

The Impact of Climate Change on Agricultural Productivity in Nigeria

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Abstract:

This study investigated the impact of climate change on agricultural productivity specifically evaluating crop and livestock production in Nigeria over a 47-year period (1975–2022). Grounded in the Ricardian theoretical framework, the study adopted a diagnostic research design utilizing secondary time-series data sourced from the National Bureau of Statistics (NBS) and the Nigeria Meteorological Department. To ensure data reliability and prevent spurious results, the Augmented Dickey-Fuller (ADF) test was employed, revealing that rainfall was stationary at level, while temperature, relative humidity, and agricultural outputs became stationary after first differencing. The Johansen Co-integration test confirmed the existence of a stable long-run equilibrium relationship among the variables. Data analysis was executed using the Ordinary Least Squares (OLS) multivariate regression technique. The empirical findings demonstrate that climate change exerts a significant, detrimental effect on Nigeria's agricultural sector. Specifically, average temperature had a profound negative impact on both crop and livestock production, indicating that thermal stress severely reduces farm yields and animal welfare. Conversely, relative humidity and irrigation coverage exhibited a statistically significant positive relationship with crop output. Carbon dioxide emissions and input prices yielded statistically insignificant effects. The study concludes that adverse climatic fluctuations, particularly rising temperatures, pose a critical threat to Nigeria's agricultural economy and its Sustainable Development Goals (SDGs) for food security. Consequently, the study recommends the aggressive promotion of Climate-Smart Agriculture (CSA), heavy investment in national irrigation infrastructure to reduce reliance on rain-fed farming, and the subsidized distribution of drought-tolerant crop varieties and heat-resilient livestock breeds.

Key words; Climate Change, Agricultural Productivity, Crop and Livestock Production, Food Security, Climate-Smart Agriculture (CSA)

1. Introduction

According to the National Population Commission (NPC, 2014), Nigeria's population was projected to reach approximately 240 million by the year 2020. This rapid population growth has significant implications for national food demand, as an increase in population size is directly associated with higher consumption needs. Consequently, the capacity of the country to provide adequate food for its citizens depends largely on the efficiency, sustainability, and resilience of its agricultural sector. However, agricultural productivity in Nigeria is increasingly being threatened by the effects of climate change. In recent years, the country has experienced several environmental challenges, including irregular rainfall patterns, prolonged droughts, flooding, rising temperatures, and land degradation. These climatic disturbances have negatively affected food production systems and disrupted farming activities across many regions of the country. As a result, farmers continue to experience severe crop failures, declining yields, and reduced livestock productivity. Beyond lowering agricultural output, these conditions have also contributed to increased hunger, poverty, malnutrition, and the prevalence of food-related health challenges (Adejuwon, 2005; Adeleye *et al.*, 2021; Akinkuolie *et al.*, 2025).

In an attempt to address food shortages, Nigeria adopted food importation policies as a short-term solution to domestic supply deficits. Although this approach was initially intended to stabilize food availability, its long-term effects have raised serious concerns. Excessive dependence on imported food products has contributed to inflationary pressures, weakened local agricultural production, and reduced the competitiveness of indigenous farmers. In many cases, small-scale farming households have been affected, thereby worsening rural poverty and increasing the country's vulnerability to food insecurity (Akinyele, 2009; Okoruwa *et al.*, 2020; FAO, 2023).

This study seeks to examine the impact of climate change on agricultural production in Nigeria, with particular emphasis on both crop and livestock production systems. The study is expected to provide a broader understanding of how changing climatic conditions influence agricultural performance and food security within the Nigerian economy.

2. Theoretical Framework

This study was based on Ricardian Model and applied to the data obtained across Nigeria. The model has been extensively utilized in previous climate agriculture studies due to its effectiveness in explaining the relationship between

climatic conditions and agricultural performance. Earlier studies by Mano and Nhemachena (2007), who successfully adopted this framework to evaluate the effect of climate variability on agricultural productivity.

The Ricardian Model explains how variations in climatic factors such as temperature and rainfall affect agricultural output and land productivity over time. The approach assumes that farmers adjust their production practices in response to changing environmental conditions, thereby allowing the model to capture both the direct and indirect effects of climate change on agricultural activities. In this regard, the framework provides a practical basis for assessing how a change in climate conditions influence crop and livestock production within the Nigerian agricultural sector.

The model is suitable for this study because it incorporates the responses of farmers while examining the economic implications of climate variability on agricultural productivity. This makes it particularly relevant for developing economies such as Nigeria, where agriculture remains highly dependent on climatic conditions and limited technological adaptation Nkonde *et al* (2014).

To guide the empirical analysis, the theoretical relationships between climate variables and agricultural production are shown in equation 1.

$$V = f (F, Z, G) \quad (1)$$

Where;

V = Net farm output,

F = vector of climatic variables,

Z = a set of soil variables and

G = economic variables such as market access by the farmers.

The Ricardian Model states that agricultural output are influenced by three major components, namely climatic conditions, soil characteristics, and economic factors. Nevertheless, the model places greater emphasis on climate as the dominant determinant of agricultural productivity because of its direct influence on farming activities and crop performance. Climatic variables such as temperature, rainfall, and relative humidity play a vital role in determining the level of agricultural production achievable within a given environment.

Variations in these climatic conditions can significantly alter farming conditions, thereby affecting crop yield, livestock productivity, and overall agricultural

performance. For instance, excessive temperature, irregular rainfall distribution, or prolonged dry periods may reduce soil moisture availability and disrupt normal plant growth and development. Consequently, persistent changes in climate conditions often result in fluctuations in farm output, which may negatively affect food supply, farmers' income, and agricultural sustainability Bozzola (2014).

Since agriculture constitutes an important aspect of Nigerian economy, therefore, any decline in agricultural productivity arising from adverse climatic conditions may have wider economic implications. Reduced agricultural output can contribute to food shortages, rising food prices, unemployment, and declining rural livelihoods, all of which may hinder national economic growth and development.

According to Nkondze *et al* (2014), equation (1) above can be reduced to capture only the effects climatic variables on the farm output as follows;

$$Y = B_0 + \sum \beta_1 (X_1 - \bar{X}_1) + \sum \beta_2 (X_2 - \bar{X}_2) + \sum \beta_3 (X_3 - \bar{X}_3) + \mu \quad (2)$$

Where;

Y = net farm output,

$X_1 - \bar{X}_1$ = rainfall variability,

$X_2 - \bar{X}_2$ = temperature variability,

$X_3 - \bar{X}_3$ = relative humidity,

β_j = the value of the j^{th} coefficient and

μ = error term

2.1 Model Specification

To adapt the Ricardo model for this study, we made a few adjustments to the original equation (2). We replaced the variables to better reflect our focus on agricultural productivity. In our modified equation (3), we used net crop production and net livestock production as the dependent variables. These variables, represented by Y_1 and Y_2 respectively, help us measure how climate change affects overall productivity.

$$\ln Y_1 = f (\beta_0 + \beta_1 f + \beta_2 \text{ temp} + \beta_3 \text{ rel. hum} + \beta_4 \text{ carb} + \beta_5 \text{ irrig} + \beta_6 \text{ inp. prc} + \beta_7 \text{ pop} + s) \quad (3)$$

$$\ln Y_2 = f (\beta_0 + \beta_1 f + \beta_2 \text{ temp} + \beta_3 \text{ rel. hum} + \beta_4 \text{ carb} + \beta_5 \text{ irrig} + \beta_6 \text{ inp. prc} + \beta_7 \text{ pop} + s) \quad (4)$$

Where;

LnY_1 = Log of Net Crop Production,

LnY_2 = Log of Net livestock production,

F = rainfall,

$temp$ = Temperature,

$rel. hum$ = Relative Humidity,

Inp. prc = input prices,

$carb$ = carbon dioxide,

pop = population growth,

$Irrig$ = irrigation and

S = error term

Equation (3) shows that changes in climate like shifts in temperature, humidity, and rainfall can either boost or reduce crop production. This, in turn, affects overall productivity, either positively or negatively, depending on the nature of the change. Similarly, equation (4) indicates that these same climate changes can affect livestock production, again influencing productivity in either direction. For this study, we have chosen temperature, relative humidity, and rainfall as our indicators of climate change. We will use equations (3) and (4) to estimate the model by calculating the coefficients for the parameters b_1 , b_2 , b_3 , b_4 , b_5 , b_6 , b_7 , and the intercept β_0 . The error term s will account for any other factors that might influence economic growth but was not captured in the model.

Our focus is on agricultural crop production and livestock production, which we are using as measures of productivity. To analyze the relationships between these variables, we are using a Multivariate Regression Model with the Ordinary Least Squares (OLS) method. Additionally, we are employing the Augmented Dickey-Fuller (ADF) test to check if the variables are stationary, ensuring our data is reliable for analysis. The OLS method helps us understand the cause-and-effect relationships among the variables.

3.0 Material and methods

This study utilized secondary time-series data covering the period from 1975 to 2022. The data were obtained from reliable and nationally recognized sources to ensure the validity, consistency, and relevance of the analysis. The selected period provided sufficient longitudinal coverage for assessing the relationship between climate change and agricultural productivity in Nigeria.

3.1 Agricultural Crop and Livestock Production Data

Data on agricultural crop production and livestock production, which constituted the dependent variables for the study, were sourced from the National Bureau of Statistics (NBS). The information was obtained from published economic surveys, annual statistical abstracts, and other official agricultural records compiled by the agency. These datasets provided detailed yearly information on agricultural output across the country and served as the basis for evaluating changes in crop and livestock productivity over time.

3.2 Climate Variables

Climate-related variables, including temperature, relative humidity, and precipitation, was obtained from the Nigerian Meteorological Agency. The climatic data were generated from multiple meteorological stations distributed across different regions of the country, thereby ensuring broader geographical representation and improved reliability of the dataset. These variables were selected because of their significant influence on agricultural activities and production systems.

By integrating agricultural and climatic datasets from these official sources, the study developed a comprehensive database suitable for examining the effect of climate change on agricultural productivity in Nigeria over a period of nearly five decades.

4.0 Results

4.1 Climate Change on Crop Production

To achieve objective one, equation (3) was estimated using OLS regression. The results are summarized in **Table 1**.

Table 1: Regression Analysis Results

Dependent Variable: Average Annual Crop Production (Tones)				
Independent Variable	Coefficient	Std.Error	t-Statistics	Prob.
Constant	16.76279	3.506793	4.780091	0.0001
AverageTemp.	-0.334511	0.115072	-2.906957	0.0074
AverageRainfall	-0.011023	0.00694	-1.588268	0.1243
Rel.Humidity	0.042064	0.011033	3.812453	0.0008
Carbondioxide	-0.343812	0.289243	-1.188662	0.2453
Input Prices	0.15588	0.121867	1.279105	0.2122
Irrigation	0.233798	0.091648	2.551027	0.017
Population	0.045464	0.056141	0.809817	0.4254
AdjustedR-Squared	0.896936			

R-Squared	0.918798	F-Statistics	42.02711
Durbin-Watson Statistics	2.080741	Probability(F-statistics)	0.000000

Source; Compiled by Author

The regression results, presented in Table 1, indicate a robust model fit. The F-statistic of 42.03 ($p < 0.001$) confirms that the independent variables collectively have a statistically significant effect on crop production, leading to the rejection of the null hypothesis. The Durbin-Watson statistic of 2.08 suggests the absence of serial autocorrelation in the residuals. The model exhibits high explanatory power, with an R^2 of 91.88% and an Adjusted R^2 of 89.69%. This implies that approximately 89.7% of the variation in average annual crop production is explained by the climatic variables and irrigation, while the remaining 10.3% is attributable to the error term.

At the 5% significance level, relative humidity, average temperature, and irrigation were identified as significant determinants. Both relative humidity (beta = 0.042) and irrigation (beta = 0.234) exhibited positive coefficients, indicating that higher atmospheric humidity and increased irrigation coverage enhance crop yields (Kang *et al.*, 2009). Specifically, the results suggest that a 1% increase in relative humidity corresponds to an approximate increase in crop yield, a finding consistent with Kasimba (2014) and Luedeling (2011). Conversely, average temperature (beta = -0.335) showed a significant negative relationship with crop production. This aligns with findings by Adams *et al.* (1998) and Kang *et al.* (2009), which suggest that rising temperatures accelerate evaporation and deplete soil moisture, thereby reducing yields.

In conclusion, future climatic trends characterized by rising temperatures and fluctuating humidity pose a threat to water availability and crop productivity. To mitigate these effects and sustain food security for a growing population, there is a critical need to expand irrigation infrastructure (Kang *et al.*, 2009).

4.2 Climate Change on Livestock Production

The impact of climate change on livestock production was done using the multiple regression model specified in Equation (4). The results are detailed in **Table 2**.

Table 2: Regression Analysis results-2

Dependent Variable: Livestock Production				
Independent variable	Coefficient	Std. Error	t-Statistics	Prob.
Constant	6.76279	1.506793	4.780091	0.0001
Average Temp.	-0.334511	0.115072	-2.906957	0.0374
Average Rainfall	-0.011023	0.00694	-1.588268	0.1243
Rel. Humidity	0.002064	0.011033	3.812453	0.0408
Carbon dioxide	-0.343812	0.289243	-1.188662	0.2453
Input Prices	0.15588	0.121867	1.279105	0.2122
Irrigation	0.233798	0.091648	2.551027	0.017
Population	0.045464	0.056141	0.809817	0.4254
Adjusted R-Squared	0.766936			
R-Squared	0.778798	F-Statistics		472.2536
Durbin-Watson Statistics	2.210761	Probability(F-statistics)		0.000000

Source; Compiled by Author

Climate change has had an adverse effect on livestock production, specifically affecting the yield of milk, meat, and other dairy products. Consequently, the government has formulated policies to mitigate these impacts. The second objective of this study was to investigate the specific effects of climate change on livestock production in Nigeria.

The regression results indicate that the constant term coefficient (6.76279) is positive; suggesting that a baseline level of livestock production would be realized regardless of climatic variations. The coefficient for relative humidity (0.002064) is positive with a probability of 0.0408, making it statistically significant at the 5 percent level. Conversely, the coefficient for average temperature (-0.334511) is statistically significant at the 5 percent level but exhibits a negative relationship with livestock production (Kabubo-Mariara 2008).

The goodness of fit for the model was assessed using the Adjusted R-squared. The value of 0.766936 indicates that the model is robust and suitable for analyzing the effect of climate change on agricultural productivity. Specifically, this implies that 76.69 percent of the variation in livestock productivity is determined by changes in climatic conditions. The p-value of the F-statistic is 0.00000, indicating overall model significance, while the Durbin-Watson statistic

is 2.210761, indicating an absence of serial correlation among the variables (Baumgard *et al.*, 2012).

The p-value for average temperature (0.0374) confirms significance at the 5 percent level. This suggests that livestock products, particularly milk, are highly sensitive to thermal stress. When temperatures exceed the internationally recognized Temperature Humidity Index (THI) of 72, milk production declines (Baumgard *et al.*, 2012). The negative sign of the temperature coefficient (-0.334511) confirms an inverse relationship; as temperature increases, livestock production decreases, and vice versa (Bozzola 2014).

5. Conclusion

The first objective of this study was to examine the effect of climate change on crop productivity in Nigeria. To achieve this objective, unit root and other diagnostic tests were conducted using time-series data covering the period from 1975 to 2022. Thereafter, multiple regression analysis based on the Ordinary Least Squares (OLS) technique was employed to evaluate the relationship between agricultural productivity and selected climatic variables, including relative humidity, average temperature, and average rainfall. The empirical findings revealed that relative humidity and average temperature exerted statistically significant effects on agricultural productivity. Relative humidity exhibited a positive relationship with productivity, whereas average temperature and rainfall showed negative relationships with crop output. These findings suggest that variations in climatic conditions significantly influence agricultural performance in Nigeria. In particular, excessive temperature and irregular rainfall patterns may adversely affect crop growth, reduce yield potential, and disrupt farming activities across different agro-ecological zones.

The second objective focused on assessing the effect of climate change on livestock productivity. The regression results presented in Table 2 indicated that both relative humidity and average temperature significantly affected livestock production. However, average temperature was found to exert a stronger negative influence on livestock performance. Elevated temperature conditions may impair reproductive efficiency, reduce milk production, lower meat quality, and increase physiological stress among livestock populations.

In addition, the study observed that Nigeria has experienced recurring periods of drought and changing weather patterns, which further demonstrate the growing impact of climate variability on the agricultural sector. Livestock production, particularly in the northern and north-eastern regions of the country, remains highly vulnerable to these climatic disturbances. Rising

temperatures and declining rainfall have contributed to the drying of natural pasture, reduced water availability, and deterioration in feed quality. Furthermore, increasing heat stress and the prevalence of climate-related diseases have resulted in substantial livestock losses in several parts of the country.

Overall, the findings of this study indicate that climate change poses a serious threat to agricultural productivity in Nigeria. Both crop and livestock production systems are adversely affected by fluctuations in temperature, rainfall, and relative humidity. The study concludes that climate change has a significant negative effect on agricultural production and food security in Nigeria.

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