



## Effect of Climate Change on Agricultural Output in Nigeria

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### Abstract

Climate change has been affecting agricultural output in Nigeria adversely. Several research outcomes predict more severe effects from this change. This study examined the effect of climate change on agricultural output in Nigeria from 2000 to 2023. Data used for this study were drawn from the Central Bank of Nigeria (CBN) statistical bulletin and the World Bank Climate Change Database. The Error Correction Model (ECM) was adopted following the test of stationary status of the time series data. Parameters were estimated using the Ordinary Least Squares (OLS). Results of the estimation revealed that climate change had negative effects on agricultural output in Nigeria during the period under review. Thus, to ensure food security and enhance resilience public policy on climate change need to take into account measures such as the adoption of climate-resilient crop varieties, improvements in irrigation systems and the implementation of sustainable agricultural practices to reduce the potential drawbacks of climate change on agricultural output in Nigeria. Furthermore, farmers should be encouraged through functional extension officer-community engagement to cultivate crop varieties that tolerate heat, resist drought and withstand high humidity and the diseases linked to high humidity.

**Keywords:** Climate change, agricultural output, rainfall, humidity, temperature, sunshine

## Introduction

Climate change is one of the most urgent global issues today, involving long-term changes in climate patterns driven by human activities that increase greenhouse gas emissions (Costello et al., 2023). The burning of fossil fuels like coal, oil, and gas are primary causes, releasing carbon dioxide (CO<sub>2</sub>) and other greenhouse gases (GHGs) into the atmosphere. These gases trap heat from the sun, causing the Earth's temperature to rise at an unprecedented rate (Martinez & Iglesias, 2024). Climate change is a worldwide phenomenon with significant environmental, social, and economic consequences. The consequences of climate change are diverse and severe on agriculture, health, and economic stability. For instance, Nigeria a country in Africa faces high vulnerability due to its reliance on agriculture (AfDB, 2022). This is as a result of erratic rainfall and increased droughts (IPCC, 2021).

Since 1961, agricultural productivity in Africa has dropped by 34%, the highest decline among all regions globally (Canton, 2021). In 2022, over 110 million people in Africa were directly affected by climate-related hazards, with economic losses exceeding \$8.5 billion, according to the World Meteorological Organization. The socio-economic effects of climate change in Africa are profound, threatening food security as agricultural yields decrease and increased reliance on food imports. In Nigeria, the economic consequences of climate change are severe, particularly in the agricultural sector, which employs a large portion of the population. Changing weather patterns have resulted in food insecurity and heightened

poverty levels, while health risks-such as the spread of vector-borne diseases and heat-related illnesses-are also increasing, further straining an already challenged healthcare system (DeFries et al., 2021).

Agriculture is critical to Nigeria's economy, employing around two-thirds of the workforce and contributing significantly to the country's GDP (Olanma, 2023). However, the sector is highly dependent on rain-fed agriculture, making it particularly vulnerable to climate variability. With Nigeria's population expected to exceed 400 million by 2050, the pressure on agricultural systems to provide sufficient food is growing, but climate change is undermining these efforts, resulting in lower agricultural output and increased food insecurity (Eke & Onafalujo, 2023).

Studies have shown that Nigeria has already witnessed a significant rise in average temperatures, with projections indicating that temperatures will continue to rise across all ecological zones. It is on record that, higher temperatures negatively affect crop yields, especially for temperature-sensitive crops like maize and cassava. However, in the northern regions, crops like millet may benefit from increased temperatures, but the overall impact on agricultural productivity due to heat stress is negative (Onyeneke et al., 2024). Secondly, erratic rainfall patterns, with some areas witnessing excessive rainfall and flooding, while others experiencing prolonged droughts distorted farming practices, making it difficult to plan planting and harvesting schedules. For example, excessive rainfall in southern Nigeria can cause flooding, damaging crops, while northern states may face drought conditions that stunt crop growth (Eke & Onafalujo, 2023).

In addition, increasing intensity of rainfall also accelerates soil erosion and degradation, reducing agricultural productivity. The loss of fertile soil and arable land further exacerbates food shortages (Canton, 2021). Changing climate conditions also encourage the spread of pests and diseases that threaten crops and livestock. Warmer temperatures and higher humidity create favorable conditions for pests, which can decimate agricultural production. As such, farmers, who often lack access to effective pest control strategies, face even greater challenges (Olumba et al., 2024).

In the light of the developments above, this study investigates the effects of climate change on Nigeria's agricultural output between 2000 and 2023. Therefore, the objectives of this study were to: (1) ascertain the relationship between mean annual temperature and agricultural output (2) examine the effect of mean annual rainfall on agricultural output (3) find out the relationship between mean annual relative humidity and agricultural output and (4) determine the effect of sunshine duration on agricultural output.

## **Conceptual Review**

### **Climate Change**

Climate change refers to significant, long-term shifts in the Earth's climate, including changes in temperature, precipitation, and weather patterns. While it can be influenced by natural processes, human activities, especially the burning of fossil fuels, deforestation, and other actions that increase greenhouse gas emissions, have become the primary drivers in

recent decades. These changes can lead to various impacts, such as more frequent extreme weather events, rising sea levels, and disruptions to ecosystems and biodiversity. Climate change is a complex issue that affects multiple aspects of life, including agriculture, health, and economies (Wamsler et al., 2023).

Climate change is typically marked by a sustained rise in global or regional temperatures over extended periods, often decades or more. While natural factors play a role, human activities like fossil fuel combustion and deforestation are now the dominant contributors to the observed changes (Reser & Bradley, 2020). This alteration in the Earth's climate system leads to shifts in weather patterns, rising sea levels, and increased frequency and intensity of extreme weather events, all of which have significant consequences for ecosystems, biodiversity, and natural resources (Reser & Bradley, 2020).

Addressing climate change is an urgent global challenge that requires coordinated action at the international, national, and local levels to both mitigate its effects and adapt to its ongoing impacts. This involves international agreements, national policies, and local initiatives aimed at reducing greenhouse gas emissions and preparing for the changes already underway (Bentz, 2020). Economically, climate change can result in severe consequences, including infrastructure damage, higher disaster response costs, and changes in agricultural productivity, all of which demand investments in sustainable practices and technologies to manage and reduce associated risks (Bentz, 2020).

Climate change is characterized by long-term changes in weather patterns across local, regional, and global climates; climate change is distinct from short-term weather fluctuations (Rubenstein et al., 2023). The primary driver of recent climate change is human activity, particularly fossil fuel burning, which increases greenhouse gas concentrations in the atmosphere, leading to global warming. This, in turn, contributes to rising sea levels, ice mass loss, and more extreme weather events (Macchi, 2021).

### **Agricultural Output**

Agricultural output refers to the efficiency with which agricultural inputs such as labor, land, and capital are converted into outputs, primarily crops and livestock. It plays a vital role in ensuring food security, economic stability, and sustainable development. Over the past century, technological advancements, improvements in crop science, and better farming practices have significantly enhanced agricultural output. However, the sector continues to face various challenges that threaten its long-term sustainability and effectiveness.

### **Agricultural Productivity**

Agricultural productivity is typically the ratio of agricultural output to the inputs used in production. This can be expressed in different ways, such as yield per hectare or output per unit of labor. High agricultural productivity indicates that more food or other agricultural products are produced with fewer resources, which is essential for feeding an expanding global population and ensuring the efficient use of resources (Liu et al., 2020). Agricultural

output, on the other hand, refers to the total quantity of products produced through agricultural activities over a specific period. These products include crops, livestock, dairy, and other goods derived from farming. Output can be measured in various units depending on the product, such as tons of grain, liters of milk, or kilograms of meat. It is a direct indicator of the volume of production and is crucial for evaluating the performance and capacity of the agricultural sector (Liu et al., 2020).

## Theoretical Review

### Structural Change Theory of Agriculture

Both Rostow and agricultural development stage theorists have highlighted the importance of structural changes during the early stages of economic development. Key reforms such as tenure reform, fiscal policy reform, and others are recognized as crucial for reducing the political influence of those invested in maintaining the status quo, while also unlocking the productive potential of peasants and the emerging middle class.

These reforms are expected to foster agricultural prosperity, which, in turn, can drive industrial development by generating the mass purchasing power necessary to support a growing urban-industrial sector. Since the Philippines began implementing measures toward exchange decontrol in 1961, the agricultural and commodity sectors have seen sustained increases in prices, output, and income. However, sectors focused primarily on domestic consumption, with the notable exceptions of domestic agriculture and construction, have not fully benefited from this growth.

### Mellor's Theory of Agricultural Development

In 1966, Mellor proposed that "the faster agriculture grows, the faster its relative size declines," a concept later referred to as *Mellor's Law*. His observation highlights the idea that technological advancements in agriculture can offset the effects of population growth. Drawing on Engel's Law, Mellor suggested that as per capita income rises, the proportion of income spent on food decreases, leading to a relative decline in the agricultural sector. When agriculture constitutes a large portion of total output, structural transformation requires improvements in agricultural productivity. As agricultural productivity increases, agriculture becomes less dominant, thus facilitating the growth of the nonagricultural sector.

Nearly four decades later, this concept remains central in the international development community, with many leaders agreeing that it encapsulates the fundamental relationship between agricultural growth, structural transformation, and overall economic growth. Mellor further illustrated this by comparing the agricultural and nonagricultural growth rates of countries across the world's three major geographical regions.

Mellor's Theory of Agricultural Development provides a comprehensive framework for understanding the impacts of climate change on agricultural output in Enugu State. By emphasizing the importance of agricultural growth, technological innovation, supportive policies, rural livelihoods, economic multiplier effects, investment in infrastructure, and integrated planning, the theory offers valuable insights into how climate change affects

agriculture and what strategies can be implemented to mitigate its challenges. This perspective highlights the need for policies that promote sustainable agricultural practices, improve productivity, and address the adverse effects of climate change to enhance the resilience of agricultural systems in regions like Enugu State.

### **Empirical Review**

This section reviewed studies on climate change and agricultural output under the following sub headings, foreign and local studies.

#### **Foreign Studies**

Rezaei *et al.* (2023) conducted an empirical study on the impact of climate change on crop yields in Australia using the Principal Component Analysis (PCA) method. Their findings indicated that elevated CO<sub>2</sub> levels could have a compensatory effect on the yields of C3 crops (e.g., wheat and rice), although this benefit could be offset by heat and drought. Conversely, C4 crops (e.g., maize, millet, and sorghum) only benefited from CO<sub>2</sub> fertilization under drought stress. The study also projected that, under severe climate change scenarios and without adaptation, crop yield losses could range from 7% to 23%. Adaptation strategies such as irrigation and nutrient management were found to be effective, but they require substantial investments, especially in areas facing water constraints.

Abeysekara, Siriwardana, and Meng (2023) examined the economic impacts of climate change-induced agricultural productivity changes in Sri Lanka using the ORANI-G-SL Computable General Equilibrium (CGE) model. Their study found that reductions in agricultural output would result in higher consumer prices for agricultural commodities and a decline in household consumption. This would increase the risk of food insecurity, with negative consequences for Sri Lanka's overall GDP and macroeconomic variables. The study emphasized the need for climate change adaptation strategies and policy responses to mitigate the impacts on agriculture and food security.

Shah *et al.* (2024) investigated the impact of climate change and production technology heterogeneity on China's agricultural total factor productivity (TFP) and production efficiency. Using the DEA-Malmquist Productivity Index, the study found that climate factors could overestimate China's average agricultural productivity. The study revealed diverse effects of climate change across China's regions, with the Qinghai-Tibet Plateau showing the most significant positive impact. The analysis suggested that the influence of climate on technological change was greater than on efficiency change, with certain regions demonstrating superior agricultural production technology.

Chandio *et al.* (2024) examined the effects of temperature changes caused by climate change and the use of renewable energy on agricultural productivity in emerging Asian economies. Using FMOLS and DOLS methods, the study found that renewable energy positively influenced agricultural production, while climate change had a negative effect. Factors like agricultural land, fertilizer use, and the rural labor force were also critical in

boosting agricultural production. The study highlighted the importance of integrating renewable energy and climate-adaptive practices to ensure sustainable agricultural production.

### Local Studies

Onyeneke *et al.* (2024) analyzed the impact of climate change on six major crops in Nigeria over 39 years using time-series data. The study found that temperature had a negative impact on the output of crops such as yam, cassava, millet, rice, and sorghum, while rainfall positively influenced rice and maize production. Access to credit and fertilizers also played a role in enhancing crop yields, with the study recommending increased access to credit, precision use of fertilizers, and the adoption of climate-smart agricultural practices to mitigate the effects of climate change.

Ajiboye and Olanrewaju (2024) assessed the impact of climate change on cassava productivity in southwest Nigeria using a fixed effect panel regression model. Their findings revealed a general increase in cassava yield, with Ogun state showing a notable decline. The study found that cassava price had a significant positive impact on yield, counteracting the expected negative influence of climate change. The authors recommended formulating climate-resilient policies and supporting adaptive practices among farmers.

Oyita (2024) examined the effect of climate change variables on rice Total Factor Productivity (TFP) in Nigeria from 1961 to 2020. The study found a positive trend in rice TFP but noted that the average TFP was regressive, indicating less than optimal productivity. Rainfall was found to have a positive effect on rice TFP, while temperature and other climatic factors played a less consistent role.

Igelige (2024) studied the effect of climate change on palm oil output in Nigeria from 1965 to 2015. The study revealed that climatic factors such as rainfall, temperature, relative humidity, and solar radiation significantly affected palm oil production. The findings were validated using statistical tests, including the Johansen cointegration test and Error Correction Mechanism (ECM), which confirmed a long-run equilibrium relationship between climatic factors and palm oil output.

### Methodology

#### Research Design

This study adopted an *Ex post Facto* research design. By *Ex post Facto* research design we mean it is a quasi-experimental study examining how an independent variable, present prior to the study, affects a dependent variable. *Ex post facto* research design, also known as causal-comparative research, is employed to investigate the impact of climate change on agricultural productivity in Nigeria by examining data collected from past events. This design is particularly useful when the researcher cannot manipulate variables directly and must rely on pre-existing data to explore relationships between independent and dependent variables.

#### Model specification for this research

This research is anchored on the study Oyita (2024) with strategic adjustments:

In Implicit Form:  $AGO = f(MAT, MAR, MARH, SD)$

The econometric specification takes the following form:

$$AGO_t = \beta_0 + \beta_1 MAT_t + \beta_2 MAR_t + \beta_3 MARH_t + \beta_4 SD_t + \mu_t$$

Where;

AGO = Agricultural Output

MAT = Mean Annual Temperature

MAR = Mean Annual Rainfall

MARH = Mean Annual Relative Humidity

SD = Sunshine Duration

$\beta' s$  = The Parameters of the independent variables to be estimated.

$\mu$  = Stochastic Error Term

### Unit Root Test

Unit-root test was carried out on the series to avoid the production and usage of spurious regression results. A time series is considered to have a unit root if it is non-stationary, meaning its statistical properties (such as mean and variance) change over time. This can lead to issues with spurious regressions in time series analysis. The Unit Root Test checks whether a time series is non-stationary.

The study adopted the Augmented Dickey Fuller (ADF) statistic. The ADF test is an extended version of the Dickey-Fuller test that accounts for higher-order correlation by adding lagged terms of the differenced variable to the model.

### Autocorrelation Test

In order to avoid some of the pitfalls of Durbin-Watson d test of autocorrelation, the Breusch-Godfrey Serial Correlation LM Test was used to carry out the test of autocorrelation.

### Sources of Data

Data for the study were sourced from the Central Bank of Nigeria Statistical Bulletin (CBN), Nigerian National Bureau of Statistics (NBS), and World Bank Climate Data.

## Results and Discussion

### Empirical Results

Time series data are typically considered non-stationary, making it crucial to conduct a unit root test to confirm the data's stationarity. This step is essential to prevent the issue of spurious regression. In this study, the Augmented Dickey-Fuller (ADF) unit root test was utilized to assess the stationarity of the data. The decision rule for the ADF test is that the test statistic must exceed the Mackinnon Critical Value at a 5% significance level in absolute terms. The results of the unit root test are presented in Table 1 below.

### Unit-Root Test Result

**Table 1:** Unit Root Test Result

VARIABLE	ADF STAT.	CRITICAL VAL.	ORDER
AGO	-6.214514	-3.580623	I(1)
MAT	-3.742041	-1.950117	I(1)
MAR	-6.120706	-1.950394	I(1)
MARH	-5.338853	-2.951125	I(1)
SD	-4.418777	-1.950117	I(1)

**Source:** Author's Computation Using E-views 10.

Table 1 clearly shows that all the variables are stationary at first difference (I(1)). This means that the variables have unit-root until differenced in the first order.

### Cointegration Analysis (Johansen Methodology)

**Table 2: Cointegration Test Result**

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.730726	84.95638	69.81889	0.0019
At most 1	0.332691	36.41144	47.85613	0.3759
At most 2	0.300437	21.44486	29.79707	0.3305
At most 3	0.197890	8.224774	15.49471	0.4417
At most 4	0.001781	0.065938	3.841466	0.7973

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

The Johansen method of cointegration was used for the study because all the variables are stationary at first difference. The Johansen result as displayed in table 2 clearly shows evidence of cointegration as trace statistics test indicates 1 cointegrating equations as the trace statistic value is greater than that of 5% critical value ( $84.95638 > 69.81889$ ).

### Regression Results (ECM Inclusive)

**Table 3: ECM Result**

Dependent Variable: D(AGO)

Method: Least Squares

Date: 09/10/25 Time: 12:03

Sample (adjusted): 2000 – 2023

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.396664	18.46299	0.400621	0.6914
D(MAT)	-0.211061	0.930543	-0.226815	0.8220
D(MAR)	-2.413835	4.166413	0.579356	0.5664
D(MARH)	-0.283296	0.997878	-0.283899	0.7783
D(SD)	-2204.281	421.1445	-5.234026	0.0000
ECM(-1)	-0.103685	0.104430	-0.992862	0.3282

R-squared	0.511527	Mean dependent var	37.73313
Adjusted R-squared	0.435204	S.D. dependent var	130.8872
S.E. of regression	98.36561	Akaike info criterion	12.15920
Sum squared resid	309625.4	Schwarz criterion	12.41777
Log likelihood	-225.0248	Hannan-Quinn criter.	12.25119
F-statistic	6.702067	Durbin-Watson stat	1.538525
Prob(F-statistic)	0.000225		

**Source:** *Author's Computation Using E-views 10.*

The regression analysis presented in Table 3 reveals that the Mean Annual Temperature (MAT) has a negative coefficient of -0.211061, indicating that climate change, as measured by mean annual temperature, negatively impacts agricultural output in Nigeria over the analyzed period. This negative relationship suggests that as temperatures rises, agricultural output declines, possibly due to factors such as increased heat stress on crops, and decreased soil moisture, all of which can hinder plant growth and yield.

Similarly, the regression results show that Mean Annual Rainfall (MAR) has a negative coefficient of -2.413835, indicating that rainfall also negatively affects agricultural output in Nigeria. This could imply that excessive rainfall, irregular distribution, or variability in rainfall patterns reduce crop productivity. Such conditions may cause water logging, soil erosion, crop diseases, or delays in planting and harvesting due to unpredictable rainfall.

The relationship between Mean Annual Relative Humidity (MARH) and agricultural output is also negative, with a coefficient of -0.283296, as shown in Table 3. This suggests that higher humidity levels negatively influence agricultural productivity in Nigeria. Increased humidity can create favorable conditions for pests and diseases, particularly fungal infections, which can reduce crop yield and quality.

The Sunshine Duration (SD) also has a negative coefficient of -2204.281, indicating that variability in sunshine duration negatively affects agricultural output in Nigeria. Prolonged exposure to sunlight, combined with higher temperatures, may exacerbate issues like soil moisture depletion, higher evaporation rates, and increased plant stress, particularly in regions already experiencing water scarcity or high temperatures. These factors can lower crop yields and disrupt farming, highlighting Nigeria's agricultural system's vulnerability to extended or intense sunlight.

The F-statistic of 6.702067, with a corresponding probability value of 0.000225 (less than 0.05), suggests that the regression model is statistically significant, indicating a reliable relationship between the variables.

Furthermore, the coefficient of determination ( $R^2$ ) is 0.511527, meaning that approximately 51% of the variation in agricultural output is explained by the climate change variables in this study. This is considered a relatively high and significant explanatory power.

**Table 4: Serial Correlation Test Result**

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.403813	Prob. F(2,30)	0.2613
Obs*R-squared	3.251982	Prob. Chi-Square(2)	5.1967

**Source:** Researcher's Computation Using E-views

The Breusch-Godfrey Serial Correlation LM Test was used to carry out the test of autocorrelation. It is clearly seen that the Obs\*R-squared which follows the computed Chi-Square distribution yielded 3.251982 and it is clearly less than the Chi-Square probability which yielded 5.1967. This compels us to accept the null hypothesis that there is no serial correlation of any order. Hence; there is no presence of autocorrelation problem in the model.

### Discussion of Results

The regression analysis conducted in this study showed that climate change variables which include mean annual temperature, mean annual rainfall, mean annual relative humidity, and sunshine duration, affected agricultural output in Nigeria negatively within the period under review. This suggests that changes in temperature, irregular rainfall patterns, and an increase in extreme weather events like droughts and floods disrupt crop growth cycles, leading to reduced yields. Such disruptions make it challenging to maintain stable agricultural production, which in turn contributed to food insecurity.

These findings are consistent with those of Rezaei et al. (2023), who examined the impact of climate change on crop yields in Australia and found that while elevated CO<sub>2</sub> levels could compensate for crop yield losses in C3 crops (such as wheat and rice), heat and drought could counteract this effect. Similarly, the results align with the study by Abeysekara, Siriwardana, and Meng (2023), who used the ORANI-G-SL model to assess the economic effects of climate change-induced changes in agricultural productivity in Sri Lanka. Their findings indicated that reductions in crop output would lead to higher consumer prices for agricultural products, thereby decreasing household consumption over the next few decades. Furthermore, this study's results are in agreement with those of Onyeneke et al. (2024), who investigated the impact of climate change on six major crops in Nigeria over a 39-year period using time-series data. They found that temperature had a negative effect on the outputs of yam, cassava, millet, rice, and sorghum in the long run, while rainfall had a positive impact on rice and maize production, although it had a less significant effect on other crops like yam, cassava, millet, and sorghum.

### Conclusion

From the findings of this study, we concluded that climate change has significantly harmed agricultural output in Nigeria from 2000 to 2023. Rising temperatures, unpredictable rainfall patterns, droughts, and floods have led to a decline in crop yields, adversely affecting food security and economic stability. The agricultural sector, particularly crop production, has

been highly vulnerable to fluctuations in precipitation and extreme weather events, which have disrupted planting and harvesting schedules. Additionally, soil degradation and water scarcity resulting from climate changes have further hindered agricultural productivity.

Therefore, the negative effects of climate change on Nigeria's agriculture highlight the urgent need for adaptive measures. Implementing effective strategies such as the development of climate-resilient crop varieties, improving irrigation infrastructure, and promoting sustainable farming practices are essential for building resilience and ensuring food security in the face of ongoing environmental challenges.

### Recommendations

Sequel to the findings of this study, the researchers recommended the following:

1. There is a pressing need to invest in research and development for crop varieties that are specifically designed to withstand heat and drought. These crops would be more capable of enduring higher temperatures and variable climate conditions, thus ensuring stable yields under challenging environmental circumstances.
2. Investment in efficient irrigation systems is critical to mitigating the adverse effects of unpredictable rainfall patterns. The promotion and adoption of systems like drip and sprinkler irrigation can ensure that crops receive sufficient water, enhancing agricultural productivity, especially during dry spells.
3. Farmers should be encouraged to adopt farming practices that are resilient to high humidity. This could involve cultivating crop varieties that are more resistant to humidity and associated diseases. Additionally, implementing integrated pest management strategies will help address the negative impacts of increased humidity on crop health.
4. There is a need to promote agroforestry practices, where trees are integrated into crop production systems. This approach can provide shade, lower soil temperatures, and conserve moisture, thus mitigating the harmful effects of excessive sunshine. Providing training and incentives to farmers for incorporating trees into their farming systems can improve biodiversity and enhance overall agricultural resilience.

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