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Perceived Climate Variability and Smallholder Maize Production in Kaduna State, Nigeria

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ABSTRACT
Maize (Zea mays) is a vital staple crop for food security and rural livelihoods across the West African Northern Guinea Savannah. However, changing weather patterns pose severe operational risks to smallholder rainfed agricultural systems. This study evaluates smallholder maize farmers' socio-economic profiles, assesses their perceptions of climate variability, quantifies the perceived impacts of microclimatic shifts on grain yields, and ranks key adaptation barriers in Kaduna State, Nigeria. A multi-stage sampling framework was used to select 120 smallholders across three agroecological zones. Data were analysed using descriptive statistics and multiple linear regression model. Findings revealed that 94.2% of farmers were male, with a mean age of 36.3 years, 10.3 years of farming experience, a mean farm size of 1.67 ha, and average household size of 6 persons. The mean maize yield was 1,850.5 kg/ha (SD = 420.3). OLS regression analysis (R2 = 0.642, F (6, 113) = 33.78, p < 0.001) indicated that perceived rainfall instability (β = -142.30 kg/ha, p = 0.004) and perceived thermal stress (β = -98.60 kg/ha, p = 0.012) significantly reduced maize output per ha. Conversely, access to drought-tolerant seed varieties (β = 215.40 kg/ha, p = 0.001) and extension contact frequency (β = 48.20 kg/ha/visit, p = 0.008) significantly enhanced yield outcomes. Financial deficits (MBS = 4.45) and limited access to early-maturing hybrid seeds (MBS = 4.20) as primary constraints to climate-smart adaptation. Enhancing smallholder resilience requires transitioning from reactive coping mechanisms to structured policy support (localised digital climate advisories and subsidised drought-tolerant hybrid seeds).

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INTRODUCTION

Globally, climate variability poses systemic risks to agro-ecological systems, rural food security, and agricultural trade networks. The Intergovernmental Panel on Climate Change (IPCC, 2014) defines climate variability as variations in the mean state and other statistics (such as standard deviations and the occurrence of extremes) of climate parameters across spatial and temporal scales beyond individual weather events. In Sub-Saharan Africa (SSA), the agricultural sector is acutely vulnerable to climate shifts due to its heavy reliance on rainfed cultivation, low capital reserves, limited mechanisation, and constrained institutional adaptive capacity (Beddington et al., 2012; Mortimore, 2010).

Perception refers to the beliefs or opinions that individuals hold based on appearances, while awareness involves being informed and encompasses how individuals interpret and assign meaning to their experiences (Blaikie et al., 1997). Both perception and awareness influence decision-making processes and, consequently, shape farmers' responses to climate change adaptation. Indigenous farmers are recognised as keen observers of climate variability and are actively engaged in adapting to evolving environmental conditions (Stott & Kettleborough, 2002). In this context, numerous scholars, including Deressa et al. (2008), Ogunleye & Yekini (2012), Ejeh (2014), Umar et al. (2015), and Ikpe (2021), viewed farmers' perceptions of climate change as an important issue in adopting coping strategies.

In Nigeria, maize (*Zea mays*) is a foundational cereal crop that provides essential dietary calories, livestock feed, and industrial raw materials (FAOSTAT, 2022). In the Northern Guinea Savannah agro-ecological zone of Kaduna State, smallholder maize productivity is closely tied to seasonal rainfall dynamics and thermal stability. Declining total seasonal rainfall, erratic precipitation onset, prolonged intra-season dry spells during critical phenological stages (such as tasseling and silking), and rising mean temperatures directly threaten crop growth and reduce grain yields (Elisha et al., 2017; Kamara et al., 2014).

While global macro-level models project regional yield trajectories based on gridded atmospheric data (USDA, 2015), these aggregate models often miss micro-level operational realities, socio-economic dynamics, and local farmer perceptions in rural communities. Aggregate regional data do not capture how smallholder decision-making responds to perceived micro-climatic disruptions. Existing research in Northern Nigeria has focused on regional environmental degradation or national macroeconomic trends, leaving a gap in micro-level empirical evidence that connects farmers' perceptions of climate variability directly to farm-level maize yield outcomes. To address this knowledge gap, this study presents perception-based empirical evidence regarding climate variability and smallholder maize productivity in Kaduna State, Nigeria. The specific objectives of this study are to:

1. describe the socio-economic profile of smallholder maize farmers across selected Local Government Areas (LGAs) in Kaduna State.
2. evaluate local farmers' perceptions and awareness of 10-year microclimatic shifts.
3. quantify the influence of perceived climate variability parameters and institutional input variables on maize yield outcomes (kg/ha).
4. identify and rank the operational and structural constraints hindering smallholder adoption of Climate-Smart Agricultural (CSA) practices.

Review of Literature

The literature review used systematic and purposive sampling of relevant peer-reviewed studies from databases such as Google Scholar, Scopus, JSTOR and Web of Science. Studies were selected based on their relevance to climate change, impacts of climate variability on smallholder maize production in Nigeria and CSA practices globally. Understanding how climate change affects agriculture requires a theoretical framework (vulnerability, resilience, and socio-ecological systems) that integrates environmental stressors with human adaptive capacity. This study adopts the IPCC Climate Vulnerability Framework (IPCC, 2014), which conceptualizes vulnerability (V) as a function of climate exposure (E), system sensitivity (S), and adaptive capacity (AC):

$V = f(E, S, AC)$

In smallholder maize cropping systems:

i. Exposure (E): Refers to the frequency, magnitude, and duration of micro-climatic stressors, such as intra-season dry spells and elevated maximum temperatures during grain filling.
ii. Sensitivity (S): Represents the structural dependency of the farming system on natural rainfall and baseline soil fertility (such as sandy loam soils with low organic matter).
iii. Adaptive Capacity (AC): Denotes the farmer's ability to adjust to climatic shocks through the adoption of climate-smart agricultural (CSA) interventions, such as drought-tolerant hybrid seeds, conservation tillage, supplementary irrigation, and reliance on institutional extension networks.

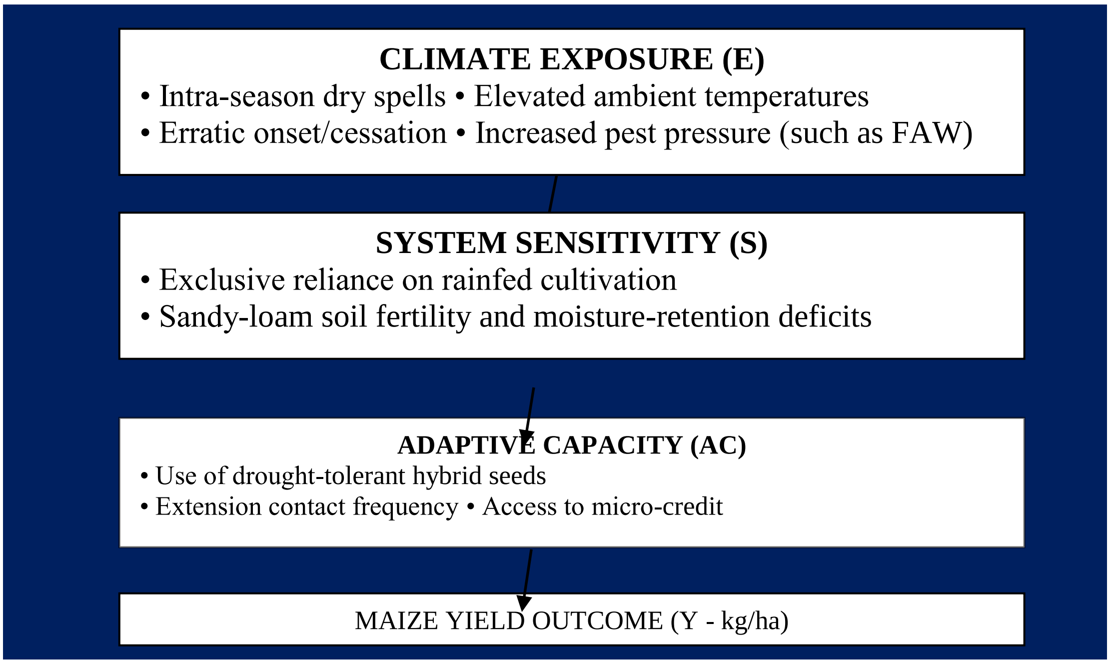

Figure 1: Conceptualization of the IPCC Vulnerability Framework Applied to Smallholder Maize Systems Adapted with Modification Source: (IPCC, 2014)

MATERIALS AND METHODS

Study Area

The study was conducted in Kaduna State, located within the Northern Guinea Savannah zone of Nigeria (Latitude 10°20′ N 7°45′ to and Longitude 10.333 °N 7.75 °E of the Equator. The state experiences a tropical continental climate characterized by a wet season (May to October, with annual rainfall between 900 mm and 1,200 mm) and a prolonged dry season (November to April). Ambient temperatures range from 21^0 C and 36^0 C (Institute for Agricultural Research [IAR] Meteorological Unit, 2021). The local rural economy is predominantly agrarian, with smallholders primarily cultivating maize, sorghum, rice, cowpea, and vegetables.

Sampling frame and Sample Size

A multi-stage sampling procedure was used to select 120 smallholder maize farming households:

i. Stage 1 (Purposive Sampling): Three LGAs Zaria, Soba, and Lere were selected due to their high concentration of maize producers and known exposure to seasonal rainfall variations.
ii. Stage 2 (Stratified Selection of Communities): Two major farming communities were selected per LGA: Dutsen Abba and Wucicciri (Zaria LGA); Awai and Tashan Kaya (Soba LGA); Ramin Kura and Kayarda (Lere LGA).

iii. Stage 3 (Random Household Selection): Twenty (20) smallholder maize-farming households were randomly drawn from active farmer rosters maintained by local extension agents in each community, yielding a total sample size of N = 120.

Sample Size (N) = 3LGAs × 2 Communities/LGA × 20 Farmers/Community = 120 Respondents

Data Collection, Validation, and Ethics

Primary data were collected during the 2024 harvest season using structured, pre-tested questionnaires administered through face-to-face field interviews. The instrument was pre-tested on 15 non-sampled maize farmers in Sabon Gari LGA to establish construct validity and internal consistency (Cronbach's $\alpha = 0.82$).

The survey gathered data on:

i. Socio-economic attributes (age, gender, education, experience, household size, farm size).
ii. Perceptions of 10-year micro-climatic trends (rainfall onset/cessation, dry spell frequency, ambient heat).
iii. Production metrics (grain yield in kg/ha, seed variety, fertilizer application rates, credit access, extension contact).
iv. Adaptation constraints evaluated on a 5-point Likert scale.

Ethical approval and community consent were obtained prior to survey administration. Participation was voluntary, and individual survey responses were anonymised.

Geographically, this study is delimited to selected agricultural rural areas in Kaduna State. Content-wise, it focuses on smallholder maize farming systems, evaluates socio-economic characteristics, climate perceptions, productivity impacts, and adaptation constraints. This research provides localised empirical data essential for designing targeted climate-smart agricultural (CSA) interventions in the Northern Guinea Savannah. By clarifying the links between climate perception, farmer decision-making, and yield outcomes, the findings offer actionable insights for agricultural extension units, municipal policymakers, and non-governmental organisations working to improve food security and rural livelihoods in West Africa.

Analytical and Model Specifications

Mean Benchmark Severity (MBS) Index

Farmers' perceived climate variability and adaptation constraints were evaluated using a 5-point Likert scale ranging from 1 (*Strongly Disagree / Very Low*) to 5 (*Strongly Agree / Very High*). The Mean Benchmark Severity (MBS) index was calculated as:

$$\text{MBS} = \frac{\sum_{i=1}^{n}(fi \times wi)}{\text{N}}$$

i. fi = frequency of respondents assigning rating i.
ii. w_i = numerical weight assigned to rating i (1, 2, 3, 4, 5).
iii. N = total sample size (120).

The theoretical mean benchmark for decision-making was set at 3.00:

$$\text{Benchmark} = \frac{1+2+3+4+5}{5} = 3.00$$

Items with an MBS ≥ 3.00 were classified as significant climate perceptions or critical adaptation constraints.

Multiple Linear Crop Yield Response Model

To quantify the impact of climate perception, input availability, and socio-economic variables on maize yield productivity (Y), an Ordinary Least Squares (OLS) regression model was specified:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \varepsilon_i$$

Where:

i. Y_i = Maize Productivity (Grain Yield in kg/ha).
ii. X_{1i} = Perceived Rainfall Instability Index (1= Low, 5= High).
iii. X_{2i} = Perceived Thermal Stress Index (1= Low, 5= High).
iv. X_{3i} = Cultivated Farm Size (Hectares).
v. X_{4i} = Access to Improved/Drought-Tolerant Seeds (1= Yes, 0 = No).
vi. X_{5i} = Extension Contact Frequency (Number of visits per season).
vii. X_{6i} = Access to Agricultural Credit (1= Yes, 0 = No).
viii. β_0= Intercept term.
ix. $\beta_1 \ldots \beta_6$ = Estimated regression coefficients.
x. ε_i = Random error term.

Diagnostic tests were performed prior to model estimation:

i. Multicollinearity: Assessed using the Variance Inflation Factor (VIF). All variables exhibited VIF < 2.3, well below the threshold of 10.0.
ii. Heteroscedasticity: Tested via the Breusch-Pagan test ($x^2 = 2.41$, p = 0.121), failing to reject the null hypothesis of homoscedasticity.
iii. Normality of Residuals: Confirmed using the Jarque-Bera test ($JB = 1.15$, p = 0.562).

RESULTS AND DISCUSSION

Sex, Age, Farming Experience, Household Size, Farm Size, and Educational Level

Table 1 showed that the majority (94%) of the studied maize farmers are male, while 6% are female. This finding supports the Gombe State Agricultural Development Program (GSADP, 2014), which shows that most farming activities are carried out by males in most of northern Nigeria. This implies that maize farming is dominated by males in the study area. This finding aligns with studies by Akintobi (2023), Umar et al. (2015) and Muhammad et al. (2020), who reported that sampled farmers are predominantly male and that social and religious beliefs are reflected in land ownership in the study area. This suggests that the high proportion reflects cultural, religious, and institutional barriers to land ownership and agricultural credit for women in Northern Nigeria. Also, age revealed that more than half (55%) of the maize farmers fall within the age range of 35-44 years. With the farmers under 45 years old and a mean age of 36.3 years, the workforce is economically active and open to innovation, contrasting with studies in other regions where ageing agricultural populations hinder technology adoption. These findings closely agree with Otitioju and Arene (2010) and Muhammad et al. (2020), who reported an average age of farmers to be 33 years in the study area. Farming experience revealed that 74% of the studied maize farmers had farming experience of 7 - 11 years, with a mean farming experience of 10.3 years, showing moderate experience in local farming practices in the study area. The mean age of 36.3 years pairs with a mean farming experience of 10.3 years. Implies that farmers enter maize production in their mid-20s, gaining over a decade of hands-on experience by early middle age. This finding correlates with Akintobi (2023), who reported that respondents are well-experienced farmers, and should help them tackle climate change effects as they are well-experienced farmers who might have experienced climate change effects on crop production at one time or another. Studies by Hassan and Nhemachena (2008) and Muhammad et al. (2020) show that farming experience matters more than age, as it significantly affects farm management and decision-making.

The household size result revealed that more than half (53%) of the maize farmers sampled have 1-5 persons per household. With a mean household size of 6 persons, this represents a medium household size capable of supplying family labour. This means that the maize farmers studied were small to medium-sized families. Farm size revealed that the average farm size owned is 2 hectares, as indicated by the majority (70%) of the maize farmers; the mean farm size of 1.67 hectares confirms that production relies on smallholders in the study area. With a mean farm size of 1.67 hectares and an average household size of 6 persons, the land-to-person ratio stands at 0.27 hectares per person. This suggests small farm plots with sufficient family labour available to reduce hired labour costs during clearing, weeding, and harvesting. This suggests that operating on an average of 1.67 hectares limits economies of scale. These farmers remain vulnerable to sudden crop losses from drought or heat stress. Adaptation policies must deliver micro-credit, subsidised drought-tolerant hybrid seeds, and localised micro-irrigation systems designed for small landholdings.

Table 1: Distribution of Maize Farmers based on Socio-economic Characteristics (N=120)

Variable Category	Farmers (%)	Class Midpoint (x)	Calculated Mean (μ)
Sex			
Male	94.0		
Female	6.0		
Total	**100.0**		
Level of Education			
Primary	16.0		
Secondary	75.0		
Tertiary	9.0		
Total	**100.0**		
Age (Years)			
25 – 34	39.0	29.5	
35 – 44	55.0	39.5	**36.3**
45 – 54	3.0	49.5	
55 – 64	3.0	59.5	
Total	**100.0**		
Household Size (Persons)			
1 – 5	53.0	3.0	
6 – 10	41.0	8.0	**6.1**
11 – 15	2.0	13.0	
16 – 20	4.0	18.0	
Total	**100.0**		
Farming Experience (Years)			
7 – 11	74.0	9.0	
12 – 15	23.0	13.5	**10.3**
16 – 19	3.0	17.5	
Total	**100.0**		
Farm Size (Hectares)			
0.5	5.0	0.5	
1.0	25.0	1.0	**1.67**
2.0	70.0	2.0	
Total	**100.0**		

Source: Fieldwork, 2024 Note: The land-to-person ratio is calculated as Mean Farm Size (1.67ha) divided by Mean Household Size (6.1 persons), yielding +0.274 ha/person.

The results in Table 1 on educational level revealed that most (75%) of the maize farmers were secondary school certificate holders; (16) % had a primary school certificate, and only 9% had tertiary education at the time the study was conducted. This finding agrees with Bello and Paul (2023), who reported that most farmers were senior secondary school certificate holders in the study area. It means that high secondary education completion among young-to-middle-aged farmers provides a literate workforce capable of processing climate information, applying input instructions, and adopting extension recommendations. This finding complements the studies by Akintobi (2023) and Sofoluwe et. al. (2011), which reported that educated farmers are more knowledgeable about better practices and may be more willing to bear risk and adopt better farming techniques because of their exposure to education and better understanding of innovation and its importance. This suggests that possessing secondary or tertiary education means the population can quickly adopt digital weather advisories, written extension guides, and proper chemical dosage instructions for pest management (such as Fall Armyworm treatments).

Farmers' Perceptions of Climate Variability

The results presented in Table 2 revealed that the number of sampled farmers perceived climatic changes over the preceding decade; this inferred that the farmers are, at one time or another, aware of changes in climate variables. They knew changes in climatic conditions brought severe stress, high exposure and moderate stress in the study area. This study's findings agree with Bello and Paul (2023), who reported an increasing incidence of climate change in the study area. Intra-season dry spells during critical crop growth stages (MBS = 4.45) and delayed onset of rains (MBS = 4.38) received the highest severity scores, while (MBS = 3.89) incidence of pest/disease surges (FAW), indicating that precipitation instability is perceived as the primary environmental threat to maize cultivation. This study's finding correlates with Adebayo (2012), who indicated that respondents have an unfavourable disposition towards climate change.

Table 2: Distribution of Farmer's Perceived Climate Variability Indicators (N=120)

Climate Indicator	**Mean Severity (MBS)**	**Std. Deviation**	**Decision (MBS≥3.00)**
Delayed Onset of Seasonal Rains	4.38	0.62	High Exposure
Early Cessation of Rainfall	4.21	0.71	High Exposure
Intra-Season Dry Spells during Silking	4.45	0.55	Severe Stress
Increased Daytime Thermal Stress	4.12	0.68	High Exposure
Incidence of Pest/Disease Surges (FAW)	3.89	0.79	Moderate Stress
Overall Climate Perception Index	**4.21**	**0.67**	**High Exposure**

Source: Fieldwork, 2024

Determinants of Maize Productivity (OLS Model)

Table 3: OLS multiple linear regression estimates evaluated the effects of perceived climatic parameters, farm size, and institutional variables on maize output per hectare (kg/ha). The diagnostic results showed a significant fit (R2 = 0.642, Adjusted R2 = 0.623, with F = 33.78, p < 0.001) for the effects of perceived climatic parameters, farm size, and institutional variables on maize output per hectare (kg/ha). The model explained 64.2% of the variation in maize yields among sampled farmers and was a good fit.

The variables had a significant effect on maize yields, as specified by the climate variability. Perceived rainfall instability had a statistically significant negative with 1% effect on yield (β = -142.30 kg/ha, p = 0.004). This suggests that every 1-unit increase in perceived rainfall instability was associated with a 142.30 kg/ha decrease in maize output, holding other factors constant. This finding agrees with Yusuf and Paul (2023), who reported that during the forty-year period, there was incessant fluctuation in annual rainfall totals in the study area. Contrasts with the study by Abdulrahim (2012), which reported an increasing trend in rainfall in Sokoto State.

Perceived thermal stress significantly reduced maize yield by 5% (β = -98.60 kg/ha, p = 0.012). Thermal stress affects maize yield. This finding agrees with Yusuf and Paul (2023), who reported that climate is changing and dry spells affect growth, maturity and crop yield in the study area. In line with empirical findings in savannah cropping systems (Elisha et al., 2017; Kamara et al., 2014), which reported that rainfall instability and thermal stress have significant negative impacts (-0.05) on maize yield per hectare.

Access to improved/drought-tolerant (hybrid seeds) exerted a strong positive effect at 1% on output (β = 215.40 kg/ha, p = 0.001), increasing yields by over 215 kg/ha relative to non-adopters. The result is in agreement with the findings of Ademola and Bello (2014, as cited in Yusuf and Paul, 2023), who stated that farmers in the northern part of Nigeria should adopt mulching, the use of improved seeds that can adapt to the climatic change of the place, and early planting utilising the first rain for crop production. Planting of drought resistant/ improve variety of seed should be the best option for the study area since major impacts are increased temperature, dry spells, drought and decreased soil moisture.

Extension contact frequency and credit access were both significant at 1% and 5% enhanced maize productivity (β = 48.20, p = 0.008 and β = 134.80, p = 0.014, respectively). This suggests exposure to knowledge management on climate change and opportunities to receive credit for farmers' financial strengths. This finding is in accord with Afolabi et al. (2025, pp 266 – 273), who found that adaptation practices and initiatives used by farmers in rural communities are motivated by economic values, indigenous knowledge systems, socio-cultural and behavioural factors. This further suggests that farmers who plant drought-tolerant hybrid seeds and receive regular extension advice are better equipped to adjust planting dates and manage climate-induced pest pressures (such as Fall Armyworm outbreaks).

Table 3: OLS Crop Yield Response Regression Model Output

Variable Name	**Coefficient (*β*)**	**Standard Error (SE)**	**t-statistic**	**p-value**	**VIF**
Perceived Rainfall Instability	-142.30***	48.60	-2.93	0.004	1.42
Perceived Thermal Stress	-98.60**	38.90	-2.53	0.012	1.38
Farm Size (Hectares)	072.10*	41.20	1.75	0.083	1.15
Access to Hybrid Seeds	0215.40***	62.30	3.46	0.001	1.28
Extension Contact Frequency	048.20***	17.80	2.71	0.008	1.31
Access to Agricultural Credit	0134.80**	54.10	2.49	0.014	1.22
Constant	1,640.20***	185.40	8.85	<0.001	—
Model Diagnostics					
R^2 = 0.642					
Adjusted R^2 = 0.623					
F (6, 113) = 33.78					

Source: Fieldwork, 2024 Note: Significance levels: *** p < 0.01, p < 0.05, * p < 0.10

Constraints to Climate-Smart Agricultural (CSA) Adaptation

Table 4 showed that operational and institutional barriers hindering the adoption of climate-smart adaptation practices were ranked using the Mean Benchmark Severity index. The results revealed that capital constraints (MBS = 4.45), limited access to improved, early-maturing hybrid seeds (MBS = 4.20), and poor weather information/ forecasting (MBS = 4.20) were identified as the leading structural bottlenecks to climate adaptation. This suggests that these constraints will negatively affect maize production and yield in the Northern Guinea Savannah, Nigeria.

Table 4: Distribution of Constraints to Climate-Smart Agricultural Adaptation (N=120)

Constraint Category	Mean Severity (MBS)	Std. Deviation	Rank Order
High cost / limited access to financial credit	4.45	0.52	1st
Inadequate access to drought-tolerant seeds	4.20	0.61	2nd
Poor weather information / Forecasting access	4.08	0.69	3rd
Infrequent extension advisory visits	3.85	0.74	4th
High cost of inorganic fertilizers	3.72	0.81	5th
Insecure land tenure rights for Women/Youth	3.15	0.92	6th

Source: ***Fieldwork, 2024***

Summary

The demographic profile reflects systemic socio-cultural patterns in Northern Nigerian agriculture. The low representation of female farmers (5.8%) aligns with previous studies in Kaduna State (Auta, 2004), which highlighted socio-cultural barriers to direct land ownership and credit access for women. The mean landholding of 1.67ha confirms that production remains fragmented among smallholders. The positive land-to-person ratio (0.274ha/person) highlights land fragmentation pressures driven by population growth, which limits fallowing and land restoration. Also, OLS regression results confirm that smallholders' perceptions of climate instability correspond with real reductions in grain yield. The negative coefficient for perceived rainfall variability (β = -142.30 kg/ha) aligns with agronomic research showing that mid-season dry spells disrupt pollen viability, silking, and grain filling in maize (Kamara et al., 2014; Elisha et al., 2017). Similarly, perceived thermal stress (β= -98.60 kg/ha) accelerates evapotranspiration, reducing photosynthetic efficiency during critical growth periods. Furthermore, these micro-level findings contextualise macro-level climate studies (IPCC, 2014) by demonstrating that intra-seasonal rainfall timing and dry spells are often more critical to smallholder outcomes than total annual rainfall volume. Additionally, access to improved, drought-tolerant hybrid seeds (β= 215.40 kg/ha) provided the strongest positive impact on yield outcomes. This finding supports research by Amadu et al. (2020), who observed substantial yield advantages among smallholders adopting stress-tolerant crop varieties in comparable savannah environments. In addition, extension contact frequency (β= 48.20 kg/ha/visit) and credit access (β= 134.80 kg/ha) further demonstrate the importance of institutional support mechanisms. Regular extension contact improves farmer awareness of early-maturing seed varieties, recommended planting windows, and proper input application methods (Afolabi et al., 2025). Conversely, financial capital deficits remain the top-ranked constraint (MBS = 4.45), preventing resource-poor farmers from purchasing certified hybrid seeds and necessary inputs.

CONCLUSION

Majorly, smallholder maize production is managed primarily by male farmers operating small landholdings with baseline yields below optimal potential. The farmers perceived intra-season dry spells and delayed rainfall onset as major threats to crop production. They perceived that rainfall variability and thermal stress significantly reduce maize yields, whereas access to hybrid seeds, extension contact, and credit access significantly improved yield outcomes. Conversely, capital constraints and limited seed availability represent the primary constraints to adopting climate-smart practices. Based on these findings, the study recommended that the Kaduna State Ministry of Agriculture should expand distribution networks for certified hybrid maize varieties to offset the impact of intra-season dry spells. Agricultural extension agencies should implement localised mobile text and audio advisory services and provide real-time weather forecasts. Create low-interest micro-credit for smallholders, with dedicated allocations for female farmer groups. Increase the number of extension visits to promote recommended CSA practices.

Study Limitations and Directions for Future Research

A key limitation of this study is its reliance on cross-sectional survey data and farmer perception indices to measure climate variability, rather than continuous daily meteorological station observations. Future research should integrate multi-decadal historical rainfall and temperature datasets from local meteorological stations with farm-level longitudinal panel data. Combining physical climate monitoring with socio-economic field surveys will further refine crop yield response models across Northern Nigeria's savannah ecosystems.

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