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THE IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTION IN NIGERIA

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Abstract

Climate change is a global phenomenon that affects agricultural activities. However, the study of the implications of climate change agricultural production and productivity is yet to receive needed attention. On this premise, and with a focus on Nigeria, this study examined the impacts of climate change on agricultural production and productivity using the last Nigeria General Households Survey (NGHS) 2018/2019. The specific objectives were to determine the impact of climate change on both crop and livestock production as well as productivity.. The data was analysed using the Ordinary Least Squares (OLS) estimation technique. The results revealed that climate variability significantly influences crop and livestock production and productivity. Increasing rainfall negatively impacts livestock income, milk and egg production whereas, less exposure to normal rainfall reduces crop production. Specifically, drought shock negatively affects crop production with a magnitude negative impact of about 35%, and heat stress results show a higher negative impact on crop production by 56%. However, the study found no significant negative result for livestock production.. Surprisingly, heat stress increases livestock sales by 63% at 5% significance level, and the mean of annual maximum temperature increases milk production by 6%. The study, therefore, recommends that the policy makers should establish a national strategy to encourage adaptation measures because the current trend of rising temperatures and variations in precipitation is unavoidable and are likely to be magnified in the future. Scaling up these adaptive benefits also necessitates government investment to promote awareness and give technological assistance.

INTRODUCTION

Climate change is one of the major global challenges at the moment and it affects various sectors. One of those sectors is agriculture which is vulnerable due to extreme weather conditions and changes in rainfall patterns. In Nigeria, agricultural activities are a means of livelihood for many households. Therefore changes in the earth's climate have significant consequences. Agricultural production in Nigeria has been affected by climate change and this poses a threat to livelihoods, food security, and economic stability. It's however important to note that climate change is not the only factor that affects agricultural production in Nigeria. The other factors include infrastructural limitations, limited access to finance, and insecurity. The aim of this research is to investigate the impact of climate change on the agricultural sector in Nigeria and the need for adaptive measures to ensure food production.

Nigeria's agriculture sector serves as a backbone of its economy, employing a large portion of the population and contributing significantly to the country's Gross Domestic Product (GDP). The sector predominantly engages in rain-fed farming, which makes it highly susceptible to changing climate patterns. Over the past few decades, Nigeria has experienced a noticeable increase in extreme weather events, such as prolonged droughts, erratic rainfall, and intense heat waves, disrupting the traditional agricultural calendar and production systems.

Farmers in Nigeria face the challenge of unpredictable rainfall patterns. The unpredictable nature of rainfall affects harvesting and planting schedules as well as the crop yields and total agricultural productivity. Low levels of rainfall and its irregularity in most cases leads to soil degradation, scarcity of water, and crop failure which consequently affects the livelihoods of farmers who rely on rain-fed agriculture.

In addition, the rising temperatures worsen the vulnerability of crops to diseases and pests, which in turn leads to lower yields and quality. The most essential staple crops such as maize, rice, sorghum, and millet are at risk because of their sensitivity to changes in temperature. These crops are essential for food security in the country.

Livestock production is also affected by climate change. Changes in the rainfall patterns and higher temperatures result in reduced water sources and forage availability, this in turn leads to lower productivity of livestock due to malnourishment. All of this puts the livelihoods of pastoralists and the supply of animal-derived products in jeopardy.

Furthermore, climate change-induced extreme weather events, such as flooding and storms, frequently cause damage to agricultural infrastructure, including irrigation systems, storage facilities, and transportation networks. These disruptions not only impede agricultural activities but also increase post-harvest losses, further impacting food security and economic stability.

The Nigerian government has recognized the importance of agriculture for the country's development and it has collaborated with international agencies to address the effects of climate change on the sector. Some of the measures that have been explored to boost adaptability and resilience in the face of a changing climate include the promotion of sustainable land use and the adoption of drought-resistant and heat-tolerant crop varieties.

In conclusion, the effects of climate change on agricultural production in Nigeria are undeniable, and the implications for food security and rural livelihoods are significant. Urgent and coordinated efforts are required to mitigate the impact of climate change and to build resilience within the agricultural sector. By adopting sustainable practices and investing in climate adaptation strategies, Nigeria can pave the way for a more sustainable and secure agricultural future.

CHAPTER ONE
STUDY OVERVIEW

1.1 Background to the study

Globally, climate change is a severe issue that drastically changes the environment and permanently alters Earth's ecosystems (Arora, 2019). For instance, climate change impacts rainfall variability, influenced by the hydrological cycle and observed rainfall patterns. Therefore, climate change adaptation is crucial in ensuring sustainable agricultural production (Easterling et al., 2007). Climate change affects several scales (global, regional, and national) and sectors (including agriculture) (Olayide, Tetteh & Popoola, 2016). The global rate of climate change has accelerated recently compared to the previous century (Onyeneke et al., 2019; Nwaiwu, 2014). On a global scale, the average temperatures have risen by 0.90C since the nineteenth century (Arora, 2019). According to projections, warming will continue, with a probable average increase of 1.5 ^{0}C to 4^{0}C over the next century (IPCC, 2021). According to the IPCC (2021) report, all regions will experience increased climate change over the next few decades. There will be more frequent heat waves, longer warm seasons, and shorter cold seasons with a 1.5°C increase in global warming. As a result, seasonal patterns would become distorted due to climate change, affecting temperature and rainfall (Chikezie et al., 2019; Tajudeen et al., 2022).

Despite its small proportion of greenhouse gas emissions, the African region remains the most vulnerable continent to climate change impacts. Africa faces systemic risks to its economies, infrastructure investments, water and food systems, public health, agriculture, and livelihoods that threaten to undermine its modest development gains and cause it to relapse into deeper levels of extreme poverty. Africa's agriculture relies heavily on rainfall and most countries' GDP and employment is tied to agricultural production. Climate change could result in decreased income and an increase in food insecurity.

Nigeria is one of the SSA countries badly hit by climate change (Tajudeen et al., 2022). The rising climate variability in Nigeria is bringing on more intense and sporadic rainfall. The effects of climate change have increased gully erosion, landslides, and flash floods, which have exacerbated land degradation (Oladipo, 2022). In rural and urban Nigeria, there were reportedly 6,000 gullies causing damage to houses, pipelines, and roadways (Oladipo, 2022). These catastrophic weather events are severely impacting the lives of many Nigerians.

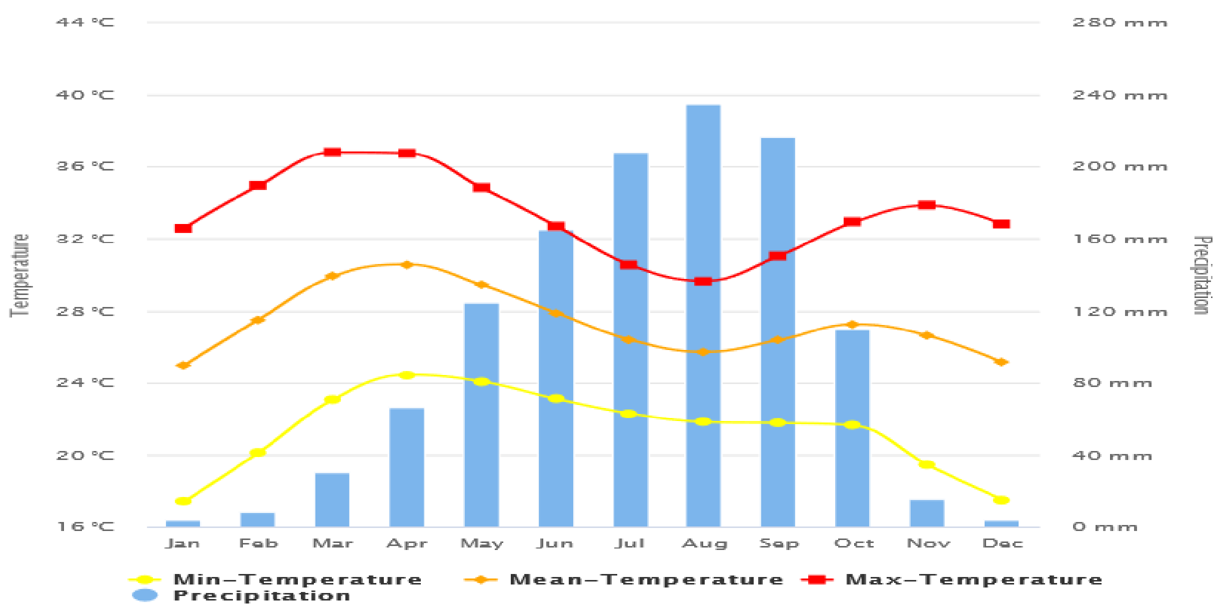
In the last few years, combating climate change has risen to the top of the global development agenda. Establishing the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 provided the institutional foundation for effective climate change mitigation. Later in 1997, the Kyoto Protocol provided legally binding targets for wealthier nations to reduce greenhouse gas emissions and enabled each nation to work domestically to meet these goals. Additionally, some flexible methods, like Joint Implementation (JI), the Clean Development Mechanism (CDM), and International Emissions Trading (IET) were established. Later, the UNFCCC (2015) parties agreed in the Paris Agreement to assist countries in managing potential impacts of climate change. The following commitments guide the Paris Agreement; significantly reduce global greenhouse gas emissions to keep the increase in global temperature this century to 2 degrees Celsius while pursuing efforts to keep it to 1.5 degrees; review countries' commitments every five years; finance developing nations to help them combat climate change, build resilience, and improve their capacity to adapt to its effects (UNFCCC, 2015).

However, despite global and domestic efforts, climate variability has posed numerous risks and has severely impacted productivity in different areas of the economy, including energy, agriculture, and tourism (Tesfaye, 2019). Therefore, it is imperative to alert that the issue of climate change is more evident in the agriculture sector and food security. Climate shocks such as excessive rainfall, temperatures, or complicated events like droughts are part of the low agricultural production and income volatility, especially in Sub-Saharan Africa (SSA), due to a high number of households in SSA countries being agrarian. Therefore, high erratic rainfall patterns and rising temperatures make farmers' production choices a gamble to the point that they need to forecast the perfect circumstances to grow their crops. The attendant implication is rising household food insecurity exacerbating the persistently high poverty and food insecurity in SSA (Barrett et al., 2017; Jayne et al., 2018; Master’s et al., 2018).

There is a growing concern as future forecasts foretell that unpredictable rainfall and rising temperatures will likely decrease SSA's cereal production levels and primary food crop yields

(Tajudeen et al., 2022). The stylized facts provided in Figure 1.1 shows Nigeria's monthly minimum, mean and maximum temperature and precipitation from 1991 to 2020. The Figure depicts a fluctuating trend in precipitation amount and temperature during the periods captured.

Figure 1.1: Monthly Climatology of Min-Temperature, Mean-Temperature, Max-Temperature & Precipitation 1991-2020 Nigeria



Source: World Bank Database.

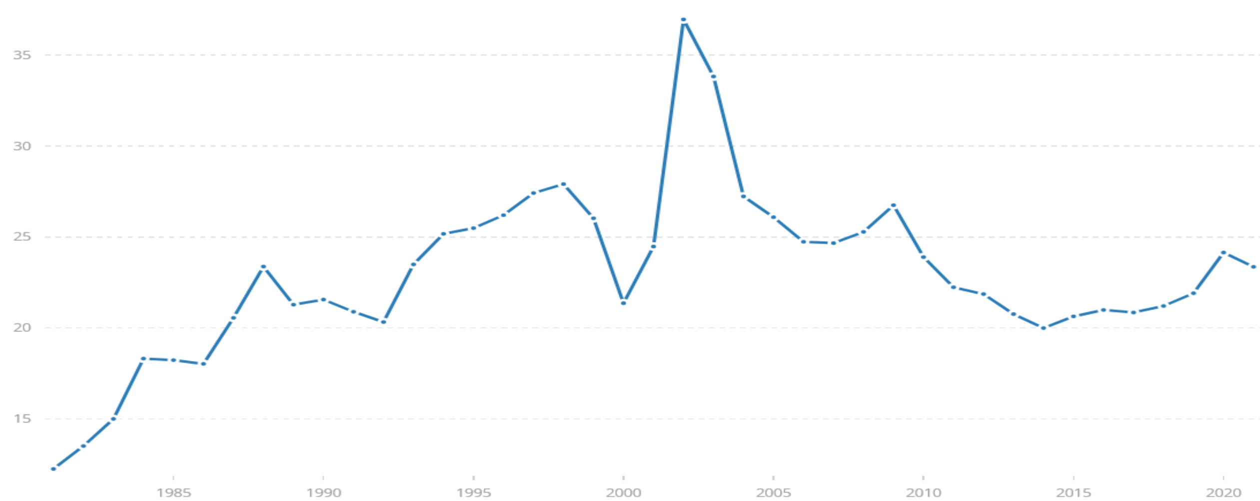
Rainfall variation occasioned by climate change is projected to continue to grow in Nigeria (Haider, 2019). These variations are highlighted by the predicted rise in precipitation within Southern Nigeria, (advancing the risk of flooding and the potential submersion of coastal cities) (Akande et al., 2017) and with temperature increases (a forerunner to droughts) in the Northern Nigeria (Amanchukwu, Amadi-Ali, Ololube, 2015). Hence, climate change has already started to advance drought and flood events that could negatively impact crop production and livestock across Nigeria (Haider, 2019), forcing farmers in some ecosystems (e.g., mangrove swamps, rain forests, and parts of the Sahel and Guinea Savanna) to adjust planting dates to later in the season due to the onset of seasonal rains and drought (Agbo, 2012).

1.2 Problem statement

Nigerian agricultural sector productivity exhibits poor growth despite being endowed with diversified ecological zones, which is capable of producing a cross-section of food crops and sufficient agricultural land, capable of providing forage for a large variety of livestock. According to the African Development Bank Group (2014), Nigeria's land area is estimated to be 91 million hectares, with 90% of the land being arable for agricultural productivity.

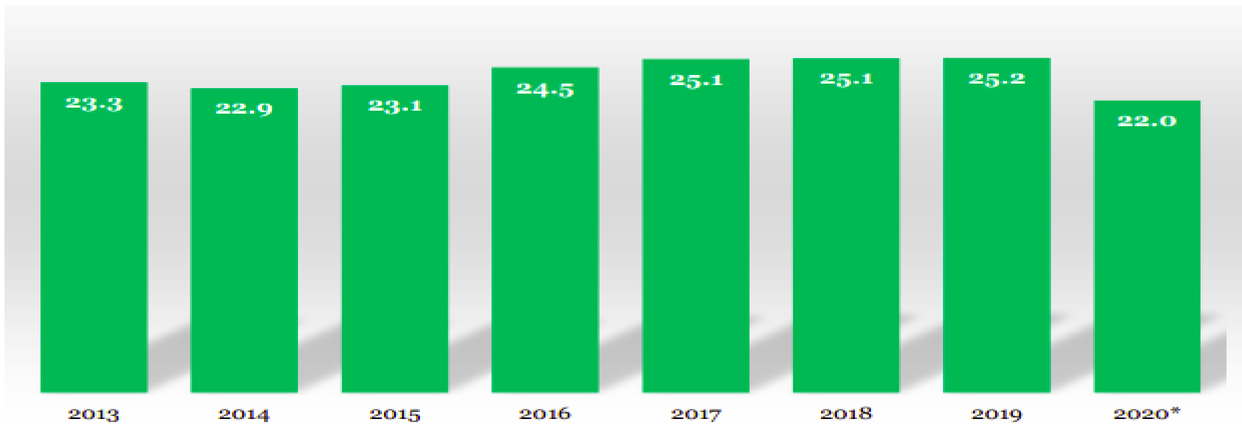
According to the Central Bank Nigeria report, the Nigerian agricultural sector has made 64.4%, 47.6%, and 30.8% contributions to the Nigerian Gross Domestic Product (GDP) in 1960, 1970, and 1980, respectively (CBN, 2002). However, the trend of Nigeria's agricultural sector contribution to GDP depicted in figure 1.2 raised fears that the Nigerian agricultural sector may not be able to provide enough food for the Nigerian population. As depicted in figure 1.2, over the past couple of decades, Nigeria's agricultural sector contribution to GDP has oscillated between 21.4% and 23.4%, far less than its contribution in the 1960s and 1970s (World Bank, 2022).

Figure 1.2: Trend of Nigeria's Agricultural sector value added (% of GDP) 1981-2021.



***Source**: World Bank Database*

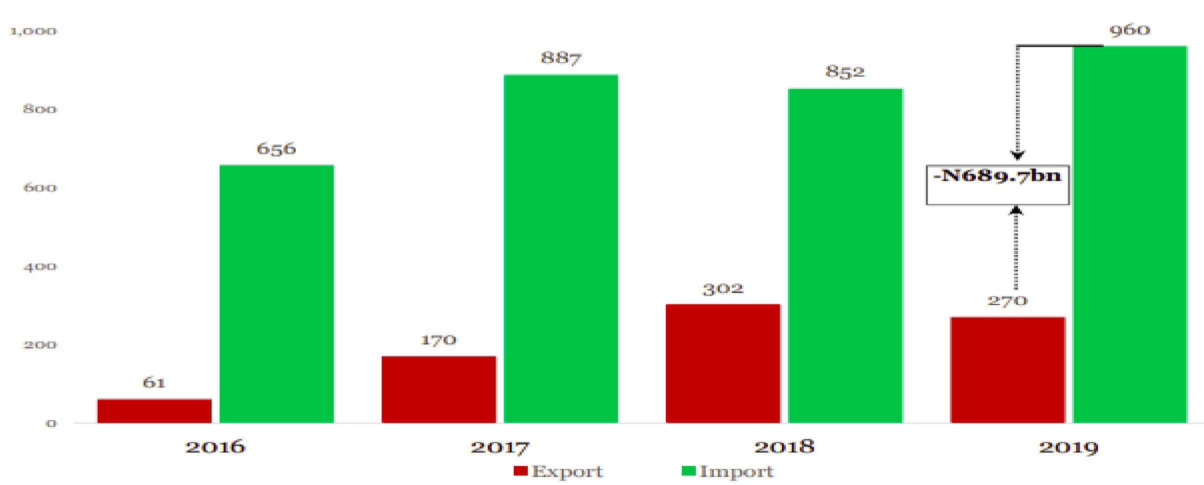
Fig 1.3: Chart of Nigeria's Agricultural Sector's Contribution to GDP (%) 2013 - 2020



Source: NBS PwC Analysis [afcfta-agribusiness-current-state-nigeria-agriculture-sector.pdf (pwc.com)]

The production and growth of the Nigerian agricultural sector has remained low in relation to Nigeria's population growth (FAO, 2015). This has led to rising food imports, food prices, and declining levels of national food self-sufficiency. For instance, Nigeria's total agricultural imports from 2016 to 2019 was , which is four times the country's total agricultural export of N803 billion over the same period (FAO, 2023).

Fig 1.4: Nigeria's Agricultural Trade Deficits (billion naira) 2016 - 2019



Source: NBS PwC Analysis [afcfta-agribusiness-current-state-nigeria-agriculture-sector.pdf (pwc.com)]

More so, the low agricultural productivity has exposed over 80% of the Nigerian rural population to an unprecedented level of poverty and hunger, projecting Nigeria to the rank of 40 out 79 countries in the Global Hunger Index (IFAD, 2012; Agostini, 2018). One of attendant implications is that Nigeria could be unable to meet the United Nations Sustainable Development Goal 2 (SDG 2) which focuses on zero hunger by 2030 (UN, 2016).

Nevertheless, Nigeria's agricultural low productivity has been attributed to poor land tenure system, low level of irrigation farming, land degradation, climate change, among others (FAO, 2023). The impact of climate change on declining agricultural output has worsened during the previous two to three decades (FAO, 2015). The situation is more worrisome for developing countries, such as Nigeria, that heavily depend on direct rainfall for their agricultural activities. More than 80% of Nigeria's crop production depends on rainfall (Tajudeen et al., 2022). Farmers in Nigeria have noted that the length and start of the growing season, as well as the length and frequency of rainfall, are all affected by climate change (Essien, 2013; Mgbenka, Mbah & Ezeano, 2015). The intensity and frequency of plant illnesses and insect outbreaks are also correlated with rainfall and temperature changes, both of which further reduce crop productivity and complicate farming (Conrow, 2021).

Successive government in Nigeria has put in place a number of initiatives and programs to mitigate the effect of climate change on agricultural sector production, such as the Agriculture Promotion Policy (APP), Nigeria-Africa Trade and Investment Promotion Programme, Presidential Economic Diversification Initiative, Economic and Export Promotion Incentives, and the Zero Reject Initiative, Reducing Emission from Deforestation and Forest Degradation (REDD+), Nigeria Erosion and Watershed Management Project (NEWMAP), and Action Against Desertification (ADD) programme, National Climate Change Policy and Response Strategy (NCCPRS), Nigeria's Climate Change Act, among others. Despite these efforts to mitigate the effects of climate change and increase agricultural sector productivity, Nigeria remains heavily food import dependent. Nigeria's expanding population and overall food crop production are currently separated by a large gap, with the population growing geometrically and food production increasing arithmetically. Nigeria imported N3.35 trillion of agricultural products between 2016 and 2019, four times more than the country's food export of about N803 billion during the same time (PwC, 2020). All of these, point to the possibility of climate change undermining attempts to address current and future food security in Nigeria.

The aim of this study is to investigate the impact of climate change on agricultural productivity in Nigeria. Previous studies adopted cross-sectional data with limited scope and varying methodology, however by using time series data to investigate the impact of climate change on agricultural production, this study will accommodate data robustness, and variations in trends.

The study used the latest round of the Nigeria General Household Survey (NGHS) 2018/2019. The data are comprehensive in coverage, and they collect information on household characteristics, including demographics of household members (education, health, labor, food, and non-food expenditures, income generating activities, housing conditions, assets, food security, and exposure to shocks).

1.3 Research questions

The following research questions guided this study.

i) What is the impact of drought shock on crop production and productivity in Nigeria?

ii) What is the effect of drought shock on livestock production in Nigeria?

1.4. Literature gap and value added

The study contributes to existing literature in several respects. First although several empirical studies provide evidence on the impact of climate change on agricultural productivity (Ayinde, Muchie, & Olatunji, 2011; Madu, 2012; Agba et al., 2017; Gbenga et al., 2020), studies that explicitly accounts for climate variability considering crop and specific livestock produce, as well as account for geographical differences using microlevel datasets is still nascent. The study fills a literature gap that exists in developing countries like Nigeria on how climate variability impacts on crop and livestock production and productivity.

The aim of this study is to examine the extent to which climate shocks impact Nigerian agricultural crop production and to make recommendations that may improve the growth of the

Nigerian agricultural sector from its findings. This study will provide a basic and unique understanding of the independent variable (climate change) and the dependent variable (crop and livestock production) as well as how the independent variable affects the dependent variable. This study aims to add to the knowledge about the relationship between climate change and agricultural production and productivity.

The study's findings would be significant to farmers who are already losing money due to climate change by encouraging them to cultivate drought-tolerant crops and keep livestock that can adapt to changing weather patterns. Also, climate researchers will leverage the result of this study to enhance their analysis of climate change and agricultural production. Furthermore, agricultural scientists and farmers will take advantage of this study to understand the relationship between climate change and agricultural productivity in Nigeria.

CHAPTER TWO
LITERATURE AND CONCEPTUAL REVIEW

2.1 Conceptual framework

This section provides conceptual meaning and linkages of climate change, crop and livestock production and productivity within the focus of the study.

2.1.1 Climate change

The term "climate change" refers to changes in the mean and variation in basic climate parameters (temperature, precipitation and wind) that result from both natural and man-made factors, such as the concentration of greenhouse gases and aerosols in the atmosphere and the earth's orbit, volcanic activity, and crustal movements (Kim, N.A). Among the natural reasons are variations in solar activity, volcanic eruptions, marine water temperature, ice cap distribution, westerly waves, and atmospheric waves, whereas man-made causes include carbon emissions from industrial activities, agricultural mechanization, deforestation, and Freon gas ozone layer destruction, with global warming as the representative (Presidential Advisory Council on Education, Science & Technology: PACEST, 2007).

Climate change disrupts the agricultural environment by changing agricultural climatic factors like temperature, precipitation, and sunlight and impacting the livestock, agriculture, and hydrology industries. Floods, droughts, and increasing rainfall variability are already affecting agriculture due to climate change-induced changes in the global hydrological cycle, which negatively influence the yields of important crops, including maize, soybeans, rice, and wheat. In a warmer world, these shifts are anticipated to persist, resulting in lower crop yields from rain-fed agriculture and less water available for irrigation in areas with water scarcity (IPCC, 2022).

2.1.2 Crop production and productivity

Crop production and crop productivity are important concepts in agriculture. They are closely related but also represent different aspects of the agricultural process. In this section, we will start by explaining each concept and highlighting the differences.

Crop production

This process of cultivating crops involves all the activities from the initial stage of planting seeds or seedlings to the final stage of harvesting the mature crops. Crop production embodies all farming practices, such as soil preparation, planting, irrigation, fertilization, pest and disease management, and harvesting. The primary aim for crop production is to make available a certain quantity of crops that meet human demands for food, fiber, or other purposes. The yield and value of crops is a key measure of crop production, and it is usually expressed in terms of weight (e.g., kilograms or tons).

Crop productivity

Crop productivity can be said to mean the efficiency of crop production in terms of output generated per unit of input. It measures the effectiveness of the resources used in the crop production process within a given area. The inputs can include land, water, seeds, fertilizers, pesticides, labor, and machinery. In more simple terms, it is a measure of how well a farmer can use available resources to produce higher yields. It can be expressed in various ways, such as yield per unit area, yield per unit of water, yield per unit of fertilizer, or yield per unit of labor. The higher the crop productivity, the more efficient and sustainable the agricultural system

Table 1: Comparing Crop production and Productivity

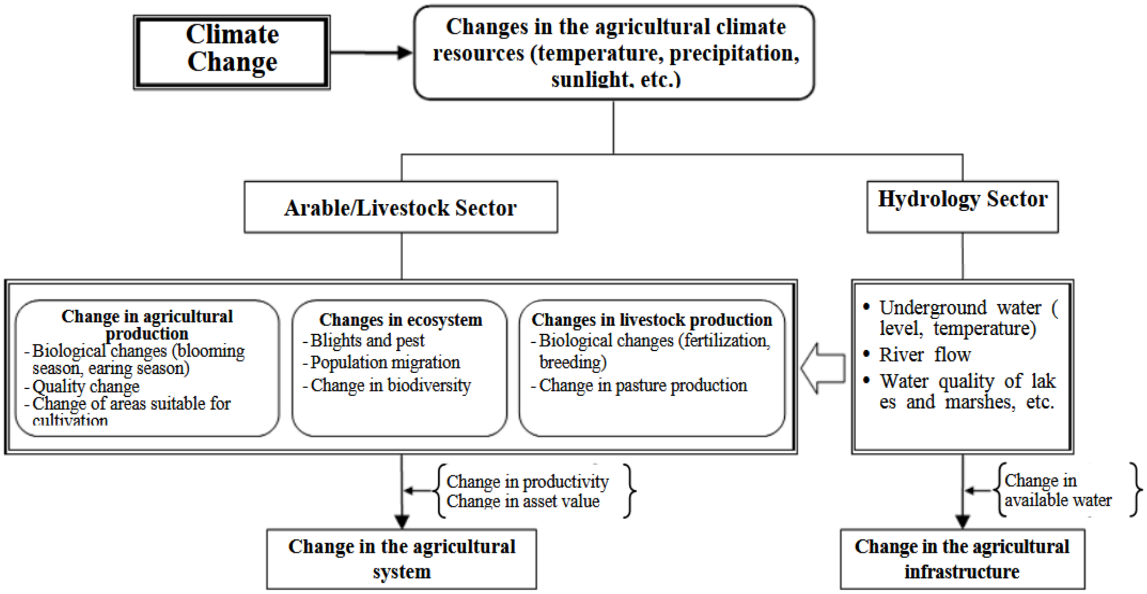
S/N	Measures	Crop Production	Crop productivity
1.	Focus	Crop production is most important for a food subsistence	Crop productivity takes the form of an economic perspective on efficient use of resources.

2.	Measurement	Crop production measures the total quantity of crops harvested from a given area.	Crop productivity measures the output (yield) generated per unit of input (yield per unit area, yield per unit of water, etc.).
3.	Purpose	The aim here is to meet the demand for agricultural products, ensuring an adequate supply of food, feed, fiber, and other raw materials	This aims to optimize resource use to achieve higher yields while minimizing input wastage and environmental impact.
4.	Evaluation	Crop production evaluation is concerned with the success of the farming operation in terms of the quantity and value of crops produced.	Crop productivity evaluation focuses on assessing the efficiency and effectiveness of the farming practices as well as resource management.

2.1.3. Climate change and agricultural productivity linkages

Climate change is an important and lasting change in the distribution of weather patterns. It can cause off-season rain, drought, erosion, and flooding among others. These changes can either foster agriculture or dampen its performance. Figure 2.1 below shows the links between climate change and agricultural production.

Figure 2.1 Diagrammatic representation of the climate change impact on agricultural productivity



Source: Kim, Chang-Gil et al. (2009).

The effects of climate variability on the arable and livestock sector are clearly evident in the biological changes, such as altered blooming and harvesting seasons, altered quality, and shifted cultivation-friendly regions. Climate change has an impact on the agricultural environment, leading to pests and blights, population shifts, and changes in biodiversity. In the livestock industry, biological changes brought about by climate change impact pasture growth patterns as well as processes like fertilization and breeding. By affecting precipitation, evaporation, and soil moisture content, climate change has an effect on the hydrology, which includes underground water level, water temperature, river flow, and water quality of lakes and marshes. In particular, the rise in temperature raises evaporation, which causes a reduction in outflow, while the increase in precipitation due to climate change causes an increase in outflow.

2.3 Empirical literature

Climate change is a broad topic that crosses several academic disciplines. However, due to the rising level of interest in the issue worldwide, numerous economic and non-economic experts have tried to investigate it from various perspectives. Here is a survey of a few relevant empirical literature.

In Asia, studies found that climate shock significantly and negatively impacts agricultural productivity (Mathauda et al., 2000; Faisal & Parveen, 2004; Zhiu et al., 2022; Bai et al., 2022). According to Mathauda, Mavi, Bhangoo, and Dhaliwal (2000), rising temperatures hurt rice yield in the Punjab region of India. Their finding is consistent with the study by Faisal and Parveen (2004), which confirmed that climate change adversely affects rice and wheat production in a proportion of about 8% and 32%, respectively. A recent study in Asia by Bai et al. (2022) examined the correlation between climate change and agricultural productivity using China's provincial agricultural input–output data from 2000 to 2019 and the climatic data of the ground meteorological stations. Their study adopted a combination of spatial Durbin model and entropy approaches and found that there has been a considerable decrease in agricultural output due to climate change, which was confirmed by robustness tests such as index replacement, quantile regression, and tail reduction. The study's findings also showed that when the climatic factors were divided, annual precipitation had no discernible effect on the rise in agricultural productivity; in contrast, other climatic factors, such as wind speed and temperature, had a significant negative impact on agricultural productivity. The heterogeneity test revealed that climate change had no impact on the eastern or central parts of China; only the western portion of China was adversely affected by it. Their finding is consistent with that of Zhou et al. (2022), who found that climate shock has a significant effect on farmers' productivity and productive investment choices.

Another study conducted in Asia by Habib-ur-Rahman et al. (2022) used five climate models (GCMs), two crop models (DSSAT and APSIM), and an economic model (Trade-off Analysis, Minimum Data Model Approach (TOAMD)) to analyze the effects of climate change on agricultural productivity. The yield reductions projected by DSSAT and APSIM were 15.2% and 14.1%, respectively, for rice; 12%, 17.2% and 12%, respectively, for wheat. Under climate change scenarios, adaptation technology can potentially increase the total productivity and profitability of the rice-wheat cropping system by modifying crop management practices like sowing time and density, nitrogen application, and irrigation application.

In the United States, Deschenes and Greenstone (2004) looked into the financial effects of climate change on US farmland. Their findings point to a $40 to $80 billion, or 3–6%, decrease in the value of agricultural land due to the benchmark climate change, but the null of zero effect cannot be ruled out. Similarly, Schlenker and Roberts (2009) analysed the heat resistance of different crops and what it implies for US agriculture under climate change. Their study found that precipitation and temperature have a relationship with crop yields.

In Europe, some studies found climate change was found to be non-detrimental to agricultural production. For instance, Olesen and Bindi (2002) found that increasing atmospheric CO_2 levels will immediately increase plant productivity and improve resource use effectiveness. According to their study, climate change may positively impact agriculture in northern regions by introducing new crop species and varieties, increasing crop yield, and extending areas suitable for crop cultivation. Similarly, Torvanger, Twena, and Romstad (2004) examined the effects of climate change on Norwegian agricultural productivity from 1958 to 2001. The study used time series data and a biophysical statistical model to investigate the dynamic relationships between wheat, barley, oat, and potato yields and factors related to climate change, such as temperature and precipitation. According to their study, temperature had a beneficial effect on 18% of crop yields. For potatoes, the effect is shown to be most potent. This finding is also consistent with the study by Shrestha et al. (2013), who found an increasing relationship between crop yields and climate change, especially for the central and Northern EU.

In Africa, the effects of climate change on agricultural productivity are mixed. For example, Benhin (2006) found that increasing temperature and precipitation benefit crop farming, but effects beyond a certain point will be detrimental. Similarly, Ayinde et al. (2011) investigated how climate change affected Nigerian agriculture. The study covered the years 1980 to 2002 and used time series data. They used the most recent cointegration analysis technique to examine their data, and the results showed that while rainfall was shown to have a beneficial impact on agricultural productivity, temperature had a negative impact. The findings by Jiduana, Dab, and Dia (2012) and Ayinde, Muchie, and Olatunji (2011) also demonstrate that climate change has a detrimental impact on Nigerian agriculture. It was found that the previous year's abundant rainfall could have caused erosion and leaching, but that temperature and rainfall variability did not appear to have significant impacts on agricultural productivity in Nigeria's economy. Other studies in Nigeria discovered the differential effects of climate change on agricultural productivity. For example, Madu (2012) and Apata (2012) discovered that northern states are more vulnerable due to greater exposure to environmental risks brought on by climate change. As a result, climate shock significantly affects agricultural productivity in the northern region relative to the southern region.

Using recent and more exhaustive scope time series data, Agba et al. (2017) and Gbenga et al. (2020), though with a different empirical approach, found that climate change significantly negatively impacts agricultural productivity in Nigeria. Their finding is consistent with other previous African studies, such as Eid, El-Marsafawy, and Ouda (2006), who found that temperature rise adversely affects net farm revenue in Egypt, and Nhemachena, Hassan, and Kurukulasuriya (2010), who found that drier and warmer climates often harm agricultural productivity and net farm revenues in 11 African countries studied. In the same vein, Bernard Jr et al. (2023) used panel data from 42 African countries from 1999 to 2019 to investigate the nexus of climate change and agricultural productivity. They found that climate change has a detrimental effect on agricultural productivity, and the distribution of climate effects varies among African regions.

CHAPTER THREE

THEORIES AND METHOD

3.1. THEORETICAL FRAMEWORK

3.1.1. Linking climate change to agricultural production

The research methodology begins with a brief overview of insights from theories that link climate change and agricultural outcomes and common methods used to determine the impacts of climate change on agricultural production. Smallholder agriculture is vulnerable to climate change (Howden et al., 2007), and the degree of vulnerability is contingent on a wide range of management and local environmental factors, including local biophysical conditions(soil types, fertility, etc.), types of crops or livestock kept, farmer knowledge and awareness of expected climate change effects, access to resources to support adaptation, the existence of government aids to support adaptation to mention a few factors (Thornton et al., 2009; Kurukulasuriya & Rosenthal, 2013).

The impact of climate change increases the uncertainty of agricultural production, an additional burden that farming decisions must consider. This idea is plausible given that the farmer faces other constraints in production, such as lack of credit to buy inputs, land degradation, poor soil quality, lack of labour, land, and other factors that support productivity. Climate change uncertainty comes as an additional burden to the farmer. The effects of climate change hence are felt in the increased uncertainty in the form of extreme climate events (drought, floods, landslides, cyclones), which translate to production risks associated with crop failure and low productivity. (Kurukulasuriya & Rosenthal, 2013; Mendelsohn & Wang, 2017).

The mechanisms through which climate change affects agricultural production are specific to context and value chains (crops, livestock, etc.). For instance, impacts of climate change on livestock production are felt through,

- How forage is affected by higher CO_2. (An increase in CO_2 can lead to a higher biomass production. The quality might also be affected)

- ➢ The impacts of temperature changes on water, forage, reproduction, livestock production, and health.
- ➢ The impacts of precipitation changes on forage and diseases (Thornton et al., 2009; Rojas-Downing et al., 2017).

Likewise, the impacts of climate change on crop production, as summarized by Hulme (1996) are felt in four different ways:

- ➢ Increased losses of agricultural production and productivity from the increased frequency of extreme climate events such as floods and drought, and or changes in temperature and precipitation variance.
- ➢ The effects of carbon dioxide on plants (for example effects of carbon dioxide on photosynthesis).
- ➢ The effects of changes in precipitation and temperature changes in the distribution of agro-ecological zones, crop suitability in different regions, length of growing seasons.
- ➢ The impact of water availability or runoff on agricultural production (Hulme, 1996; Kurukulasuriya & Rosenthal, 2013).

3.1.2. Approaches for evaluating the impacts of climate change on agricultural production

Various approaches have been used in the literature to evaluate the impact of climate change on agricultural production. The broad category of methods used to estimate the effects of climate change includes experimental approaches and cross-sectional studies. The experimental approaches include agro-economic simulation models. An example is that of a study by Reilly et al. (2003), who examined the historical shifts in the location of crops and trends in the variability of average crop yields in the US using simulations. Various other examples of crop simulation models are available in the literature (Hulme, 1996; Reilly et al., 2003; Mendelsohn & Wang, 2017). However, such models have been criticized because they overestimate damages from climate change mainly because they do not account for adaptation efforts that farmers make on their farms (Mendelsohn et al., 1994; Mendelsohn & Reinsborough, 2007; Kurukulasuriya & Rosenthal, 2013).

Cross-sectional models deal with the overestimation of climate change impacts and control for adaptation. Some examples of cross-sectional climate change estimation models include:

- The Ricardian approach
- The crop and land suitability approach
- The production function approach

The Ricardian approach analyses a cross-section of farms under different climatic situations and examines the relationship between the value of land or net revenue and agro-climatic factors (Mendelsohn et al., 1994; Kumar & Parikh, 1998; Deressa, 2007; Deressa & Hassan, 2009). Some of the key merits of the approach are that it includes all of the agricultural activities of farms and not just gains from farming (Van Passel et al., 2017) and that it incorporates or controls for adaptation (Deressa & Hassan, 2009; Van Passel et al., 2017). However, the Ricardian approach also has noted weaknesses. For instance, it is not based on experimental data across farms and excludes carbon fertilization and price effects (Cline, 1996; Van Passel et al., 2017).

The crop and land suitability approach is sometimes called the agroecological zoning approach. The method is often used to assess the suitability of land and other biophysical attributes for crop production and other land uses. The approach treats crop characteristics, existing technology, climate, and soil factors as determinants of the suitability of crop production (FAO, 1996). In addition, the model evaluates the impact of climate change on agricultural production and land use patterns as it includes climate as a covariate of land suitability for production (Du Toit et al., 2001; Xiao, 2002). The main advantage and weakness of the approach are that it accounts for adaptation and that it cannot predict outcomes without explicitly modeling all relevant components, and hence model predictions can be substantially affected if one major factor is omitted (Mendelsohn & Tiwari, 2000; Deressa & Hassan, 2009).

The production function is another method that has been widely used to examine the impacts of climate change on agricultural production. The approach is based on an experimental production function that estimates the relationship between climate change and agricultural production (Mendelsohn et al., 1994; Dinar et al., 1998). The approach specifies a production function that includes environmental variables such as rainfall, temperature, and carbon dioxide as inputs. The effect of climate change is measured by changes in yield induced by changes in environmental variables as analysed at experimental sites (Alexandrov & Hoogenboom, 2000; Olesen et al., 2000).

Different production function forms are used in the production function, including the Leontief production function, constant elasticity of substitution, and the Cobb-Douglass production function, of which the Cobb-Douglass function is the most common. The production function approach has the advantage of careful control, randomized application of climate conditions, and control for farmer adaptation behavior (Deschenes & Greenstone, 2007). However, the experimental nature may not suit or resemble real farmer conditions and hence their adaptation behavior (Mqadi, 2005; Deschenes & Greenstone, 2007; Deressa & Hassan, 2009).

3.2. Model specification and hypotheses

Our study aligns with the production function approach to study the impacts of climate change on crop and livestock production in Nigeria. Within the production function approach, climate variables and shocks are added as factors of production. Following the literature linking climate variables and shocks to agricultural production outcomes (reviewed earlier), the main hypothesis we test is that climate shocks in the form of drought and heat stress reduce crop and livestock production outcomes amongst smallholder farmers in Nigeria. This is a plausible hypothesis as several studies have studied the relationship between agricultural production outcomes including yield under the assumption that extreme heat stress and drought stress (too little rainfall) may damage crops and or livestock (Challinor, Wheeler, Craufurd, & Slingo, 2005; Porter & Semenov, 2005; Li et al., 2010; Schlenker & Lobell, 2010; Welch et al., 2010; Rowhani, Lobell, Linderman, & Ramankutty, 2011; Rojas-Downing, Nejadhashemi, Harrigan, & Woznicki, 2017; Michler, Baylis, Arends-Kuenning, & Mazvimavi, 2019). We hence expect climate shocks such as drought and heat stress to hurt crop and livestock production outcomes.

We specify a Cobb Douglas production function for farmer i that take the following form:

$$Y_i = AX_i^{\beta_i} exp^{e_i} \qquad [1]$$

Where Yi is the dependent variable, i.e., a measure of crop or livestock production, Xi is a vector of explanatory variables (climate variables, household characteristics including inputs of factors of production- land, labor, capital) and i is a vector regression parameters to be estimated, A, is a constant term and e_i is the disturbance term. We present the descriptive statistics of all variables used in the study in Table 1. Often studies have used the linear log-log (double log) of equation (2) and expressed the production function of the form:

$$LnY_i = A + \beta_i \sum_{i=1}^{n} ln\, X_i + e_i \qquad [2]$$

The double log form of the Cobb-Douglas production function has been applied in studying the impact of climate change on crop production in Pakistan (Afzal et al., 2016). The double log production function implies that inputs affect output in a proportional manner. For example, a 1% increase in seed or fertilizer use will increase output by ϑ% rather than by a specific amount of kgs/ha. The implication is that inputs will be more effective on land with advantageous markets access and natural endowments. Our focus is on the effects of climate on livestock and crop production, so we consider inputs, other factors of production, and regional heterogeneity aspects only as control variables. The agricultural production function approach has been used in previous studies that aims to understand the impacts of climate change on agricultural production using survey data (Thornton et al., 2009; Kurukulasuriya & Rosenthal, 2013; Afzal et al., 2016; Mendelsohn & Wang, 2017).

3.3. Household survey and climate data

The data used in this research is obtained from the latest round of the Nigeria General Household Survey (NGHS), which consists of 3 137 households with agricultural and livestock production information. This data was collected in 2018/19 by the National Bureau of Statistics (NBS) in collaboration with the World Bank and Bill and Melinda Gates Foundation. The data are comprehensive and have a strong focus on agriculture. They contain variables on crop production that range from land preparation and input use to crop harvest and marketing. They also have comprehensive coverage of livestock production and contain information on animal holdings, diversity, meat, egg, and milk production.

We use all this crop and livestock production data to define our outcome variable in the thesis. We specifically include crop production, measured as the value of crop production in local currency (Naira) and crop productivity measured as the value of crop production in Naira per ha (Naira/hectare) as proxies for crop production. For livestock production, we include three proxies including,

i. The value of livestock sales in the past 12 months (Naira)
ii. Egg production (number of eggs laid in the last three months)
iii. Average quantity of milk produced per day (litres).

Inclusively, we measure for livestock diversity in the form of the Shannon entropy index, which captures the diversity of the livestock portfolio. We show the descriptive statistics of these variables in Table 1.

In addition, these data also collect information on household characteristics, including demographics of household members (education, health, labour, food, and non-food expenditures, income generating activities, housing conditions, assets, food security, and exposure to shocks) which our study uses to generate several control variables used in the analysis. The control variables we use are household farm size (hectares), family labour days spent in agriculture activities during the season, total household annual consumption expenditure (a proxy for household income), household size, distance to the nearest market(km), gender of household head, age of household head (years), and Agricultural capital index which we derive using principal components analysis.

We use a collection of agricultural equipment owned by the household covered in the household questionnaire and summarize them to make an index using Principal components analysis (McKenzie, 2005). In addition, we also include regional variables, specifically dummies for regions from which these data were collected. We give detailed descriptions and summary statistics of all the variables we used in the analysis in Table 2.

The households covered in the survey also have their location geo-referenced, hence, it is possible to link these data with other geospatial data such as rainfall and temperature. We use these location data to extract climate variables (temperature and rainfall) for ten years, 2010-2019, from WorldClim, which we process and combine with the household for analysis. We specifically generate measures of rainfall and temperature variability and indicators of exposure to heat and water stress and test their impact on livestock and crop production in Nigeria. We include two groups (climate conditions and shocks) of climate variables and four specific climate variables in the study:

Climatic Conditions: We include two variables to control for average long-term climatic conditions, which include:

1. Mean average annual rainfall (2010-2019) in mm, which proxies average long-term rainfall conditions in the village in which the farmer resides.
2. Mean average annual maximum temperature (degree Celsius), which proxy average long term temperature conditions in the village in which the farmer resides.

Climatic Shocks: We include two measures of exposure to shocks in the recent past. We are guided by related literature that proxy climate shocks such as drought and heat stress as deviations of climatic conditions (rainfall and temperature) from their long-term averages (Letta, Montalbano, & Tol, 2018; Michler et al., 2019; Bora, 2022). First, we include a proxy measure for exposure to less than long-term average rainfall which we term drought shock, and a measure of heat stress which proxy exposure to more than average maximum temperatures in the recent past. We measure these two specifically as follows:

- **Drought shock**=; $\left[\sum_{I=-1}^{i=-3}\left(\boldsymbol{R_{it}} - \boldsymbol{\widehat{R}_i}/\boldsymbol{\sigma_{Ri}}\right)/\mathbf{3}\right] < \mathbf{0}$, where R_{it} is the observed amount of rainfall for the year(t), $\boldsymbol{\widehat{R}}i$ is the average annual rainfall for household (i) over the reference period (2010-2019), and σ_{R_i} is the corresponding standard deviation of rainfall during the same period. We find an average drought shock in the previous three seasons before the season for which the agricultural data is defined (previous season (-1), two seasons before the season (-2), and three seasons before the season (-3) and assign one if the average for the three seasons is negative (less than average rainfall) and zero otherwise.

- **Heat stress**= $\left[\sum_{I=-1}^{i=-3}\left(T_{it} - \hat{T}_i / \sigma_{Ti}\right)/3\right] > 0$, where T_{it} is the observed maximum temperature for the year(t), $\hat{T}i$ is the average annual maximum temperature for the household (i) over the reference period (2010-2019), and σ_{T_i} is the corresponding standard deviation of maximum temperature during the same period. We find an average of temperature shock exposure in the previous three seasons before the season for which the agricultural data is defined (previous season (-1), two seasons before the season (-2), and three seasons before the season (-3) and assign one if the average for the three seasons is positive (higher than average temperature) and zero otherwise (Bora K, 2022)

The measures of drought and heat stress capture variations in rainfall and temperature from average conditions and are hence relative measures of shock exposure. Despite the advantages of these relative measures of shocks in capturing deviations from the normal (climate anomalies), they also have some limitations. For instance, the rainfall and temperature shock variables capture conditions in a given location relative to its reference (baseline value), thus, the interpretation is not straightforward as dry or wet, or heat or cold conditions mean different things depending on the context, even if expressed in relative terms. We summarize the semi-processed temperature and rainfall data we use in Figures 1 and 2. The figures show the distribution of monthly rainfall and temperature variables which we download and based on the sample of households we analyse. The rainfall and temperature variables show trends that align with the known climate conditions in Nigeria, which shows that we use good data which reflect climatic conditions in Nigeria.

In addition, in Table 1, we summarize the four climate variables defining climate conditions and exposure to shocks in the sample of farmers that we analyse together with other variables we have used in the analysis.

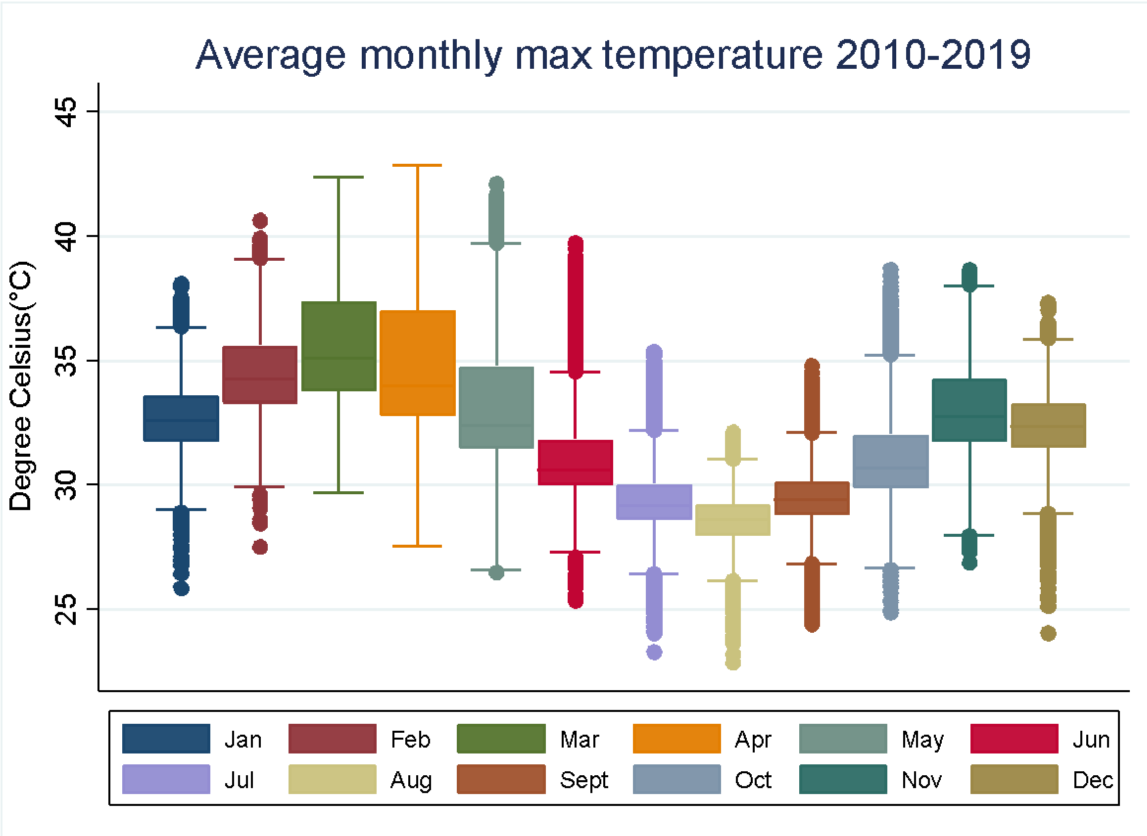


Figure 1: Average monthly maximum temperature for the period 2010-2019 based on the sample of farmers covered in the 2018/19 Nigeria General Household Survey. The temperature data is downloaded from WorldClim.

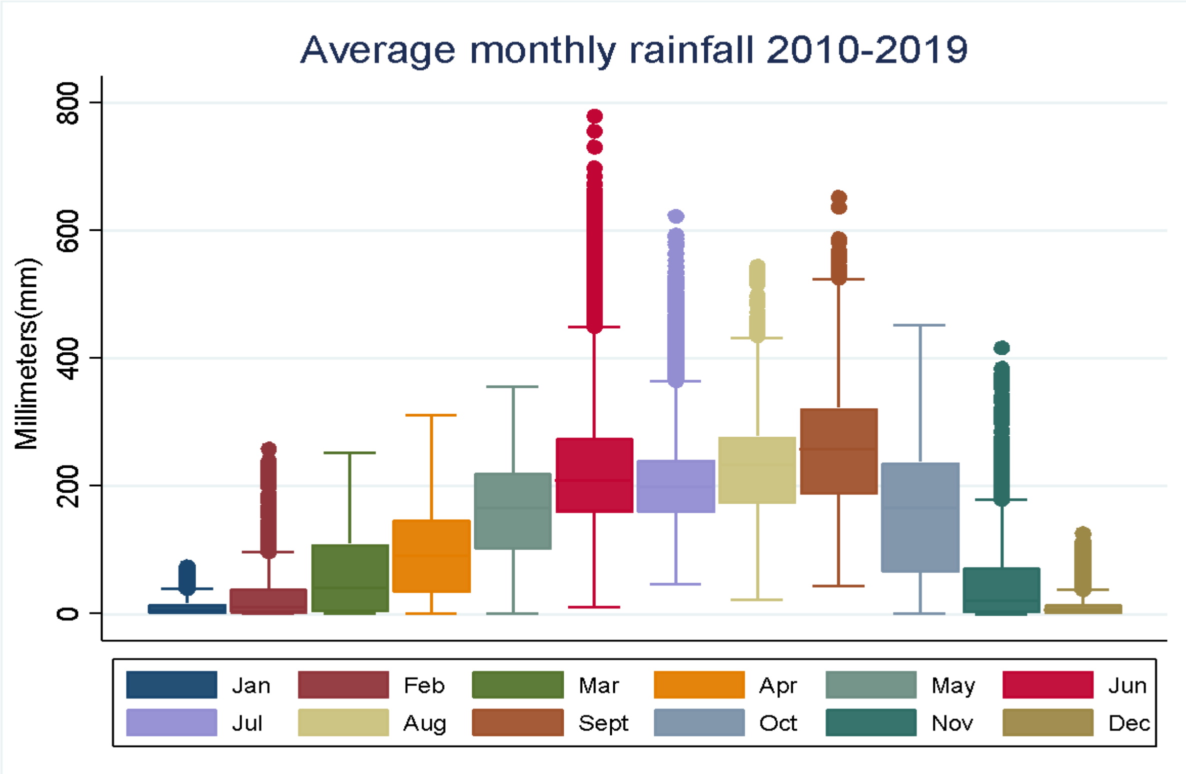


Figure 2: Average monthly rainfall for the period 2010-2019 based on the sample of farmers covered in the 2018/19 Nigeria General Household Survey. The temperature data is downloaded from WorldClim.

3.4 Estimation Strategy

Using cross-sectional regressions, we estimate the log-linear production function (equation 2). To interpret results from the analysis we assume that exposure to covariate shocks such as drought and heat stress is an exogenous variable since individual households do not have any influence on shocks that they experience. Specifically, we apply ordinary least squares regression to investigate climate change-related stocks, such as rainfall and heat stress, on crop production and productivity. This is motivated by the fact that crop production and productivity outcomes are continuous variables and hence can be used with linear regression. When using the ordinary least square regression, we make the following assumptions;

- The linear regression model is linear

- ➢ There is no multicollinearity
- ➢ No autocorrelation
- ➢ The observations are sampled randomly.
- ➢ The conditional mean is zero

In modeling the impact of climate shocks on crop production outcomes we use log-transformed production and yield as the dependent variable and measures of shocks as explanatory variables. Transforming the crop yield data also helps us in dealing with skewness in the data. Exploiting the exogenous temporal and spatial variation in climate conditions and shocks we estimate the effects of drought and heat stress of household crop production and productivity as follows:

$$Y_i = B_0 + B_1 R_{iv} + B_2 Ds_{iv} + B_3 T_{iv} + B_4 Hs_{iv} + B_5 C_i + \theta_i \quad [3]$$

Where Y_i is the outcome variable of interest, for crop production and productivity Y_i is expressed as log value of crop production (Naira) or log value of production per hectare (Naira/ha). R_{iv}, and T_{iv} are respectively measures of mean annual rainfall(log) and mean annual maximum temperature(log) for household i in village v. Ds_{iv} and Hs_{iv} are respectively dummies for drought and heat stress. C_i is a vector of control variables, and θ_i is the respective error term.

Also, for livestock production outcomes we exploit exogenous variation in climate variables and shocks and estimate the effect of drought and heat stress on livestock production as follows:

$$L_i = \emptyset_0 + \emptyset_1 R_{iv} + \emptyset_2 Ds_{iv} + \emptyset_3 T_{iv} + \emptyset_4 Hs_{iv} + \emptyset_5 C_i + \varphi_i \quad [4]$$

Where L_i is the livestock production outcome variable of interest, which include log value of livestock sales in the past 12 months (Naira), log value of egg production (Naira), Log of milk production(litres), and livestock diversity (entropy index of livestock diversity). φ_i is the error term and the rest of the variables are as described earlier.

For livestock production, only a section of respondents had livestock, implying that the data is censored. Accordingly, we use censored Tobit regressions (Tobin, 1958) for livestock production outcomes. The assumption that climate shocks are exogenously determined (farmers do not influence weather and climate events); help us infer causal effects from the analysis. We apply regression OLS (or Tobit) in two steps; first, we run naïve regressions where we control only for our variables of interest (climate shocks). Then, to test the possible impact of omitted variable bias, we include household and farm control variables in the next step. We run separate models for each outcome variable we use for analysis, including crop production, crop productivity, livestock sales, milk, and egg production. We present the results from the regression analysis in Tables 2 and 4 (Naïve regression) and 3 and 5 (Models with full controls).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Descriptive Statistics

All the variables used in the analysis are described in Table 1. We show the average (mean), corresponding standard deviation (SD), minimum (min), and maximum (max) of variables we used in the analysis. Based on the results presented, on average, the value of crop production is about Naira 137 367 (USD 178)/household and 241 368/hectare, respectively.

In Figure 3, we show the corresponding distribution of the log of crop production and productivity.

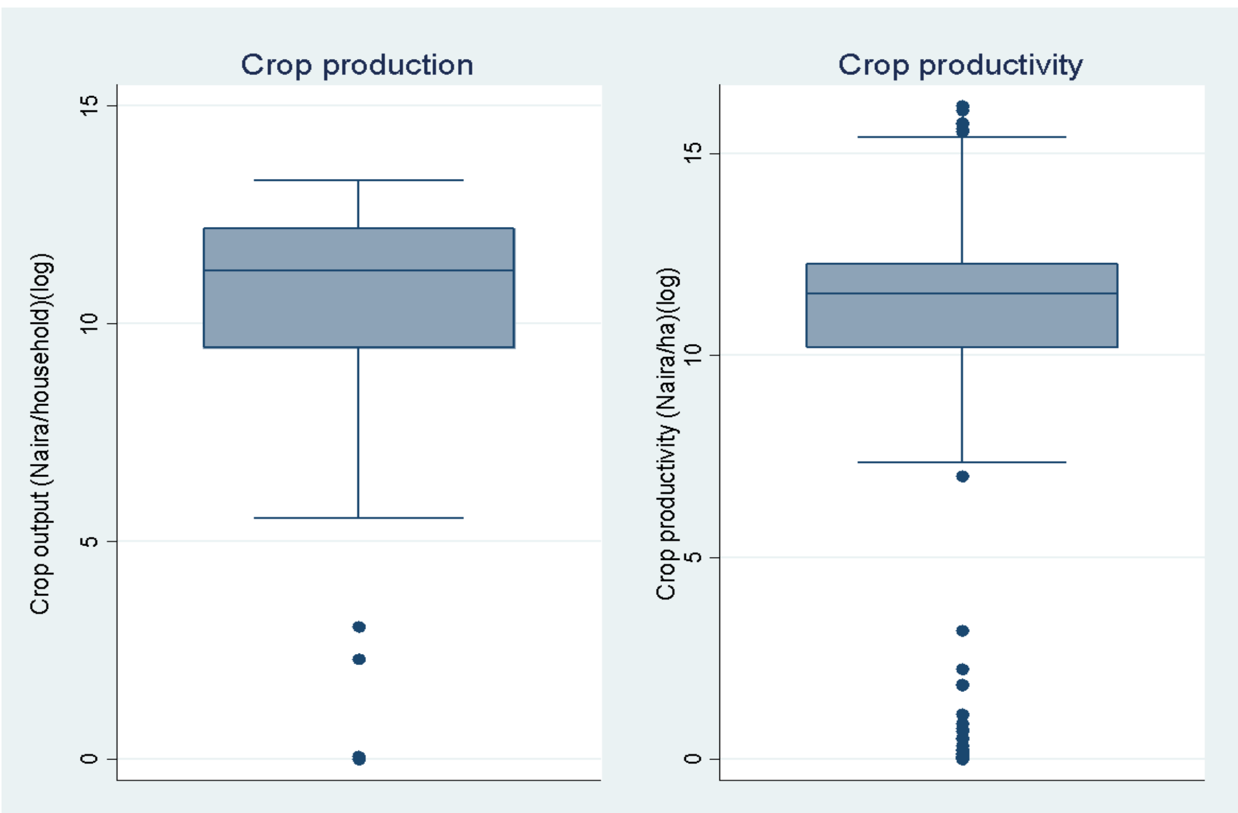


Figure 3: Crop production and productivity. Crop production is measured as the total value of crop output produced, whilst crop productivity is measured as the log value of crop output per hectare.

In addition, the average total earnings from livestock sales per household in the analysed sample is about 30 202 Naira. Egg production and milk production are less common in the sample, with respectively about 24 and 4% of the sample with non-zero values in the two outcomes. The corresponding average egg production in the last three months and average milk produced per day are, respectively, 28 eggs and 0.1 litres. In addition, the average livestock diversity index in the sample is 0.39, which indicates low diversity (close to zero- specialization).

Table 2: Descriptive statistics for variables used in the analysis.

	NGHS 2018/19			
Variable descriptions	mean	sd	min	max
Outcome variables				
Value of crop harvest(Naira)	137 364	162 701.	0.00	583 500
Log of Value of crop harvest(Naira)	9.70	4.09	0.00	13.28
Crop productivity (Naira/ha)	241 638	518 100	0.00	10558804.00
Log of Crop productivity (Naira/ha)	9.50	4.77	0.00	16.17
Value of livestock sales in the past 12 months(Naira)	30 202	94 803	0.00	1297500.00
Log value of livestock sales in the past 12 months(Naira)	2.79	4.55	0.00	14.08
Number of eggs laid in the last 3 months	27.91	580.71	0.00	25200.00
Average quantity of milk per day(litres)	0.08	1.07	0.00	50.00
Shannon Entropy Index(Livestock)	0.39	0.57	0.00	2.25
Climate variables				
Mean annual rainfall (2010-2019) in mm	1450.89	646.87	465.17	3549.27

Drought shock (On average rainfall received in the past 3 seasons was below normal)(yes)	0.55	0.50	0.00	1.00
Mean annual maximum temperature(Deg)	32.41	1.57	27.18	36.15
Heat stress (On average maximum temperature in the past 3 seasons was above normal)(yes)	0.37	0.48	0.00	1.00
Control variables				
Total farm size(ha)	1.08	1.74	0.00	46.78
Family labor(days)	49.31	68.58	0.06	953.00
Total annual consumption expenditure nominal	170 330	145 950	24410.74	320 6738
Total annual consumption expenditure nominal(log)	11.83	0.64	10.10	14.98
Agriculture capital index(PCA)	0.06	1.31	-1.22	28.49
Household size	5.77	3.44	1.00	29.00
Distance to the nearest market(km)	66.97	48.10	0.40	227.00
Household head is female(1=yes)	0.18	0.39	0.00	1.00
Age of Household head	50.38	15.44	17.00	130.00
North Central region	0.18	0.38	0.00	1.00
North East region	0.22	0.41	0.00	1.00
North west region	0.21	0.41	0.00	1.00
South East region	0.19	0.39	0.00	1.00
South South region	0.15	0.36	0.00	1.00

South West region	0.06	0.23	0.00	1.00
Observations	3137			

Note: The statistics are derived from the Nigeria Household survey 2018/2019.

The mean annual rainfall (2010-2019) in the analysed sample is 1451 mm, and the proportion of households who experienced below-normal rainfall in the recent past is 55%. In addition, the average maximum temperature (2010-2018) in the analysed sample is 34.4 degrees Celsius (Table 1). On average, 37% of the sampled households were exposed to heat stress (on average maximum temperature in the past three seasons was above normal). Descriptive statistics for the rest of the control variables we used are given at the bottom of Table 2.

On average, the farmers in the sample were cultivating about 1 hectare of land, and they spent, on average, a total of 49 family labour days in the field. On average, total annual household consumption expenditures are about 170 330 Naira. On average, the distance travelled to the main market is about 67 km. The proportion of households with a female household head is 18%, and the average age of household heads in the sample is about 50 years. The sample we analyse covers six regions in Nigeria, including the North Central region (18%), Northeast region (22%), Northwest region (21%), South East region (19%), South-South region (15%), and South West region (6%).

4.2. Regression Results

4.2.1. Impact of Climate Shocks on Crop Production and Productivity

Tables 3 and 4 present results showing the impact of climate variables and shocks on crop production and productivity. Table 3 presents naïve regression where we do not control for other household and control variables, while Table 4 presents full tables showing all control variables.

Table 3: OLS Naïve: Impact of climate variability on crop production and productivity in Nigeria 2018/19

	log(Crop production)		log(Crop Productivity)	
Variables	Coeff	Std	Coeff	Std
Mean annual rainfall (2010-2019) in mm(log)	-1.107**	0.457	-1.131**	0.550
Drought shock (1=yes)	-0.298**	0.134	-0.218	0.163
Mean annual maximum temperature(Deg)(log)	3.701	3.162	1.917	3.823
Heat stress (1=yes)	-0.657***	0.239	-0.882***	0.284
North Central region(reference)	0.000	.	0.000	.
North East region	0.723***	0.249	0.623**	0.271
North west region	0.575**	0.257	0.485	0.296
South East region	-1.376***	0.274	0.130	0.331
South South region	-2.687***	0.352	-2.401***	0.415
South West region	-2.923***	0.442	-4.586***	0.480
N	3137		3137	
r2	0.169		0.111	

*Notes: ***significant at 1% level; **significant at 5% level; *significant at 10% level. All estimates are based on robust standard errors. Crop production and productivity are measured respectively as log values of crop output/household and log value of crop output/hectare.*

Both drought shock and heat stress negatively impact crop production and productivity (Tables 3 and 4). For instance, exposure to less than normal rainfall (Drought shock) reduce crop production by between 35% (exp (0.298)-1) *100) (naïve specification), and about 24% (exp(0.217)-1)*100) (specification with full controls). For heat stress, results show heat stress to have significantly higher and negative impacts as exposure to heat stress (relative to non-exposure) result in a decrease in crop production by between 56% and 93% (Table 2 and 3).

These results imply that both heat and rainfall stress reduce crop output and yields in Nigeria, which aligns well with the theory and available empirical evidence (Barrios et al., 2008; Deressa & Hassan, 2009; Nelson et al., 2009; Kurukulasuriya & Rosenthal, 2013; Mendelsohn & Wang, 2017). The mechanisms through which drought and heat stress negatively impact crop production in Nigeria might include effects on water shortage during the growing season and excessive heat stress on crops, which aligns well with Hulme (1996)'s theory and the general literature (Mendelsohn, 2009; Kurukulasuriya & Rosenthal, 2013).

Table 4: OLS Full controls: Impact of climate variability on crop production and productivity in Nigeria 2018/19

	log(Crop production)		**log(Crop Productivity)**	
Variables	Coeff	Std	Coeff	Std
Mean annual rainfall (2010-2019) in mm(log)	-0.628*	0.352	-0.537	0.468
Drought shock (1=yes)	-0.217**	0.108	-0.160	0.143
Mean annual maximum temperature(Deg)(log)	-4.325*	2.464	-6.327*	3.267
Heat stress (1=yes)	-0.447**	0.187	-0.749***	0.249
Farm size in Ha(log)	1.606***	0.132	1.923***	0.190
Labor days (log)	1.262***	0.051	1.179***	0.058
Household income (log)	0.183	0.117	-0.228	0.152
Agriculture capital index	-0.051	0.039	0.010	0.050
Household size	0.005	0.019	-0.068***	0.025
Distance to market in km (log)	-0.146***	0.049	-0.236***	0.066
Female household head(1=yes)	-0.390**	0.168	-0.188	0.214
Age of household head(years)	-0.011***	0.004	-0.004	0.005
North Central region(reference)	0.000	.	0.000	.

North East region	0.793***	0.181	0.628***	0.221
North west region	2.016***	0.203	1.977***	0.258
South East region	0.089	0.234	1.572***	0.313
South South region	-1.436***	0.292	-1.103***	0.373
South West region	-1.471***	0.335	-3.207***	0.405
N	3137		3137	
r2	0.471		0.325	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. All estimates are based on robust standard errors. Crop production and productivity are measured respectively as log values of crop output/household and log value of crop output/hectare.

In addition to climate variables, we also see that crop production and productivity are significantly explained by household characteristics (Table 4). For instance, crop production and productivity are strongly and positively associated with farm size and labour, which implies that labour and farm size are key factors of production that enhance production. Distance to market, age, and female head, negatively associated with crop production/productivity, which gives further insights. First, as we move further from agricultural markets, access to productive inputs becomes more costly because associated transaction costs constrain access to inputs and other important services. This possibly explains why farmers close to the market are more productive compared to those living further from the market.

Second, farming is labour intensive, and the elderly farmers are likely to be less effective (less energy) in production compared to the more energetic younger farmers. This possibly explains the negative association we found between crop production/productivity and the household head's age. In addition, households headed by females are significantly less productive than their male-headed household counterparts. This notion probably confirms the existence of the gender productivity gap in smallholder agriculture in Africa, including Nigeria (Mukasa & Salami, 2015).

4.3. Impact of Climate Shocks on Livestock Production

In Tables 5 and 6, we present results showing the impact of climate variables and shocks on livestock production outcomes. Table 5 presents naïve regression where we only add climate variables and regional dummies as explanatory variables, while Table 6 presents full tables showing all control variables (household controls, climate variables, and regional controls).

Table 5: Tobit Naïve: Impact of climate variability on livestock production and diversity in Nigeria 2018/19

	log(livestock sales)		**log(Egg production)**		**log(Milk production)**		**Livestock diversity**	
	Coeff	Std	Coeff	Std	Coeff	Std	Coeff	Std
Variables								
Mean annual rainfall (2010-2019) in mm(log)	-9.255***	1.680	-2.939***	0.645	-2.695**	1.096	-1.196***	0.165
Drought shock (1=yes)	-0.658	0.553	-0.033	0.216	0.817**	0.332	0.020	0.054
Mean annual maximum temperature(Deg)(log)	-12.941	11.521	-2.704	4.453	14.752*	8.298	1.531	1.112
Heat stress (1=yes)	1.459	1.027	0.632	0.415	0.138	0.587	0.032	0.098
North Central region(reference)	0.000	.	0.000	.	0.000	.	0.000	.
North East region	0.819	0.909	-2.618***	0.378	-0.973*	0.508	-0.348***	0.088
North west region	-0.453	0.984	-1.664***	0.389	-1.059**	0.529	-0.253***	0.094
South East region	0.317	1.155	1.276***	0.430	-16.043	0.662	-0.332***	0.112
South South region	-2.944**	1.384	-0.638	0.515	-14.820	0.778	-0.632***	0.137
South West region	-3.686**	1.462	-1.057*	0.540	0.670	0.734	-0.958***	0.151
Var(e.Outcome)	145.630***	8.400	20.785***	1.310	7.750***	1.681	1.466***	0.075
N	3137		3137		3137		3137	
Pseudo r2								

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. All estimates are based on robust standard errors.

Results show that increasing rainfall, negatively associates with livestock income, diversity, milk, and egg production. Also, drought shock and maximum temperature is associated positively with average daily milk production. Heat stress is positively associated with livestock income, egg production, milk production, and diversity but is not significant at 5%. Results generally show that, unlike crop production, livestock production reacts more positively to stress (heat and drought stress). This is possible because livestock production, including for cattle and small ruminants, is also favorable in drier regions which are also prone to stress (Rojas-Downing et al., 2017). Hence heat and drought stress which might be too much for crop production, may actually support livestock production and diversity.

Table 6: Tobit Full controls: Impact of climate variability on livestock production and diversity in Nigeria 2018/19

	log(livestock sales)		log(Egg production)		log(Milk production)		Livestock diversity	
	Coeff	Std	Coeff	Std	Coeff	Std	Coeff	Std
Variables								
Mean annual rainfall (2010-2019) in mm(log)	-7.907***	1.665	-2.755***	0.642	-2.329**	1.131	-1.026***	0.158
Drought shock (1=yes)	-0.657	0.548	-0.067	0.214	0.708**	0.330	0.015	0.052
Mean annual maximum temperature(Deg)(log)	-20.250*	11.666	-3.247	4.535	16.554*	8.864	0.211	1.089
Heat stress (1=yes)	1.584	1.049	0.266	0.422	-0.362	0.600	0.010	0.097
Farm size in Ha(log)	2.635***	0.633	0.832***	0.257	0.966***	0.308	0.435***	0.059
Labor days (log)	0.075	0.205	0.087	0.081	-0.222*	0.116	0.031	0.019
Household income (log)	-0.672	0.567	-0.122	0.220	-1.317***	0.372	-0.202***	0.054
Agriculture capital index	0.292	0.209	0.206**	0.080	0.100	0.081	0.062***	0.019
Household size	0.315***	0.095	0.126***	0.038	-0.028	0.049	0.031***	0.009
Distance to market in km (log)	0.109	0.265	-0.360***	0.102	-0.271*	0.145	-0.033	0.025

Female household head(1=yes)	0.109	0.817	0.234	0.304	-13.991	0.180	-0.208**	0.081
Age of household head(years)	0.066***	0.019	0.011	0.007	0.025**	0.011	0.006***	0.002
North Central region(reference)	0.000	.	0.000	.	0.000	.	0.000	.
North East region	0.314	0.917	-2.982***	0.384	-1.393***	0.537	-0.494***	0.086
North west region	0.028	1.028	-1.781***	0.409	-1.139**	0.542	-0.205**	0.094
South East region	1.646	1.214	1.554***	0.454	-12.732	0.525	-0.011	0.114
South South region	-2.138	1.394	-0.485	0.519	-11.633	0.273	-0.409***	0.133
South West region	-2.220	1.472	-0.693	0.545	1.303*	0.774	-0.660***	0.146
Var(e.Outcome)	139.948***	8.057	19.955***	1.255	6.772***	1.456	1.306***	0.067
N	3137		3137		3137		3137	
Pseudo r2								

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. All estimates are based on robust standard errors.

In addition, several control variables are also significantly associated with livestock production outcomes. For instance, farm size positively associates with livestock income, egg production, milk production, and diversity, and this implies that larger farmer sizes significantly support livestock production. Larger farm sizes support livestock production with space for keeping the animals and also producing food for the animals. Agricultural asset endowments also positively explain milk production and livestock diversity. Asset capital endowments support agricultural production, including both crop and livestock, which explains the result.

Household size also positively explains livestock income, egg production, and livestock diversity. This is possibly linked to the importance of larger family sizes in providing labour important for livestock production. In addition, the age of the household head is found to correlate positively with livestock income, milk production, and livestock diversity. This possibly reflects the fact that older farmers own more livestock compared to the resource-constrained youthful farmers and hence are more likely to experience positive outcomes from livestock production.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND POLICY RECOMMENDATIONS

5.1 Summary of Major Findings

The study examined the impacts of climate change on crop and livestock production and productivity in Nigeria using the latest round of the Nigeria General Household Survey (NGHS) collected in 2018/19. Variables used to capture climate change were mean rainfall, drought shock, mean annual maximum temperature, and heat stress. On the other hand, crop and livestock production and productivity were captured with the value of crop harvest, the value of crop harvest per ha, the value of livestock sales, the number of eggs laid in the last three months, and the average quantity of milk per day. The study applied an Ordinary Least Squares estimation technique on the assumption that climate shocks are exogenously determined (farmers do not influence weather and climate events); hence we do not worry about the endogeneity of climate shocks in the analysis. The OLS estimation was applied in two steps; first, we ran naïve OLS regressions where we controlled only for our variables of interest (climate shocks). Then, to test the possible impact of omitted variable bias, we included household and farm control variables in the next step.

The study revealed that climate variability significantly influences crop production and productivity. Specifically, higher mean annual rainfall significantly implies lower crop and livestock production and productivity at 1% significance level. The result suggests that rainfall shock reduces crop production and productivity by an average of 1%. This may be because crop production hazards posed by rainfall shocks raise the risk of adopting agricultural technology, especially in rainfed, liquidity-constrained, and unfavorable market environments, which lowers production and productivity. Also, an extreme rainfall season could result in flooding, which could dilute plant nutrients and promote transmission of diseases like anthrax (Prins & Weyerhaus, 1987) and infestation with parasites (Fosbrooke, 1962).

Furthermore, drought shock negatively affects crop production at 5% significance level, suggesting that an increase in drought caused by climate variability poses a strong negative impact on household crop production by approximately 31%.

However, no significant negative result was found for livestock production. Heat stress strongly affects crop production and productivity by 62% and 87%, respectively at 1% significance level. This implies that an increase in heat stress by 1 degree, significantly harms crop production and productivity, which reduces crop yield considerably. Conversely, heat stress increases livestock sales by 63% at 10% significance level, and the mean of annual maximum temperature increases milk production by 6% at 1% significance level. The finding is inconsistent with apriori expectation; heat stress is expected to directly affect animal health and performance, thereby decreasing milk production and reproductive efficiency (Sejian et al., 2016).

Other control variables that significantly influence crop and livestock production and productivity were farm size per ha, labour input, distance to market, household size, gender of household head, head of household age, agriculture capital index, and total consumption per capita. Differences in geopolitical zones also influence crop and livestock production and productivity significantly.

5.2 Limitations of the study

The approach of this study was based on OLS technique which cannot rule out omitted variable bias. Als, the study used cross-sectional data from one time period, thereby limiting the robustness and poses potential constraints through which climate variables are configured.

5.3 Policy Recommendations

Based on the study's findings, some recommendations have been compiled to accommodate the impacts of climate change on agricultural production. A national strategy should be established to encourage adaptation measures because the current trend of rising temperatures and variations in precipitation is unavoidable. Therefore, scaling up these adaptive benefits also necessitates government investment to promote awareness and give technological assistance.

It’s also necessary for farmers to counteract the negative consequences of climate change, educating them about the changing climate patterns is necessary. Farmers must be alerted to the impacts of climate change on their crops and livestock at the proper time through appropriate channels.

In addition, constructing an integrated agricultural production and development system to either adjust to, mitigate, or reverse the ever-increasing climate impacts and consequently boost productivity, output, and net revenue will be of great value.

Finally, climate-smart resource allocation and usage through coordinated efforts between state and non-state entities should be utilized to increase productivity and maximize agricultural return. In order for this to be successful, the government must provide farmers with livestock varieties and seeds that are resistant to drought in order to boost productivity and preserve Nigeria's food security.

5.4 Conclusion

Based on the empirical findings of the study, the conclusion of this study is drawn from the hypotheses of the study. The study hypothesized that; climate change has no significant impact on crop production and productivity, climate change has no significant effect on livestock production, and climate change has no significant impact on Egg and milk production. The study used the latest round of the Nigeria General Household Survey (NGHS) which was linked with other geospatial data such as rainfall and temperature. The data linking was possible because the households covered in the NGHS survey also have their location georeferenced; hence, it was possible to use their location data to extract climate variables (temperature and rainfall) for ten years, 2010-2019, from WorldClim.

The empirical result revealed that climate variability indicators, like rainfall shock, drought shock, heat stress and mean of annual temperature are significantly related to crop and livestock production. Specifically, the result shows that rainfall is significantly associated with crop and livestock production and productivity at 1% significance level. Therefore, precipitation exacts a negative influence on households’ crop and livestock production in Nigeria. More so, heat stress exhibits a negative relationship towards crop production. Suggesting that increase in heat stress is associated with a decrease in crop production and productivity at 1% significance level. However, an increase in heat stress surprisingly increases livestock sales by 63% at 5% significance level.

Drought shock significantly and negatively impacts households' crop production and productivity with a magnitude impact of 34% and 27%, respectively. The finding suggests that an increase in drought shock decreases households' crop production by 34% and crop production by 27%; however, drought has no significant influence on livestock production. Mean of annual temperature exacts a significant positive influence on milk production at 1% significance level with a magnitude of about 5%. The finding suggests that a positive increase in temperature is associated with an increase in households' milk production.

Also, households' socioeconomic and geographical characteristics significantly influence crop and livestock production and productivity, like farm size, labour inputs, total consumption per capita, distance to market, agricultural capital index, household size, age of household head and gender of household head.

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