

RESEARCH ARTICLE

Impact of Climate Change on Food Security in Northern Nigeria



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Abstract: Climate change is gradually transforming the globe into a difficult zone of survival for all faunas and floras owing to the existential threat that some changes are causing in the environment. The careless and unguarded activities and detrimental practices of man created a chain of reaction of nature in the surrounding environment leading to the collapse of the green zone and global warming which are all tantamount to undesired repercussions. One of the regions heavily affected by the impacts of climate change in Nigeria, specifically Northern Nigeria. The Northern part of Nigeria is known for many centuries as an agrarian region that is producing sufficient food which sustained the region and supplies Lake Chad and other West African states with food. However, this productive trend was radically reversed owing to many factors with climate change as the prime. This study examines analytically how climate change influences or affects food production and food security in Northern Nigeria. The study used documented sources including books, journal articles, reports, media sources, maps, and charts where applicable for data collection while thematic analytical interpretations were used for data analysis. The study explored the roots of the problem uniquely in the Northern Nigerian context, which is the impact of climate change, and it reveals that the worsening food security crisis in Northern Nigeria affects socioeconomic and political systems in the country resulting in violence, insurgency, forced migration, ethnic and religious clashes, famine, diseases, and malnourishment. The study used the discoveries and findings from the investigation to proffer alternative remedies, models, and practical policy suggestions for addressing the phenomenon permanently.

Keywords: climate change, food security, impact, northern Nigeria

1. Introduction

Climate change is a global threat and a challenge that the world is facing in contemporary times. Changes in the environmental and climatic condition in the 21st century are affecting the mode of living of mankind across the world. Man is boastful of his ability to conquer time and space and demystify his environmental obstacles through innovation in science, technology, and revolution in computers and the internet (Behnassi, 2018). However, the development which simplifies life for a man at the same time is heralded with negative repercussions that are making living difficult in our communities. Climate change is both natural and man-made in nature (Cheshmehzangi & Dawodu, 2019). The unethical practices of mankind in terms of too many activities in industries, pollution, environmental hazards, the release of carbon emission, destabilization of water, encroachment into forests, bushfires and bush burning, excessive rainfall and drought, desertification, and other ecological problems all coalesced into issues that are affecting the ozone layer, stirring seas leading to flooding consequent of melting of glaciers and ice and other harmful practices are all the processes that are causing climate change (Lieberman & Gordon, 2021).

Climate change has several impacts specifically negative on mankind and its environment. Excessive drought and flooding are

causing food scarcity, food insecurity, hunger, and starvation (Parenti, 2018). Pollution is causing several health hazards, and desecration of the ozone layer is leading to excessive burning, heat, and melting of ice which are resulting in rising sea levels that are threatening man's settlement. Millions are pushed toward forceful migration and displacement (Shrivastav, 2019). However, climate change is not left unregulated by mankind. There are tremendous efforts by international key players such as the United Nations (UN), the World Bank, the European Union, G-20, the African Union, and other economically powerful and industrial countries who are pushing for negotiations, agreements, and other measures on regulating such detrimental activities including the substitution of gas emission and other pollution for renewable energy and other actions (The United Nations, 2019). Yet, climate change continues to dominate debates in global gatherings such as the UN and other agencies and its impacts continue unabated.

Although industrial countries released more harmful and toxic substances as well as pollution, developing countries faced the challenges of climate change more. This is due to the low level of technology and the provision of protection measures (Mbaye, 2019). Developing countries bear the brunt, particularly in Africa where bush burning, bushfires, depletion of lakes and rivers, desertification, deforestation, wasteful management of water, and a lower mechanized process of agriculture are affecting the countries in the continent (Mbiyozo, 2021). Nigeria is one of the countries that is suffering heavily from climate change being one

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of the sub-Saharan countries with a high tendency for unpredictable weather and climate. Climate change has many effects on Nigeria, but food security is the most annoying. Nigeria relies on subsistence agriculture with over 90% of it depending on natural sources of rainfall for farming (The United States Agency for International Development, 2019a). The effects of climate change are creating food scarcity coupled with other complementing factors such as insecurity and harmful practices that affect Northern Nigeria more than any other part of the country because it is a farming region in which about 70% of the farmers are depending on rainy season for their cultivation but the volume of rainfall is gradually declining. This is resulting in food insecurity, hunger, and other economic crises (Future Learn, 2021).

The effects of climate change affect negatively the trend of cereal production in Nigeria in 2022. Excessive floods, high costs of production such as fertilizer and chemicals, and conflicts declined productivity by over 40% in the 2022 season in the country (Relief Web, 2022a). In 2022, 12,000 tons of maize, 8,000 tons of paddy rice, 6,500 tons of sorghum, and 2,000 tons of other cereals were produced (Food and Agriculture Organization of the United Nations, 2022b). This indicates an average decline in percentage of 3.5 compared to 2021. FAO (2022a) reports that in 2022, around 33 countries in Africa faced food insecurity from floods, droughts, conflicts, and other climate-induced factors. This affects about 38 million Africans who are facing acute shortage of food and needs a critical external intervention. The cereals production in the 33 countries of Africa studied declined by an average of 4% leading to scarcity and above the global average of 2% (Food and Agriculture Organization of the United Nations, 2022c).

This chapter explored critically the impacts of climate change on food security in Northern Nigeria. Nigeria emerged as a state from the vicissitudes of history-making after the various independent states were forcefully merged by Britain for the convenience of colonialism. The Northern and Southern Regions and Colony of Lagos were later subdivided in post-colonial Nigeria into state and local governments alongside the Federal Government. Nigeria is a multi-ethnic society with over 400 ethnic groups but three dominant ones of Hausa/Fulani, Igbo, and Yoruba and two dominant religions of Christianity and Islam (Campbell & Page, 2018). With a projected population of 206 million from the 2006 Population Census, 36 States and 774 Local Governments, Nigeria is subdivided into North and South. The North occupies 80% of the total land giving it an edge in agriculture while the South possesses crude oil in the Niger Delta which accounted for over 70% of Nigeria's foreign exchange and the Lagos seashore which hosts cargoes and ships from international waters and which linked Nigeria to Atlantic Ocean (Siollun, 2021). There are numerous agricultural policies in the country, but they are yet to proliferate a reliable agricultural output that will absorb shocks and unforeseen circumstances emanating from climate change to guarantee food security. This study, therefore, is an effort in a policy-oriented investigation which is structured into the background, nature of climate change, climate change, climate change in Nigeria, and climate change and food security in Northern Nigeria. In doing so, the chapter consulted documented sources of data in which a textual analysis of the collected data was made critically using content analysis for discussion. The study presented some alternative models for practical policy implications that are plausible to avert disaster of food insecurity and hunger in future.

2. Method

The study used a qualitative research design where documented sources were consulted for data collection. These sources consist of books, journal articles, reports, internet sources, and data from

institutions and organizations. The justification for adopting this method is the nature of the topic which is broad and practically difficult to cover using other methods such as interview and questionnaires, the insecurity in the area of study which made data collection unsafe for the researchers and financial constraints. The data collected were discussed, analyzed, and interpreted using thematic analytical expressions where some themes were identified and issues were discussed under them.

3. Nature and Trends of Climate Change

Climate change is the set of activities of mankind and nature which lead to emissions of billions of tons of CO₂ from industries and other related sources. Climate change is associated with global warming, extreme increases in temperature, air and water pollution, flood, drought, irregular rainfall, health hazards, deforestation, desertification, forceful migration, and displacement (Siegel, 2020). Gaseous emissions, biofuels, melting of ice, increasing fluctuation in water atmosphere and water vapor, and bushfires are all affecting negatively our environment putting intense pressure on natural resources (Goel et al., 2019). The consequences are global warming and climate change that are threatening the survival of mankind, aquatic animals, wildlife, and forestry and their environment (Akhtar & Palagiano, 2017). For many years, evidence of climate change is revealed by Intergovernmental Panel on Climate Change (IPCC) and many other scientific researchers. The major changes that are reported include an increase in water temperature, ocean currents, ice melting, changes in rainfall leading to severe scarcity of drinking water and flooding, and desert encroachment. The meteorological weather stations of nation-states, worldwide projects of the International Geophysical Year, the Global Atmospheric Research Programme, and the Global Climate Observing System are all research-based sources that provide valid and scientific data on climate change (Bush, 2020).

Central to the drivers of climate change are actions of mankind, natural disasters, harmful practices, and unethical operations. Climate change is fueled and escalated by the release of industrial waste which emits billions of gaseous and other harmful substances, pollution in both air and water, bushfires, bush burning, flooding, drought, increased penetration of industrialization, and increased usage of automobiles and other machines globally, pressing energy consumption and expanding technology (Woodward, 2021). Naturally, climate change is triggered by solar radiation, volcanic activities and their associated emissions, meteorites, and acceleration of the natural greenhouse emanating from the anthropogenic activities that enrich the atmospheric concentration of greenhouse gases (GHGs), which are all natural causes of climate change (Mal et al., 2018). Electromagnetic radiation, the greenhouse effect, geographical and seasonal variations in energy balance, and the earth's radiation balance are also considered natural causes of climate change and global warming. But the actions of man in terms of stressing the ecosystem are doing more harm to the environment as observed above (Lomba et al., 2019). The USA and China only contribute 38% of the emissions globally, yet the USA under President Donald Trump decided to exit the agreement on regulations of global warming and climate change. Although Biden's Administration restored the States in the agreements, the USA as a global leader in the emission should not be seen as foot-dragging in proffering measures to counter the problem (Prager, 2020).

Global climate change is one of the most daunting challenges that the 21st-century world is facing. It is a process that is leading to the depletion of soil reserve and quality, greenhouse effects, and global warming leading to a decline in food production and health hazards in man's environment because it has the potential to trigger risk for human security in terms of water, food, health, and livelihood

security (Morel, 2020). Climate change also has several implications for global water supply, food security, health, migration, and other factors. Climate change is exacerbating pressure on global resources making millions of global inhabitants vulnerable to insecurity, and depletion of water, lakes, rivers, and natural reserve, thereby impacting agricultural productivity and energy consumption (Thomas, 2019). Global warming affects the cryosphere leading to ice melting, the rise of the sea above the anticipated level, the retreat of Arctic sea ice, and changes in glaciers. The ocean is affected in many different ways including changes in sea level, changes in sea salinity, and changes in dissolved carbon dioxide and ocean acidification in the same way the biosphere is influenced by climate change in many ways such as migration in the North Atlantic, coral bleaching, and ocean acidification (Sarkar et al., 2019).

The effects of climate change resulted in prolonged global warming, precipitation and drought, scarcity in water supply in many communities from the depletion of lakes and sea drawback, severe storms and tsunamis, and security threats for mankind. Climate change is creating a huge gap in the food supply globally (Sarkar et al., 2019). There is an increasing difficulty in feeding the nearly 8 billion humans on earth currently. Meeting food security is already a serious challenge around the globe because of the effects of climate change. While the environment is pressurising for an increased yield in agricultural productivity, a decline is recorded emerging from global warming activities. The Food and Agriculture Organization (FAO) projected that to meet food demand for all mankind in the year 2050, the annual world production of crops and livestock will need to be improved by 60% more than what was produced in 2006. In developing countries particularly in Africa, about 80% of the above-required improvement should come from an increased yield which is highly challenging and seemingly difficult to surmount presently (Oliveira et al., 2019). The developing countries will suffer most from the effects of climate change than other parts of the world because it has other human security threats in the region. Climate change may directly link soon with security threats and conflicts in Global South (Morano, 2018). Food production would be affected by climate change in future. For instance, by the year 2080, the production of cereals will decline by 2.2% according to FAO (Oliveira et al. 2019). Climate change is a serious threat to agriculture globally and the impact is palpable more in developing countries such as sub-Saharan Africa which nearly 70% of its population relies on peasant farming (Anyorigya, 2022). The alteration in temperature, rainfall, drought, and floods is affecting agricultural productivity in countries like Nigeria leading to issues of food security. In Africa, climate change is compounding the already harsh weather of the arid and semi-arid land resulting in drought which causes famine, economic hardship, mass migration, conflict, and death (De Blasi, 2019).

The international community responded positively to the challenge of climate change and global warming in many approaches and stages. The first effort was a Conference which was held on the environment in 1972 titled "The United Nations Conference on the Human Environment (UNCHE)" which awakened the consent of the global key players in environmental protection and policies. The outcome of the Conference was the formation of the IPCC from the Montreal Protocol spearheaded by the UN in 1987 (Fleming, 2019). The major concern of the 1987 agreement was a reduction in the industrial chemicals that are puncturing the ozone layer. The United Nations Framework Convention on Climate Change (UNFCCC) of 1992 later followed which came into action in 1994 to stabilizing GHG emissions at a level that would prevent dangerous anthropogenic interference with the climate system (Jahren, 2020). For the actualization of this goal, the Kyoto Protocol was signed in 1997 in Japan. Under the terms of the Kyoto Protocol, the parties or

negotiating states agreed to make cuts in carbon emissions measured from 1990 levels (Singh, 2018). The Protocol suffered a setback when the USA refused to sign the attempt in 2001 while Canada withdrew in 2011. The Protocol also neglected mandatory cuts in emissions in emerging economies like China, Brazil, and India which later became some of the major forces of emissions and global warming. Still, the UN is further pushing for a more decisive agreement and commitment from the industrialized countries to cutting emissions and other less harmful practices (Emanuel, 2018).

4. Climate Change and Food Security: A Global View

Climate change is correlated with the food security crisis in the contemporary world because food productivity is directly affected by changes in biodiversity, global warming, increased flood, drought, desertification, and bush farming from the effects of excessive emissions of gaseous substances and other detrimental practices. It is recommendable that since 1961, food production is increasing significantly by about 30% facilitated by the revolution in nitrogen fertilizers which increased by 800% and the expansion of water resources for irrigation and dry season farming by more than 100% (Mbow et al., 2020). As of 2015, about 800 million people are chronically undernourished. A projected 161 million children under 5 years are malnourished. Furthermore, 500 million people are obese. Two billion people suffer from inadequate essential micronutrients for their health safety. FAO estimates that to satisfy the growing demand driven by population growth and dietary changes, food production will have to increase by 60% by 2050 (Food and Agriculture Organization of the United Nations, 2015).

From 2015 to 2019, an improvement in food production and food security was recorded. However, despite a tremendous improvement in food production globally, an estimated 821 million are malnourished, 151 million children below the age of 5 are famished, 613 million females gender aged 15–49 face the threat of deficiency in iron, and 2 billion adults are overweight or obese (Mbow et al., 2020) while at the same time, about 1 billion are undernourished (Sova et al., 2019). Food security crisis is escalated by both climatic and non-climatic factors. Apart from climatic changes, population bulge, income variation, and excessive demands for animal-sourced products contributed to the food scarcity that the world is facing currently. Climatic factors affect food productivity and food supply through low crop yields such as maize and wheat in lower latitude regions. Global warming caused drying in the Mediterranean region affecting productivity and food supply in the region. Climate-induced factors such as floods and drought are causing food insecurity in the drylands of Africa and peak mountains of Asia and South America (Yadav et al., 2019).

Global food production continues to decline emanating from the hazardous impacts of climate change. Some estimates predicted that but for proper adaptation, global food production could decline by 30% by 2050. Countries such as sub-Saharan Africa that are battling conflicts, deforestation, bush burning, flood, drought, and other environmental hazards may suffer the effects more. The 2 billion people without adequate food currently would suffer more and the number may likely increase (Hobert & Negra, 2020).

Climate change between 1981 and 2010 has reduced global mean yields of maize, wheat, and soybeans by 4.1, 1.8, and 4.5%, respectively. Areas that are identified as dry lands are vulnerable to the risk of climatic factors induced food security issues because they have low capacities for climate resilience strategies in measuring up declining crop yields and they constitute 40% of the earth's land area also home to 2.5 billion people (Mbow et al., 2020). In Asia, crop

yields, especially wheat decreased by 5.2% in 30 years from the 1980s in India and agricultural productivity in China, Pakistan, and other parts of Asia, are steadily declining despite improved technological methods due to climate change impacts. Climate change is affecting crop yields in South America and Africa, particularly Nigeria where climate change is having an impact on the livelihoods of the arable farming population (Mbow et al., 2020). The Global Hunger Index reported that “climate change is a threat multiplier for hunger, destroying livelihoods, driving displacement, widening social inequalities, and undermining sustainable development” (Global Hunger Index, 2021). If climate change can decrease food production, then it can decrease access to food also. This directly established a correlation between climate change and food security globally. It is indisputable that carbon emission and other toxins such as methane will continue to diminish the arability and fertility of the land and by extension, food productivity, and it is also observed in the long run that carbon dioxide will have a positive impact on arable lands in future (Chandio et al., 2022).

Despite the reported improvement in crop yields in some parts of the world, global warming recorded at an average of 1.5°C since the mid-1800s during Industrial Revolution. The impacts of climate change on agriculture in highly technologically advanced countries are mitigated by resilience cropping and farming strategies. Specifically, the strong Asian economies are witnessing an improvement in food production emanating from the adoption of Agri-Tech and resilience strategies (Chandio et al., 2022). In places like sub-Saharan Africa, agriculture engages a larger percentage of the population employing 80% of rural people (Sova et al., 2019). Farming in these areas is vulnerable to high risks of climate change with low-quality fertilizer, lack of access to improved technology, and modern strategies of farming exposing the inhabitants to food insecurity, this explains why about half of the world’s hungry people are from this zone. The United Nations World Food Programme indicates that 80% of the people affected by hunger in the world are from places that are vulnerable to natural disasters, environmental degradation, and other climate change factors (Sova et al., 2019).

Climate change affects food security in many ways. The high concentrations of carbon dioxide in plants reduce their protein, zinc, and iron content. By 2050, an estimated 175 million people could develop zinc deficiencies. An estimated 122 million people may suffer from protein deficiency. Climate change also affects the quality of livestock, which rely on the same resources as humans to eat, grow, and produce meat, eggs, and milk. Cattle, goats, and other livestock accounts for 36% of all drought-related losses with crops making up 49% of the total losses. Likewise, climate extremes threaten fish populations, especially in areas like Southeast Asia (Concern Worldwide, 2022). FAO further reports that climate change induced food wastage. About one-third of the food produced by farmers is wasted between the farms and the market in developing countries. The food system is currently contributing about 21–37% of GHG emissions meaning that food losses are adding to the climate crisis without abetting food insecurity or malnutrition (Concern Worldwide, 2022). In 2017, extreme weather events caused worldwide economic losses of \$326 billion (Von Braun, 2021).

Food security is an outcome of the food production system (Mbow et al., 2020). Climate change affects food security in four ways: availability, access, utilization, and stability (Mbow et al., 2020). Food security is a term that refers to the accessibility of individuals, families, and communities to eat adequately both quantitatively and qualitatively as standardized by calorie, protein, and vitamin intake. For food security to be actualized, it must be accessed and for food to be accessed, there must be availability and stability (Ashley, 2016). Food insecurity is measured through

some determinants or variables hierarchically composed of availability, access, and utilization. Availability is measured through the national population level and agricultural output. Access is determined by the quality and quantity that individuals, households, and the community consumed daily and within a specific period of data gathering while utilization is measured by the ability to acquire the minimum sufficiency of dietary combination (Ashley, 2016). However, risks of food insecurity or lack of access and availability are heralded by chronic poverty and other factors. For instance, the UN 2015 reported that about 836 million people are in extreme poverty spending less than \$1.25 per day making it difficult for this category to access food in sufficient quantity even where it is available (Food and Agriculture Organization of the United Nations, 2015).

Africa, particularly sub-Saharan African states, is the worse hit by food insecurity. The majority of the African population relies on subsistence agriculture which accounted for 3% and 45% of the Gross Domestic Product (GDP) of many countries in the region and a continental average of 30% of GDP in 2017 (Africa Group of Negotiators Experts Support Policy Brief, 2020). Climate change has direct impacts on the food system and food security in Africa including nutrition, and the deployment of technology-based food production systems. In recent years, crop production yields decreased in Africa such as maize, wheat, sorghum, and fruits. The situation emerged from climatic factors including flood, drought, deforestation, bush burning, depletion of Lake Chad in the Sahel, and other related factors. The repercussions of food shortage accentuated by climate change are malnutrition in Africa, hunger, resource conflicts, and illegal cross-border migration. Nigeria is the most affected with the highest population and heavily dependent arable crop farming inhabitants (Africa Group of Negotiators Experts Support Policy Brief, 2020). In this regard, African states can take a leaf from the practices of the ASEAN states by integrating financial development in countering climate change and improving agricultural productivity (Chandio et al., 2022). Because the agricultural sector has the highest vulnerability to climate change compared to other sectors, sustainable resilience strategies are necessary to promote national economies because the short-term and long-term effects of climate change on cereal crops and other agricultural commodities can be countered through strategies of adaptation and resilience as revealed by a study with Turkey as the case study (Chandio et al., 2021).

Climate change induced food security threats in Africa in many ways. About 39 million people have been pushed into chronic food shortage due to climate-related events in 2018, and another 74 million faced the risk of food insecurity from conflict driven by climate factors such as competition and struggles over resources by farmers and herders, specifically in the Horn of Africa, the Sahel, and Central Africa (Ogunrotimi & Kayode, 2018). Currently, in Africa, the average cereal yield stands at 1.6 t/ha, making it less than half the global average of 3.9 t/ha. The average maize yields in sub-Saharan Africa presently are within 15–27% of their potential 11. By 2050, climate-related yield losses in sub-Saharan Africa are estimated to be around –22% (maize), –17% (millet and sorghum), and –8% (cassava) (Von Braun, 2021). Climate variability such as floods and drought will subject Africa to the vulnerability of food insecurity as reported by the World Meteorological Organization in 2019 and 2020. Floods may likely wash farmlands, destroy croplands, and reverse average food products which may cause hunger and food sufficiency problems (Schlein, 2020). Environmental and Energy Study Institute (2017) reported that climate change has the potential of aggravating food insecurity in Africa because the zone is currently malnourished. Africa added Environmental and Energy Study Institute (2017), which has 70% of

its population as subsistence farmers, and the population is projected to grow by 4 billion up from 1.2 billion (an increase of 70%) by 2080 amidst global warming and declining food production. This portends danger to food security in the region (Environmental and Energy Study Institute, 2017). In sub-Saharan Africa, climate change could decrease GDP by up to 3% by 2050. This presents a serious challenge for climate adaptation and resilience actions because not only are physical conditions getting worse but also the number of people being affected is increasing (The World Meteorological Organization, 2021).

To avert a food security crisis in future, the FAO projects that there is a need to supply at least 50% more of the current production by 2050 to meet up the challenge of population bulge and increasing food demand. This will enhance a substantial increase in GHG emissions and similar environmental effects including a decline in biodiversity. FAO predicts that cropland area will increase in 2050 by 90–325 Mha more than the 1567 Mha, an increase of between 6% and 21% of cropland area in 2010, relying on the climate change phenomenon and unfolding developments in the future (Mbow et al. 2020). Despite the global commitments toward eradicating hunger and food insecurity, the trend escalates tremendously. According to the State of Food Security and Nutrition in the World report, there are 750 million people suffered food insecurity in 2019 and the number of undernourished people in the world is continuously raising (Hobert & Negra, 2020). Hobert and Negra stress that some sustainable practices and adaptation methods may counter the trend positively. Some of the practices consist of reducing food loss and waste which account for 8% of GHG emissions globally, agroforestry which can cut emissions, better soil management, and restoring degraded farmlands (Hobert & Negra, 2020).

5. Perspectives on Climate Change and Food Security in Nigeria

Nigeria, like other states, is not exempted from the debilitating effects of climate change, particularly in the realm of food security challenges. Evidence in increased temperature, rainfall variation seasonally, rise in sea level and flooding, drought, desertification, land degradation, and loss of biodiversity resulting in declining farming output all point to climate change impacts on Nigeria (Haider, 2019). Climate change variation is observed in Nigeria with increasing rainfall and rising sea level and flooding in the South and drought and other rising temperature in the North. This is precipitated by the drying of Lake Chad currently at risk of extinction (Haider, 2019). The North is reported (Ignatius, 2016) as more vulnerable to climate change than the South. The Northeast and Northwest are more susceptible to climate change impacts than other zones in the country (Abdulkadir et al. 2017).

Nigeria has no uniform climatic condition or projection, particularly between the tropical rainforest South and the Savanna North. Nigeria has nine different ecological zones including arid zones, lowlands, plateau, tropical south, and intermediate central Nigerian climate. In Southern Nigeria, average temperatures range from 17 to 37°C while in the North the average temperatures range from 12°C to 45°C. The annual average rainfall in the South is measured at 3,000 mm while it is 500 mm in the North. The rainy season in the South is usually experienced between February and November while in the North it is between April and October (United States Agency for International Development, 2019a). With a population of 214, Nigeria's GHG emissions are 2.72% and the forested area is 7.20% (The United States Agency for International Development, 2022). Historically, the Nigerian climate experienced changes from 1960 to date. An increase of 0.8°C temperatures is

recorded from 1960 to 2006. This increase affects the North more than the South. A decrease of 3.5 mm per month in each decade from 1960 to 2006 is recorded in precipitation across the country (World Bank Group, 2021). The future climate projections in Nigeria portray a rise in temperatures of 1.1–2.5°C by 2060 with extreme heat anticipated in the North. The number of extreme heat days increases projection discloses 260 days by 2100 up from only 10 days in 1990. A significant reduction in the number of cold days and nights is estimated at near zero by 2090. Rainfall unpredictability and variability are likely to escalate in an unconfirmed number, and a rise in sea levels by 2100 will hit 0.4–1.0 m (The United States Agency for International Development, 2019a).

The major causes of climate change in Nigeria include natural hazards and man-made causes. The natural hazards consist of volcanic eruptions, floods, drought, rising sea levels, rainfall variability, and increased heat. The human activities that caused climate change in Nigeria include GHG emissions from vehicles like sulphur dioxide and carbon monoxide from their exhaust. Other factors are the burning of hydro-carbon substances releasing carbon dioxide and gaseous substances into the atmosphere, deforestation perpetuated in bush burning, firewoods cutting, and industrial emissions. Another cause is gas flaring and environmental degradation in the Niger Delta facilitated by activities of oil companies accompanied by oil spillage and contamination of water resources and farming lands (Future Learn, 2021).

Climate change has sectoral impacts on Nigeria. In agriculture, the country is populated by 70% subsistence farmers who relied solely on farming to survive. Agricultural produce in Nigeria has rain as its mainstay of sustenance. Unpredictable rainfall variations affect farm produce and agricultural outputs across the country (Onwutuebe, 2019). Higher temperatures, low rainfall, drought, flood, desertification, rising sea levels, and erosion erode farmlands and reduce agricultural productivity (Fasona et al. 2018). In the aquatic sector, climate change is affecting freshwater resources rising sea level and increased sea salinity is affecting fishing in Nigeria (Ebele & Emodi, 2016). Food production is affected by unpredictable rainfall and drought which is causing food security challenges (Haider, 2019). Erosion is threatening to wipe out a wide land of forest while extreme weather such as heat waves is causing health risks among Nigerians (Abdulkadir et al. 2017). The Nigerian economy is affected negatively by climate change because agriculture is an important contributor to the GDP and declining productivity means falling revenue and economic activities (Haider, 2019).

Climate change is also projected to affect the energy supply and stability in Nigeria. The limited electrical supply is sometimes affected by high temperatures while the use of firewood is causing a rapid encroachment into the Nigerian forests leading to desertification (Ebele & Emodi, 2016). For instance, in the first and second quarters of 2022 alone, the national grid collapsed more than seven times (reference recent). Climate change impacted security risks because the changing environment is causing resource conflict including farmers–herders clashes and ethno-religious crises in a bid to compete over scarce resources (Sule et al. 2022). The depleting Lake Chad is setting herders against farmers in Nigeria while in the Northwest, it is causing increasing bandit activities (Beyioku, 2016). Climate change is generating migration from and outside Nigeria both legal and illegal further stressing and straining the scarce resources and dwindling infrastructure (Olaoluwa et al., 2019).

There is scientific evidence to establish a correlation between climate change and food security in Nigeria. FAO (2019) reports that the prevalence of malnourishment in Nigeria exists and increasing from 6% in 2006 to 13.45 in 2018. The Global Hunger

Index (2021) reports 31.6% of Nigerian households faced food scarcity in 2020. The link between food shortage and climate change is established in rising temperatures and declining rainfall directly attached to low food production. This is evident in a report by World Bank Group (2021) that the yearly temperature means increased to 27.8% in 2016 from 26.8% in 2000. Kralovec (2020) and Ani et al. (2022) argue that food shortage motivated by climatic changes has the consequences of human security threats as manifested in the displacement caused by the Boko Haram insurgency, farmers–herders clash, and banditry in Northeast, Northcentral, and Northwest, respectively. The Federal Ministry of Agriculture reported that 65% of Nigerians are food insecure (Ogunpaimo & Surajudeen, 2021). Ogunpaimo & Surajudeen (2021) further emphasize that negative environmental influences such as erosions and floods are responsible for the food insecurity of most of Nigeria’s population. This is directly interpreted as the impacts of climate change in causing food insecurity as Figure 1 (Shiru & Park, 2020) and Figure 2 (Nabegu, 2023) shown.

The ND-GAIN 2019 Vulnerability Index reported Nigeria as 129th out of 187 countries in terms of vulnerability to the negative effects of climatic events. By 2018, Nigeria lost an estimated 30–40% of food valued at \$750 million annually. This stressed the Nigerian economy by pushing for food imports which rose to over N951 billion in 2020 (Premium Times, 2021). In essence, estimated research by Christian Aid revealed that climate change may cost many world countries about 64% of their GDP and Nigeria is listed among them (Premium Times, 2021). The figure spent by Nigeria

Figure 1
Nigeria’s climatic conditions

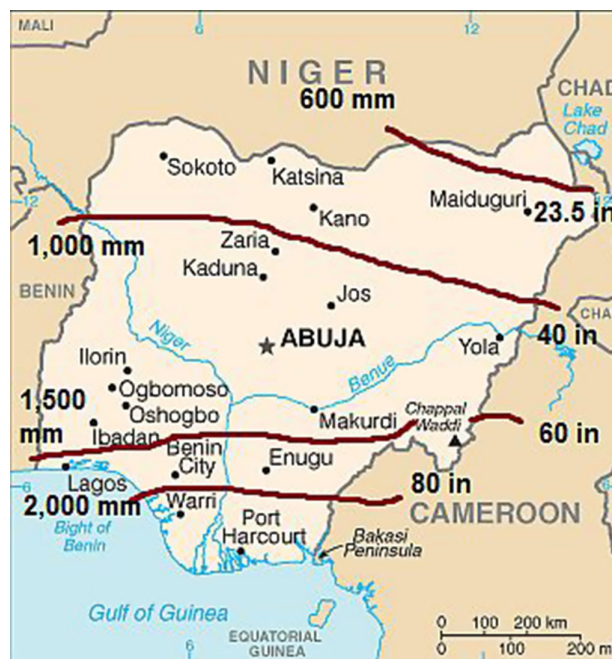
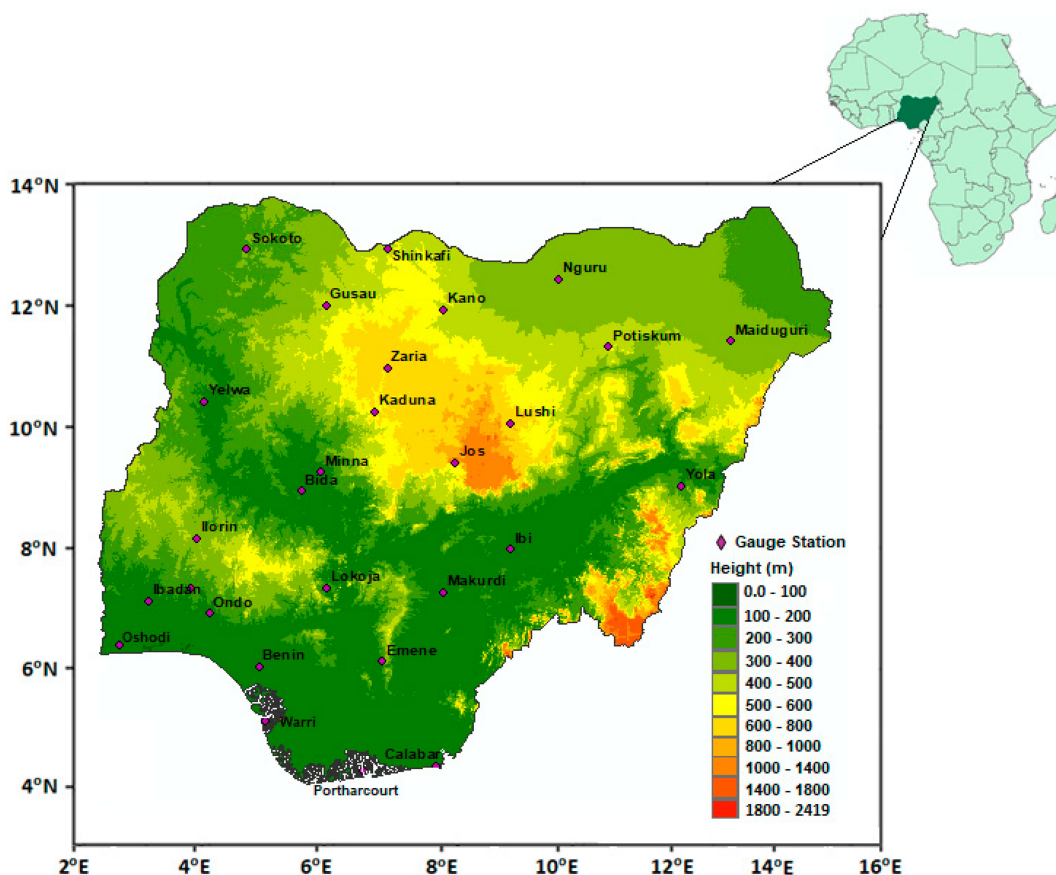


Figure 2
Average annual rainfall in Nigeria



on importing food to meet up with the low agricultural productivity is continuously alarming and is straining the economy. Nigerian President Muhammadu Buhari reiterates that Nigeria could not afford to continue to import food because of the economic impacts (Leddy, 2020). For instance, Nigeria spent \$5 billion of the \$35 billion Africa pays annually for food imports (Leddy, 2020). In 2018 alone, 25% of Nigerians were undernourished. The annual average demand for wheat is 3 million tons, but only 100,000 tons is produced in the country due to climatic factors and antiquated techniques of farming. This is because Nigerian farmers continue to rely on rain-fed agriculture leaving crop yields to unpredictable natural vulnerability (Leddy, 2020). The above statistics glaringly exhibit food insecurity among the majority population in Nigeria meaning urgent adaptation and resilient methods are paramount immediately to counter hunger and starvation disasters.

Other factors closely related to climatic factors that affect food production in Nigeria are fertilizer application. Nigeria consumed 19.6 kg per hectare in 2020 and 2021, but it is projected that the 2022 consumption declined due to the soaring price of fertilizer and the high cost of living (World Data Atlas, 2022). The pesticide usage in Nigeria indicates that only 41% of farmers are applying the products while it is discovered that 80% of the pesticide applied in Nigeria by farmers are fake (Rahman & Chima, 2018). The elements or nutrients that determine groundwater quality are present at concentrations below the respective WHO health-based guideline values (World Data Atlas, 2022). Regarding Nigeria's agriculture waste, Rhoda Dia, project manager in charge of the food security project at the United Nations Development Programme (UNDP), noted that Nigeria's palm oil production industry alone generated over 90 million tons of effluent (liquid waste) annually, while an estimated 19.5 million cows also generate a large amount of waste. Dia added that Africa's largest rice producer generates 4.34 million tons of rice straw and 900 thousand tons of rice husk (Food and Agriculture Organization of the United Nations, 2022c). Thus, if Nigeria utilizes its waste products for agricultural productivity, it will generate additional food production that will remedy the food gap created by climate change.

Nigeria responded to climate change adaptation and resilience in many ways using policies, action plans, and international collaboration. For instance, the Nigerian Government approved the National Policy on Climate Change (NPCC) in 2013. The objectives of NPCC are to achieve low carbon and sustainable adaptation and resilience strategies practically operative domestically. Nigeria is also a signatory to the UNFCCC and the country ratified the Kyoto Protocol in 2004 (The United States Agency for International Development, 2019b). In 2012, Nigeria became a voluntary member of the United Nations Environment's Climate and Clean Air Coalition to stem climate pollutants in ten sectors. In 2015, the Nigerian Government reiterated its stance with the Paris Agreement presenting Nigeria's Nationally Determined Contribution after a pledge to decrease GHG emissions by 45% conditionally by 2030 (The United States Agency for International Development, 2019b). Additionally, the Nigerian Government is ever committed to utilizing renewable energy and the country is making efforts in introducing techniques of adaptation and resilience to farmers including ethical practices and new resilient varieties of crops (The United States Agency for International Development, 2019b). However, despite the stupendous efforts by the Nigerian Government, it is facing challenges in mitigating climate change effects of gas flaring, the low substitution of non-renewable energy, transportation, afforestation, and climate-smart agriculture strategies (Adeleke et al., 2019; Climate Action Tracker, 2022). The Climate Change Act was reviewed in 2021 introducing some measures and new changes. In essence, the Climate Change Act 2021 is the most comprehensive law in West Africa demonstrating Nigeria's seriousness

in tackling climate change effects. The Act set a net-zero target for 2050–2070 (Ladan, 2022).

6. Impact of Climate Change on Food Security in Northern Nigeria

Climate change is palpable in Northern Nigeria, and it has astounding effects on agricultural productivity and food security. It is observed (The United States Agency for International Development, 2019a) that the temperature in Nigeria varies between the North and the South at 12–45°C for the North and 17–37°C for the South, respectively. The annual average rainfall in the North of 500 mm is far below that in the South of 3,000 mm indicating that the North is more prone to climatic conditions than the South. Likewise, the length of the rainy season in the South stretches from February to November while in the North is from April to October (The United States Agency for International Development, 2022). Climate change is scientifically established in Nigeria by an increase of 0.8°C from 1960 to 2006. A decrease of 3.5 mm per month in each decade from 1960 to the 2000s is noticed. The report further indicates that the North is affected more than the South (World Bank Group, 2021). Future climate projections in Nigeria are pegged at a temperature rise of 1.1–2.5°C by 2060 with extreme heat anticipated in the North. The number of extreme heat days increases projection discloses 260 days by 2100 up from only 10 days in 1990. A significant reduction in the number of cold days and nights is estimated at near zero by 2090. Rainfall unpredictability and variability are likely to escalate in an unconfirmed number and a rise in sea levels by 2100 will hit 0.4–1.0 m (The United States Agency for International Development, 2019a).

Agriculture contributed between January and March 2021 to the Nigerian GDP by 22.35%. An estimated 70% of Nigerians are engaged in the agriculture sector and are mainly at a subsistence level. Amidst its contribution to the economy, Nigeria's agricultural sector faces many challenges which affect its productivity. These factors include poor land tenure system, low level of irrigation farming, climate change and land degradation, low technology, high production cost and poor distribution of inputs, limited financing, high post-harvest losses, and poor access to markets. These challenges have stifled agricultural productivity affecting the sector's contribution to the country's GDP as well as increased food imports due to population rise, hence declining levels of food sufficiency. For instance, between 2016 and 2019, Nigeria's cumulative agricultural imports stood at N3.35 trillion, four times higher than the agricultural export of N803 billion within the same period (Food and Agriculture Organization of the United Nations, 2022a).

Nigeria has a total estimated arable land area of about 70.8 million ha. About 43 million ha (60.23%) are being cultivated, with a low incidence of irrigation farming. Nigeria's climate motivates the variability of crop production across the two regions. The Northern area which experiences sparse rainfall cultivates more grains such as rice, millet, cowpeas, guinea corn, maize, and yams, while the Southern areas grow more roots and tubers such as cassava, plantain, yams, and cocoyam in addition to oil palm, maize and rice (Chiaka et al., 2022). But this has been contradicted by another report from the President of the Country. In the report, due to climatic conditions such as drought, flood, and low level of capacity for enhanced irrigation systems, Nigeria is only able to cultivate 2.5% of its arable land. This was disclosed by President Muhammadu Buhari during the Idel Kabir festival in 2021 while expressing shock and frustration with the low yields and productivity (Channel Television, 2021). This level of food production is not enough to feed the country and this is interpreted as a food security challenge.

The North has a total population of 115,560,000 (54%) while the South has 98,440,000 (46%) (Chiaka et al., 2022). This means the North needs more food than the South, but the North is poorer and has less food security than the South. The North has 75% poorer households than the South 25% despite the North having a landmass that constitutes 80% of the total landmass in the country as against the South 20% (Chiaka et al., 2022). The North has a total land area (ha) of 73,088,500 with the South at 19,377,700 land area (ha) as observed by Chiaka et al. (2022) meaning that the North has the most land for cultivation of crops, particularly maize, wheat, rice, sorghum, millet, groundnut, beans, vegetables, and other staples. The study by Chiaka et al. (2022) further reveals that food consumption per household in the South is more than in the North and the level of food insecure households in the North is more than in the South. The explanation behind low consumption in the North may not be linked to the level of productivity but other factors including poverty, conflicts, and inequality, and most of the arable land in Northern Nigeria is uncultivated as examined above due to the low level of irrigation emanating from the low level of the rainy season in the North, floods, drought, desertification, erosion, and deforestation.

Nigeria's rice production rose from 3.7 million metric tons in 2017 to 4.0 million metric tons in 2018. In spite of this, only 57% of metric tons of rice consumed in Nigeria annually is locally produced leading to a deficit of about 3 million metric tons, which is either imported or smuggled into the country illegally. To stimulate local production, the Government banned the importation of rice in 2019. As for cassava, Nigeria produced 59 million tons in 2017, making it the world's largest producer, with approximately 20% of global production. Animal production has remained underexploited. Livestock mostly reared by farm families in Nigeria are the small ruminants like goats (76 million), sheep (43.4 million), and cattle (18.4 million). The ecology in the Northern part of the country makes it famous for livestock keeping. In addition to small and large ruminants, the poultry population stands at 180 million poultry. Here too domestic demand outweighs production (Food and Agriculture Organization of the United Nations, 2022a).

A study (Sedano et al., 2020) on a land use map focusing on the 2015 agricultural landscapes in northern Nigeria reveals the extent of land use and agricultural productivity. The map provides up-to-date information with a high level of spatial and thematic detail, resulting in a more precise characterization of agriculture in the region. The map reveals that agriculture is the main land use in the region engaging about 65% of the Northern population mostly populated by rural areas. Arable land in Northern Nigeria represents on average 52.5% of the area, which is higher than the reported national average of 38.4% for Nigeria. Irrigation farming covers nearly 2.2% of the total area, reaching nearly 20% of the cultivated land when traditional floodplain agriculture systems are included, which is above the reported national average of 0.63%. There is significant variability in land use in the region (Sedano et al., 2020). The study (Sedano et al., 2020) reveals that crop yields in Northern Nigeria such as maize, rice, millet, wheat, groundnut, beans, vegetables such as tomato and onion, and livestock constitute 70% of the total national production. By interpretation, food insecurity in Northern Nigeria is not an exclusive issue of declining productivity influenced by climate change only. Poverty, unemployment, income inequality, conflicts, and insecurity contributed immensely to the food crisis in Northern Nigeria. This notwithstanding does not exclude the possibility of low yields escalated by climate change.

Climate change aggravated the food crisis in Northern Nigeria through the depletion of Lake Chad. Lake Chad is sharply affected

by climate change both human activities and nature. About 80–90% of the inhabitants of the Lake depend on agriculture, livestock, and fishing (Frimpong, 2020). The Lake is economically important providing reliable drinking water for 30 million inhabitants from the 4 surrounding countries. It is also home to multi-million Dollar fishing ventures annually, a source of irrigation farming throughout the seasons and a means of international transportation among the beneficiary countries. Lake Chad covered an area of 1,000,000 km² (390,000 sq. m). The Lake is shallow 10.5 m (34 ft.) at its deepest making it sensitive to small changes in weather and climate. Lake Chad is the fourth largest body of water in Africa and the third largest enclosed water on earth. Surrounded by deserts, the Lake provides succour for the inhabitants of the Sahel and is a link between West Africa and North Africa (The United Nations Educational, Scientific and Cultural Organization, 2020).

In the 1960s, Lake Chad had an area of more than 26,000 km. However, it had shrunk to less than 1,500 km by 1997 and dwindled further to 1,350 km by 2014 (Frimpong, 2020). Agriculture is the major occupation of the occupants of the Lake Chad Basin. About 80–90% of the population depends on farming, livestock rearing, and fishing. In the 1960s, fishermen captured around 200,000 metric tons of fish annually providing a means of subsistence for over 200,000 inhabitants in the fishing business. The growing depletion of the water in Lake Chad arising from climate change is making survival for aquatic animals such as fish difficult, agricultural production is steadily declining, and the means of drinking water are shrinking continuously (The United Nations, 2020). The Lake Chad Basin covers a total of 8% of the size of the African Continent. The Lake has several benefits for the surrounding countries. For instance, in Nigeria, the planned irrigation under the current water management project from Lake Chad is estimated at 185,000 ha, out of which only 32,000 ha has been utilized so far. The total identified potential is measured at 356,000 ha (Frimpong, 2020). According to some sources (Brown & Vivekananda, 2019; Owonikoko, 2020), over 90% of the Lake has shrunk from its actual size and depth in the 1960s and 1990s. Although the Lake improved from the 1990s to the 2000s, climate change is depleting the water recently. With global warming, desert encroachment, and Boko Haram insurgency in the Sahel, the Lake is not providing the much-needed sustenance for the inhabitants.

Climate change and its effects on Lake Chad are witnessed in the recent humanitarian crisis in the area. The FAO reported that out of the 704,000 inhabitants in the Lake area, 340,000 are in critical need of urgent humanitarian assistance. Out of the affected population, 134,800 is facing food security issues and 12,000 children are suffering from acute malnutrition. Out of the four countries, Nigeria is the most affected. The country is reported to have 8,500,000 population around the Lake Chad area requiring humanitarian assistance, with 5,200,000 facing food insecurity out of the 12,000,000 Nigerians that are living in the area (Frimpong, 2020). The depletion of Lake Chad and climate change correspond with the growing conflicts and insecurity in the region. Armed violence by the Boko Haram group further compounded the socioeconomic crises in the Chad Basin. The growing and expanding insurgency displaced many inhabitants of Lake Chad and the migration of people from the area led to the desertion of farming activities and fishing which stops the replenishing process and hence further depletion of the Lake in recent years (Frimpong, 2020). There are strong arguments (World Economic Forum, 2019; Medicins Sans Frontieres, 2020; Pham-Duc et al. 2020).

The Northeast geopolitical zone is the most affected by hunger and food insecurity. About 8.4 million of the estimated 26 million are in danger of food shortage and nutrition crisis and are in dire need of humanitarian intervention to avert the food crisis. Some of the

affected are the IDPs (Internally Displaced Persons) ostracized by the Boko Haram crisis. About \$1.1 billion is required to intervene and avoid the food security crises in the Northeast while \$351 is urgently needed for immediate intervention (Relief Web, 2022a). The announcement was made as underlined by the Foreign, Commonwealth & Development Office in partnership with the United Nations Office for the Coordination of Humanitarian Affairs, World Food Programme, FAO, and United Nations Children Fund (UNICEF) at a Joint Advocacy Event on Food Security and Nutrition in North-East Nigeria in Abuja on April 8, 2022 (Relief Web, 2022b). In Northwest Nigeria, about 2.53 million are food insecure affecting mostly the displaced in Katsina, and Zamfara where banditry is operating currently (Relief Web, 2021). In Northcentral, about 1.8 million are food insecure with the majority being displaced people by conflicts between farmers and herders. The conflicts are driven by climate change factors driving herders into farmlands, dispersing farmers from cultivation, and sometimes the products are lost because of a flood that washed away the crops or drought that perished the produce before harvest (FEWS NET, 2022).

There is a debate on the role of climate change in causing conflicts and vice versa. In Northeast Nigeria and Northwest, for example, Boko Haram insurgency and banditry were caused by climate change factors (Idika-Kalu, 2020; Okoli, 2021) and the conflicts further worsen food production decline by displacing farmers. About 40% of total farmland is not cultivated since the intensity of the Boko Haram conflict in Northeast Nigeria. Farming output falls by over 50% in the region. It was reported that climate change drives insurgents and armed conflicts due to draining Lake Chad and the crisis is fueled by a lack of economic activities in Lake Chad. About 2.5 million people most of them farmers were displaced (Sule et al., 2022). In the Northwest, 250,000 were displaced, over 250,000 cattle rustled, and around 225,000 hectares of farmlands remain uncultivated in 2020 and 2021 between 2016 and 2018. It is believed that herders were pushed into banditry in the Northwest when the effects of climate change affected their livestock pushing them to forcefully encroach into the farmers' land, and in retaliation, the farmers attacked the livestock and the consequences of these reprisals ended up in banditry (Ogbonnaya, 2021). In Northcentral Nigeria, climate change caused a food security crisis when the herders were driven away by the depletion of Lake Chad, declining rainfall, flood, and drought from other African countries, specifically Mali, Niger Republic, Chad, Cameroon, Burkina Faso, and the Central African Republic. The herders entered Nigeria through porous borders, criminally transcended the farmlands boundaries, and destroyed farm produce in the region. This situation led to declining food productivity and a food security crisis (Verjee & Kwaja, 2021).

A study (Ibrahim et al., 2014) using regression analysis reported maize production in Northern Nigeria will face a decline in yield and income due to climate change impact. The study (Ibrahim et al., 2014) shows a decline of N5,995 in revenue due to a 1°C rise in temperature and an increase in net revenue of N3,272 for a 1 mm increase in rainfall. A projected rise in temperature of 1°C by 2030 will lead to a decline in revenue of N4,281 ha for maize production in Northern Nigeria and a projected rise in temperature of 2.1°C in 2060 will lead to a decline in net revenue of about N8,620 ha. This decline in food production, especially staple crops such as maize, rice, and other related ones, will lead to food insufficiency escalated by climate change. Other studies (Balogun et al., 2013; Halliru, 2013; Ugbem, 2019; Adeleke et al., 2019; Ibrahim et al., 2018; Ojo et al., 2020; Olajumoke et al., 2020, Awolala, 2020; Maikudi, 2021; Obayelu et al., 2019) established a direct link between climate change, declining food productivity,

and food insecurity in Northern Nigeria. Additionally, the All Farmers Association (AFAN) raised an alarm about the threatening climate change impacts and looming food crises in Nigeria, especially in Northern Nigeria. The association warns that unless critical adaptation and resilient farming strategies are quickly introduced, Nigeria cannot feed its over 200 million people and the dangers ahead are more frightening with a projected population of 400 by 2050 accompanied by an estimated rise in temperature and declining precipitation (Ewepu, 2021). The FAO and UNDP also warned that acute food insecurity and shortage loom in Northern Nigeria estimating that about 13 million will face food shortages in the last quarter of 2021 and 2022. The FAO and UNDP reiterate that insecurity, and conflicts fueled by factors such as climate change, competition over resources, and extremism are the major causes (Premium Times, 2021). In another report by FAO in 2022, about 19.4 million Nigerians including 416,000 IDPs in 21 states and FCTA (Federal Capital Territory Abuja) will face food insecurity. The majority of the victims will fall in Northern Nigeria, added the report. The key factors identified as responsible for this prediction include high temperatures, poor rainfall distribution, declining rainfall, flood, drought, COVID-19 pandemic, poverty, and insecurity according to the report (The Nation, 2022).

7. Conclusion

The chapter empirically explored and analyzed the patterns and dimensions of climate change impacts on food production and food security in Northern Nigeria. It is observed from the study that climate change is a global issue and it is affecting all countries in the world including all sectors, specifically agriculture and food production leading to food security problems. Nigeria is one of the areas facing this crisis, especially Northern Nigeria where subsistence farming dominates and employs a substantial number of the population. It is reported in the chapter that scientific evidence abounds to showcase the increasing high temperature, reducing rainfall quantity, flood, drought, desertification, erosion, deforestation, and depleting lakes with rising sea levels. This, according to the chapter, is evident more in Northern Nigeria where grain production is dominant. However, the chapter established that climate change is further aggravated by conflicts of Boko Haram, banditry, and farmers versus herders armed conflicts in Northeast, Northwest, and Northcentral Nigeria while in some instances, climate change compelled these conflicts. Insecurity is thus a formidable driver of food shortage in Northern Nigeria. The influence of climate change in Northern Nigeria caused a severe food security crisis where the findings of the study reveal that over 19 million Nigerians faced a food security crisis in 2022.

Based on the intensity of the food crisis and the looming danger of malnutrition and hunger, this study finds it imperative to counter this trend objectively and strategically immediately. To this end, the following measures are recommended. One of the ways is to design adaptation and resilience measures in farming techniques by introducing crops that can manage to produce high yield within a shorter period of the rainy season and the ones that have roots and stems that can absorb more water during floods while can resist doggedly during drought to avoid harvest losses. The government should put all sincere efforts into restoring peace through deradicalization, post-conflict peacebuilding, and other techniques of achieving tranquillity in Northern Nigeria to allow farmers to cultivate the idle arable land. An irrigation system should be enhanced through multiple financing systems to increase the potential for dry-season farming across Northern Nigeria. Nigeria should continue to engage stakeholders on the modalities of

replenishing Lake Chad to restore its full potential for farming and other economic activities in addition to peacebuilding in the area. The farmers should be engaged rigorously in training and retraining on the strategies of adaptation and resilience using both local models and some models elsewhere that prove vibrant. Mechanization should be introduced to boost harvest and productivity while providing modern tools to subsistence farmers at an affordable rate.

It should be understood that this study has several limitations that future studies should take care of. The availability of data is a big problem. Ideally, a grant should be provided by policymakers to sponsor the data collection from the field but such has not been provided. Furthermore, out of the 19 Northern states and FCT Abuja, only 3 states are marked safe for fieldwork due to security challenges of Boko Haram insurgency, banditry, farmers–herders clashes, and ethno-religious conflicts. Additionally, the geographical size of Northern Nigeria is large and difficult to cover using fieldwork. It is suggested that future studies should take a miniature point like 2 or 3 states even though in this way, the comparison will be difficult and arriving at a uniform conclusion for the region as done in this work is practically impossible, it is still relevant to have individual studies and field data in future.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interests

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data sharing not applicable – no new data generated.

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