scarcity, such as water shortages or soil degradation, leading to increased input costs for farmers. Elevated input costs can influence labor demand due to changes in agricultural practices or technology adoption can potentially affect employment levels in the sector (Ettah and Ukwuaba, 2017). Another channel through which climate change is expected to impact agricultural sector employment in Nigeria is through changes in land use. Change in climate is expected to lead to changes in temperature and precipitation patterns in Nigeria, which could make some areas less suitable for agriculture. As a result, farmers may be forced to abandon some land or switch to crops that are more tolerant to climate change (Terfa *et. al.*, 2019). This could lead to job losses in the agricultural sector, as fewer workers will be needed to farm less land.

It is also expected that changing climate can impact agricultural sector employment in Nigeria through changes in labor productivity. NEWMAP (2022) noted that climate change could lead to increased heat stress and other health problems for agricultural workers in Nigeria, which could reduce their productivity. Additionally, climate change could damage agricultural infrastructure in Nigeria, such as irrigation systems and roads, which could also reduce labor productivity. The impact of climate change on agricultural sector employment is expected to be particularly severe in rural Nigeria, where the agricultural sector is the main source of employment. As a result, climate change could lead to widespread unemployment and poverty in rural Nigeria.

Climate Change and Agricultural Sector Performance: Changes in agricultural sector performance due to unpredictability of climatic outcomes have remained a dominant issue in low income countries including Nigeria as both flora and fauna are sensitive to climate change. Agriculture is an inherently risky business because of climate change. Its biological nature owing to climate change has made agricultural performance very uncertain. This is because agriculture is climate dependent; the vagaries of weather, resulting to pests and diseases outbreak to crops and livestock enterprises, widespread changes in rainfall, temperature patterns, technologies, health conditions (sickness and even death) in agriculture are all outcomes of climate change (Enete and Onyekuru,

2019). When all these occur, which is almost inevitable, farmers are forced to make decisions based on imperfect information and knowledge, hence there is therefore the possibility of agricultural ‘injury’ or loss. Studies by Terfa *et.al.*, (2019) shows that about 85% of these losses are attributed to weather related incidences, of which floods, droughts and diseases are the key players and are directly related to climate change. National Bureau of Statistics (NBS) (2021) predicted that crop yield in Nigeria may decline by 15 to 30 percent or even up to 50 percent by 2040 due to climate change. This is why in Nigeria, experts have advocated for technological improvements in agricultural production through genetically modified crops or irrigation systems, climatic conditions and weather patterns as key elixirs to food production potentials (Abraham, 2018).

According to Eneji *et.al.*, (2020) inconsistency of climatic conditions or changing weather events can alter the productive capacities of farmers, especially when the potential capacity to adapt to changing weather conditions are lacking. Increasing atmospheric carbon dioxide emissions, higher temperature, variation in annual and seasonal precipitation patterns amongst others seem to threaten the quantity of food production and natural environment. Altogether, the impact of climate change is very comprehensive but its far reaching effects are now clearly visible on agricultural sector, on which relies the food production and economy of the world. The severity of the effects of climate change in agriculture depends largely on the vulnerability of the existing technologies and adaptive capacity available to farmers considering the dynamism of agricultural environmental conditions (Onoja and Achike 2019). A situation therefore arises of uncertain availability of adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways.

Climate Change and Management Practices: Nigeria is the country with the greatest biophysical potential for climate management from natural climate solutions, such as increased trees in agricultural lands, reforestation, and improved natural forest management. Effective adaptation and mitigation has been identified by both climate change scholars and policy makers as crucial in coping with climate change menace by farmers, especially in a climate sensitive agricultural system like Nigeria. Reports indicates that most of the problems (or constraints) encountered by

farmers in adaptation of management practices to climate change are associated with poverty (Uyigüe and Agbo, 2020). This is because poor and hungry farmers would naturally divert their limited farm income towards the basic necessities like feeding and medication rather than ploughing them into climate change adaptation measures. As climate is a natural phenomenon, it is impossible for man to stop it, but measures can be used to reduce the effects. Mitigation and adaptation of management practices are two central issues to tackle climate change, there is the need for an emphasis on “anticipatory mitigation and adaptation of management practices”, that is the proactive rather than the reactive management of climate change risk (UNFCCC, 2017). This can only be feasible if the potential problems/challenges to mitigation and adaptation are preemptively analyzed. Adaptation of management practices is one of the policy responses projected with the goal of maintaining the capacity to deal with current future changes (Eneji *et al.*, 2020). The terms coping, adaptation and mitigation strategies are often used interchangeably and refer mainly to short-term actions taken to counteract the immediate negative impacts of climate variability including flood.

Coping and adaptation can also be differentiated in terms of the institutional aspects that need to be considered. Coping strategies are taken within the existing institutional structures of the system under consideration, while adaptation strategies may demand some transformation in terms of the structures’ composition and functioning (Terfa *et al.*, 2019). Some scholars believe that adaptation strategies are more tactical in action and futuristic while coping strategies may be changed into adaptive strategies through institutional support. Adaptation is defined as initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. On the other hand, according to Enete and Onyekuru (2019) mitigation to climate change involves actions that are designed to limit the amount of long-term climate change effect. It is widely agreed that there is a limit to what adaptation can achieve and that mitigation measures must be undertaken in parallel to prevent the negative impact of climate change on agricultural practices.

Climate change seem to be less severe in developed economies due to relative high adaption techniques, endowed advantage, high technology and mechanized agricultural system, awareness and income status (Weber, 2020). Contrariwise, developing economies including Nigeria are at

the precipice of adverse effects of climate change considering the prevalent high level of temperature, poor adaptation capacity, absence of early warning and poor income status. It is therefore not surprising that African countries including Nigeria have in recent time experienced some adverse effects of climate change due to the dynamics of drought, rainfall, relative humidity and temperature amongst others (Ojoyi and Mwenge, 2018). Farmers in these climes are frequently exposed to the uncertainties of weather, prices and disease. Many farmers live on the edge of extreme risk and uncertainty, sometimes falling just below, and sometimes rising just above the threshold of survival. Farmers do not know whether rainfall will be good or bad over a season; they do not know the prices they will receive for their produce; and they do not know whether their crops will be infected by disease (Ofoebu and New, 2021). These risks and uncertainties are not under the control of farmers but some farmers have developed ways of adapting and managing them. Risk disrupts the most crucial decisions of the farming households whose prospects could be to make farming a life business venture. This is one of the reasons which have not allowed investors to benefit from the great potential in agriculture in the developing world. To this end therefore, farmers need to understand climate change phenomena in order to better anticipate problems. They also need to acquire more professional skills especially skills bordering on adaptation and management practices to reduce consequence of climate change.

Considering the adverse effects of climate change on agricultural performance and economic growth, adaptation of management practices should be highly integrated into policy actions of governments geared towards stimulating agricultural production (Ettah and Chima, 2018). This is unarguable because of the important role played by agriculture in food security and poverty reduction in most developing economies. In a twist from being very vulnerable to climate change, agriculture has equally been identified as one of the causes of climate change in recent years. Elum *et. al.*, (2017) held that the traditional and seemingly outdated agricultural methods employed by farmers tend to worsen the incidences of climate change in developing economies. These activities increase the tendencies of greenhouse gases concentrations in the atmosphere which cause global warming. Increase in emissions of greenhouse gases will continue as long as farming and other climate change driven agricultural activities continue in the model of business-as-usual. The commitment made at national and State levels seems inadequate to engender

efficient adaptations of the agricultural sector to climate change scenarios. More importantly, the policy environment required for the development of dynamic agricultural systems in view of the growing climate change seems to be sub-optimal in Nigeria. Weak infrastructural development and inconsistent policies of climate change adaptation of management practices have been identified as major impediments to agricultural development in Nigeria (NEWMAP) (2022). This has remained a major concern to stakeholders in the agricultural sector considering the adaptability of this climate sensitive sector to varying dimensions of climate change.

Both the existing international and local institutions that are available for supporting adaptation and mitigation actions in developing countries like Nigeria fall far short of what is required (IPCC, 2022). The region should enhance institutional capacity to make better use of existing and potential international and local funding sources. This is because as noted by IPCC, (2022); the pathways by which economic and sectorial reforms can influence climate policy depend on the existing institutional framework. With appropriate institutions, a high degree of consistency between development and climate policies can be achieved and without these, there will be considerable conflicting approaches of our farmers towards solving the problem of climate change on their agricultural practices.

The level of climate variability stress or the effects of the shock will depend on what coping strategies are available to the farmers to respond to or buffer the effects. Farmers' ability to perceive the effects of climate variability on livelihood and the farm is a key precondition for the choice of strategies to cope with or mitigate the effects (Ettah and Chiemela, 2018). In order to develop effective adaptation strategies or mitigation strategies that would reduce vulnerability and cope with unavoidable consequences as well as exploit opportunities, a sound scientific knowledge of the country's climate as well as the possible impacts of its variability and changes on the various socio-economic sectors is necessary. According to NBS (2021) the approaches as adopted by all the global and regional climate change adaptation frameworks such as the United Nations Farmers' Convention on Climate Change (UNFCCC), IPCC, the Nairobi framework and recently the World Meteorological Organization (WMO)'s, Global Framework for Climate Services (G.F.C.S) all of which aim at enhancing the weather observation and climate information services capabilities of national meteorological services to better adapt to climate change in their

various countries, should remain the bases of Nigeria's intervention. In this regard, NIMET long historical climate data, some of which span over centuries coupled with its unlimited access to the World Meteorological Organization and enormous global database, constitute an invaluable tool for climate change adaptation in Nigeria especially in the agricultural sector (NBS, 2021). Traditional adaptation strategies have been part of agricultural production systems in Nigeria, however, convergence of unprecedented levels of land use change coupled with increasing climate uncertainty is eroding the resilience of ecological and social systems alike (Echendu, 2020).

The Earth's climate has been undergoing noticeable changes which present major challenges to human existence and development. In Nigeria, climate change, variability and associated increased disaster risks are an additional burden to Sustainable Development Goals. The vulnerability of the developing countries like Nigeria is worsened by heavy reliance on renewable natural resources for livelihoods, employment and income. Agriculture and food security is a sector that is most sensitive to global warming in developing economies like Nigeria, due primarily to the heavy reliance on rain-fed agriculture, thus, the need for conscious adaptation to cope with the changes occasioned by climate change or a long term shift in the climatic pattern of an area as a result of man's activities and natural variability (Ettah and Ukwuaba, 2017).

Effective adaptation to climate change is therefore crucial. It would involve adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Research efforts indigenous to Nigeria, have identified common climate change adaptation measures such as: intensification of irrigation, crop diversification, multiple/intercropping, agro-forestry/afforestation, mulching, use of new crop varieties and livestock species that are more suited to drier conditions, increased seed rate, crop diversification, crop rotation, tree planting, mixed crop livestock farming systems, changing planting dates and use of family labour (Terfa *et.al.*,2019, Abraham, 2018, Elum *et.al.*,2017, Eneji *et.al.*,2020).

Adaptation and management of climate change

In Nigeria, rural farmers are faced with numerous challenges which affect climate change adaptation. Majority of these rural farmers lack the necessary capacity to adapt to climate change, in addition to limited policy response, weak institutional arrangements and poorly conceived interventions not carefully matched to needs. Some of the reported challenges and factors affecting climate change adaptation include but not limited to: land tenure system, access to weather information, cooperative societies, poor infrastructure, access to credit facilities and extension services, educational training and development, access to processing and storage facilities, age, sex, farm size, labour availability and poverty (IPCC, 2022).

Challenges of adaptation according to Ofoebu and New (2021) can include individual or independent adaptations which are measured to be those that take place in response to climatic stimuli (after appearance and expression of early impact), that is, as an issue devoid of supports from any public agency. The authors contended that policy-driven or planned adaptation is frequently understood as being the response of a conscious and deliberate policy decisiveness on the part of a public organization, based on the knowledge and consciousness that situations are about to alter or have been altered, and that reaction is necessary to reduce losses and increase profit from opportunities. Thus independent and policy-driven adaptation mainly tallies to private and public adaptation respectively. As implied, independent adaptation reactions will be assessed by the individual farmers in terms of availability of inputs and outputs. It is predictable that farmer will adapt effectively, and that markets only can strengthen effectiveness of adaptation in exchange to agricultural produce (Weber, 2020).

The cumulative effects of lack of adaptation and management strategies have led to food crisis, water scarcity, high temperature and humidity which often lead to loss of lives and other resources. This is so because climate change exerts great influence on resource use efficiency in agricultural productivity, thereby affecting the income of farmers by reducing the profit they make from their production. Hence investigating the effect of climate change in this part of the world becomes imperative as this will provide realistic information on the changes of major climate elements that affect agricultural production. Experts have averred that understanding the overall effect of climate change on agricultural production is still ambiguous to farmers in this part of the world, because increase in temperature and carbon dioxide can be beneficial for some crops in

some places (Ojoyi and Mwenge, 2018, Abrahm, 2018 and Ettah and Chiemela, 2018). But for such plants to realize that benefit, other factors like nutrient level, soil moisture, water availability and other necessary condition must be met.

Some of the ways to achieve adaptation of management practices according to Uyigüe and Agho (2020): biocontrol and crop rotation to ensure pest control instead of excessive use of pesticides and conservative tillage should be engaged to maintain physical properties of the soil. Also concepts such as climate-smart agriculture (CSA) emerged to bring about an adjustment in agriculture to enhance food production while dealing with the changing climatic conditions and their increasing variability. CSA as a concept, is aimed at helping farmers adjust to climate change and minimize its plausible unfavorable effect on their agricultural activities and livelihoods. The concept focuses on three main goals, which are:

(i) a sustainable increase in agricultural productivity to enhance income levels, food security, and development

(ii) climate change adaptation and resilience from the micro to the macro level and

(iii) a reduction or total removal of greenhouse emissions where possible. CSA as a concept enhances the resilience of agricultural systems by balancing the priorities between adaptation, mitigation, and food security. There are some productivity-enhancing adaptation of management practices adopted by farmers in Nigeria, which fall within the CSA framework. Many farmers, especially those in areas with lower rainfall, have substituted crops requiring a high level of water with those requiring a lesser degree of water for cultivation. Farmers in areas with frequent flooding have shifted to short-cycle crops. Some farmers have moved to crop diversification, changing plant days and mixed cropping, etc.

Theoretical framework for adaptation and management

The theoretical framework suggested by this author is the sustainable livelihoods framework (SLF) to proffer solution to the melee of climate phenomena. It offers a comprehensive perspective on the intricate interplay between climate change, agricultural sector employment, and

sustainable livelihoods (food production) in Nigeria (Ettah and Chiemela, 2018). It takes into account five key types of assets crucial for livelihoods, including human, social, natural, physical, and financial capital. In the context of agriculture, these assets are essential for adaptation to climate change and the sustainability of employment in the sector. Human capital involves the knowledge and skills needed for climate-resilient farming practices, while social capital supports knowledge-sharing and community support. Natural capital encompasses land and water resources that can be affected by climate change, and physical capital includes critical infrastructure for agricultural activities. Financial capital is related to income and access to credit and is vital for investments in climate-resilient agriculture.

Livelihood strategies, vulnerability context, and transforming structures and processes are examined within the framework, emphasizing the importance of adapting livelihood strategies in response to climate change, recognizing external influences, and considering institutional support for sustainable agriculture and employment. The framework's relevance in the context of Nigeria is evident as climate change poses challenges to the agricultural sector. Shifts in rainfall patterns, temperature, and extreme weather events can impact crop yields and water resources, leading to vulnerability among smallholder farmers and disruptions in employment. Government policies and support structures play a significant role in enabling adaptation to climate change and sustaining employment in the agricultural sector.

Effective policies that promote climate-smart agriculture, enhance access to credit, and improve market opportunities are critical for achieving sustainable livelihoods are advocated (Enete, 2018). Transforming the agricultural sector towards climate-resilient practices is essential for safeguarding employment opportunities and overall well-being amidst climate challenges. In summary, the SLF provides a holistic approach to understanding how climate change affects agricultural sector employment and livelihoods in Nigeria. It emphasizes the importance of adaptation and management strategies, institutional support, and the management of various assets to enhance the resilience and sustainability of livelihoods in the face of climate change impacts in the agricultural sector.

Other empirical framework that can be relied upon for solutions to climate change problems in agriculture and the environment may include: the role of meteorological stations in providing

weather information for farming and other agricultural activities is not just desirable but a necessity especially in the developing country like Nigeria where majority of the people are predominantly farmers as stated earlier, who engage in agriculture as a means of livelihood (Enete and Onyekuru, 2019). It is in an effort to deal with the challenges posed by climate change that the Federal Government of Nigeria considered as a necessity, the establishment of meteorological stations across the states and local government areas through the agency known as NIMET (IPCC, 2017). The agency was charged with the responsibility of measuring weather elements, forecasting and disseminating critical weather/climate information through a designated medium such as radio, internet, periodic publications, etc. to the relevant bodies such as farmers. As part of their responsibility, meteorological stations act as a guide to farmer, through the provision of climate change and adaptation information that will help farmers to improve strategies for adaptation in their farming operations. The present government effort at improving agriculture production, will remain a mirage if concerted effort is not made on strengthening NIMET and climate change and adaptation information that will aid farmers in planning and minimizing risk inherent in farming activities that emanate from climate change (NEWMAP, 2022). Some other experts Ofoebu and New (2021), Enete and Onyekuru, (2019), Eneji *et. al.*, (2020), Ettah and Chima (2018) and Elum, Modise and Marr, (2017) in climate change have advocated the following:

- i.. phase out of fossil fuels and leapfrog into renewables in a just and inclusive way: Nigeria could leverage its vast renewable energy potential and pivot from coal, oil, and gas that could engineer to 100 per cent renewables, addressing both climate and sustainable development goals and solar should be set to overtake oil production investment.
- ii. strengthen alignment between biodiversity and climate: Nigeria's biodiversity and natural resources are its strongest allies in the fight against climate change. Nigeria is a frontrunner in delivering nature-based solutions through initiatives such as the Nigeria Forest Landscape Restoration Initiative (NFLRI). Another opportunity lies in the revision and update of National Biodiversity Strategies and Action Plans (NBSAPs) and ensuring climate change is mainstreamed in the NBSAPs. The majority of African countries have submitted revised Nationally Determined Contributions (NDCs) that curb global temperature rise to 1.5 degrees. Strengthening the implementation of these NDCs requires a clearly defined roadmap for effective execution.

Conclusion: Climate change noticeably in temperatures rise and precipitation patterns shift has become a new normal, therefore farmers are facing devastating new challenges such as severe drought, floods, and pest infestations, along with increasing desertification and dwindling groundwater supplies. These shocks come at a time when food production need to be significantly increase to feed the growing human population and curb the ongoing hunger crisis. There is need for a favourable climate as an all important ingredient or input in agriculture, which can only be guaranteed by climate. The effect of climate, a major requirement in agricultural production need not be over emphasized. This is in consideration of the crucial roles of its various elements, especially rainfall, in relation to agricultural production. The post-primary effect of climate change in Nigeria is also raising competition for available resources and extinction of biodiversity. This situation calls for a significant transformation in the agricultural sector to ensure adequate food supplies for increasing demand. It is time more than ever for concerted efforts toward more appropriate agricultural production practices for sustainable food production for the growing population, characterized by economically beneficial, environmentally friendly and socially fair agriculture for providing the nutritional needs of the people of Nigeria, thereby guaranteeing food security.

Recommendations The following are recommended based on this paper review: the surest way to protect agriculture is by phasing out fossil fuels to prevent catastrophic levels of global warming, which is one of the main causes of climate change; there should be a sustained advocacy to farmers for a shift from industrial modes of agriculture that degrade the environment and fuels the climate crisis to regenerative forms of agriculture that rather improve on the ecosystems; governments at all levels should support by way of grants, credit, subsidy, etc. investment in food production that promotes biodiversity; farmers should also be encouraged to engage in climate-smart agriculture (CSA), which emerged to bring about an adjustment in agriculture to enhance food production; there should be technological improvements in agricultural production through genetically modified crops or irrigation systems, climatic conditions and weather patterns.

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