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Climate Change and Agricultural Productivity in Kaduna State, Nigeria: Implications for Food Security

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Abstract

This study examined the influence of climate change on agricultural productivity and its implications for food security in Kaduna State, Nigeria, between 2015 and 2023. The study was motivated by the increasing incidence of irregular rainfall, rising temperatures, prolonged dry spells, and flooding, which have adversely affected agricultural production and threatened household food security in the state. Despite growing literature on climate change and agriculture, limited empirical evidence exists on how climate change has influenced agricultural productivity and food security specifically within Kaduna State. The study adopted a quantitative research design anchored on **Food Security Theory**, as propounded by Sen (1981), Maxwell and Smith (1992), and Frankenberger (1992). The study population comprised the projected population of Kaduna State, while a sample size of 400 respondents was determined using the Taro Yamane formula. Data were collected through structured questionnaires, of which 390 were successfully retrieved and analysed using descriptive statistics and multiple regression analysis. The findings revealed a significant nexus between climate change and agricultural productivity, with irregular rainfall and rising temperatures reducing crop yields and agricultural output. The study further found that declining agricultural productivity has worsened household food insecurity, while inadequate irrigation facilities, weak extension services, and limited access to climate information constrained farmers' adaptive capacity. The study concludes that climate change has become a major driver of declining agricultural productivity and food insecurity in Kaduna State. It contributes to knowledge by extending Food Security Theory through demonstrating that institutional adaptation mechanisms mediate the relationship between climate change, agricultural productivity, and food security at the subnational level. The study recommends expanding irrigation infrastructure, strengthening climate smart agricultural extension services, increasing investment in climate resilient farming technologies, and integrating climate adaptation into agricultural and food security policies.

Keywords: Climate change, agricultural productivity, food security, climate adaptation, Kaduna State, Nigeria.

1.1 Introduction

Climate change has become one of the most significant factors influencing agricultural productivity and food security worldwide. Agricultural production depends on stable climatic conditions, particularly predictable rainfall, moderate temperatures, and healthy ecosystems. However, increasing climate variability has disrupted these conditions, leading to declining crop yields, reduced livestock productivity, and worsening food insecurity. Although many studies have established a relationship between climate change and agricultural performance, most have focused on global or national trends, with limited attention to subnational contexts where climatic impacts and adaptive capacities differ. This study addresses that gap by examining how climate change influenced agricultural productivity and its implications for food security in Kaduna State between 2015 and 2023.

Globally, agriculture remains highly vulnerable to climate change because it depends directly on weather and climatic conditions. Rising temperatures, changing rainfall patterns, prolonged droughts, floods, and pest outbreaks have disrupted food production systems across developed and developing countries. The Intergovernmental Panel on Climate Change reported that climate change has already reduced agricultural productivity in several regions, with developing countries experiencing the greatest impacts because of limited adaptive capacity (IPCC, 2023). Similarly, the Food and Agriculture Organization estimated that climate-related disasters caused agricultural losses exceeding US$3.8 trillion between 1991 and 2021, while approximately 735 million people experienced hunger in 2022, partly because of climate extremes (FAO, 2023; FAO, IFAD, UNICEF, WFP, & WHO, 2023). Recent experiences in India and China further demonstrate how heatwaves and flooding continue to reduce crop production and threaten food security (World Bank, 2024; FAO, 2024).

Africa is particularly vulnerable because agriculture is predominantly rain-fed and supports rural livelihoods and national economies. More than 95 percent of cultivated land in Sub-Saharan Africa depends on rainfall, making agricultural productivity highly sensitive to climate variability (African Development Bank, 2023). Rising temperatures, erratic rainfall, droughts, and floods have reduced crop yields and increased food prices across the continent (IPCC, 2023). Countries such as Kenya and Ghana have experienced declining agricultural output because of prolonged droughts and irregular rainfall, leading to increased food insecurity and reduced farmers' incomes (World Food Programme, 2024; International Food Policy Research Institute, 2024). These experiences illustrate that climate change has become a major challenge to sustainable agricultural development across Africa.

Nigeria reflects these continental trends because agriculture contributes about one quarter of the country's Gross Domestic Product and provides livelihoods for millions of rural households (National Bureau of Statistics, 2024). However, delayed rainfall, shortened growing seasons, flooding, desertification, rising temperatures, and pest infestations have increasingly constrained agricultural productivity. The Nigerian Meteorological Agency reported increasing rainfall variability and more frequent extreme weather events between 2015 and 2023, while the Federal Ministry of Agriculture and Food Security identified climate change as a major driver of declining crop production and worsening food insecurity (NiMet, 2024; Federal Ministry of Agriculture and Food Security, 2024). The Cadre Harmonisé further projected that about 31.5 million Nigerians would face acute food insecurity during the 2024 lean season because of climate shocks, insecurity, and economic pressures (Cadre Harmonisé, 2024).

Kaduna State is one of Nigeria's leading agricultural producers, supplying maize, sorghum, millet, soybeans, ginger, tomatoes, and vegetables. Agriculture remains the primary source of livelihood for a large proportion of the state's population. Between 2015 and 2023, however, farmers across several local government areas experienced delayed rainfall, prolonged dry spells, flash floods, declining soil fertility, and increased pest infestations, all of which disrupted planting seasons, reduced crop yields, increased production costs, and weakened household food security. Although previous studies have examined climate change, agricultural productivity, or food security separately, few have comprehensively analysed how climate change has influenced agricultural productivity and its implications for food security specifically in Kaduna State. This study fills that gap by providing state-specific empirical evidence to improve understanding of climate-related agricultural challenges and to support the formulation of effective climate adaptation and food security policies.

1.1 Statement of the Research Problem

Agricultural productivity has declined in many farming communities across Kaduna State due to increasing climate variability from 2015 to 2023, despite the state's strategic importance as one of Nigeria's major agricultural producers. Rising temperatures, delayed rainfall onset, prolonged dry spells, flooding, and more frequent extreme weather events have disrupted traditional farming calendars, reduced crop yields, increased production costs, and weakened the resilience of farming households. The Nigerian Meteorological Agency reported increasing rainfall variability and rising temperatures across northern Nigeria during this period, while the Intergovernmental Panel on Climate Change identified Sub-Saharan Africa as one of the regions most vulnerable to climate-induced agricultural losses (IPCC, 2023; NiMet, 2024). In

Kaduna State, these climatic changes have affected the production of maize, sorghum, millet, soybean, ginger, and vegetables, resulting in reduced farm output and unstable food supplies. At the national level, the Cadre Harmonisé projected that about 31.5 million Nigerians would face acute food insecurity during the 2024 lean season, with climate shocks identified as a major driver (Cadre Harmonisé, 2024). Since Kaduna is an important supplier of staple crops to several northern states, declining agricultural productivity has implications not only for household food availability and farmers' incomes but also for regional food markets, food prices, and nutritional security.

Although previous studies have examined climate change, agricultural production, and food security in Nigeria, most have focused on national trends or broad regional assessments, with limited empirical attention to Kaduna State from 2015 to 2023. Existing studies also tend to examine food security or climate change independently, rather than analysing how specific climate-related changes have influenced agricultural productivity and, subsequently, affected food security within the state. This leaves insufficient evidence to support location-specific adaptation policies and agricultural planning. Addressing this gap is important because effective interventions require an understanding of the local nature of climate impacts on agricultural production. Therefore, the main objective of this study is to examine the influence of climate change on agricultural productivity in Kaduna State and assess its implications for food security between 2015 and 2023. Also to propose strategies for improving agricultural productivity and food Security in Kaduna State.

1.3 Conceptual Clarification

Climate Change

Climate change refers to long-term alterations in the Earth's climate system, reflected in changes in temperature, rainfall patterns, humidity, and the frequency and intensity of extreme weather events. In the Nigerian context, Ayanlade and Radeny (2020) argue that climate change manifests as rising temperatures, irregular rainfall, droughts, flooding, and environmental degradation, all of which directly affect agricultural production and rural livelihoods. In this study, climate change refers to persistent changes in climatic conditions, particularly rainfall variability, rising temperatures, floods, and droughts, that influence agricultural productivity in Kaduna State.

Agricultural Productivity

Agricultural productivity refers to the efficiency with which agricultural inputs such as land, labour, capital, water, and technology are transformed into agricultural outputs. It is commonly measured by crop yield per hectare, livestock output, or total agricultural production relative to the resources used. Manyong, Arene, and Diao (2019) describe agricultural productivity as the capacity of farmers to increase output through efficient resource utilisation while maintaining environmental sustainability. Likewise, Liverpool Tasie and Kuku (2022) argue that agricultural productivity should not be assessed only by output volume but also by the stability and resilience of production under changing climatic conditions.

Food Security

Food security exists when all people have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Although this definition originates from the Food and Agriculture Organization,

Nigerian scholars have contextualised it within the country's agricultural and socioeconomic realities. Ojo and Adebayo (2019) define food security as the ability of households to consistently produce or obtain adequate food despite economic or environmental shocks. In this study, food security refers to the sustained availability, accessibility, affordability, and utilisation of adequate food by households in Kaduna State despite the effects of climate change.

1.4 **Methodology**

This study adopted a quantitative research design to examine the influence of climate change on agricultural productivity and its implications for food security in Kaduna State, Nigeria. The study population comprised the projected population of 9,577,300 for Kaduna State as reported by the National Population Commission (NPC, 2022). The sample size was scientifically determined using the Taro Yamane (1968) formula: n = N1 + N (e)2, where N = 9,577,300 and e = 0.05. This produced a sample size of 400 respondents. A multistage probability sampling technique was employed. First, respondents were selected using systematic random sampling to ensure equal chances of participation. Primary data were collected using a structured questionnaire, while secondary data were obtained from government publications and relevant literature. Data were analysed using descriptive statistics, including frequencies and percentages, to determine the effects of climate change variables on agricultural productivity and food security. All analyses were conducted using SPSS version 29 at a 0.05 level of significance.

1.5 Theoretical Framework

This study adopted Food Security Theory**,** originally developed **by** Amartya Sen (1981)**,** Maxwell and Smith (1992)**,** and Frankenberger (1992)**.** The theory explains that food security depends not only on food production but also on food availability, access, utilization, and stability. This study extends the application of the theory by examining how climate change affects agricultural productivity and how reduced productivity influences food security in Kaduna State between 2015 and 2023, rather than focusing solely on household access or poverty. The theory has been applied in studies on climate change and food security in Nigeria and Sub-Saharan Africa (Ayanlade & Radeny, 2020; Nnadi et al., 2021). Its relevance lies in explaining how climate-induced declines in crop production reduce food availability and household access to adequate nutrition. Critics argue that the theory pays limited attention to governance, conflict, and market failures that also shape food security outcomes (Clapp et al., 2022; FAO, IFAD, UNICEF, WFP, & WHO, 2023). However, these limitations do not diminish its suitability because climate change directly affects the four pillars of food security, making the theory appropriate for analysing the relationship between agricultural productivity and food security in Kaduna State.

1.6 Climate Change and Agricultural Productivity in Nigeria

Climate change has become one of the leading constraints on agricultural productivity in Nigeria, as the country's agricultural sector largely depends on rain-fed farming. Nigerian empirical studies consistently show that increasing temperatures, irregular rainfall, flooding, drought, and land degradation have reduced crop output. However, the magnitude of these impacts differs across ecological zones and farming systems.

According to **Ayanlade and Radeny (2020),** climate change has significantly altered agricultural productivity across Nigeria by increasing rainfall variability, prolonging dry spells, and raising temperatures, which affect crop growth and livestock production. Using evidence from across Nigeria's agroecological zones, the study found that farmers experienced delayed planting seasons, declining crop yields, increased pest infestations, and reduced soil moisture, particularly in northern Nigeria, where rain-fed agriculture predominates.

In the study of Nwalieji and Uzuegbunam (2021**),** the relationship between climate variability and agricultural productivity was examined among farming households in southeastern Nigeria using survey data collected from crop farmers. The authors found that irregular rainfall, flooding, excessive heat, and increasing pest and disease incidence significantly reduced the productivity of cassava, maize, and vegetable farmers.

Similarly, Adebayo, Onu, Adebisi, and Anyanwu (2022) investigated the effects of climate change on crop production and farmers' livelihoods in northern Nigeria using survey and meteorological data. The authors established that increasing temperatures and declining rainfall reliability significantly reduced the productivity of maize, sorghum, and millet, while increasing production costs due to higher demand for irrigation and pest control. They also observed that climate-related production shocks contributed to declining farm incomes and increased vulnerability among rural households.

1.8 Climate change, Agricultural Productivity and Food Security in Kaduna State

Climate change has increasingly affected agricultural productivity and food security in Kaduna State because farming remains predominantly rain-fed and highly sensitive to climatic

variability. Empirical studies conducted in Kaduna and neighbouring areas provide evidence that changing rainfall patterns, rising temperatures, and extreme weather events have reduced agricultural output and threatened household food security, although important contextual gaps remain.

According to Ayanlade and Radeny (2020)**,** climate change has intensified rainfall variability and rising temperatures across northern Nigeria, including Kaduna State, resulting in declining crop productivity and increased food insecurity among farming households. Drawing on empirical evidence from different agroecological zones, the authors found that delayed rainfall onset, prolonged dry spells, flooding, and heat stress disrupted planting calendars and reduced yields of staple crops such as maize, sorghum, and millet. They further observed that farmers adopted adaptation measures, including crop diversification, drought-tolerant varieties, and altered planting dates. However, these responses were constrained by weak institutional support and limited climate information services.

In the study of Usman and Muktar (2022), the effects of climatic conditions on agricultural output in Kaduna State were examined using the Autoregressive Distributed Lag (ARDL) model and secondary data obtained from the Nigerian Meteorological Agency and the Kaduna Agricultural Development Agency. The study found that fluctuations in rainfall, rising temperatures, and changes in relative humidity significantly affected agricultural output in the state, with rainfall variability exerting the greatest influence on crop productivity. The authors concluded that persistent climatic variability reduces agricultural output, increases production uncertainty, and poses a serious threat to food security in Kaduna State. The study makes an

important contribution by providing state-specific empirical evidence based on long-term climatic and agricultural data rather than relying solely on farmers' perceptions.

Similarly, Nnadi, Chikaire, and Echetama (2021) investigated the effects of climate variability on agricultural production and food security among rural farming households in Nigeria, including evidence from northern states. The study established that increasing temperatures, erratic rainfall, and extreme weather events significantly reduced agricultural productivity while increasing household vulnerability to food shortages. The authors further concluded that inadequate extension services, poor access to improved farm inputs, and limited adaptation financing weakened farmers' resilience to climate change.

1.9 Data Presentation and Analysis

This session presents the analysis and interpretation of data collected through structured questionnaires during the fieldwork on Climate Change and Agricultural Productivity in Kaduna State, Nigeria: Implications for Food Security**.** The findings are presented systematically in line with the study's research questions and objectives to provide empirical evidence on the relationship between climate change, agricultural productivity, and food security in the study area. A total of 400 questionnaires were administered to respondents across the selected study locations. Of these, 390 questionnaires were successfully retrieved, completed, and deemed suitable for analysis, yielding a 97.5% response rate. This high response rate indicates strong participation among respondents and enhances the reliability and validity of the findings presented.

1.9.1 Socio-Bio Data of Respondents

The socio-demographic characteristics of respondents included gender, age, marital status, educational qualifications, occupation, and LGAs. These variables provided important background information on the respondents and helped to explain variations in perceptions and experiences in the study area.

Table 1.1: Socio-Demographic Characteristics of Respondents (390)

Variables	Category	Frequency (f)	Percentage (%)
Sex	Male	245	62.8
	Female	145	37.2
	Total	**390**	**100.0**
Age (Years)	18 to 29	78	20.0
	30 to 39	118	30.3
	40 to 49	104	26.7
	50 to 59	62	15.9
	60 years and above	28	7.1
	Total	**390**	**100.0**
Marital Status	Single	81	20.8
	Married	267	68.5
	Divorced	18	4.6
	Widowed	24	6.1
	Total	**390**	**100.0**
Educational Qualification	Islamic Education	52	13.3
	Primary Education	69	17.7
	Secondary Education	118	30.3
	Tertiary Education	151	38.7
	Total	**390**	**100.0**
Occupation	Farming	174	44.6
	Civil Servant	72	18.5
	Trading/Business	81	20.8
	Artisan	39	10.0
	Others	24	6.1
	Total	**390**	**100.0**

Source: Field Survey, 2026.

Table 1.1 presents the socio-demographic characteristics of the 390 respondents. The results show that 245 respondents (62.8%) were male and 145 (37.2%) were female. This indicates that male respondents constituted the majority of the study participants, reflecting the dominant

role of men in agricultural production across many parts of Kaduna State. Regarding age distribution, respondents aged 30 to 39 years formed the largest group, with 118 respondents (30.3 percent), followed by those aged 40 to 49 years, with 104 respondents (26.7 percent). This suggests that most respondents were within the economically active and productive age brackets.

The findings further reveal that 267 respondents, representing 68.5 percent, were married, indicating that the majority had family responsibilities that could influence agricultural production and household food security decisions. Regarding educational qualifications, 151 respondents (38.7%) had tertiary education. In comparison, 118 respondents, representing 30.3 percent, had secondary education, suggesting that a substantial proportion had formal education that could enhance their understanding of climate-related agricultural practices. Regarding occupation, farming accounted for the highest proportion, with 174 respondents (44.6 percent), followed by trading and business (20.8 percent). This distribution confirms that the respondents possess the relevant knowledge and practical experience necessary to assess the influence of climate change on agricultural productivity and its implications for food security in Kaduna State.

Data Analysis

Table 1.2: Nexus between Climate Change and Agricultural Productivity in Kaduna State (Objective 1)

S/N	Variables	Strongly Disagree f (%)	Disagree f (%)	Undecided f (%)	Agree f (%)	Strongly Agree f (%)	Total f (%)
1	Climate change has significantly affected agricultural	18 (4.6)	27 (6.9)	24 (6.2)	172 (44.1)	149 (38.2)	390 (100.0)

	productivity in Kaduna State.						
2	Irregular rainfall and rising temperatures have reduced crop yields in the study area.	15 (3.8)	30 (7.7)	21 (5.4)	181 (46.4)	143 (36.7)	390 (100.0)

Source: Field Survey, 2026.

Table 1.2 indicates a strong consensus among respondents on the nexus between climate change and agricultural productivity in Kaduna State. The findings show that 172 respondents (44.1 percent) agreed and 149 respondents (38.2 percent) strongly agreed that climate change has significantly affected agricultural productivity, while only 11.5 percent expressed disagreement. Similarly, 181 respondents (46.4 percent) agreed, and 143 respondents (36.7 percent) strongly agreed that irregular rainfall and rising temperatures have reduced crop yields, representing a combined positive response of 83.1 percent. These findings are consistent with the Intergovernmental Panel on Climate Change (IPCC, 2023), which concludes that increasing temperatures and rainfall variability continue to reduce agricultural productivity, particularly in rain-fed farming systems across Sub-Saharan Africa. The findings also support the Nigerian Meteorological Agency (NiMet, 2024), which reported increasing rainfall irregularities and temperature fluctuations across northern Nigeria, including Kaduna State. The results validate the assumptions of Food Security Theory advanced by Sen (1981), Maxwell and Smith (1992), and Frankenberger (1992), which maintains that reduced agricultural production weakens food availability and threatens household food security. The convergence between the survey findings, empirical evidence, and the theoretical framework confirms that climate change has become a significant factor influencing agricultural

productivity and food security in Kaduna State.

Table 1.3: Effects of Climate Change on Agricultural Productivity and Food Security (Objective 2)

S/N	Variables	Strongly Disagree f (%)	Disagree f (%)	Undecided f (%)	Agree f (%)	Strongly Agree f (%)	Total f (%)
1	Climate change has reduced agricultural output in Kaduna State.	20 (5.1)	25 (6.4)	19 (4.9)	176 (45.1)	150 (38.5)	390 (100.0)
2	Declining agricultural productivity has increased household food insecurity.	17 (4.4)	28 (7.2)	22 (5.6)	170 (43.6)	153 (39.2)	390 (100.0)

Source: Field Survey, 2026.

Table 1.3 shows that respondents overwhelmingly agreed that climate change has adversely affected agricultural productivity and food security in Kaduna State. Specifically, 176 respondents (45.1 percent) agreed, and 150 respondents (38.5 percent) strongly agreed that climate change has reduced agricultural output. In comparison, 170 respondents (43.6 percent) agreed, and 153 respondents (39.2 percent) strongly agreed that declining agricultural productivity has increased household food insecurity. These combined responses of 83.6 percent and 82.8 percent, respectively, indicate a strong perceived relationship between climate change, reduced farm production, and food insecurity. The findings are consistent with the Food and Agriculture Organization (FAO et al., 2023), which reported that climate-related shocks have significantly reduced food production and increased food insecurity globally, particularly in countries dependent on rain-fed agriculture. They also support the Cadre Harmonisé (2024) assessment, which identified climate variability as a major contributor to

worsening food insecurity in northern Nigeria. The findings validate the propositions of Food Security Theory advanced by Sen (1981), Maxwell and Smith (1992), and Frankenberger (1992), which posit that reduced agricultural production directly undermines food availability and access. The convergence between the primary findings, empirical evidence, and the theoretical framework confirms that climate change has significantly reduced agricultural productivity, thereby worsening household food security in Kaduna State.

Table 1.4: Challenges Affecting Agricultural Productivity under Climate Change (Objective 3)

S/N	Variables	Strongly Disagree f (%)	Disagree f (%)	Undecided f (%)	Agree f (%)	Strongly Agree f (%)	Total f (%)
1	A lack of irrigation facilities limits farmers' ability to adapt to climate change.	16 (4.1)	26 (6.7)	23 (5.9)	175 (44.9)	150 (38.4)	390 (100.0)
2	Limited access to climate information and extension services affects farm productivity.	18 (4.6)	24 (6.2)	25 (6.4)	169 (43.3)	154 (39.5)	390 (100.0)

Source: Field Survey, 2026.

Table 1.4 reveals that respondents identified inadequate irrigation facilities and limited access to climate information and extension services as major challenges affecting agricultural productivity under climate change in Kaduna State. The findings show that 175 respondents (44.9 percent) agreed and 150 respondents (38.4 percent) strongly agreed that inadequate irrigation limits farmers' ability to adapt to climate change. Similarly, 169 respondents (43.3 percent) agreed, and 154 respondents (39.5 percent) strongly agreed that limited climate

information and extension services adversely affect farm productivity. These findings are consistent with the **Food and Agriculture Organization (FAO, 2024),** which reported that insufficient irrigation infrastructure and weak agricultural advisory services reduce farmers' adaptive capacity and agricultural output in Sub-Saharan Africa. They also support the **World Bank (2024),** which identified inadequate climate-resilient infrastructure and poor access to agricultural extension services as major barriers to sustainable agricultural production in Nigeria. The findings align with **Food Security Theory**, advanced by Sen (1981), Maxwell and Smith (1992), and Frankenberger (1992), which emphasises that sustained food security depends on stable agricultural production supported by adequate institutional and physical resources. The consistency among the survey results, empirical evidence, and the theoretical framework validates the importance of strengthening irrigation systems and extension services for improving agricultural productivity and food security in Kaduna State.

Table 1.5: Strategies for Improving Agricultural Productivity and Food Security (Objective 4)

S/N	Variables	Strongly Disagree f (%)	Disagree f (%)	Undecided f (%)	Agree f (%)	Strongly Agree f (%)	Total f (%)
1	Expanding irrigation and water management systems will improve agricultural productivity.	14 (3.6)	23 (5.9)	20 (5.1)	179 (45.9)	154 (39.5)	390 (100.0)
2	Providing climate-smart agricultural technologies and extension services will strengthen food security.	12 (3.1)	25 (6.4)	18 (4.6)	176 (45.1)	159 (40.8)	390 (100.0)

Source: Field Survey, 2026.

Table 1.5 shows that respondents strongly supported strategies to improve agricultural productivity and food security in Kaduna State. The findings indicate that 179 respondents (45.9 percent) agreed and 154 respondents (39.5 percent) strongly agreed that expanding irrigation and water management systems would improve agricultural productivity. Likewise, 176 respondents (45.1 percent) agreed, and 159 respondents (40.8 percent) strongly agreed that providing climate-smart agricultural technologies and extension services would strengthen food security. These findings are consistent with the Food and Agriculture Organization (FAO, 2024), which identified climate-smart agriculture, efficient irrigation, and strengthened extension services as effective measures to improve agricultural resilience and sustainable food production. The findings also support the Intergovernmental Panel on Climate Change (IPCC, 2023), which concluded that investments in climate adaptation technologies and water resource management significantly reduce climate-related agricultural losses. The results validate the assumptions of Food Security Theory, advanced by Sen (1981), Maxwell and Smith (1992), and Frankenberger (1992), which emphasises that improving agricultural productivity enhances food availability, accessibility, and stability. The convergence of survey findings, empirical evidence, and the theoretical framework confirms that climate-resilient agricultural interventions are essential to strengthening food security in Kaduna State.

Discussion of Major Findings

The first major finding established a strong nexus between climate change and agricultural productivity in Kaduna State. This finding confirms that increasing temperatures and irregular rainfall have become significant determinants of agricultural performance in the state. While this finding supports the conclusions of Ayanlade and Radeny (2020) and the IPCC (2023), the

present study advances existing knowledge by providing empirical evidence from Kaduna State rather than relying on broader national or regional assessments.

The second major finding revealed that reduced agricultural productivity has significantly increased household food insecurity in Kaduna State. This finding is consistent with FAO et al. (2023), who identified climate-induced production losses as a major contributor to global food insecurity, and with the Cadre Harmonisé (2024), which projected worsening food insecurity across northern Nigeria.

The third major finding identified inadequate irrigation facilities, limited climate information, and weak agricultural extension services as major barriers to farmers' adaptation to climate change. Although this finding agrees with the World Bank (2024) and FAO (2024), which emphasised institutional weaknesses as constraints to climate-resilient agriculture, this study demonstrates that these factors operate simultaneously to reduce productivity in Kaduna State.

The fourth major finding showed that expanding irrigation infrastructure, promoting climate-smart agricultural technologies, and strengthening extension services are the most effective strategies for improving agricultural productivity and food security. While previous studies recommended similar interventions, they often addressed climate adaptation or food security independently. This study differs by empirically demonstrating that these strategies simultaneously improve agricultural productivity and strengthen food security.

Conclusion

This study demonstrates that the relationship between climate change, agricultural productivity, and food security in Kaduna State is both direct and interdependent.

Conceptually, the findings extend existing scholarship by showing that climate change should not be examined as an isolated environmental phenomenon but as a critical factor shaping agricultural productivity and, ultimately, household food security. While previous studies, including Ayanlade and Radeny (2020), the IPCC (2023), and FAO et al. (2023), established the broader effects of climate variability on agriculture and food security, this study provides state-specific empirical evidence from Kaduna State, thereby addressing an important contextual gap in the literature.

The findings also reinforce the assumptions of Food Security Theory by confirming that reduced agricultural productivity weakens food availability and access. However, this study advances the theory by demonstrating that institutional factors, particularly irrigation infrastructure, climate information, and agricultural extension services, mediate the relationship between climate change and food security. Therefore, sustainable food security in Kaduna State depends not only on increasing agricultural production but also on strengthening farmers' adaptive capacity through climate-resilient policies, technologies, and institutional support. The study contributes to both theory and practice by providing evidence that can guide climate adaptation planning and agricultural policy in Kaduna State and other regions with similar climatic conditions.

Recommendations

1. The Kaduna State Government should expand irrigation infrastructure and promote sustainable water management systems to reduce farmers' dependence on unpredictable rainfall and improve year-round agricultural production.

2. The Federal and Kaduna State Ministries of Agriculture should strengthen agricultural extension services by providing timely climate information, climate-smart farming technologies, and regular farmer training on climate adaptation practices.
3. Government and development partners should increase investment in climate-resilient agricultural inputs, including improved drought-tolerant and flood-resistant crop varieties, while improving farmers' access to affordable agricultural credit.
4. Policymakers should integrate climate adaptation measures into agricultural and food security policies by continuously monitoring climate risks, improving early warning systems, and strengthening collaboration among meteorological agencies, research institutions, and farming communities.

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