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CLIMATE CHANGE AND AGRICULTURAL PRODUCTIVITY IN NIGERIA (2000 – 2023)

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ABSTRACT: *This study investigated the effects of climate change on agricultural productivity in Nigeria from 2000 to 2023. Data were sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin and the World Bank Climate Change Database. The study employed an ex-post facto research design, and the data were analyzed using linear regression with an Error Correction Model (ECM). The findings revealed that climate change had a negative impact on agricultural output in Nigeria during the examined period. Based on these results, the study concludes that the detrimental effects of climate change on Nigeria's agricultural sector highlight the need for immediate adaptive strategies. Key measures such as the adoption of climate-resilient crop varieties, enhanced irrigation systems, and sustainable farming practices are essential for building resilience and ensuring food security amid current environmental challenges. The study recommends prioritizing research, development, and dissemination of crop varieties engineered for drought and heat resistance. Additionally, farmers should be supported to adopt climate-resilient agricultural techniques capable of withstanding high humidity and associated crop diseases, including the use of humidity-tolerant crop varieties.*

KEYWORDS: Agriculture, Climate change, Crop, Productivity.

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INTRODUCTION

Climate change remains one of the most critical challenges confronting humanity in the 21st century. It refers to long-term alterations in global or regional climate patterns, largely driven by human activities that increase greenhouse gas emissions (Costello *et al.,* 2023). The principal contributors to climate change are the combustion of fossil fuels—such as coal, oil, and natural gas—which release carbon dioxide (CO_2) and other greenhouse gases into the atmosphere. These gases trap solar radiation, causing the earth's temperature to rise at an alarming and unprecedented pace (Martinez & Iglesias, 2024). This global warming phenomenon has far-reaching consequences that threaten the stability of ecosystems, societies, and economies around the world.

Scientific evidence overwhelmingly attributes climate change to human activities, including industrial processes, deforestation, and unsustainable land use. As greenhouse gas emissions continue to rise, the Earth's temperature increases, triggering extreme weather events, rising sea levels, and disruptions to ecosystems (de Souza & Weaver, 2024). These changes pose significant risks to both developed and developing nations, with disproportionate effects on regions that are least equipped to adapt.

Africa, in particular, bears the brunt of climate change. According to the World Meteorological Organization, over 110 million people across the continent were directly impacted by climate-related hazards in 2022, resulting in economic damages exceeding $8.5 billion. Africa's agricultural productivity has declined by approximately 34% since 1961 due to climate change, marking the steepest decline globally (Canton, 2021). This reduction in agricultural output has significant socio-economic implications, including food insecurity, increased poverty, and economic dependency on food imports. The African Union estimates that annual food imports could triple in the near future, further straining fragile economies already burdened by poverty, unemployment, and inadequate infrastructure.

In Nigeria, the economic repercussions of climate change are particularly severe. The agricultural sector, which provides employment for a substantial proportion of the population, faces challenges from unpredictable weather patterns, reduced rainfall, and rising temperatures. These factors have led to declining agricultural yields, food insecurity, and exacerbated poverty levels, particularly in rural communities that rely on farming as their primary source of livelihood. Furthermore, climate change intensifies health challenges, including the spread of vector-borne diseases like malaria, heat-related illnesses, and other conditions that strain Nigeria's already fragile healthcare system (DeFries et al., 2021).

Addressing these challenges requires a concerted effort to adopt adaptive strategies and sustainable solutions. Effective measures, such as promoting climate-resilient agricultural practices, enhancing irrigation systems, and investing in renewable energy sources, are critical to mitigating the impacts of climate change. Additionally, policies aimed at improving rural infrastructure, supporting vulnerable populations, and fostering innovation in agriculture can help build resilience and ensure long-term food security in Nigeria. The urgency to act cannot be overstated, as climate change continues to pose an existential threat to the country's economic growth, human health, and overall development.

Nigeria, Africa's most populous nation, faces significant challenges arising from climate change, which pose a serious threat to its development, food security, and overall stability (Alhassan & Haruna, 2024). The adverse effects of climate change on Nigeria's agricultural

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sector are particularly concerning, as agriculture plays a pivotal role in the economy and serves as the main livelihood for a large portion of the population. Rising temperatures, erratic rainfall patterns, and an increase in extreme weather events have created severe obstacles for food production, jeopardizing both food security and economic stability (Eke & Onafalujo, 2023).

Agriculture in Nigeria employs nearly two-thirds of the workforce and makes a substantial contribution to the nation's Gross Domestic Product (GDP) (Olanma, 2023). However, the sector's heavy reliance on rain-fed farming makes it highly susceptible to climate variability. With Nigeria's population projected to surpass 400 million by 2050, the demand for food is increasing, placing enormous pressure on the country's agricultural systems. Unfortunately, climate change is undermining these efforts, leading to declining productivity and worsening food insecurity (Eke & Onafalujo, 2023).

The country has experienced a significant rise in average temperatures in recent years, with forecasts predicting further increases across all ecological zones. Elevated temperatures adversely affect crop yields, particularly for temperature-sensitive staples such as maize and cassava. While certain crops like millet may exhibit limited resilience to rising temperatures in northern regions, the overall impact remains negative due to heat stress (Onyeneke, Ejike, Osuji & Chidiebere-Mark, 2024).

Unpredictable rainfall patterns further complicate agricultural production. Some regions face excessive rainfall and flooding, while others suffer prolonged droughts. For example, southern Nigeria often experiences heavy rainfall that causes flooding and damages crops, whereas northern states grapple with droughts that inhibit crop growth (Eke & Onafalujo, 2023). In addition, the increasing intensity of rainfall accelerates soil erosion and land degradation, which diminish soil fertility and water retention capacity. The erosion of fertile topsoil reduces crop yields, and the loss of arable land due to flooding exacerbates food shortages (Canton, 2021).

Climate change also contributes to the spread of pests and diseases that threaten both crops and livestock. Warmer temperatures and heightened humidity create ideal conditions for pests, which can devastate agricultural output. Unfortunately, many farmers lack access to effective pest control strategies, further compounding the challenges they face (Olumba, Ihemezie & Olumba, 2024).

Given these pressing issues, this study examined the impact of climate change on Nigeria's agricultural output over the period 2000–2023. It seeks to provide insights into the extent of the impact and identify potential pathways for mitigating these challenges to safeguard food production and economic stability.

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LITERATURE REVIEW

Conceptual Review

Dynamics of Climate Change

Climate change refers to long-term and significant shifts in the earth's climate system, including variations in temperature, precipitation, and weather patterns over decades or longer. While natural processes play a role, human activities—such as the burning of fossil fuels, deforestation, and industrialization—have significantly accelerated the recent changes by increasing greenhouse gas concentrations in the atmosphere (Reser & Bradley, 2020; Rubenstein *et al.*, 2023). These gases trap heat, causing global temperatures to rise and leading to severe consequences such as extreme weather events, rising sea levels, melting ice masses, and disruptions to ecosystems and biodiversity (Macchi, 2021; Wamsler *et al.*, 2023).

The impacts of climate change are far-reaching, affecting agriculture, human health, natural resources, and economic stability. In agriculture, for instance, shifts in weather patterns and extreme temperature directly reduce crop yields and livestock productivity, creating food insecurity and economic strain. Climate change also increases the frequency and intensity of natural disasters, resulting in infrastructure damage and rising costs for disaster response and recovery efforts (Bentz, 2020).

Addressing this complex global challenge requires coordinated actions at international, national, and local levels. Initiatives such as reducing greenhouse gas emissions, adopting sustainable practices, investing in climate-resilient technologies, and promoting policies that enhance environmental and economic sustainability are crucial to mitigating its effects. Furthermore, proactive adaptation strategies are needed to manage ongoing changes and minimize risks to ecosystems, economies, and human well-being (Bentz, 2020).

In summary, climate change represents a pressing and multifaceted issue that demands urgent action to protect both the planet and its inhabitants. It calls for integrated approaches to ensure sustainable development, safeguard biodiversity, and build resilience against its adverse impacts.

Agricultural Output/Productivity

Agricultural productivity plays a pivotal role in achieving food security, economic stability, and sustainable development. It reflects the efficiency with which agricultural inputs—such as labor, land, and capital—are utilized to produce outputs, including crops and livestock. Over the last century, advancements in technology, crop science, and innovative farming techniques have substantially enhanced productivity. Despite these gains, the agricultural sector continues to encounter significant challenges that threaten its sustainability and long-term effectiveness. This section examines the concept of agricultural productivity, the factors that influence it, the challenges it faces, and strategies for improvement.

Agricultural productivity is commonly measured as the ratio of agricultural output to the inputs utilized in production. It can be expressed through various metrics, such as yield per hectare of land or output per unit of labor. High productivity indicates that greater quantities of food or other agricultural products are produced using fewer resources, which is vital for feeding a growing global population and promoting resource efficiency (Liu et al., 2020).

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Agricultural output refers to the total quantity of goods generated through agricultural activities within a defined timeframe. These outputs include crops, livestock, dairy products, and other farm-derived commodities. Output can be quantified in different units, such as tons of grains, kilograms of meat, or liters of milk, depending on the product type. As a direct indicator of production volume, agricultural output serves as a key metric for assessing the performance, capacity, and productivity of the agricultural sector (Liu et al., 2020).

Improving agricultural productivity is crucial for addressing global food demands, reducing poverty, and promoting sustainable resource management. However, the sector faces a range of challenges, including climate change, land degradation, limited access to technology, and inefficient farming practices. Implementing strategies such as adopting modern technologies, enhancing irrigation systems, and promoting sustainable agricultural practices can significantly improve productivity, ensure food security, and support economic growth.

Theoretical Review

Structural Change Theory of Agriculture

The Structural Change Theory of Agriculture highlights the critical role of structural transformations during the early phases of economic development. Prominent theorists like Rostow and agricultural development stage proponents stress that reforms—such as tenure reform, fiscal policy reform, and other institutional changes—are essential for dismantling the influence of groups with vested interests in maintaining the status quo. These reforms aim to empower the peasant class and emerging middle class, unleashing their productive potential.

Agricultural prosperity, in turn, is expected to act as a catalyst for industrial development. By boosting rural incomes and increasing purchasing power, agriculture stimulates demand for industrial goods, thus supporting the expansion of the urban-industrial sector. A historical example of this dynamic can be observed in the Philippines following the gradual relaxation of exchange controls in 1961. The agricultural and commodity sectors witnessed sustained growth in prices, output, and incomes. However, this growth was not uniformly distributed. Sectors primarily producing for domestic consumption—excluding domestic agriculture and construction—generally failed to benefit from these gains.

This uneven growth underscores the importance of carefully designed policies to ensure that structural changes in agriculture contribute not only to rural prosperity but also to broader economic development across sectors.

Mellor's Theory of Agricultural Development

In 1966, Mellor proposed that "the faster agriculture grows, the faster its relative size declines," a phenomenon later termed "Mellor's Law." Mellor's insight builds on two key factors: the ability of technological advancements to offset the pressures of population growth and Engel's Law, which states that as per capita income rises, the proportion of income spent on food decreases. Consequently, even with increased agricultural productivity, the agricultural sector's share of the economy gradually diminishes, giving way to the expansion of non-agricultural sectors.

When agriculture constitutes a significant share of total economic output, structural transformation requires notable increases in agricultural productivity. This growth in

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productivity initially strengthens the agricultural sector but subsequently reduces its relative importance in the economy while facilitating the growth of industry and services. Decades later, Mellor's perspective remains highly relevant in global development discussions, as it succinctly captures the relationship between agricultural growth, structural transformation, and overall economic growth.

Mellor also highlights this relationship by comparing agricultural and non-agricultural growth rates across the major regions of the world. His theory underscores that technological innovation, supportive policies, and increased agricultural productivity are key drivers of economic transformation.

Mellor's Theory of Agricultural Development provides a useful lens for analyzing the effects of climate change on agricultural output, particularly in regions like Enugu State. By emphasizing the need for agricultural growth, technological progress, rural livelihood improvement, and infrastructure investment, Mellor's framework identifies strategies to mitigate the challenges posed by climate change. Integrated planning, policy support, and economic multiplier effects can ensure that agriculture adapts to environmental changes while contributing to broader economic development.

Empirical Review

This section of the study presents a review of previous and related research on the relationship between climate change and agricultural output. To ensure a comprehensive analysis, the review is organized into two categories: foreign studies and local studies. This division allows for a balanced perspective, capturing global insights and contextualizing findings within the local realities of Nigeria.

Igelige (2024) examined the effect of climate change on palm oil output in Nigeria from 1965-2015. It focused on the trend of oil palm output during the period, the effects of climatic factors on the output. Secondary data were used for the analyses using tables, graph and time series analyses. The result of the Augmented Dickey Fuller (ADF) unit root test showed that all the variables became stationary after the first difference was taken while the Johansen cointegration test indicated the existence of a long run equilibrium relationship among the variables. Error Correction Mechanism (ECM) result indicated that rainfall ($t= 3.01$), relative humidity ($t=2.56$), temperature ($t=4.50$) and solar radiation ($t=4.23$) were significant at 5% level ($p<0.05$) were significant climatic factors affecting palm oil output. This validates the alternative hypothesis one (Ha1), that climatic factors have significant effect on palm oil output in Nigeria.

Oyita (2024) examined the effect of climate change variables on rice Total Factor Productivity (TFP) in Nigeria. Data for this study such as the mean annual temperature, mean annual rainfall, land area, labour, capital and rice output from 1961 to 2020 were collected from various sources such as Nigeria Meteorological Agency (NIMET), World Bank online statistical depository, United Nations online database, United States Department of Agriculture Economic Research Service (USDA ERS, 2022), Food and Agriculture Organisation Corporate Statistical Database (FAOSTAT, 2022) and National Rice Development Strategy (NRDS, 2020). Data were analysed using descriptive and inferential statistics. Specifically in this study, it was established that although there is a positive trend in rice TFP in Nigeria over the years, the average rice TFP (0.953) is regressive (i.e., less than 1).

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Abeysekara, Siriwardana and Meng (2023) used the ORANI-G-SL, a single-country, static Computable General Equilibrium (CGE) model to investigate the economic impacts of climate change-induced agricultural productivity changes on Sri Lanka, as a South Asian case study. In comparison with a baseline scenario, the results show reductions in the output of most agricultural crops will cause increased consumer prices for these agricultural commodities, with a consequential decline in overall household consumption within the next few decades. The projected decline in crop production and increases in food prices will enhance the potential for food insecurity. Thus, climate change will negatively impact the overall GDP and most of the macro and microeconomic variables of the Sri Lankan economy. These results highlight the need for future scientific research on climate change adaptation strategies and the importance of developing policy responses to counter adverse effects on agriculture and food security.

Shah *et al.* (2024) carried out a study on impact of climate change and production technology heterogeneity on China's agricultural total factor productivity and production efficiency. To this end, this study employed the DEA-Malmquist Productivity Index to gauge the total factor productivity change (TFPC) in 31 provinces and administrative units of China from 2000 to 2021. Additional inputs of climate factors were added to the estimation process to explore the impact of climate change on TFPC for different periods and regions. The meta-frontier analysis estimates the agriculture production technology gap among nine regions of China. Results revealed that climate factors could overestimate China's average total factor agricultural productivity over the study period. Eight out of nine regions in China witnessed the diverse effects of climate factors; however, it positively impacted agricultural TFPC in the Qinghai Tibet Plateau and surrounding regions performed best, ranked top in China with an average growth rate of 22.3 % in TFPC. Decomposing the TFPC into efficiency and technological change, the study found that the influence of climate on technological change is greater than compared to efficiency change. Northeast China Plain and Sichuan Basin and surrounding regions have superior agriculture production technology with a TGR score 1. Mann-Whitney U and Kruskal-Wallis test proved the statistically significant difference among agricultural productivity scores estimated with and without climate factors and production technology gaps among nine regions of China.

Chandio *et al.* (2024) examined how agricultural productivity in emerging Asian economies; China, India, Japan, Malaysia, Indonesia, Bangladesh, Nepal, Pakistan, Sri Lanka, The Philippines, Thailand, and Vietnam is affected by temperature changes brought by climate change and the use of renewable energy sources. This study used the FMOLS and DOLS methods to analyze data from Asian developing economies from 1990 to 2018. The long-run estimates reveal that renewable energy positively enhances agricultural production, while climate change negatively affects agricultural production. Furthermore, the input factors such as agricultural land, fertilizer use, and rural labor force play an essential role and increase agricultural production. Additionally, the causality tests confirm that all studied variables significantly influenced agricultural production in the selected Asian-12 economies. Finally, based on these outcomes, several implications for sustainable agricultural production and better environmental quality are suggested for Asian economies.

Onyeneke *et al.* (2024) investigated the impact of climate change on six major crops in Nigeria using time-series data for a period of 39 years. They used the Augmented Dickey–Fuller and Phillips–Perron tests to determine the stationarity of the data and applied the Autoregressive Distributed Lag (ARDL) regression to model the impacts of climate change, factors of

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production on the outputs of the crops. All the six ARDL models were structurally stable and they exhibited both short-run and long-run relationships between climate change, production factors and outputs of the crops. Specifically, land exhibited long-run positive relationships with the outputs of all the crops except for millet. Temperature had a negative impact on crop yam, cassava, millet, rice and sorghum outputs in the long run while rainfall significantly increased rice and maize production but insignificantly reduced yam, cassava, millet, and sorghum production in the long run. Credit significantly increased cassava, maize, and rice in the long run, while fertilizers showed mixed impacts on yam, cassava, rice and sorghum production in the long run. They recommended policies and programs that would increase access to credit to farmers, encourage nutrient budgeting and precision use of fertilizer, and promote uptake of climate smart agriculture through research on crop improvement by breeding crop varieties that would be resilient to climate shocks.

Ajiboye and Olanrewaju (2024) assessed the impact of climate change on cassava productivity in southwest Nigeria using a panel fixed effect approach, 1990 to 2020. Data on market price, output, yield and cultivated area of cassava were obtained from FAO statistical database while that of rainfall and temperature were sourced from the Nigeria Meteorological Agency (NIMET). The data were analyzed with descriptive statistics, graphs and a fixed effect panel regression. The cassava yield trends revealed a general increase in five states, with Ogun experiencing a notable decline. Land allocation, Growing Degree Days (GDD), and rainfall exhibited an uneven variability among states. Ogun state had the highest mean output values and land area devoted to cassava production. The regression results emphasized the significant positive impact of cassava price on yield, challenging the expected negative influence of climate change. Recommendations include formulating climate-resilient policies, encouraging adaptive practices among farmers, and providing support through donor agencies.

METHODOLOGY

Research Design

This study adopted an ex-post facto research design, which is a type of quasi-experimental study. In this context, it refers to an approach where the independent variable—climate change—already exists prior to the commencement of the research, and its effects on the dependent variable—agricultural productivity—are analyzed. The ex-post facto research design, also known as causal-comparative research, is particularly appropriate for this study because it investigates the impact of climate change on agricultural productivity in Nigeria using historical data. This design is valuable when direct manipulation of variables is not possible, allowing the researcher to rely on pre-existing data to explore and analyze relationships between variables over time.

Model Specification for this Research

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

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

The econometric specification takes the following form:

$$AGOt = \beta_0 + \beta_1 MATt + \beta_2 MARt + \beta_3 MARHt + \beta_4 SDt + \mu t$$

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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.

μ = 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 the Durbin-Watson 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.

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RESULTS AND DISCUSSION

Empirical Results

Time series data are often assumed to be non-stationary and thus, it is necessary to perform unit root tests to ensure that the data are stationary. The test was employed to avoid the problem of spurious regression. Therefore, the Augmented Dickey-Fuller (ADF) unit root test was used to determine the stationarity of the data to complement each other. The decision rule based on the ADF test is that its statistic must be greater than Mackinnon Critical Value at 5% level of significance and in absolute terms. The results of the unit-root test are reported 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 Eviews 10.*

Table 1 clearly shows that all the variables are stationary at first difference (1). This means that the variables have unit-root until differences 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
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: *Author's Computation Using Eviews 10.*

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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 equation 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: 09/10/24 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 Eviews 10.*

The regression analysis from table 3 clearly shows that Mean Annual Temperature (MAT) yielded a negative numerical coefficient at the magnitude of -0.211061. This entails that climate change measured with mean annual temperature contributes negatively to agricultural output in Nigeria for the years analyzed. A negative contribution of annual temperature to agricultural output indicates that as temperatures rise, agricultural productivity tends to decline. This could stem from factors like increased evapotranspiration, heat stress on crops, and reduced soil moisture, all of which can negatively impact plant growth and yield.

The regression result also shows that Mean Annual Rainfall (MAR) yielded a negative numerical coefficient at the value of -2.413835. This clearly shows that mean annual rainfall contributes negatively to agricultural output in Nigeria. A negative contribution of annual rainfall to agricultural output might suggest that excessive rainfall, variability, or irregular distribution negatively impacts crop productivity in Nigeria. This could be due to factors like

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waterlogging, soil erosion, crop disease, or delays in planting and harvesting due to unpredictable rain patterns.

The relationship between Mean Annual Relative Humidity (MARH) and agricultural output was also demonstrated in the regression output in table 3. The numerical coefficient yielded a negative value at -0.283296. This shows a negative relationship and contribution flowing from MARH to agricultural output in Nigeria. This conforms to economic a priori expectation because a negative contribution from relative humidity to agricultural output suggests that higher humidity levels may have adverse effects on crop productivity in Nigeria. Excessive humidity can foster conditions favorable for pests and diseases, especially fungal infections, which can impact crop quality and yield.

The Sunshine Duration (SD) also yielded a negative numerical coefficient (-2204.281). This entails that sunshine duration variability contributes negatively to agricultural output in Nigeria for the years analyzed. A negative contribution of sunshine duration to agricultural output in Nigeria suggests that increased exposure to sunlight possibly coupled with higher temperatures may be having an adverse effect on crops. Extended sunshine duration can lead to soil moisture depletion, higher evaporation rates, and increased plant stress, especially in regions where water scarcity or high temperatures are already a challenge. These factors can diminish crop yields and disrupt farming activities, indicating a potential vulnerability in Nigeria's agricultural system to prolonged or intense sunlight.

The F-statistics which is employed to test for the statistical significance of the entire regression plane yielded 6.702067 with a corresponding probability value of 0.000225 < 0.05. This entails that the test is statistically significant at the entire regression plane.

The coefficient of determination (R^2) which measures the explanatory power of the independent variables yielded 0.511527. This implies that approximately 51% of the variations in agricultural output are explained by changes in climate change variables in this study. This is however relatively high and significant.

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 Eviews*

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 problems in the model.

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DISCUSSION OF RESULTS

The regression analysis carried out reveals that the climate change variables (mean annual temperature, mean annual rainfall, mean annual relative humidity and sunshine duration) contributed negatively to agricultural output in Nigeria. This entails that changes in temperature, erratic rainfall patterns, and increased frequency of extreme weather events like droughts and floods directly affect crop growth cycles, reducing yields. This makes it difficult to maintain consistent agricultural production, which can lead to food insecurity. The result is in agreement with the findings of Rezaei *et al.* (2023) who carried out an empirical study on the impact of climate change on crop yields in Australia and discovered that elevated CO_2 can have a compensatory effect on crop yield for C3 crops (wheat and rice), but it can be offset by heat and drought. The findings of the result also align with Abeysekara, Siriwardana and Meng (2023) who adopted the ORANI-G-SL, a single-country, static Computable General Equilibrium (CGE) model to investigate the economic impacts of climate change-induced agricultural productivity changes on Sri Lanka. The results show reductions in the output of most agricultural crops which will cause increased consumer prices for these agricultural commodities, with a consequential decline in overall household consumption within the next few decades. The findings of the study also align with findings of Onyeneke *et al.* (2024) who investigated the impact of climate change on six major crops in Nigeria using time-series data for a period of 39 years. They used the Augmented Dickey–Fuller and Phillips–Perron tests to determine the stationarity of the data and applied the Autoregressive Distributed Lag (ARDL) regression to model the impacts. Temperature had a negative impact on crop yam, cassava, millet, rice and sorghum outputs in the long run while rainfall significantly increased rice and maize production but insignificantly reduced yam, cassava, millet, and sorghum production in the long run.

CONCLUSION AND RECOMMENDATIONS

The results reveal that climate change has had a significant negative impact on agricultural output in Nigeria from 2000 to 2023. Key contributing factors include rising temperatures, erratic rainfall patterns, droughts, and floods, all of which have led to declining crop yields. These changes have disrupted planting and harvesting schedules, creating challenges for food production and exacerbating food insecurity. Moreover, extreme weather events and fluctuating precipitation levels have made crop production especially vulnerable. Additional challenges, such as soil degradation and water scarcity caused by climate variability, have further strained agricultural productivity and undermined economic stability.

Recommendations

i. There is an urgent need to promote the research, development, and distribution of crop varieties specifically bred for heat tolerance and drought resistance. These crops are better equipped to withstand higher temperatures and changing climate conditions, ensuring stable yields even under environmental stress.

ii. It is essential to invest in and promote the use of efficient irrigation systems to mitigate the adverse effects of irregular rainfall patterns. Drip and sprinkler irrigation systems can ensure that crops receive adequate water, thereby enhancing agricultural productivity even during periods of low rainfall.

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iii. Farmers should be encouraged to adopt climate-resilient agricultural practices that can withstand high humidity levels. This includes selecting and planting crop varieties that are more tolerant to humidity and diseases associated with it. Additionally, integrated pest management strategies should be implemented to help mitigate the adverse effects of increased humidity on crop health.

iv. There is an urgent need to promote agroforestry systems, where trees and crops are grown together. This approach provides shade, reduces soil temperature, and conserves moisture, thereby mitigating the adverse effects of excessive sunshine. Training programs and incentives for farmers to integrate trees into their farming systems can enhance biodiversity and improve overall agricultural resilience

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