



Climate Change and the Food Production Cycle in Kaduna State, Nigeria: Farmers' Perceptions, Production Impacts, Adaptation Constraints and Resilience Priorities

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Abstract

Climate change increasingly threatens agricultural productivity and food-system stability in sub-Saharan Africa, where much agricultural production depends on rainfall. Kaduna State, Nigeria, is an important agricultural region whose farming systems are vulnerable to rising temperatures, rainfall variability, drought, flooding, and climate-sensitive pest and disease pressures. This study examined the effects of climate change on the food production cycle in Kaduna State, focusing on four dimensions: manifestations of climate change, effects across stages of food production, constraints to farmer adaptation, and strategies for reducing adverse effects and improving food production. A survey research design was adopted. From an estimated population of 10,000 registered food-crop farmers in selected study areas, 385 respondents were selected using Yamane's formula and a multistage sampling procedure. Of these, 371 valid questionnaires were returned, representing a 96.4% response rate. Data were analysed using descriptive statistics, including frequencies, percentages, means, standard deviations, and variances. Findings indicate strong farmer agreement that climate change is manifested through rising temperatures, irregular rainfall, drought, flooding, and increased pest and disease infestation, with a grand mean of 4.31. Climate change was also perceived to substantially affect the food production cycle, with a grand mean of 4.34. Rising temperatures reducing crop yields recorded the highest mean score (4.53), followed by irregular rainfall affecting germination (4.45). Major adaptation constraints included inadequate finance (4.47), high irrigation costs (4.41), limited access to improved seeds (4.37), inadequate climate information (4.31), and weak extension services (4.24). The highest-ranked adaptation priorities were improved seed varieties (4.58), government support and extension services (4.55), irrigation (4.51), climate-smart agriculture (4.48), and climate information (4.39). The study concludes that climate risks affect the entire food production cycle and require an integrated resilience approach. It recommends combining climate information, affordable finance, improved climate-resilient seeds, irrigation, extension services, climate-smart agricultural practices, and resilient post-harvest and transport infrastructure to strengthen food-system resilience in Kaduna State.

Keywords: Climate change; food production cycle; agricultural adaptation; climate-smart agriculture; food security; smallholder farmers

Introduction

Climate change is one of the defining environmental and development challenges of the twenty-first century. Its significance for agriculture arises from the dependence of crop and livestock production on temperature, rainfall, soil moisture, water availability, and seasonal conditions. The

Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) confirms that human-induced climate change is already affecting natural and human systems, with risks increasing as warming intensifies (IPCC, 2023). Agriculture is particularly vulnerable because climatic shocks can simultaneously affect biological processes, farm decisions, infrastructure, markets, and household welfare.

The implications of climate change are especially significant in Africa. Although African countries have contributed relatively little to historical global greenhouse-gas emissions, the continent is experiencing disproportionate climate-related losses and adaptation costs (World Meteorological Organization [WMO], 2023, 2024). Increasing temperatures, rainfall variability, droughts, floods, heatwaves, and other extremes interact with structural constraints such as dependence on rain-fed agriculture, limited irrigation, inadequate rural infrastructure, weak extension systems, and restricted access to credit and insurance. Climate change can therefore deepen existing vulnerabilities within agricultural communities rather than acting as an isolated environmental stressor.

The effects extend beyond primary agricultural production. Food systems encompass interconnected activities involving production, harvesting, storage, processing, transportation, marketing, and consumption. Climate-related disruptions at one stage can generate consequences at subsequent stages. The IPCC identifies climate change as a threat to food availability, access, utilisation, and stability, while the Food and Agriculture Organization of the United Nations (FAO) emphasizes the need to understand agrifood systems as interconnected systems rather than isolated farm enterprises (FAO, 2024a; IPCC, 2022a). Rising temperatures may reduce crop yields, irregular rainfall may disrupt planting and germination, flooding may damage crops and rural roads, while excessive humidity can increase post-harvest and storage losses. These disruptions can ultimately influence food supply, prices, and household food access.

Nigeria provides an important context for examining these interactions. The country's agricultural sector is dominated by smallholder and predominantly rain-fed farming systems, making farmers highly sensitive to changes in rainfall and temperature. Recent Nigerian studies indicate that access to extension services, climate information, credit, improved seeds, and farmer organizations can enhance farmers' capacity to adopt adaptation measures (Adeagbo et al., 2021; Madaki et al., 2024; Solaja et al., 2024). Evidence also suggests that climate adaptation can improve food-security outcomes when farmers have access to appropriate technologies and institutional support (Madaki et al., 2024).

Kaduna State is one of Nigeria's important agricultural regions, with food crops including maize, sorghum, millet, rice, beans, soybean, ginger, and vegetables. Agricultural production across the state is increasingly exposed to rising temperatures, irregular rainfall, prolonged dry spells, flooding, and land degradation. Evidence indicates that farmers have experienced declining crop yields and that rainfall timing and distribution may be increasingly important to agricultural production (Abubakar & Sani, 2024). These conditions make Kaduna an important setting for examining climate impacts across the entire food production cycle, including production, post-harvest handling, transportation, and distribution.

Farmers' perceptions are important in understanding climate vulnerability because production decisions are influenced by

observed environmental conditions, experience, and available information. Perceptions of climate change can influence planting dates, crop choices, seed selection, irrigation decisions, and livelihood diversification. However, awareness does not necessarily guarantee effective adaptation. Research across Nigeria shows that farmers may recognize climate risks while facing financial, technological, informational, and institutional constraints (Akinkuolie et al., 2024; Oluwatimilehin & Ayanlade, 2023). Similar patterns have been reported elsewhere in Africa, where unpredictable rainfall, heat stress, and financial limitations constrain farmers' adaptive capacity (Bello et al., 2024; Fadina et al., 2023).

This study contributes to the literature by examining climate change as a food-production-cycle challenge rather than focusing solely on farm-level production. It assesses farmers' perceptions of climate manifestations, effects across different stages of the production cycle, constraints to adaptation, and preferred adaptation strategies. This integrated approach provides a broader understanding of climate vulnerability and resilience in Kaduna State.

Existing research has established important relationships between climate change and agricultural adaptation in Nigeria, but several gaps remain. Much of the literature is crop-specific, focusing on individual crops such as rice, maize, or cassava (Adeagbo et al., 2023; Ayanlade & Oluwatimilehin, 2023; Solaja et al., 2024). Other studies emphasize adaptation adoption without examining the complete sequence from production through post-harvest distribution. Evidence from Kaduna State also remains comparatively limited, while farmers' preferred adaptation strategies are not always examined alongside the constraints that hinder their implementation.

This study addresses these gaps by treating climate change as a food-production-cycle problem and identifying the stages perceived as most affected. It further connects these impacts with farmers' adaptive capacity and priorities. This perspective aligns with recent agrifood-system scholarship emphasizing interactions among production, infrastructure, institutions, and markets (FAO, 2024a; IPCC, 2022a).

The study is also relevant to Sustainable Development Goal (SDG) 2, which promotes zero hunger and sustainable agriculture, and SDG 13, which calls for urgent climate action. Strengthening agricultural adaptation can contribute to both goals by improving productivity and reducing vulnerability. However, effective adaptation must be accessible and affordable to smallholder farmers, since technically effective technologies that remain economically or institutionally inaccessible cannot deliver broad-based climate resilience.

Accordingly, the aim of this study is to examine the effects of climate change on the food production cycle in Kaduna State, Nigeria. Specifically, it seeks to:

- i. identify the major manifestations of climate change affecting agricultural activities;

- ii. examine effects on different stages of the food production cycle;
- iii. assess challenges faced by farmers in adapting to climate change; and
- iv. determine strategies for mitigating climate effects and enhancing the food production cycle.

Climate Change and Agricultural Systems

Climate change affects agriculture through multiple interacting pathways. Temperature influences photosynthesis, respiration, crop development and evapotranspiration, while rainfall determines water availability and affects planting and crop establishment. Extreme climatic events can also cause direct physical damage to crops, farms and agricultural infrastructure. The IPCC reports that climate change is already affecting agricultural productivity and food systems, with risks expected to increase as global warming intensifies (IPCC, 2022a, 2022b, 2023).

In Africa, rising temperatures are accompanied by significant spatial and temporal changes in rainfall. The WMO reports increasing temperatures across the continent, alongside droughts, floods, heatwaves and heavy precipitation events that are generating growing losses and damages (WMO, 2023, 2024). These impacts are particularly severe in agricultural communities, where climate shocks interact with poverty, inadequate infrastructure and limited adaptive capacity.

The relationship between climate variability and farmers' perceptions is complex. Farmers may not interpret climate change through statistical averages but through changes in planting dates, wet-season duration, dry spells, heat stress, crop performance and extreme events. Studies in Nigeria and other African countries indicate considerable correspondence between observed climatic conditions and farmers' perceptions, although variations may occur because of differences in local experience, knowledge and access to climate information (Adeagbo et al., 2021; Ayanlade et al., 2019; Yaro et al., 2022).

Climate Change and the Food Production Cycle

The food production cycle considered in this study comprises land preparation, planting, germination, crop growth, harvesting, storage and processing, transportation and distribution. This broad definition is consistent with the agrifood-system perspective advanced by FAO (2024a), which views food as moving through interconnected production and value-chain processes.

At the land-preparation and planting stages, rainfall variability can create uncertainty regarding when fields should be prepared and seeds planted. A false onset of rainfall may encourage premature planting followed by a dry spell, while delayed rainfall may shorten the effective growing period. Such uncertainties can reduce farmers' ability to optimise planting decisions (Ayanlade & Oluwatimilehin, 2023).

During germination and crop establishment, water stress can cause poor emergence and uneven crop stands, whereas excessive rainfall may result in waterlogging, erosion and nutrient loss. During crop growth, high temperatures and

moisture stress can reduce photosynthetic efficiency and reproductive success. Climate-related warming and changes in rainfall regimes have consequently been associated with agricultural yield losses across Africa (IPCC, 2022b).

Harvesting is similarly climate-sensitive. Excessive rainfall can delay harvesting, increase grain moisture and accelerate deterioration. Following harvest, high temperatures, humidity, pests and inadequate storage facilities can increase post-harvest losses. Flooding and damaged roads may further disrupt transportation and restrict market access. Therefore, effective agricultural adaptation must extend beyond farm-level production to include storage, processing, transportation and other components of the food system.

Farmer Adaptation and Adaptive Capacity

Agricultural adaptation involves adjustments in response to actual or expected climatic conditions. Common strategies include changing planting dates, adopting improved or drought-tolerant varieties, irrigation, crop diversification, soil and water conservation, agroforestry, improved nutrient management, livelihood diversification and participation in farmer organisations.

Evidence from Nigeria suggests that adaptation is often a portfolio of complementary practices rather than a single response. Adeagbo et al. (2023) found that credit and climate information, farmer organisations, education and farming experience influenced the adoption of multiple adaptation strategies among smallholder maize farmers. Similarly, Solaja et al. (2024) reported that extension visits, credit and climate information influenced adaptation choices among smallholder rice farmers in Kebbi State.

Financial capacity is a particularly important component of adaptive capacity. Ayinde et al. (2024) reported low resilience to climate shocks among many Nigerian farmers and identified infrastructure and improved resistant seed varieties as important intervention areas. Similarly, Ogunniyi et al. (2024) found that reducing financial constraints could strengthen farmers' adaptive capacity. This is relevant to the present study, in which inadequate finance recorded the highest mean among reported adaptation constraints.

Climate information and institutional support are also essential. Timely and localised information can help farmers adjust planting dates, select appropriate varieties and prepare for extreme events. Extension services can translate climate forecasts into practical agricultural recommendations, while cooperatives can facilitate access to inputs, information and markets. Social-capital networks can further strengthen adaptation by promoting information sharing and collective action (Ogunleye et al., 2021). Thus, strengthening farmers' adaptive capacity requires an integrated approach combining finance, climate information, extension services, infrastructure, technology and institutional support.

Climate-smart agriculture as an adaptation pathway

Climate-smart agriculture (CSA) seeks to address productivity, adaptation and, where possible, mitigation simultaneously. CSA is not a single technology but an

approach that includes practices such as improved varieties, conservation agriculture, agroforestry, integrated nutrient management, water management, diversification and climate information.

Recent Nigerian evidence shows that CSA adoption is influenced by socioeconomic and institutional conditions. Mbanasor et al. (2024) found that cooperative membership, extension exposure, education, income and credit access influenced CSA adoption among crop farmers in Southeast Nigeria. Bello et al. (2024) found that packages of climate-smart agricultural technologies improved crop sales and income among smallholders in the Sahelian region. These findings suggest that adaptation policies should promote combinations of practices rather than isolated technologies.

Research gap

Existing literature confirms climate change impacts on agriculture and the importance of adaptation but remains geographically and thematically fragmented. Many studies are crop-specific or focus on adaptation determinants. This study addresses the gap by providing integrated state-level evidence linking climate hazards, production-cycle impacts, adaptation constraints, and farmer priorities in Kaduna State.

Conceptual framework

The conceptual framework proposes that food-system vulnerability results from the interaction of climate exposure, production sensitivity, and adaptive capacity. Climate hazards include rising temperatures, irregular rainfall, drought, flooding, and pest and disease pressures. These affect critical production stages from land preparation and planting to harvesting, post-harvest handling, and transportation. Adaptive capacity, shaped by access to finance, improved seeds, irrigation, climate information, extension services, farmer organizations, and government support, determines farmers' ability to manage these impacts. The interaction ultimately influences crop productivity, post-harvest losses, farm income, food availability, prices, and household food security.

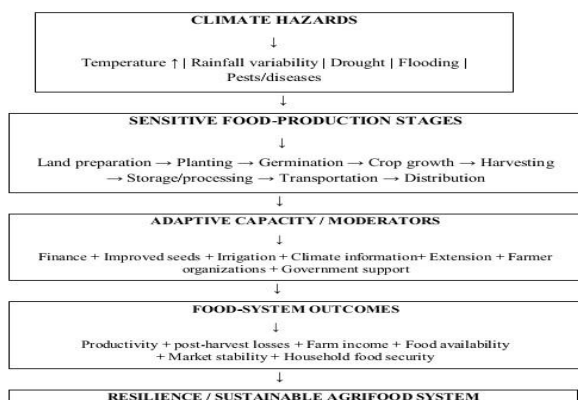


Figure 1. Framework on the food production cycle

Source: Author's Design, 2026

Materials and methods

Study area

Kaduna State is located in northwestern Nigeria and occupies

an important agricultural position within the country. The state lies between Latitudes 9°02'N and 11°32'N of the Equator and Longitudes 6°15'E and 8°50'E of the Greenwich Meridian (see figure 2). The state was created on 27th May 1967 and is one of the largest states in Northern Nigeria. Kaduna State shares boundaries with Katsina State to the north, Kano State to the northeast, Bauchi State to the east, Plateau State to the southeast, Nasarawa State and the Federal Capital Territory to the south, Niger State to the southwest, and Zamfara State to the northwest. The state occupies a strategic position within Nigeria and serves as a major agricultural and commercial hub in the northern region.

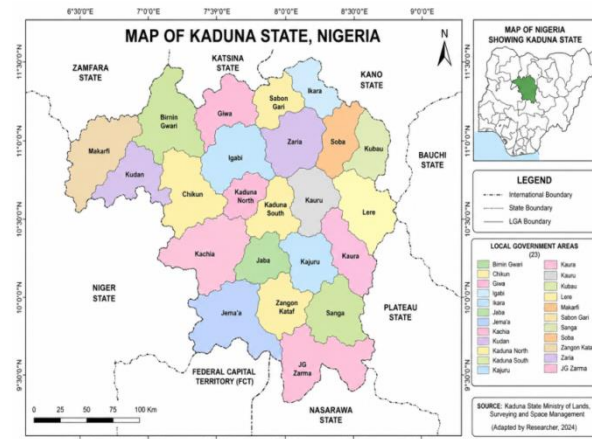


Figure 2: The Study Area

Source: Adopted from the Administrative Map of Nigeria

The state is characterized by a tropical continental climate with distinct wet and dry seasons. Agriculture is widely practiced across the state, with food crops including maize, sorghum, millet, rice, beans, soybean, ginger and vegetables. The combination of rain-fed production, climatic variability and dependence on agriculture makes the state appropriate for examining climate effects on the food production cycle.

The study identifies rising temperature, rainfall variability, drought, flooding and other extreme events as important climate pressures affecting the state. It further indicates that the study covers climate effects during the period 2015–2025. The geographical scope is Kaduna State, while the empirical population comprises registered food-crop farmers in selected intensive agricultural areas.

Methodology

A survey research design was adopted. Primary information was collected through a structured questionnaire administered to food-crop farmers. The questionnaire was organized around the four objectives of the study and contained items measuring climate manifestations, food-production-cycle impacts, adaptation constraints and adaptation strategies.

Population, sample size and sampling

The estimated population of registered food-crop farmers in the selected study areas was 10,000.

Yamane's formula was used:

$$n = N / [1 + N(e^2)] \text{ ----- (1)}$$

where:

- n is the required sample size,
- N is the population size and
- e is the level of precision.

At N = 10,000 and e = 0.05:

$$\begin{aligned} \text{➤ } n &= 10,000 / [1 + 10,000(0.05^2)] \\ n &= 10,000 / 26 \\ n &= 384.6 \end{aligned}$$

The sample was therefore rounded to 385 respondents. A multistage sampling technique was used. Three Local Government Areas (LGAs) (Kauru, Kachia, and Lere LGAs) with intensive food-crop production were purposively selected from the three senatorial zones (one each). Farming communities were then selected, and registered food-crop farmers were selected using simple random sampling. The study reports that the sample was proportionately distributed according to the number of registered farmers in the selected areas.

Questionnaire and measurement

The questionnaire used a five-point Likert response structure. The empirical instrument contained five statements for each of the four substantive objectives. Responses were summarized using means, standard deviations and variances. A higher mean indicates stronger agreement with the statement.

Data collection and response rate

A total of 385 questionnaires were administered. Three hundred and seventy-one were returned and considered usable, while 14 were not returned or were unsuitable for analysis. The resulting response rate was 96.4%. The high retrieval rate provides a strong descriptive basis for interpreting the responses of the surveyed farmers.

Data analysis

The data were coded and processed using SPSS. Frequencies and percentages were used for demographic variables. Means, standard deviations and variances were used for the five-point Likert items. Grand means were used to summarize each objective. The analysis is descriptive and therefore identifies the strength and direction of farmers' agreement rather than claiming statistical causality.

Results

A total of 385 questionnaires were administered, of which 371 were duly completed, returned and found usable for analysis, representing a 96.4% response rate. The 371 valid responses were analysed, interpreted and discussed in accordance with the research objectives and questions.

Respondent characteristics

The demographic profile in Table 1 shows that 243 respondents (65.5%) were male and 128 (34.5%) were female. The age distribution was 19.4% for 18–30 years, 28.0% for 31–40 years, 31.8% for 41–50 years and 20.8% for

respondents aged 51 years and above. Educational attainment comprised 21.8% primary education, 38.8% secondary education, 27.5% tertiary education and 11.9% other forms of education. Farming experience was 1–5 years for 18.6%, 6–10 years for 31.5%, 11–15 years for 28.3% and more than 15 years for 21.6%.

Table 1. Selected demographic characteristics of respondents

SN	Variable	Frequency	Percentage
Gender			
A	Male	243	65.50
B	Female	128	34.50
	Total	371	100.0
Age			
A	18–30	104	28.0
B	31–40	118	31.8
C	41–50	77	20.8
D	≥51	72	19.4
	Total	371	100.0
Education			
A	Primary	81	21.8
B	Secondary	144	38.8
C	Tertiary	102	27.5
D	Other	44	11.9
	Total	371	100.0
Experience 			
A	1–5 years	117	31.5
B	6–10 years	105	28.3
C	11–15 years	80	21.6
D	>15 years	69	18.6
	Total	371	100.0

Source: Field Analysis, 2026

Manifestations of climate change

Table 2 presents farmers' perceptions of climate-change manifestations. The grand mean of 4.31 indicates agreement that the listed manifestations are occurring and affecting agricultural activities. Rising temperature recorded the highest mean (4.42), followed by increased pest and disease infestation (4.39) and irregular rainfall (4.36). Increased drought recorded 4.28 and flooding 4.11.

Table 2. Major manifestations of climate change affecting agricultural activities

SN	Statement	Mean	SD	Variance	Decision
A	Rising temperature has become more noticeable	4.42	0.71	0.50	Agree
B	Rainfall patterns have become irregular/unpredictable	4.36	0.75	0.56	Agree
C	Drought occurrence has increased	4.28	0.81	0.66	Agree
D	Flooding occurs more frequently	4.11	0.89	0.79	Agree
E	Climate change has increased pest/disease infestation	4.39	0.73	0.53	Agree
Grand mean		4.31	-	-	Agree

Source: Field Analysis, 2026

Effects on the food production cycle

As presented in Table 3, the grand mean for the food-production-cycle effects was 4.34. Rising temperatures reducing crop yields had the highest score (4.53), followed by irregular rainfall affecting germination (4.45). Climate change delaying land preparation and planting scored 4.30. Extreme weather increasing post-harvest losses scored 4.26, while disruption of transportation and distribution scored 4.18.

Table 3. Effects of climate change on the food production cycle

SN	Statement	Mean	SD	Variance	Decision
A	Delay land preparation and planting	4.30	0.79	0.62	Agree
B	Irregular rainfall negatively affects germination	4.45	0.68	0.46	Agree
C	Rising temperature reduce crop yields	4.53	0.65	0.42	Agree
D	Extreme weather increases post-harvest losses	4.26	0.77	0.59	Agree
E	Disrupts transportation and food distribution	4.18	0.82	0.67	Agree

Grand mean 4.34 - - Agree

Source: Field Analysis, 2026

Constraints to adaptation

The adaptation-constraint statements in Table 4 produced a grand mean of 4.36. Lack of finance was the highest-ranked constraint at 4.47. High irrigation costs followed at 4.41, limited access to improved seeds at 4.37, inadequate climate information at 4.31 and poor extension services at 4.24.

Table 4. Challenges faced by farmers in adapting to climate change

SN	Statement	Mean	SD	Variance	Decision
A	Lack of finance limits adaptation	4.47	0.66	0.44	Agree
B	Inadequate climate information affects adaptation	4.31	0.75	0.56	Agree
C	Poor extension services hinder adaptation	4.24	0.82	0.67	Agree
D	Limited access to improved seeds affects resilience	4.37	0.72	0.52	Agree
E	High irrigation costs discourage adaptation	4.41	0.69	0.48	Agree
Grand mean		4.36	-	-	Agree

Source: Field Analysis, 2026

Strategies for enhancing food production

The strategy domain in Table 5 produced the highest grand mean of all four domains, 4.50, indicating strong agreement. Improved seed varieties ranked first (4.58), followed by government support and extension services (4.55), irrigation (4.51), climate-smart agricultural practices (4.48) and climate information (4.39).

Table 5. Strategies for mitigating climate effects and enhancing food production

SN	Strategy	Mean	SD	Variance	Decision
A	Improved seed varieties	4.58	0.61	0.37	Strongly Agree
B	Irrigation farming	4.51	0.63	0.40	Strongly Agree
C	Climate-smart	4.48	0.67	0.45	Agree

	agriculture					
D	Access to climate information	4.39	0.71	0.50	Agree	
E	Government support and extension	4.55	0.58	0.34	Strongly Agree	
	Grand mean	4.50	-	-	Strongly Agree	

Source: Field Analysis, 2026

Cross-objective synthesis

The four grand means provide a useful synthesis of the empirical results. Climate manifestations scored 4.31, effects on the food production cycle 4.34, adaptation constraints 4.36 and adaptation strategies 4.50. The progression suggests that respondents not only recognized climate change and its effects but also expressed strong views about the constraints and solutions associated with adaptation. Importantly, the highest mean occurs in the strategy domain, indicating a strong perceived need for intervention.

Discussion

Farmers perceive climate change as an immediate agricultural risk

The first major finding is the strong agreement that climate change is manifested through rising temperatures, rainfall irregularity, drought, flooding and increased pest and disease infestation. The grand mean of 4.31 indicates that these are not abstract or distant risks for the surveyed farmers. Rising temperature received the highest score, which is consistent with the broader scientific evidence that warming is already affecting African agricultural systems (IPCC, 2022b, 2023; WMO, 2024).

The Kaduna result is also consistent with Nigerian evidence. Oluwatimilehin and Ayanlade (2023) documented the importance of climate information, rainfall variability and adaptation constraints among Nigerian farmers. Research among maize farmers in Southwest Nigeria likewise found that farmers adopt multiple strategies in response to climate change and that climate information, credit and farmer organizations influence adoption (Adeagbo et al., 2023). The consistency of these findings across ecological zones suggests that climate change is a national agricultural challenge, although its specific manifestations vary geographically.

The relatively high score for pest and disease infestation is important. Climate affects pest and pathogen dynamics through temperature, moisture and host-plant conditions. Farmers may therefore experience climate change indirectly through changes in pest pressure even where the climatic signal itself is difficult to quantify. This strengthens the case for climate-informed pest management and extension services.

Rainfall variability and the timing of agricultural operations

The findings that irregular rainfall affects germination (mean 4.45) and delays land preparation and planting (mean 4.30) highlight the importance of rainfall timing and distribution. Agricultural productivity depends not only on total rainfall but also on its occurrence during critical crop-growth stages. This aligns with Isaac and Ikpe (2024), who found that rainfall distribution influences maize germination, growth, and yield in Kaduna State. Similar studies show that farmers respond to delayed rainfall onset, shorter wet seasons, and erratic precipitation by adjusting planting dates, crop varieties, and water-management practices (Adeagbo et al., 2021; Solaja et al., 2024). Climate information can further support timely decisions (Ziervogel et al., 2022). Therefore, Kaduna’s agricultural advisories should provide operational guidance alongside seasonal forecasts, including recommendations on planting delays, short-duration varieties, irrigation preparation, and staggered planting.

Rising temperature and crop-yield reduction

Rising temperature reducing crop yields recorded the highest individual food-cycle score (4.53). The result is scientifically plausible because crops have temperature thresholds beyond which physiological processes become impaired. Heat stress can increase evapotranspiration, reduce water-use efficiency, alter flowering and grain filling, and shorten crop duration.

The IPCC identifies heat and water stress as major agricultural risks in Africa and projects further reductions in the suitability of some existing production areas as warming continues (IPCC, 2022b). A recent African meta-analysis also found an overall negative relationship between climate factors and food security across studies, reinforcing the importance of temperature and precipitation as determinants of food-system outcomes (Journal of Agriculture and Food Research, 2025).

For Kaduna, the implication is that adaptation should include heat- and drought-tolerant varieties, improved soil-moisture management, water harvesting, irrigation and adjustment of planting calendars. Improved varieties ranked first among the strategies in the present study, suggesting that farmers themselves identify varietal adaptation as an important response.

Climate impacts extend beyond production

The findings concerning post-harvest losses (4.26) and transportation/distribution (4.18) are important contributions of this study. Many agricultural studies focus on yield and overlook what happens after harvest. However, food availability depends on the quantity that survives harvest, storage, processing and transportation.

Flooding can damage rural roads and bridges, delay transportation and increase food losses. High temperature and humidity can accelerate deterioration in poorly ventilated storage facilities. Extreme rainfall can also interfere with drying and increase contamination risks. The broader agrifood-system perspective emphasizes that resilience must therefore extend across value chains (FAO, 2024a).

The finding also has implications for food prices. When production losses coincide with transport disruption, the

quantity of food reaching markets can fall while costs increase. The resulting price effects can affect consumers even where farmers are geographically distant from major urban centres.

Finance is the central adaptation constraint

Lack of finance recorded the highest adaptation-constraint mean (4.47). This finding is strongly supported by the Nigerian adaptation literature. Ogunniyi et al. (2024) found that financial vulnerability is closely associated with adaptive capacity, while Madaki et al. (2024) found that access to credit increased the likelihood of adopting climate-risk adaptation strategies and that adoption improved food-security outcomes.

The implication is that adaptation policy should not assume that farmers can independently finance climate technologies. Improved seeds, irrigation, mechanization, water harvesting, storage facilities and climate-smart inputs all require financial resources. Credit therefore acts not simply as an economic service but as an adaptation-enabling institution.

Microcredit evidence from Kwara State also demonstrates the importance of finance. Access to microcredit increased the intensity of climate-adaptation adoption among rice farmers (Adepoju et al., 2023). Similarly, non-farm employment can strengthen adaptive capacity by generating income outside the cropping season (Danso-Abbeam et al., 2021). These findings suggest that agricultural adaptation finance should be complemented by broader rural livelihood development.

Irrigation: high potential but high cost

The high mean for irrigation cost as a constraint (4.41), alongside the high priority assigned to irrigation (4.51), creates an important policy signal. Farmers recognize irrigation as a useful response to rainfall uncertainty but identify cost as a barrier.

This is a classic adaptation-access problem: the technology is perceived as desirable but is not sufficiently affordable. Public policy can address the gap through small-scale irrigation infrastructure, solar-powered pumping, water harvesting, low-cost drip systems, cooperative ownership and credit. However, irrigation expansion should be accompanied by sustainable water-resource management to prevent groundwater depletion and other unintended effects.

Improved seeds as the highest-ranked adaptation priority

Improved seed varieties received the highest strategy score (4.58), highlighting farmers' strong preference for climate-resilient planting materials. This finding agrees with Nigerian studies reporting the widespread use and perceived usefulness of improved varieties. Solaja et al. (2024) identified improved seeds among the major adaptation strategies of smallholder rice farmers, while Ikpe et al. (2024) and Madaki et al. (2024) emphasised drought-tolerant and early-maturing varieties. However, the effectiveness of improved seed systems depends on their availability, affordability, timely distribution, and farmers' knowledge of appropriate use. Seed interventions should therefore be integrated with extension services and climate information. Varieties should be selected according to

locally relevant climate risks, including drought, heat, flooding, pest and disease pressures, and shortened growing seasons.

Extension services and climate information

Government support and extension services scored 4.55, while climate information scored 4.39. These results show that farmers recognize information and institutional support as important adaptation resources.

Evidence from Nigeria indicates that extension visits, access to climate information and farmer organizations influence adaptation decisions (Adeagbo et al., 2021, 2023; Solaja et al., 2024). Mbanasor et al. (2024) likewise found that extension exposure and cooperative membership were important in CSA adoption.

The implication is that Kaduna's extension system should be strengthened as a climate-advisory service. Extension officers should be able to interpret seasonal forecasts, explain crop-specific implications and recommend adaptation packages. Climate information should be delivered through multiple channels, including radio, mobile communication, community meetings, farmer organizations and extension agents.

Adaptation should be treated as a package

The grand strategy mean of 4.50 indicates that farmers strongly support the adoption of multiple adaptation measures simultaneously. This finding is consistent with evidence that adaptation practices are often complementary rather than mutually exclusive. Ikpe and Ugbede (2025) and Adeagbo et al. (2023) found that smallholder maize farmers adopted multiple strategies, while Bello et al. (2024) reported that combinations of climate-smart technologies could improve farmer welfare. A package approach is particularly relevant to Kaduna State because the effectiveness of individual interventions may depend on complementary support. Improved seeds may perform poorly under severe drought without adequate water management; irrigation may remain inaccessible without affordable finance; climate information may be difficult to translate into action without effective extension services; and extension may have limited practical value where farmers lack access to necessary inputs. Consequently, climate adaptation policies should prioritise integrated packages of complementary interventions rather than isolated measures.

Comparison with wider African evidence

The Kaduna findings align with evidence from African drylands, where drought, rainfall variability, and heat stress are major agricultural risks. Common adaptation strategies include crop diversification, early planting, conservation agriculture, irrigation, and livelihood diversification (Abdullah et al., 2023; Bello et al., 2024). Studies from Ethiopia and Ghana also emphasize extension, climate information, education, income, and farm characteristics (Abdissa et al., 2023; Amoah et al., 2023; Awuah et al., 2023). However, adaptation must reflect local conditions; Kaduna requires context-specific strategies suited to its savanna environment.

Gender and inclusion

The sample comprised 65.5% male and 34.5% female respondents. The study did not estimate gender-differentiated adaptation effects, so causal or comparative conclusions should not be drawn from the descriptive gender distribution. Nevertheless, gender remains relevant to policy because evidence from Nigerian women farmers shows that women may experience climate shocks differently and may face constraints in access to land, inputs, information and services (Onyimadu, 2023). Future Kaduna studies should therefore examine whether adaptation access differs by gender, age, farm size, income and location.

Implications for food security and SDGs

The findings directly support SDG 2 (Zero Hunger) and SDG 13 (Climate Action). Climate change threatens food security through yield and post-harvest losses, while adaptation strengthens resilience. Nigerian evidence shows that climate-risk adaptation can improve dietary diversity and reduce food-security coping strategies (Madaki et al., 2024). However, food security also depends on affordability, storage, transportation, and market access. Climate adaptation should therefore integrate agricultural production with resilient food-system infrastructure and planning.

Conclusion

This study examined the effects of climate change on the food production cycle in Kaduna State using survey evidence from 371 food-crop farmers. Four major findings emerged. First, farmers strongly perceived climate change through rising temperatures, irregular rainfall, drought, flooding, and increased pest and disease infestation, with a grand mean of 4.31 indicating a high level of agreement.

Second, climate change significantly affected multiple stages of the food production cycle. The grand mean of 4.34 demonstrated substantial effects from land preparation and planting through germination, crop growth, post-harvest handling, transportation, and distribution. Rising temperatures reducing crop yields was the most strongly reported production effect. Third, farmers' adaptive capacity was constrained by inadequate finance, high irrigation costs, limited access to improved seeds, climate information, and extension services. The grand mean of 4.36 indicates that awareness of climate change does not necessarily translate into effective adaptation. Fourth, farmers strongly supported improved seed varieties, government assistance, extension services, irrigation, climate-smart agriculture, and access to climate information, with the highest grand mean of 4.50. The study concludes that climate resilience in Kaduna State requires an integrated approach combining improved seeds, irrigation, climate information, extension, finance, and climate-smart practices, while also strengthening storage, processing, transportation, roads, and market systems.

Recommendations

Based on the findings, the study recommends the following:

- i. Strengthen climate information services: Kaduna State should establish coordinated climate-agriculture information systems linking meteorological agencies, extension institutions, researchers, farmer organizations, and local governments to provide timely forecasts, flood alerts, and crop-specific advice.
- ii. Improve access to finance and inputs: Government and financial institutions should provide affordable credit, input financing, guarantees, and targeted subsidies for improved seeds, irrigation, water harvesting, storage, and other climate-resilient investments.
- iii. Promote improved seeds and irrigation: Investment should prioritize quality climate-tolerant seed varieties, small-scale irrigation, solar-powered water systems, and efficient water-management technologies suitable for local conditions.
- iv. Strengthen extension and farmer organizations: Extension officers should receive regular training in climate-smart agriculture, pest management, soil conservation, and climate-risk management, while farmer organizations should facilitate access to information, finance, inputs, and markets.
- v. Develop resilient agricultural infrastructure and monitoring: Government should improve storage, processing, rural roads, transportation, markets, and agricultural insurance, while mainstreaming climate adaptation into development plans and monitoring outcomes such as yield stability, adoption rates, and food security.

Limitation of the study

The study is limited by its reliance on farmers' perceptions, cross-sectional design, descriptive analysis, and selected agricultural areas, limiting causal inference and generalisability. Future research should integrate long-term meteorological, satellite, and crop-yield data, using panel and econometric approaches to examine adaptation, productivity, income, food security, gender, irrigation, and post-harvest resilience.

References

1. Abdisa, G., Tadesse, M., et al. (2023). Determinants of farmers' adaptation strategies to climate change impacts in northwestern Ethiopia. *Heliyon*, 9(8), e18514. <https://doi.org/10.1016/j.heliyon.2023.e18514>
2. Abdullah, M., et al. (2023). Understanding the farmers' choices and adoption of adaptation strategies, and plans to climate change impact in Africa: A systematic review. *Climate Services*, 30, 100362. <https://doi.org/10.1016/j.cliser.2023.100362>
3. Abdullah, et al. (2022). A systematic review of smallholder farmers' climate change adaptation and enabling conditions for knowledge integration in Sub-Saharan African drylands. *Environmental Development*, 43, 100733. <https://doi.org/10.1016/j.envdev.2022.100733>

4. Abebe, et al. (2022). Smallholder farmers' vulnerability and adaptation to climate change-induced shocks: The case of Northern Ethiopia highlands. *Journal of Agriculture and Food Research*, 8, 100312. <https://doi.org/10.1016/j.jafr.2022.100312>
5. Adeagbo, O. A., Bamire, A. S., Akinola, A. A., Adeagbo, A. D., & Emenike, C. U. (2023). The level of adoption of multiple climate change adaptation strategies: Evidence from smallholder maize farmers in Southwest Nigeria. *Scientific African*, 22, e01971. <https://doi.org/10.1016/j.sciaf.2023.e01971>
6. Adeagbo, O. A., Ojo, T. O., & Adetoro, A. A. (2021). Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west Nigeria. *Heliyon*, 7(2), e06231. <https://doi.org/10.1016/j.heliyon.2021.e06231>
7. Adepoju, A. O., et al. (2023). Impacts of microcredit access on climate change adaptation strategies adoption and rice yield in Kwara State, Nigeria. *World Development Sustainability*, 2, 100047. <https://doi.org/10.1016/j.wds.2023.100047>
8. Akinkuolie, T. A., Ogunbode, T. O., & Oyebamiji, V. O. (2024). Evaluating constraints associated with farmers' adaptation strategies to climate change impact on farming in the tropical environment. *Heliyon*, 10(16), e36086. <https://doi.org/10.1016/j.heliyon.2024.e36086>
9. Akpan, et al. (2022). Climate change perception and adaptation among farmers in coastal communities of Bayelsa State, Nigeria: A photovoice study. *International Journal of Climate Change Strategies and Management*, 15(5), 745–767. <https://doi.org/10.1108/IJCCSM-07-2022-0100>
10. Amoah, et al. (2023). Climate change and adaptation strategies in rural Ghana: A study on smallholder farmers in the Mamprugu-Moaduri district. *International Journal of Climate Change Strategies and Management*, 16(1), 112–139. <https://doi.org/10.1108/IJCCSM-08-2022-0110>
11. Ayanlade, A., & Oluwatimilehin, I. A. (2023). Climate change impacts on staple crops: Assessment of smallholder farmers' adaptation methods and barriers. *Climate Risk Management*, 41, 100542. <https://doi.org/10.1016/j.crm.2023.100542>
12. Ayanlade, A., Radeny, M., & Morton, J. F. (2019). Comparing smallholder farmers' perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather and Climate Extremes*, 24, 100208. <https://doi.org/10.1016/j.wace.2019.100208>
13. Ayinde, O. E., Oyedeji, O. A., Miranda, M. J., & Olarewaju, A. O. (2024). How resilient are farmers in Africa to climate shocks? A case study of Nigerian farmers. *Journal of Environmental Management*, 355, 120471. <https://doi.org/10.1016/j.jenvman.2024.120471>
14. Bello, L. O., Awotide, B. A., & Sakurai, T. (2024). Climate change adaptation and smallholder farmers' welfare: Empirical evidence from the Sahelian region of West Africa. *Land Use Policy*, 142, 107181. <https://doi.org/10.1016/j.landusepol.2024.107181>
15. Boateng, et al. (2023). Determinants of yam farmers' adaptation practices to climate variability in the Ejura Sekyedumase Municipality, Ghana. *Heliyon*, 9(3), e14090. <https://doi.org/10.1016/j.heliyon.2023.e14090>
16. Chakraborty, et al. (2023). Climate change risk, resilience, and adaptation among rural farmers in East Africa: A literature review. *Regional Sustainability*, 4(2), 185–193. <https://doi.org/10.1016/j.regsus.2023.05.004>
17. Danso-Abbeam, G., Ojo, T. O., Baiyegunhi, L. J. S., & Ogundeji, A. A. (2021). Climate change adaptation strategies by smallholder farmers in Nigeria: Does non-farm employment play any role? *Heliyon*, 7(6), e07162. <https://doi.org/10.1016/j.heliyon.2021.e07162>
18. Fadina, A. M., et al. (2023). Determinants of climate change adaptation strategies and existing barriers in Southwestern parts of Ethiopia. *Climate Services*, 30, 100376. <https://doi.org/10.1016/j.cliser.2023.100376>
19. Food and Agriculture Organization of the United Nations. (2023). *The state of food and agriculture 2023: Revealing the true cost of food to transform agrifood systems*. <https://doi.org/10.4060/cc7724en>
20. Food and Agriculture Organization of the United Nations. (2024a). *The state of food and agriculture 2024: Value-driven transformation of agrifood systems*. <https://doi.org/10.4060/cd2616en>
21. Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme, & World Health Organization. (2024). *The state of food security and nutrition in the world 2024: Financing to end hunger, food insecurity and malnutrition in all its forms*. <https://doi.org/10.4060/cd1254en>
22. Federal Government of Nigeria. (2021). *Nigeria's nationally determined contribution: 2021 update*. United Nations Framework Convention on Climate Change.
23. Gebre, et al. (2023). Impact and adaptation of climate variability and change on small-holders and agriculture in Ethiopia: A review. *Heliyon*, 9(8), e18972. <https://doi.org/10.1016/j.heliyon.2023.e18972>
24. Getachew, et al. (2023). Farmers' perceptions of climate variability and adaptation strategies in the rural areas of Dire Dawa Administration, eastern

- Ethiopia. *Heliyon*, 9(5), e15868. <https://doi.org/10.1016/j.heliyon.2023.e15868>
25. Ikpe, E. and Ugbede D. Omede (2025). Effect of Climate Change on the Yield of Maize and Farmers' Adaptation Strategies Towards Food in Selected Local Government Area of Benue State, Nigeria. *African Journal of Geographical Sciences (AJGS, University of Jos, Nigeria)* 6 (1 &2): 94-101.
26. Ikpe Elisha, Patrick I. Ukoh and Jude G. Ikpe (2024). Relationship between Rainfall Variability and Yield of Cassava and Farmers' Adaptation Strategies in Otukpo Local Government Area of Benue State, Nigeria, *Sokoto Journal of the Social Sciences*, 14(2): 67 – 79.
27. Isaac S. & Ikpe, E. (2024). Assessing Climate Change Adaptation Strategies and Challenges in Maize Farming: A Study of Giwa LGA, Kaduna State, Nigeria. *International Journal of Scientific Research in Multidisciplinary Studies*, 10(12): 1-9. doi: <https://doi.org/10.26438/ijrms/v10i12.14>
28. Intergovernmental Panel on Climate Change. (2022a). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press. <https://doi.org/10.1017/9781009325844>
29. Intergovernmental Panel on Climate Change. (2022b). *Climate change 2022: Impacts, adaptation and vulnerability—Chapter 9: Africa*. Cambridge University Press.
30. Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report*. <https://doi.org/10.59327/IPCC/AR6-9789291691647>
31. Journal of Agriculture and Food Research. (2025). Effects of climate change on food security in Africa: Meta-analysis. *Journal of Agriculture and Food Research*, 23, 102214. <https://doi.org/10.1016/j.jafr.2025.102214>
32. Kebede, et al. (2023). The role of integrated watershed management in climate change adaptation for small-scale farmers in Southwest Ethiopia. *Environmental and Sustainability Indicators*, 19, 100260. <https://doi.org/10.1016/j.indic.2023.100260>
33. Land Use Policy. (2024). Land use planning and climate change adaptation in river-dependent communities in Nigeria. *Environmental Development*, 49, 100970. <https://doi.org/10.1016/j.envdev.2024.100970>
34. Madaki, M. Y., Bavorova, M., Zhllima, E., & Imami, D. (2024). Effect of climate risk adaptation on food security among farming households: The case of Nigeria. *Climate Risk Management*, 44, 100600. <https://doi.org/10.1016/j.crm.2024.100600>
35. Maina, et al. (2022). Smallholders' adaptation to climate change in Western Kenya: Considering socioeconomic, institutional and biophysical determinants. *Environmental Challenges*, 7, 100489. <https://doi.org/10.1016/j.envc.2022.100489>
36. Mbanasor, J. A., Kalu, C. A., Okpokiri, C. I., Onwusiribe, C. N., Nto, P. O. O., Agwu, N. M., & Ndukwu, M. C. (2024). Climate-smart agriculture practices by crop farmers: Evidence from southeast Nigeria. *Smart Agricultural Technology*, 8, 100494. <https://doi.org/10.1016/j.atech.2024.100494>
37. Mekonnen, et al. (2023). Climate-smart agriculture in Ethiopia: Adoption of multiple crop production practices as a sustainable adaptation and mitigation strategy. *World Development Sustainability*, 3, 100099. <https://doi.org/10.1016/j.wds.2023.100099>
38. Mensah, et al. (2023). Understanding climate change adaptation in Ghana: The role of climate change anxiety, experience, and knowledge. *Environmental Science & Policy*, 150, 103594. <https://doi.org/10.1016/j.envsci.2023.103594>
39. Ogunleye, A., Kehinde, A., Mishra, A., & Ogundej, A. (2021). Impacts of farmers' participation in social capital networks on climate change adaptation strategies adoption in Nigeria. *Heliyon*, 7(12), e08624. <https://doi.org/10.1016/j.heliyon.2021.e08624>
40. Ogunniyi, A., et al. (2024). Climate change vulnerability and adaptive capacity of smallholder farmers: A financing gap perspective. *Environmental and Sustainability Indicators*, 24, 100476. <https://doi.org/10.1016/j.indic.2024.100476>
41. Onyimadu, C. O. (2023). Climate change adaptation and wellbeing among smallholder women farmers in Gwagwalada and Kokona, Nigeria. *Futures*, 153, 103238. <https://doi.org/10.1016/j.futures.2023.103238>
42. Science in One Health. (2025). Multi-impacts of climate change and mitigation strategies in Nigeria: Agricultural production and food security. *Science in One Health*, 4, 100113. <https://doi.org/10.1016/j.soh.2025.100113>
43. Solaja, S., Kolawole, A., Awe, T. E., Oriade, A. O., Ayojimi, W., Ojo, O. I., Nayan, G., Adedayo, R., Etta-Oyong, S., Olasehinde, F., Asemokhai, O., & Nsikak, I. (2024). Assessment of smallholder rice farmers' adaptation strategies to climate change in Kebbi State, Nigeria. *Heliyon*, 10(15), e35384. <https://doi.org/10.1016/j.heliyon.2024.e35384>
44. World Meteorological Organization. (2023). *State of the climate in Africa 2022*.
45. World Meteorological Organization. (2024). *State of the climate in Africa 2023*.
46. Ziervogel, et al. (2022). Climate information pathways and farmers' adaptive capacity: Insights from South Africa. *Environmental Development*, 44, 100743. <https://doi.org/10.1016/j.envdev.2022.100743>