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Assessing Climate Change Sensitivity and Adaptation Practices of Large and Small Farms: A Case Study from Northern Nigeria

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INTRODUCTION

Climate change is recognized by today's world as the most important environmental problem affecting humanity. It refers to a serious and continuous change in weather pattern. It is largely attributed to the emission of greenhouse gases such as carbon dioxide, methane, nitrous oxide and water vapor by humans. This led to extreme and violent weather events which manifest as warmer temperatures, heavy rainfall, drought, floods and cyclones (Robinson, 2024). One of the most vulnerable sector is agriculture. Findings from many studies showed evidence of rise in temperature and changes in the intensity of rainfall across Nigeria (Chiaka et. al., 2022; Farauta et. Al., 2011). It was forecasted that temperature will rise by 1.5 0C to 2.5 0C in the 21st century and there will be a general slight increase in rainfall across different parts of the country. In the current scenario most part of northern Nigeria which is arid is characterized by high temperature, low rainfall and water shortage, scanty vegetation and marginal land.

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Although the region has vast land and holds great potential for agriculture, its geographical location makes the area more vulnerable to the impact of climate change and poses a serious threat to food production (Moses- ojo et. al., 2023).

Agriculture is the dominant sector in the Nigerian economy; it contributes 25.59% to GDP in 2024 and employs a significant percentage of the labor force. It is the main source of food and raw materials in the country. However, agriculture in Nigeria like many African countries is vulnerable to the impact of climate change. Estimate of damage from scientific studies due to the impact of climate change on agriculture for Nigeria was projected to reach up to 1.5% to 3% of GDP each year by 2030; it will also lower crop yield by 5% to 25% by 2050 (Bosello et. al., 2013; Bello et. al., 2012). Other important changes are also affecting the agricultural environment and will certainly continue to 2050 unless successfully addressed. The impacts of climate change worsen pre-existing social inequalities specifically for farmers who are more vulnerable because of limited access to resources and because their livelihood depends on agriculture and natural resources, which are highly susceptible to climate variability (Amos et. al., 2021; Chimi et. al., 2022).

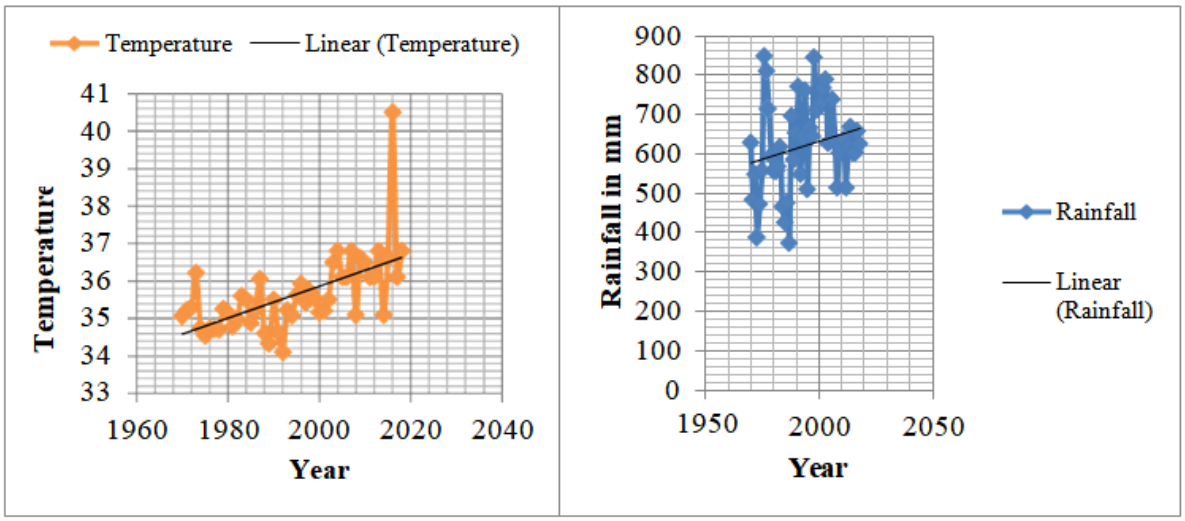
To lessen the adverse impacts of climate change, local farmers have to adjust to harsh weather conditions and have already developed coping strategies over time. If Nigeria is to meet the challenge of feeding an additional 1.6 billion people by 2050, an integrated approach to addressing climatic changes that have negative impacts in the agricultural environment is essential. It is imperative that smallholder farmers who produced the bulk of the food in Nigeria adapt their farming practices to help negate these and other projected negative impacts (Mathieu et. al., 2024). The uptake of these innovative practices and technologies, nonetheless, depends on individual characteristics, inequalities in household capital endowment and access to rural services including climate and agricultural information as well as gender. The main variables used for the analysis of the study were divided into climate variables, which include temperature and rainfall, and the non- climate variables which are soil, relevant socio economic variables.

The Problem

In Nigeria, agriculture contributed a large share of the GDP by up to 22% in 2022 and employed a significant percentage of the labor force; the sector is dominated by smallholder farmers and is rain fed dependent and thus, subjected to the adverse effects of climate change; which is currently affecting the country. It is estimated that the damage due to climate change in Nigeria and other countries in sub Saharan Africa could reach between 1.5% to 3% of GDP each year. It was predicted that crop yield could decline by 10-20% by 2050 (Bello et al., 2012). The major problem this study is lack of clear picture of how climate change will affect farms based on scale of operations in northern Nigeria, to make the matter worse although previous studies that assessed the sensitivity of farms to climate change were quite few in Nigeria Bosello et al., (2013); Ikpe et. al., (2023); Tajuddeen et. el., (2022) these studies did not base their analyses on farm size. Similarly, their revealed adaptation strategies were not based on types to be employed by farms to cushion the impact of climate change in the area.

Evidence of Climate Change in Northern Nigeria

Rise in temperature leading to severe heat, drying up of most lakes, natural ponds and dams such as the Lake Chad, and Kainji reservoir, disappearance of some species of flora and fauna, Sahara desert encroachment southward rendering land less productive, Flooding of human settlements, farm lands and public amenities were some of the current manifestations of climate change in northern Nigeria (Elisha et. al., 2023). Others are depletion of underground water table leading to severe water shortages, increased incidence of environmental diseases and pests, warmer hot season and heat wave, late onset of rainfall, reduction in the country's land area under forest cover from 37% in 1976 to 5% in 1996, and collapse of the Eco zones from 8 to 5 as the savanna is pushed further south (Elisha et. al., 2023).



Evidence of climate change in northern Nigeria from 1970-2020

Research gap

In Nigeria despite the important contribution of agriculture to the economy information and knowledge of how the agricultural sector will be affected by climate change is scanty. Farmers' especially small scale farmers who largely contributed to the sector were mostly ignorant of the impact of climate change on their farms and are mostly excluded from participation in adaptation decision making, and thus the unique knowledge and needs associated with their specific roles in farming is not considered in those decisions.

Significance of the study

In Nigeria few studies that assessed the sensitivity and adaptation practices of farms to climate change Matheau et. al., (2024): Ajetomobi et al., (2011; Bosello et al., (2013) provides a sketchy picture of the situation. The current study stands out as one of the few that analyzed how sensitive large and small farms are to climate change and how they will adapt to climate change. This analysis will make an important contribution to literature by showing

clearly how climate change will affect farms based on size and how they will adapt in the current and future scenarios.

The Major objective of the study is to assess the sensitivitivity and adaptation practices of large and small scale farms in northern Nigeria. In specific the study will:

1) Measure the sensitivity of large and small farms to climate change in northern Nigeria
2) Measure how future climate change will affect large and small farms.
3) Identify adaptation practices of farms in response to climate change
4) To identify socioeconomic factors that influence adaptation practices

This paper attempts to answer the following questions:

1) How sensitive large and small farms are under changing climate?
2) How future change in climate will affect large and small farms?
3) What are the adaptation practices employed by farms in response to climate change?

What are the socioeconomic factors that influence adaptation practices?

Concept of Climate Change Adaptation

Climate change adaptation is the ability of a system to cushion possible impacts from climate change and to cope with the outcomes. The impact of climate change in the developing nations, according to (Elisha et. al., 2023), is mostly felt by the smallholder farmers, who are highly dependent on rainwater and other climate-sensitive input and resources. Empirical studies shows that northern Nigeria is more vulnerable to the vagaries of climate change due to low adaptive capacity (Elisha et. al., 2023). In view of this, farmers need to use adaptation practices in order to cope with the effects of climate change. Studies have shown that without adaptation to climate change, farmers will become more vulnerable and agricultural product. Earlier studies show that irrigation, improved crop varieties, crop diversification, farm diversification, change of planting dates and income generating activities are among the common practices among farmers (Moses- ojo, 2023).. In addition, it was reported in literature that farmers' adaptation to climate change is determined by socioeconomic factors such as education, age, farming experience, gender, access to extension, credit, markets, farm income and farm size (Madaki et. al., 2023).

Northern Nigeria

Northern Nigeria consist of about two third of the entire area of Nigeria. It is located between latitudes 7^0 and 14^0 North and longitudes 3^0 and 15^0 East. The climate in northern Nigeria is characterized by high temperature all year round. Mean monthly temperatures can reach more than 36°C in most of the times. Northern Nigeria generally has a mean annual rainfall of about 500mm.

Two different seasons, namely, a short wet season and a prolonged dry season are the main features of climate in northern Nigeria. Agriculture is the dominant occupation for both men and Women.

MATERIALS AND METHODS

Design of the Study

Population for the Study

The target population is households who are into agriculture in northern Nigeria, the units of analysis were farmers who grow all kinds of crops in the area.

Sample for the Study

Sampling of respondents was done in stages, firstly, States and local governments that have a high potential for agriculture were purposively chosen for the study, and at the second stage, respondents from districts in 19 local government areas of Northern Nigeria were randomly selected via a lottery method. The states selected for the study were Abuja, Kaduna, Katsina, Kebbi, Kwara, Nassarawa, Niger, Sokoto and Zamfara. The states were selected in view of their agricultural potential. A total of 483 surveys were completed.

Instrument for Data Collection

Data for the study were collected in 19 local government areas, through a farm survey conducted in January 2023 using a structured questionnaire. The questionnaire was designed to obtain farm- level data on agricultural production across the study area

Data Collection Methods

Farm survey was used as the method for primary data collection. Targeted farmers were identified and a scheduled visit was made to their farms. Farmers were interviewed by the enumerators with their consent. Climate variables (temperature and rainfall) record from 1970-2020 was used as the secondary data. Soil variables, and relevant socioeconomic variables were used as the explanatory variables for the study.Net farm income was used as the dependent variable of the study.

Data analysis Techniques

Ricardian model was adopted to achieve objective 1 and 2 (equation 1&2) of the study. Objective 3 of the study was achieved using descriptive statistics. Objective 4 was achieved using multiple regression analysis equation (3). Stata 14 statistical package was used to analyze the data.

Analytical models

The standard Ricardian model is specified as a quadratic formulation of climatic variables:

$V = \beta 0 + \beta 1F + \beta 2F2 + \beta 3G + \beta 4Z + U$ equation 1

V = Net Farm revenue F = Vector for climatic variables G = Set of economic variables Z = Soil variables U = Error term. The marginal impact of climate variable (Ci) on net farm revenue evaluated at the mean of that variable is given as:

$$E\left[\frac{dR}{dCi}\right] = \beta 1i + 2 \times \beta 2i \times [Ci] \quad \text{equation 2.}$$

$$y = b_0 + b_{1X1} + b_{2X2} + b_{3X3} + b_n x_n + u \quad \text{equation 3}$$

Where βi 's are Parameters to be estimated X's = Socio economic and climatic variables u = error term

RESULTS

Sensitivity of Small and Large Farms to Climate Change

To observe the sensitivity of farms to climate change based on size (objective 1), farms that are less than 5 hectares are classified as small farms while farms with five hectares or more are categorized as large farms. Table 1 shows that small farms are sensitive to temperature in the dry season and wet seasons. Similarly, the coefficients for market, farm size and farm technology were significant. However, large farms were more sensitive to rainy season temperature and rainy season precipitation. The coefficients for soil and market were also significant for large farms.

Table 1: Regression for sensitivity of small and large farms to climate change

Variable	**Small farms**			**Large farms**		
	Coefficient	t-value	p> |t|	Coefficient	t-value	p>|t|
Constant	-38.501	-1.54	0.124	-48.080	-1.46	0.153
Dry season temperature	5.657*	-2.67	0.008	23.571	1.40	0.169
Rainy season temperature	-5.807*	-2.74	0.006	-4.518*	-1.67	0.103
Dry season precipitation	0.143	1.32	0.187	-0.296	-1.14	0.262
Rainy season precipitation	3.246	0.82	0.413	11.076*	1.98	0.055
Soil	0.106	0.64	0.519	0.418*	1.91	0.063
Market	-0.076*	-1.90	0.058	-0.074*	-1.90	0.064
Farm size	0.345***	7.94	0.000	-0.024	-0.75	0.459
Tractor	0.204*	2.88	0.004	-0.049	-0.42	0.674

No. of observations	427	56
R Squared	0.31	0.39

Marginal Impact Analysis

The results presented in Table 2 showed the marginal impacts of temperature and precipitation on net revenue. For small farms a decline of ₦1277/ha on net revenue due to slight increase in temperature in the dry season and a decrease in net revenue of N178.8ha for a marginal rise in temperature during the rainy season were observed. For small farms although marginal impact of rainfall would result in decline of less than four naira per ha in the dry season, the marginal impact of rainfall during the growing season will increase revenue with about ₦131/ha. Analysis of the results showed that for large farms a total loss in revenue of ₦5859 will be observed for increase in both dry and rainy season temperature.

Table 2: Marginal impact analysis

Climate	**Small farms**		**Large farms**	
	Marginal impact	Annual impact	Marginal impact	Annual impact
Temperature(₦/ha/$_0$C)				
Dry season	-1277		-5785	
Rainy season	-178.8	-1456	-73.94	-5859
Precipitation (₦//ha/mm)				
Dry season precipitation	-4.0		0.689	
Rainy season precipitation	131	128	1722	1723

Note: values are in Naira

Sensitivity of Farms to Future Change in Climate

To measure the sensitivity of farms to future change in climate the study used the A2 emission scenario of the Global Circulation Model (GCM) to project the future impact of climate change on net revenue (Table 3). Projection for temperature was made based on forecast of increasing temperature for Nigeria by as much as 1^{0C} in 2030, 2.3 ^{0C} in 2060 and 3.7 ^{0C} in 2090 as well as a slight increase in precipitation by 0% in 2030, 1% in 2060 and 4% in 2090 (UNFCCC 2003).

Table 3: Projected impact on future climate scenario

	Temperature			**Precipitation**		
	2030	2060	2090	2030	2060	2090
Small farms	-32	-137	-364	-902	-203	-1038
Large farms	-9841	-102472	-106973	2727	3708	4024

Note: Climate change by GCM climate projections for Nigeria based on A2 climate scenario. Values are in (₦) values

Farm Adaptation Practices by Small and Large Farms

In Table 4 the adaptation options for all the farms were mainly on the modification of the production systems ranging from crop and soil management to improved tillage practices and escaping sensitive growth stages and engaging in production activities that are more drought-tolerant and resistant to temperature stresses as well as activities that take full advantage of the prevailing water which serve as insurance against rainfall variability (Lenis et. al., 2020).

Table 4: Farm level adaptation strategies in northern Nigeria (No. of respondents=483)

	Adaptation by perception on temperature			Adaptation by perception on rainfall		
	Small farms	Large farms	All farms	Small farms	Large farms	All farms
Adaptation						
Different crops	65	7	72	82	8	90
Water harvesting	100	13	113	64	9	73
Change in irrigation	35	4	39	73	11	84
Improved soil management	81	5	86	46	7	53
Change in date of planting	46	8	54	35	5	40
Tillage operation	33	6	39	52	11	53
Change in crop varieties	22	13	38	24	2	26
No adaptation	45	1	46	51	3	54

Determinants of Farm Adaptation

To observe farm specific factors that could affect the decision of the farmer to adapt to climate change (objective 4) certain socio economic factors that were hypothesized to influence the behavior of the farmer were regressed against the decision of the farmer to adapt to climate change (Madaki et. al., 2023). The result was presented in Table 5.

Table 5: Regression results for determinants of adaptation

Variables	Coefficients for determinants of adaptation small farms	Coefficients for determinants of adaptation large farms
Temperature	0.0257**	−0.177*
Precipitation	0.006	−0.042**
Soil	0.1970*	0.615***
Credit	0.193**	5.514**
Experience	0.004*	−0.014*
Income	0.0452**	0.000***

DISCUSSION

Findings of the study from the net revenue model for small and large farms shows the importance of temperature, access to market and farm size for small farms. Farmers that cultivate smaller farm size would be able to maintain the farm and this could lead to better yield. Use of improved farm technology was also beneficial to small farms. During the dry season increase in temperature will benefit all farm, while increase in precipitation will improve revenue for small farms, for large farms increase in precipitation will results to decline in farm revenue. The implications for this result were that both for small and large farms adaptation measures to cushion the impact of temperature should be taken. For precipitation large farms should adapt to increase in precipitation during the dry season. On the impact of future change in climate from 2030 through to 2090 both small and large farms will witness a decline in revenue due to increase in temperature. In contrast only large farms will benefit from increase in precipitation from 2030 to 2090. On adaptation practices employed by farms, findings showed that water harvesting is the most predominant adaptation technique employed by small farms to cushion the impact of rise in temperature, while planting of different crop varieties was used as adaptation to unpredictable rainfall. Most of the large farmers employed water harvesting and change in crop varieties as adaptation for rise in temperature, modification of irrigation practice and tillage operation were used to cushion the impact of unpredictable rainfall. On determinants of adaptation, soil fertility, experience, access to credit and income are the main factors that could affect adaptation decision for all categories of farms**.**

CONCLUSION

Findings of the study showed that small and large farms in northern Nigeria should focus on adaptation options that will cushion the impact of climate change due to increase in temperature during the rainy season. Farmers with small farms are advised to maintain their holding and use improved source of farm power as an adaptation to changing climate. Large farms will benefit from improved soil management techniques to adapt to climate change. In future rise in temperature will lead to decline in net revenue for both small and large farms from 2030 through to 2090. However, large farms will lose more from rise in temperature than small farms. On future increase in precipitation only large farms will benefit from future

increase in rainfall. This suggests that small holder farmers should focus on adaptation choices that will build their resilience to increase in rainfall.

Recommendations

1. Large farms are vulnerable to increase in temperature should take more effective adaptation measures to protect their farms.
2. Increase in precipitation will negatively affect small farms; this category of farms should develop suitable measure that will reduce their vulnerability to future climate change.

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