CLIMATE SMART AGRICULTURE, FOOD SECURITY AND SUSTAINABLE DEVELOPMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES volume One

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate Smart Agriculture, Food Security and Sustainable Development** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate smart agriculture (CSA) food security, Sustainable Development issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate smart agriculture, food security, and sustainable development necessary in policy making process that will stimulate increase in food production and environmental sustainability.

Climate Smart Agriculture, Food Security and Sustainable Development: *Global Issues & Local Perspectives* is organized in three parts. Part One deals with The Concept of **Climate Smart Agriculture**, Part Two is concerned with The Concept of **Food Security And** and Part Three deals with the Concept of **Sustainable Development**

Eteyen Nyong; October 2025

Chapter Six

Influence of Climate Change and Soil Characteristics on the Performance of Upland Rice Varieties in the Kagoro Area, Kaduna State, Nigeria

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1. INTRODUCTION

Climate change has become a topical issue in recent times due to its largely detrimental effects on both natural and human systems. Despite recent technological advances, weather and climate remain the most critical factors influencing agricultural production. Since most agriculture is rain-fed, it is therefore of paramount importance to adopt measures that mitigate the consequences of climate change through research, innovation, and adaptation (Ikpe 2021). Upland rice cultivation in Nigeria is greatly affected by climate and soil conditions, which determine crop growth, yield, and varietal adaptability. In areas like Kagoro, Kaduna State, temperature, rainfall distribution, and soil fertility play critical roles in rice performance (Ndebeh et al., 2018). Climatic variability can cause water stress or disease outbreaks, while soil characteristics such as texture, pH, and nutrient availability influence root development and nutrient uptake (Jonah et al., 2023). These factors influence growth, yield, and adaptability of rice varieties. Understanding their effects is essential for selecting suitable genotypes, improving management practices, and enhancing sustainable rice production in the region's diverse agro-ecological conditions (Makarau, 2025).

Upland rice covers about 1.8 million hectares of the world's 4.7 million hectares of rice fields, with yields in West Africa still far below the potential of available genotypes (Ndebeh et al., 2018). In the sub-region, rice consumption has more than doubled in the past decade due to population growth and changing dietary preferences (Tollens et al., 2010). However, production has not matched demand, making the adoption of improved varieties and agronomic practices essential (Somado et al., 2008). Performance, in this context, relates to the effectiveness and efficiency of a variety or input in meeting production goals. It reflects both the level of achievement and the resources used to attain it.

Rice (*Oryza sativa* L.) is a key staple across Nigeria, consumed nationwide by diverse socio-economic groups. Although production has increased in recent years, major constraints remain—climate variability, limited access to improved varieties and poor agronomic practices (Jonah et al., 2023). The gap between production and demand has widened, with imports rising significantly as local upland production remains largely traditional (Somado et al., 2008). Phenotypic variation in genotypes is vital for breeding high-yielding, adaptable varieties.

Nigeria, the largest rice producer in West Africa, has seen demand rise by 5% annually, driven by urbanization, income growth, and changing preferences (WARDA, 2015). Consumption exceeds production, with over 3 million tonnes imported yearly, costing about US$480 million (Kamai et al., 2020). Although production rose from 3.7 million tonnes in 2017 to 4.0 million tonnes in 2018, average yields of 2.0–3.0 t/ha are far below the 6–8 t/ha achievable in research plots (Edu and Oluka, 2022). Major producing states include Kebbi, Borno, Kano, and Kaduna, with most farmers still using low-input traditional methods.

Rice is cultivated under six main environments in Sub-Saharan Africa: upland, hydromorphic, rain-fed lowland, irrigated lowland, deep inland water, and mangrove swamp (Makarau, 2025). Strengthening climatic issues, adoption of improved technologies and providing updated agronomic knowledge to extension agents remain critical for increasing yields and reducing imports.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Rice is in high demand now as a result of population growth and its importance as source of energy and required minerals. However, growth, yield, quality, and cultivation method of rice, on the other hand, are all factors to consider by rice farmers in other to have a bumper harvest. Rice yields are insufficient to meet the country's significant population growth, resulting in food shortages (Edu and Oluka, 2022). According to Ogah (2013), decreased rice output is linked to rainfall, temperature, bug and pest infestations. Rice productivity is influenced by the environment, farming method, cultural practices, varieties together with biotic and abiotic factors (Edu et al. 2021). No wonder, in the study of Yang et al, (2017), rice yield can be improved through irrigation, fertilization, use of improved varieties, disease and insect controls. Climatic factors, lack of technology and agricultural innovation for rice production are some of the reasons that restrict rice production in some developing nations like Nigeria (Okeke and Oluka, 2017).

Upland rice production accounts for about 20% of the total rice produced in Nigeria. With the development of New Rice for Africa (NERICA) for upland production systems, several farmers have shown interest in growing upland rice. Unfortunately, these farmers do not have a ready source of information on upland rice production (West Africa Rice Development Association, 2015). Several studies have been conducted in Nigeria and in similar agro ecological zones to evaluate the relationship between weather parameters (climate) and rice yield. A study by Ukoh and Ikpe (2025) showed positive and significant relationship between rainfall and rice yield in Benue south. Abubakar and Daji (2022) evaluated the yield potential of local and improved rice varieties in Gombe State and found significant variations between climatic factors, rice varieties and yield.

There are other studies on the influence of weather and soil characteristics on rice performances in Nigeria (Oyewole et al. 2010; Salleh et al., 2022; Abubakar and Daji, 2022). Based on the previous studies, there is a gap in the knowledge of the relationship between rainfall variability and rice yield in Kagoro, Kaduna State, Nigeria. This study was conducted to enable farmers identify, appreciate, and understand the effect of rainfall and temperature variability and soil characteristics on the yield of upland rice and possibly recommend the resilient measures to the vagaries of weather and soil characteristics.

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of the study is to assess the effect of rainfall, temperature and soil characteristics on selected upland rice varieties in Kagoro, Kaura LGA and its environs. The specific objectives are; to,

i. analyse the socio-economic characteristics of the rice farmers
ii. assess the relationship between rainfall, temperature and soil characteristics on upland rice varieties in the study area
iii. recommend viable adaptation strategies to rainfall and temperature variability towards boosting food security in the area.

1.4 SCOPE OF THE STUDY

The scope of this study is to examine the climatic characteristics of the study area, analyse the socio-economic characteristics of rice farmers, assess the relationship between rainfall, temperature, and soil characteristics on the performance of upland rice varieties, and recommend viable adaptation strategies to rainfall and temperature variability for enhancing food security. Upland rice was selected because previous studies have shown that it constitutes one of the major food bases of Kaduna State. The study spans fifty-two (52) years, from 1970 to 2021, as literature (Odjugo, 2010) indicates that the impacts of climate change became evident in the study area from the early 1970s.

1.5 THE STUDY AREA

The research was conducted in Kagoro, a prominent town situated in Kaura Local Government Area (LGA) of Kaduna State, Nigeria. Geographically, it lies at Latitude 9°36′27″ N and Longitude 8°23′25″ E. The LGA shares boundaries with Zangon Kataf to the northwest, Kauru to the northeast, Jema'a to the south, and Plateau State to the east (Makarau, 2025).

Based on Köppen's climate classification, Kagoro falls under the tropical savannah climate (Aw). The area experiences two distinct seasons: a rainy season from April to October and a dry season from November to March, both governed by the Inter-Tropical Discontinuity (ITD). The region typically receives between 2000 and 10,000 mm of rainfall annually, with average temperatures ranging from 24°C to 27°C. Relative humidity fluctuates between 40–60% in January and 60–80% in July (Dadah et al., 2017).

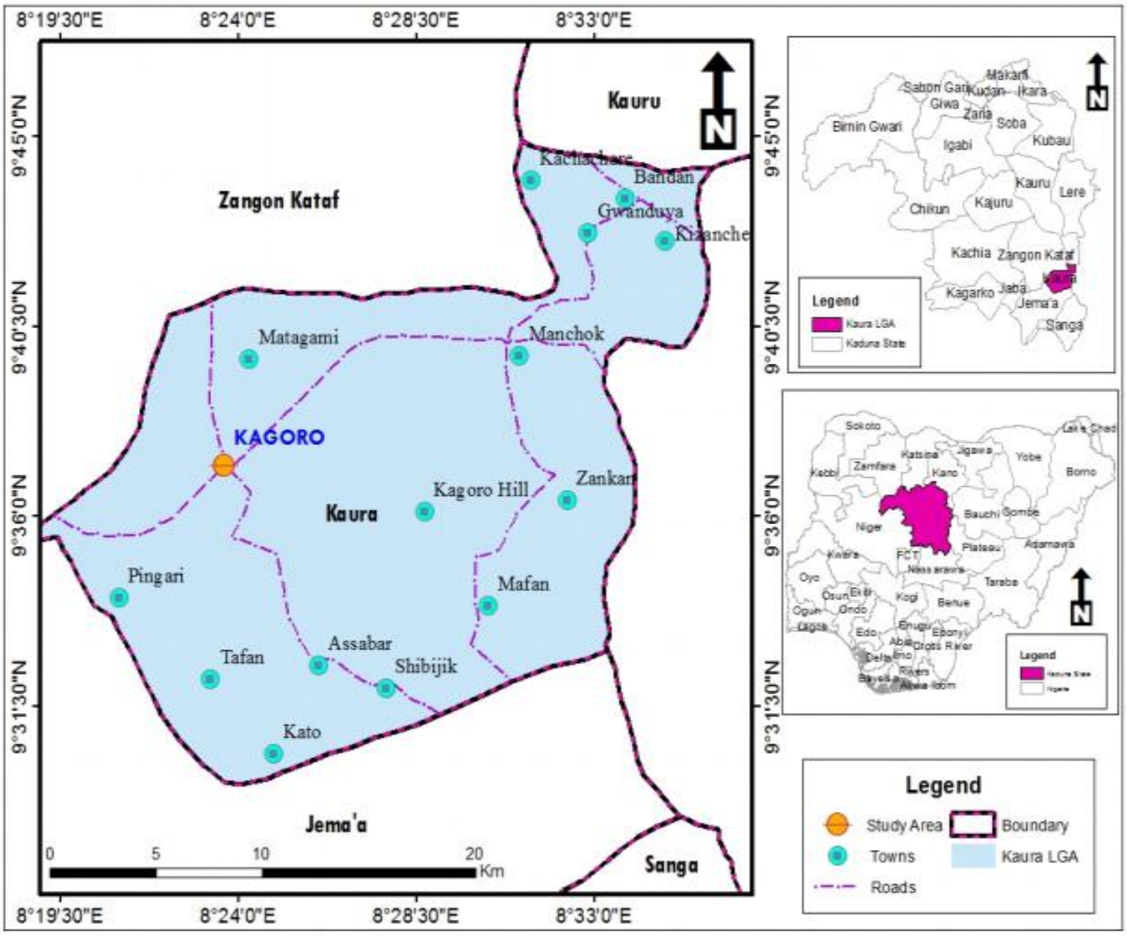

Figure 3.1: Nigeria showing the Study Area
Source: GIS and Remote Sensing Software Arc Map 10.1.

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Located within the Sudan savannah zone, Kagoro uniquely hosts rainforest-type vegetation, especially along river valleys and slopes. Its location on the southwestern slope of the plateau, on the windward side, allows it to receive more rainfall than surrounding areas (Ezealor, 2002). The vegetation presents a blend of savannah and forest, supporting rich biodiversity and favourable agricultural conditions. These climatic and ecological features make Kagoro highly suitable for upland rice cultivation.

Kagoro, situated in Kaura LGA of Kaduna State, is characterized by undulating plains and rocky hills, including the notable Kagoro Hills, with elevations ranging from 400 to 600 meters above sea level (Joel, 2012). Surrounded by mountains historically used as defense sites, the area supports farming on expansive plains and is drained by the Kaduna and Gurara Rivers, along with seasonal streams that flood farmlands during the rainy season (Dodo, 2019).

The dominant soil type is ferruginous tropical soil, derived from weathered basement rock and fine sand, rich in iron oxides, and moderately fertile—ideal for wet-season farming (Oguntoyinbo et al., 1983). Additionally, alluvial soils along riverbanks enhance rice cultivation in flood-prone areas (Mohammed et al., 2022). The vegetation falls within the Guinea Savannah zone, consisting of grasses, shrubs, and scattered trees like shea butter, oil palm, locust bean, and mango. Denser woodlands are found in valley bottoms, though human activities such as tree felling, bush burning, and overgrazing are causing degradation (Dodo, 2019).

The area is primarily inhabited by Gworok and Atyap ethnic groups, predominantly Christian, alongside small populations of Muslims and practitioners of traditional beliefs. Other groups include the Hausa, Fulani, Igbo, Yoruba, Koro, and Gbaygi. As of 2006, Kaura LGA had 83,938 people, projected to reach 147,186 by 2025 based on a 3% annual growth rate (NPC, 2009).

Agriculture is the economic backbone, with upland and lowland farming of crops like rice, maize, sorghum, yam, millet, cassava, ginger, soybean, and groundnut. Dry-season irrigation, relying on boreholes and hand-dug wells, supports vegetable farming (Joel, 2012). Other livelihoods include fishing, trading, and small-scale industries, such as bakeries and a spice processing facility. The area is served by three healthcare centers and basic educational infrastructure.

1.6 REVIEW OF RELATED LITERATURE

Tiamiyu et al. (2015) assessed rainfall variability and its effects on rice yield in Nigeria. The study analysed mean annual rainfall data from major rice-producing states alongside national average rice yields using descriptive statistics and regression models. Findings revealed significant variations in mean annual rainfall across vegetation zones, decreasing from swamp forest to Sudan savanna. While rainfall was generally adequate for rice production in all vegetation zones except the Sudan savanna—where it fell below the minimum requirement—its relationship with rice yield varied. Rainfall showed a positive association with rice yield in all zones except the Sudan savanna; however, this relationship was not statistically significant at the 5% level. The study concluded that annual rainfall variability had a negligible statistical effect on national average rice yield.

Iornongo (2021) investigated the effect of rainfall variability on the yield of selected crops in Benue State, Nigeria. The study employed statistical analysis to determine the relationship between rainfall patterns and crop yields over time. Findings revealed that rainfall variability did not have a significant influence on rice yield, suggesting that other factors such as soil fertility, farming practices, seed variety, and input use may play a more decisive role in determining productivity. The study emphasized the need for farmers to adopt improved agronomic practices and resilient crop varieties in order to mitigate the risks associated with rainfall fluctuations.

Edu and Oluka (2022) demonstrated that the adoption of Sawah technology significantly improved the growth and yield of NERICA rice varieties in South-East Nigeria. By providing controlled water management and enhanced soil conditions, Sawah fields recorded higher panicle length, grain number, grain weight, and overall yield compared to non-Sawah fields. The Sipi692033 variety performed best with a yield of 5 tons/ha, highlighting the potential of improved water-soil interactions in boosting productivity. This study underscores the importance of rainfall, temperature, and soil characteristics in rice production: while rainfall provides the primary water supply, its variability can hinder yields unless moderated through technologies like Sawah; soil fertility and structure influence nutrient uptake and root development; and temperature determines the growth rate and reproductive success of rice varieties. Hence, the findings show that integrated management of water (rainfall), temperature resilience, and soil enhancement is crucial for optimizing rice yields.

Ukoh and Ikpe (2025) examined rainfall variability and its effects on rice yield in Benue State, Nigeria. The study emphasized that rainfall variability is a critical factor rice farmers must consider in order to achieve a bumper harvest. Findings revealed a positive and significant relationship between rainfall and rice yield over the years. The study recommended the adoption of viable adaptation strategies such as irrigation farming, the use of improved seed varieties, and the application of both organic and inorganic fertilizers to enhance rice production.

1.7 METHODOLOGY

1.7.1 Types and Sources of Data

This study relied on primary and secondary sources of data. The primary data were obtained through the administration of self-structured questionnaires and field experiments. While the secondary data were rainfall and temperature data (1970-2021). The self-structured questionnaire was titled; Upland Rice Farmers Climate Change Adaptation Questionnaire (URFCCAQ). To ensure validity and reliability, the questionnaire was pre-tested on 50 purposively selected respondents across various agricultural settlements within the study area. Feedback from the pre-test led to necessary corrections and refinements, guided by expert input. To assess internal consistency, the instrument was subjected to Cronbach's Alpha analysis using SPSS, yielding a reliability coefficient of 0.68, indicating acceptable reliability for use in the study.

1.7.2 Field Experiment

The study was conducted in Kagoro, Nigeria, from May to September 2023. Field experiments were carried out during the rainy season at two different locations in Kagoro (9°36′27″N, 8°23′25″). The study utilized four experimental plots of land, designated as Plots A, B, C, and D.

1.7.3 Sampling technique and sample size

Krejcie and Morgan's (1970) method of determining sample size was used to sample 385 farmers. Only 380 of the questionnaires were returned successful and fit for analysis. Simple random sampling technique was used to select farmers within the study area. Questionnaire survey was used to elicit relevant information from the sampled farmers.

1.7.4 Data analysis

The rainfall and temperature data for 52 years (1970-2021) were used to characterise the rainfall and temperature pattern (increase or decrease). Trend line equation was used to show the trend of rainfall, while the samples of the area was tested in the Soil laboratory and analysed. The analysed results were presented using charts and tables.

1.8 RESULTS AND DISCUSSION

1.8.1 Demographic Characteristics of the Farmers

The demographic characteristics of rice farmers in the study area were examined and are presented in Table 1. The results show that 23.7% of the respondents were between the ages of 20–29 years, 33.4% between 30–39 years, 24.5% between 40–49 years, 10.2% between 50–59 years, and 8.2% were 60 years and above. Only farmers above 20 years of age were purposively selected for the study, aligning with Deressa et al. (2008), who argued that the respondents' age reflects their experience with climate variability. Older respondents are generally more knowledgeable about climatic changes, having been exposed to past and present conditions over a longer period. This indicates that the sampled farmers were above the dependent age category.

Regarding gender distribution, 67.1% of the respondents were male, while 32.9% were female. The predominance of male farmers may be attributed to their traditional role as household heads, responsible for providing essential needs such as food. In many parts of Africa, including Nigeria, women are often deprived of property rights due to socio-cultural barriers, resulting in reduced access to resources and opportunities compared to men (Umar et al. 2015).

The marital status of respondents, as shown in Table 1, revealed that 68.2% were married, 30.3% were single, and 1.6% were widowed. The predominance of married farmers suggests a higher level of household responsibilities, motivating greater involvement in farming to provide food and income. This aligns with Ikpe et al. (2023), who found that most farmers in Kubau LGA, Kaduna State, were married. An added advantage of this is the availability of family labour, which can help reduce farming costs.

Table 1: Demographic Characteristics of the Farmers (N=380)

	Age	Frequency	Percentage
a.	20 – 29	90	23.7
b.	30 – 39	127	33.4
c.	40 – 49	93	24.5
d.	50 – 59	40	10.2
e.	60 and above	30	8.2
Sex			
a.	Male	255	67.1
b.	Female	125	32.9
Marital Status			
a.	Married	259	68.2
b.	Single	115	30.3
c.	Widowed	6	1.6
Household size			
a.	Less than 5	158	41.6
b.	6 – 10	192	50.5
c.	11 – 15	24	6.3
d.	16 – 20	6	1.6

Engagement of family members			
a.	Family labour	335	88.2
b.	Non-family labour	45	11.8
Qualification			
a.	Primary school certificate owners	21	5.5
b.	Secondary school certificate owners	25	6.6
c.	Tertiary	301	80.1
d.	No formal education at all	33	7.8
Religion			
a.	Islam	18	4.7
b.	Christianity	362	95.3
Duration of farming rice			
a.	1 – 5	133	35.0
b.	6 – 10	117	30.8
c.	11 – 15	67	17.6
d.	16 – 20	12	3.2
e.	21 – 25	25	6.6
f.	26 and above	26	6.8
	Total	380	100.0

Source: Field Work 2024

Family labour is a primary source of manpower for smallholder crop production across much of Africa, including Nigeria. It comprises the contributions—both mental and physical—of all household members, including men, women, and children. The household size distribution of rice farmers in the study area is presented in Table 1. Results showed that 41.6% of respondents had fewer than five household members, 50.5% had between six and ten, 6.3% had between eleven and fifteen, and 1.6% had between sixteen and twenty members.

The average household size was 14 persons, indicating that most respondents belonged to large families. Such household sizes provide substantial labour support from spouses and children, thereby increasing the reliance on family labour for farming. When asked whether they engaged family members in farming activities, 88.2% of respondents reported doing so, while 11.8% did not. This suggests that most farmers rely heavily on family labour, possibly due to the scarcity and high cost of hired labour in the area.

The educational attainment of rice farmers, also shown in Table 1, reveals that 5.5% attended primary school, 6.6% attended secondary school, 80.1% attained higher education at various levels, and 7.8% had no formal education. This indicates that the majority of respondents had some level of formal education, which may have enhanced their farming practices. Enete et al. (2011) found a strong positive relationship between farmers' education levels and their investment in both indigenous and modern farming techniques. Educated farmers are generally better equipped to understand and adopt new technologies, thereby improving productivity and efficiency.

Regarding religion, 4.7% of farmers identified as Muslim, while 95.3% identified as Christian.
The farming experience of respondents varied: 15.8% had between 1–10 years of experience, 23.7% had 11–20 years, 30.5% had 21–30 years, 9.7% had 31–40 years, and 20.3% had over 41 years of experience. The fact that the largest proportion (30.5%) had between 21 and 30 years of farming experience supports Ikpe (2021), who noted that longer residence and farming in a specific location enhance a farmer's knowledge and understanding of that environment.

Experience in upland rice cultivation specifically shows that 35% of respondents had been engaged in it for 1–5 years, 30.8% for 6–10 years, 17.6% for 11–15 years, 3.2% for 16–20 years, 6.6% for 21–25 years, and 6.8% for 26–30 years.

1.8.2 Climatic Characteristics of the Study Area

1.8.2.1 Rainfall

The Total Annual Rainfall (TAR) and temperature of the study area (1970 - 2021) were analysed and presented in Figures 2 and 3. Rainfall is the most variable of all climatic elements and determines the growing season in developing countries like Nigeria where agriculture is predominantly rain-fed. Almost every farmer is interested in what the expected rainfall would be, more than any other climatic elements as it determines the success or failure of crop cultivation. Timely and accurate weather forecasting and sharing is crucial to improving farming activities.

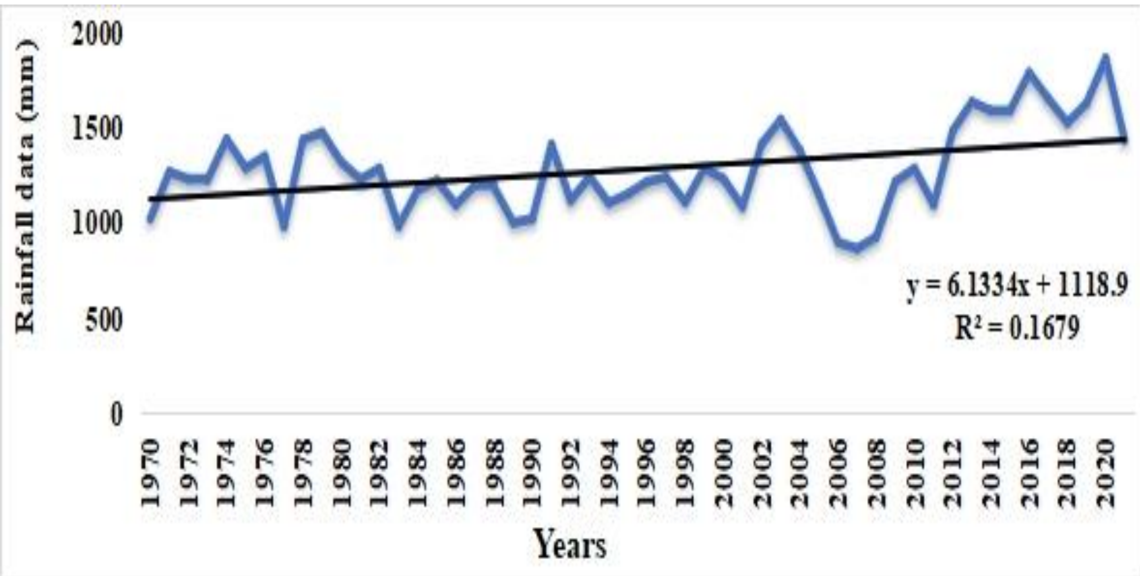

Figure 2: Trends in Total Annual Rainfall for Kaduna State (1970 – 2021)

The trend line equation $y=6.1334x+1118.9$ indicates that, over the 52-year period from 1970 to 2021, Total Annual Rainfall (TAR) increased at an average rate of approximately 6.13 mm per year. The intercept value (1118.9) suggests that the baseline TAR at the beginning of the study period was about 1,119 mm. The R^2 value of 0.1679 points to a weak correlation between time and rainfall amount, indicating that while there is a general upward trend, annual rainfall fluctuates considerably from year to year.

The positive slope confirms a long-term increase in TAR. However, the relatively low R^2 value underscores the high inter-annual variability, suggesting that other climatic and environmental factors—such as El Niño-Southern Oscillation (ENSO) events, regional atmospheric circulation changes, and land-use alterations—also exert significant influence on rainfall patterns in the study area. This variability means that, despite the overall increase, farmers may still experience years of drought or excessive rainfall.

The observed increase in TAR is consistent with the findings of Ikpe et al. (2023) in Kubau LGA, Kaduna State, and aligns with Ayoade's (2004) observation that rainfall is the primary driver of inter-annual yield variations in tropical agriculture. In such climates, increased rainfall can benefit rain-fed farming systems by improving soil moisture and enhancing groundwater recharge.

Nevertheless, the high variability revealed by the low R^2 value presents certain risks:

i. Extreme rainfall events – intense rains in some years may cause flooding, waterlogging, and soil erosion, which can damage crops and degrade farmland.

ii. Unpredictable growing seasons – variability may lead to irregular onset and cessation of rains, complicating planting schedules and affecting crop maturity.
iii. Climate change signals – while the upward trend may reflect broader regional climate change patterns, the variability indicates the need for more localised analysis before making definitive attributions.
iv. Adaptation Strategies – to maximise benefits and reduce risks, farmers may adopt measures such as water harvesting, improved drainage systems, and resilient crop varieties capable of withstanding both excess and deficit rainfall.

Although TAR has gradually increased over time, the substantial year-to-year fluctuations highlight the need for agricultural planning that emphasises climate resilience rather than reliance on average rainfall gains alone. This result corroborated with the findings of Oyewole et al. (2014) which reported rainfall variation and humidity in some parts of Nigeria.

According to Odeniyi et al. (2020), rice requires substantial water input, typically around 500–600 mm. For upland rice, optimal growth occurs when cumulative rainfall exceeds 20 mm over five consecutive days, from planting until about 15 days before harvest (approximately 90 days). In the present study area, mean TAR ranges from 1,000 mm to 2,000 mm, with rainfall extending over roughly six months (Dadah et al., 2017). These conditions make the TAR suitable for upland rice cultivation in the Kagoro area of Kaduna State, Nigeria.

1.8.2.2 Temperature

The trendline on maximum and minimum temperature is presented in Figure 3.

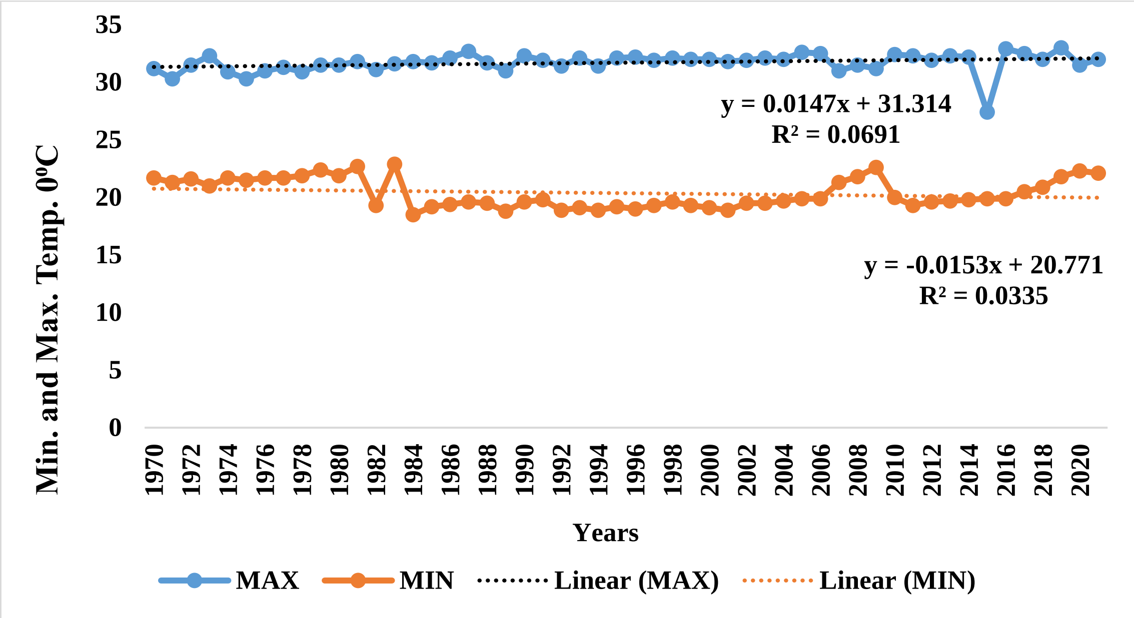

Figure 3: Trends in Annual Max. and Min. Temperature for Kaduna State (1970 – 2021)

The trend line equations show that:

- Maximum temperature trend: $y=0.0147x+31.314$ means that over the study period (1970–2021), the annual maximum temperature increased by about 0.0147 °C per year. The intercept (31.314) suggests that the baseline maximum temperature around 1970 was roughly 31.31 °C.
- Minimum temperature trend: $y=-0.0153x+20.771$ indicates a slight decrease in annual minimum temperature of about 0.0153 °C per year. The intercept (20.771) suggests a baseline minimum temperature of about 20.77 °C in 1970.

The upward trend in maximum temperature suggests that the hottest periods of the year are becoming hotter, which could stress crops through heat stress, increase evapotranspiration rates, and reduce soil moisture availability. Conversely, the slight downward trend in minimum temperature implies that nights are getting marginally cooler over time. This is unusual because climate warming often causes both minimum and maximum temperatures to rise, but local climatic influences such as altitude, vegetation changes, or atmospheric circulation patterns could explain the divergence.

These patterns have important implications for rice production in the study area:

i. Crop growth and yield – rising maximum temperatures may shorten crop growing periods for heat-sensitive crops, such as maize and rice, reducing yields unless adaptive measures are taken.

ii. Pest and disease dynamics – warmer days can accelerate pest and pathogen life cycles, potentially increasing pest pressure, while cooler nights may slow some pest reproduction rates.
iii. Water management – increased daytime heat could raise irrigation demand, further stressing water resources in dry seasons.
iv. Climate variability – the divergent maximum and minimum temperature trends might indicate changing diurnal temperature range (DTR), which can influence plant physiology, flowering patterns, and pollination success.
v. Adaptation needs – farmers may need to adopt heat-tolerant crop varieties, adjust planting dates, or use shading/mulching techniques to mitigate extreme daytime heat.

Overall, the observed trends highlight a warming pattern during the day but slight cooling at night, pointing to complex local climatic shifts that could have both positive and negative effects on agricultural productivity. These results aligned with the findings of Odeniyi et al. (2020) which stated that rainfall and temperature influences rice production in Nigeria.

According to WARDA (2015), rice can be grown under a wide range of climatic conditions, both in temperature and hot tropical climates. Germination does not take place at a soil temperature of <12°C, growth is optimal at air temperatures between 24 and 36°C. Since the average temperature of the study area is between 24 - 32°C, it is therefore suitable for upland rice cultivation. From the foregoing, it is therefore confirmed that the climate of the study area (rainfall and temperature) is suitable for upland rice cultivation in Kagoro area of Kaduna State, Nigeria.

1.8.2.3 Soil Suitability

The soil analysis results are presented in Table 2. Findings indicate that the four sampled plots (A, B, C, and D) contain a high proportion of sandy clay loam, a texture considered suitable for upland rice production. According to Edu and Oluka (2022), rice can be cultivated on various soil types, ranging from heavy clay to sandy loam. The predominant texture in the study area is sandy clay loam, which Makarau (2025) classify as moderately suitable for upland rice farming.

Table 2: Result of Soil Analysis

Sample No.	Sand	Silt	Clay	Texture	pH	EC	OM	TN	Avail P	Exchangeable bases (Meq/100g)				Meq/100g	
	%	%	%			dsm/cm	%	%	Ppm	Ca	Mg	K	Na	Exch. acidity	CEC

Plot A	61.56	18	20.44	Sandy clay loam	5.76	0.031	3.05	0.095	16	2.05	0.55	0.21	0.0091	1.60	4.93
Plot B	61.56	18	20.44	Sandy clay loam	6.26	0.016	2.98	0.092	15	2.04	0.55	0.21	0.0087	1.60	4.91
Plot C	50.56	22	27.44	Sandy clay loam	5.78	0.039	2.33	0.073	12	2.16	0.57	0.22	0.010	1.62	5.08
Plot D	61.56	18	20.44	Sandy clay loam	6.14	0.016	2.52	0.078	13	2.03	0.54	0.21	0.0087	1.60	4.89

Legends:
* pH – Acidic or Alkaline status
* EC – Electric conductivity
* OM – Organic matter
* TN – Total nitrogen
* Avail P. – Available phosphorus

Plots A and C (Table 2) exhibit slightly acidic conditions, with pH values below the neutral level of 7, while plots B and D range from slightly acidic to neutral, falling within the optimal range. Lawal et al. (2013) categorize soils with pH 5.0–5.5 as strongly acidic, 5.6–6.0 as moderately acidic, and 6.1–6.5 as slightly acidic. The study area's pH levels, therefore, fall within the moderately acidic range, making them favourable for agriculture, particularly upland rice cultivation. These results contrast with Olowolafe and Patrick's (2001) observation that soils in the semi-arid regions of northern Nigeria often have low pH and nutrient levels, resulting in poor crop yields. In contrast, Patrick et al. (2024) note that soils with pH values between 5.0 and 6.0 and electrical conductivity (EC) levels of 0.01–0.03 dS/m are suitable for crop production in Sokoto State. The cation exchange capacity (CEC) values in the study area range from 4.89 to 5.08 cmol(+)/kg clay, averaging 4.95 cmol(+)/kg, which Singh et al. (1997) also deem suitable. Additionally, the soils' EC values are below 2 dS/m, further confirming their high suitability for upland rice cultivation. Combined with the gentle land slope of less than 4%, these characteristics qualify the area as suitable for rain-fed upland rice production.

1.8.2.4 Soil Texture

All plots are Sandy Clay Loam, though Plot C has a slightly higher clay content (27.44%) compared to others (~20.44%).

Implication: Sandy clay loam has good drainage but retains enough moisture and nutrients for crops. Plot C's higher clay content may hold water and nutrients longer, but could also reduce aeration.

1.8.2.5 Soil pH

- Range: 5.76 – 6.26
- Classification: Slightly acidic (ideal for most tropical crops).
- Plot A and C are slightly more acidic (<5.8) than B and D (~6.14–6.26).

Implication: pH is within the range for rice, maize, and other common crops, but continued monitoring is necessary to prevent acidification which may limit nutrient availability.

1.8.2.6 Electrical Conductivity (EC)

- ✓ Range: 0.016 – 0.039 dS/m
- ✓ Very low salinity levels – no risk of salt stress for plants.
- ✓ Slightly higher in Plot C (0.039), which might be due to higher clay content retaining soluble salts.

Implication: Excellent for crop growth, no salinity problem.

1.8.2.7 Organic Matter (OM)

- ✓ Range: 2.33% – 3.05%
- ✓ Plot A has the highest OM (3.05%), followed closely by B (2.98%).
- ✓ Plot C is lowest (2.33%).

Implication: OM above 2% is good for tropical soils, but values could be improved to 4–5% for optimal nutrient cycling and water retention.

1.8.2.8 Total Nitrogen (TN)

- ✓ Range: 0.073% – 0.095%
- ✓ All plots are in the low to moderate range for tropical soils.
- ✓ Highest in Plot A (0.095%), lowest in Plot C (0.073%).

Implication: Nitrogen supplementation may be required for optimum crop yield.

1.8.2.8 Available Phosphorus (Avail P)

- ✓ Range: 12 – 16 ppm
- ✓ Plot A has the highest (16 ppm), Plot C the lowest (12 ppm).

Implication: Levels are generally adequate for most crops (>10 ppm is good), but phosphorus fertilization could be considered for long-term maintenance, especially in Plot C.

1.8.2.9 Exchangeable Bases

- ✓ Calcium (Ca): ~2.03 – 2.16 Meq/100g – adequate but could be improved for better structure and pH buffering.
- ✓ Magnesium (Mg): ~0.54 – 0.57 Meq/100g – sufficient for plant growth.
- ✓ Potassium (K): 0.21–0.22 Meq/100g – moderate; potassium fertilizer may be beneficial for high-yield crops.
- ✓ Sodium (Na): ~0.0087 – 0.010 Meq/100g – very low, which is good (no sodicity issues).

1.8.2.10 Exchangeable Acidity and Cation Exchange Capacity (CEC)

- ✓ Exchangeable Acidity: 1.60 – 1.62 – moderate acidity buffering, which may slightly affect sensitive crops.
- ✓ CEC: 4.89 – 5.08 Meq/100g – low to moderate CEC, meaning the soils have limited nutrient-holding capacity due to sandy texture.

1.8.3 VARIETIES PLANTED BY THE FARMERS

The farmers cultivate different varieties of upland rice in the area. The choice of varieties used by the farmers varies. The common varieties planted by the farmers in the area are: FARO 45 (*Jamila Tudu*); NEREICA 1; FADAMA; FARO 67; FARO 40 (*Jan Naira*); FARO 48 (*White jollof*); FARO 55 (*Red jollof*); FARO 65 (*Wasila*); FARO 58 (*Dan Yarima*) and FARO 54 (*Sabo Iri.* These varieties were very common among the rice farmers in the area (Makarau (2025).

1.8.3.1 Farmers' Perception on the most Productive Upland Rice Varieties

The farmers' perception on the most effective upland rice varieties in the study area is presented in Table 3. The result shows that majority of the farmers (30.3%) stated that '*jamila'* is the most effective upland rice varieties; 14.5% stated that NERICA is the most effective varieties; 14.2% reported FADAMA rice; 3.2% stated upland varieties; 7.1% FARO 45; 5.3% white jollof; 6.6% red jollof; 1.6% stated that '*jamila'* is the most effective; 1.6% reported '*dan yarima'* and 15.8% reported short variety.

Table 3: Productive varieties of upland rice

	Duration of Awareness	Frequency	Percentage	Ranking
a.	FARO 45 (*Jamila Tudu*)	115	30.3	1st
b.	NERICA1	55	14.5	3rd
c.	FADAMA	54	14.2	4th
d.	FARO 67	12	3.2	8th
e.	FARO 40 (*Jan Naira*)	27	7.1	5th
f.	FARO 48 (*White jollof*)	20	5.3	7th
g.	FARO 55 (*Red jollof*)	25	6.6	6th
h.	FARO 65 (*Wasila*)	6	1.6	9th

i.	FARO 58 (*Dan Yarima*)	6	1.6	9th
j.	FARO 54 (*Sabo Iri)*	60	15.8	2nd
	Total	380	100.0	

Source: Field Work 2024

The result (Table 3) shows that FARO 45 '*jamila'* is perceived to be the most productive upland rice varieties in the study area. This result disagrees with the results from the experimental farms which show that FARO 58 (*Dan yerima*) is the most effective upland rice variety in the area.

1.8.3.2 Reasons for the Choice FARO 45 '*jamila' as the Most* Productive Rice Variety

The reason why *'jamila'* was perceived to be the most effective upland variety is presented in Table 4. The results show that high yield of the variety is the most cited reason, with 173 respondents (45.5%) choosing it. Short growing season ranks second, with 127 respondents (33.4%). Drought resistance comes third, with 67 respondents (17.6%). Little effort for maintenance is the least common reason, with only 13 respondents (3.4%).

The reasons for the productiveness of upland rice varieties in the area is presented in Table 4.

Table 4: Farmers' Perceived Reasons for the productiveness of FARO 45 '*jamila'* variety

	Reasons	Frequency	Percentage
a.	Drought resistance	67	17.6
b.	High yield of the variety	173	45.5
c.	Short growing season	127	33.4
d.	Little effort for maintenance	13	3.4
	Total	380	100.0

Source: Field Work 2024

The data shows that farmers prioritize economic output (high yield) and time efficiency (short growing season) when evaluating the productiveness of upland rice varieties. The dominance of "high yield" suggests that income generation and food security are key motivators for variety adoption. The considerable percentage for "short growing season" indicates that seasonal climatic patterns and the need to avoid risks of late-season drought or flooding influence varietal choice. "Drought resistance" being moderately ranked shows it is valued, but perhaps not as pressing in the study area's agro-ecological context as yield and maturation period. The very low percentage for "little effort for maintenance" implies that labour-saving features are not a primary factor for adoption—farmers might already be accustomed to the labour demands of rice farming (Makarau, 2025).

1.8.3.4 Farmers' Perception on Rice yield in the Area

The farmers' perceptions of upland rice yields in the study area are presented in Table 5. Regarding whether the harvest is increasing or decreasing, 53.2% of respondents stated that the yearly harvest of rice in the area is increasing; 39.5% indicated that rice yield is decreasing; while 7.4% reported that rice yield has remained the same in the last cropping season compared to previous years (Table 5). The fact that a majority of the farmers (53.2%) observed an increase in annual harvest aligns with the findings of Emeghara (2015), who reported that maize and rice yields are rising. This result also supports the findings of Ikpe (2021), who documented an increase in the yields of grain crops in Sokoto State, attributed to the use of improved seed varieties and other viable adaptation strategies.

Table 5: Is the annual harvest increasing or decreasing over the years?

	Conditions of harvested rice	Frequency	Percentage
a.	Increasing	202	53.2
b.	Decreasing	150	39.5
c.	Remains the same	28	7.4
	Total	380	100.0

Source: Field Work 2024

According to Ejeh (2014), the impact of climate change has been identified as a contributing factor to the decline in productivity and crop yield in Kano State, Nigeria. The result of this study also aligns with the findings of Blanc (2012), who reported that climate change has a significant impact on millet and sorghum yields in sub-Saharan Africa, with grain yields declining due to late onset and early cessation of rains, as well as a shorter rainy season.

1.8.3.5 Farmers perceived reasons for the increase in yield

The farmers perceived reasons for the increase in the yield of rice is presented in Table 6.

Table 6: Perceived Reasons for the Increase in Yield

	Reasons	Frequency	Percentage
a.	Early rainfall	32	8.4
b.	Use of improved seed varieties	205	53.6
c.	favourable rainfall amount	36	9.5
d.	Use of adaptation strategies	70	18.4
e.	Suitable/fertile soil	37	10.1
	Total	380	100.0

Source: Field Work 2024

Table 6 presents respondents' reasons for the performance or success of upland rice cultivation in the area based on a total of 380 responses.

i. Use of improved seed varieties recorded the highest frequency (205 responses; 53.6%). This indicates that more than half of the farmers believe that modern, high-yielding or disease-resistant seed varieties significantly influence productivity. According to Ikpe (2021) improved seed varieties is a viable adaptation strategy among farmers.
ii. Use of adaptation strategies (e.g., crop rotation, irrigation, mulching, early planting) was the second most cited reason (70 responses; 18.4%). This suggests that farmers actively adjust their farming methods to cope with environmental conditions.
iii. Suitable/fertile soil was cited by 37 respondents (10.1%), indicating that natural soil fertility is seen as a contributing factor to good yields, though less emphasized than seed variety and adaptation methods.
iv. Favourable rainfall amount accounted for 36 responses (9.5%). This implies that the quantity of rainfall, when optimal, plays a role in determining crop performance, though farmers may not rely on it as their primary factor.
v. Early rainfall had the lowest percentage (32 responses; 8.4%). While timely rainfall at the onset of the season helps planting and seed germination, it appears less significant compared to the use of improved seeds or adaptation strategies.

Overall, the data shows a shift towards input-driven and knowledge-based agriculture, where farmers increasingly rely on innovations rather than solely depending on environmental luck. This trend is positive for resilience but requires continued support in seed distribution, extension services, and climate-smart agricultural practices.

1.9 CONCLUSION

This study has assessed the influence of climate change and soil characteristics on the performance of upland rice varieties in the Kagoro area of Kaduna State, Nigeria. The findings showed that the total annual rainfall of the area (which ranges between 1,000 mm to 2,000 mm) is suitable for upland rice cultivation. Also, since the average temperature of the study area is between 24 - 32°C, it is therefore suitable for upland rice cultivation. From the foregoing, it is therefore confirmed that the climate of the study area (rainfall and temperature) is suitable for upland rice cultivation in Kagoro area of Kaduna State, Nigeria. The soils' characteristics (texture, Ph, organic matter, total nitrogen, available phosphorus, exchangeable acidity and cation exchange capacity further confirmed their high suitability for upland rice cultivation. Combined with the gentle land slope of less than 4%, these characteristics qualify the area as suitable for rain-fed upland rice production. FARO 45 '*jamila*' is perceived to be the most productive upland rice varieties in the study area. The data shows that farmers prioritize economic output (high yield) and time efficiency (short growing season) when evaluating the productiveness of upland rice varieties. The study therefore concluded that rainfall, temperature variability and soil characteristics influences the yield of upland rice varieties in Kagoro area of Kaduna State, Nigeria.

1.10 RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made:

i. Increase Organic Matter through compost, green manure, or crop residues to improve CEC, nutrient retention, and water holding.
ii. Nitrogen Fertilization (e.g., urea, ammonium nitrate) to meet crop requirements.
iii. Balanced Fertilization to maintain phosphorus and potassium levels.
iv. Soil Conservation to prevent erosion, which could further reduce nutrient levels.
v. Periodic Soil Testing to track changes and guide precise fertilizer application.

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