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Impact of Climate Change on Agricultural Productivity in Nigeria (2000-2023)

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Abstract
This study examined the impact of climate change on agricultural productivity in Nigeria covering the period 2000 – 2023. Data for the study were extracted from the Central Bank of Nigeria (CBN) statistical bulletin and World Bank Climate Change Database. The study adopted the expo facto research design. Data was analyzed with linear regression with the application of the Error Correction Model (ECM). The result yielded that climate change contributed negatively to agricultural output in Nigeria for the years analyzed. The study therefore concludes that the adverse impacts of climate change on Nigeria's agriculture underscore the urgent need for adaptive strategies. Effective measures, such as adopting climate-resilient crop varieties, improving irrigation systems, and implementing sustainable agricultural practices, are crucial to enhancing resilience and ensuring food security amidst ongoing environmental challenges. It is therefore the recommendation of the study that there is an urgent need to promote the research, development, and distribution of crop varieties that are specifically bred for heat tolerance and drought resistance and farmers should be encouraged to adopt climate-resilient agricultural practices that can withstand high humidity levels. This could include selecting and planting crop varieties that are more tolerant to humidity and diseases associated with it.

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

Introduction

Climate change is one of the most pressing issues facing humanity today. It refers to long-term shifts in global or regional climate patterns caused by human activities that increase greenhouse gas emissions (Costello, *et al*. 2023) [6]. The primary driver of climate change is the burning of fossil fuels, such as coal, oil, and gas, which release carbon dioxide (CO2) and other greenhouse gases into the atmosphere. These gases trap heat from the sun, causing the planet to warm at an unprecedented rate (Martinez & Iglesias, 2024) [12]. Climate change is a global phenomenon with far-reaching consequences for the environment, society, and the economy. The scientific consensus is clear: human activities, primarily the burning of fossil fuels, deforestation, and industrial processes, are the primary drivers of climate change. As greenhouse gas emissions continue to rise, the Earth's temperature is increasing at an unprecedented rate, leading to a host of impacts that threaten the well-being of people and ecosystems worldwide (de Souza & Weaver 2024) [8].

According to the World Meteorological Organization, over 110 million people in Africa were directly affected by climate-related hazards in 2022, resulting in economic damages exceeding $8.5 billion. The continent's agricultural productivity has declined by 34% since 1961 due to climate change, which is the highest decline compared to other regions globally (Canton, 2021) [4]. The socio-economic implications of climate change in Africa are profound. Food security is under threat as agricultural yields decline, leading to increased reliance on food imports. The African Union estimates that projected annual food imports could triple, placing additional strain on economies already burdened by poverty and unemployment. Moreover, climate change exacerbates existing inequalities, disproportionately affecting vulnerable populations who lack the resources to adapt (Canton, 2021) [4].

The economic consequences of climate change in Nigeria are dire. The agricultural sector, which employs a significant portion of the population, is particularly affected by changing weather patterns. This has led to food insecurity and increased poverty levels. Additionally, climate change poses health risks, including the spread of vector-borne diseases and heat-related illnesses, as well as exacerbating existing health system challenges (DeFries, *et al.* 2021) [7].

Nigeria, as Africa's most populous nation, exemplifies these challenges, facing severe consequences from climate change that threaten its development, food security, and overall stability (Alhassan and Haruna, 2024) [2]. Climate change is profoundly impacting agricultural output in Nigeria, a country where agriculture is a critical component of the economy and the primary source of livelihood for a significant portion of the population. The interplay of increasing temperatures, erratic rainfall patterns, and extreme weather events poses severe challenges to food production, threatening food security and economic stability (Eke & Onafalujo, 2023) [9]. Agriculture employs approximately two-thirds of Nigeria's workforce and contributes significantly to the nation's Gross Domestic Product (GDP). The sector is predominantly rain-fed, making it highly vulnerable to climate variability. With a rapidly growing population projected to reach over 400 million by 2050, the pressure on agricultural systems to produce sufficient food is intensifying. However, climate change is undermining these efforts, leading to decreased agricultural productivity and increased food insecurity (Eke & Onafalujo, 2023) [9].

Nigeria has experienced a notable rise in average temperatures, with projections suggesting further increases across all ecological zones. Higher temperatures can adversely affect crop yields, particularly for temperature-sensitive staples such as maize and cassava. In northern regions, some crops like millet may benefit from increased temperatures, but the overall trend indicates a negative impact on agricultural productivity due to heat stress (Onyeneke, Ejike, Osuji, & Chidiebere-Mark, 2024) [14]. Climate change has led to unpredictable rainfall patterns, with some areas experiencing excessive rainfall and flooding while others suffer from prolonged droughts. This variability complicates farming practices, making it difficult for farmers to plan planting and harvesting schedules. For instance, in southern Nigeria, excessive rain can lead to flooding, which damages crops, while northern states may face drought conditions that hinder crop growth (Eke & Onafalujo, 2023) [9]. Increasing rainfall intensity contributes to soil erosion and degradation, further diminishing agricultural productivity. The erosion of fertile topsoil reduces soil fertility and water retention capacity, leading to lower crop yields. Additionally, the loss of arable land due to flooding and erosion exacerbates food scarcity (Canton, 2021) [4].

Changing climate conditions can lead to the proliferation of pests and diseases that threaten crops and livestock. Warmer temperatures and increased humidity create favorable conditions for pests, which can devastate agricultural output. Farmers often lack access to effective pest management strategies, compounding the challenges they face (Olumba, Ihemezie, & Olumba, 2024) [13]. It is based on the foregoing that this study explored the impact of climate change on agricultural output of Nigeria covering the period 2000 – 2023.

Literature Review

Conceptual Review

Dynamics of Climate Change

Climate change refers to significant and long-term changes in the Earth's climate, including variations in temperature, precipitation, and weather patterns. It encompasses both natural processes and human-induced factors, particularly the latter due to the burning of fossil fuels, deforestation, and other activities that increase greenhouse gas concentrations in the atmosphere. These changes can lead to a range of impacts, including more extreme weather events, rising sea levels, and disruptions to ecosystems and biodiversity. Climate change is a complex issue that affects various aspects of life, including agriculture, health, and economies (Wamsler, *et al.* 2023) [20].

Climate change refers to a significant and sustained shift in global or regional climate patterns, particularly a rise in average temperature, typically over a period of decades or longer. This can be due to natural factors or, more commonly in recent times, human activities such as burning fossil fuels and deforestation (Reser & Bradley, 2020) [16]. Climate change is the alteration in the Earth's climate system, resulting in changes to weather patterns, sea levels, and the frequency and intensity of extreme weather events. It affects ecosystems, biodiversity, and natural resources (Reser & Bradley, 2020) [16].

Climate change is a pressing global issue requiring coordinated efforts to mitigate its impacts and adapt to its consequences. It involves international agreements, national policies, and local actions aimed at reducing greenhouse gas emissions and preparing for the changes that are already occurring (Bentz, 2020) [3]. Climate change is a phenomenon that can have significant economic impacts, including damage to infrastructure, increased costs for disaster response, and changes in agricultural productivity. It requires investments in sustainable practices and technologies to manage and reduce economic risks (Bentz, 2020) [3].

Climate change is characterized as a long-term change in the average weather patterns that define Earth's local, regional, and global climates. This includes variations in temperature, precipitation, and wind patterns over decades or longer, distinguishing it from short-term weather fluctuations (Rubenstein, *et al.* 2023) [18]. The primary cause of recent climate change is human activity, particularly the burning of fossil fuels, which increases greenhouse gas concentrations in the atmosphere. This results in a rise in Earth's average surface temperature and associated phenomena such as sea-level rise, ice mass loss, and extreme weather events (Macchi, 2021) [11].

Agricultural Output/Productivity

Agricultural productivity is a critical factor in ensuring food security, economic stability, and sustainable development. It encompasses the efficiency with which agricultural inputs-such as labor, land, and capital-are converted into outputs, primarily crops and livestock. Over the past century, advancements in technology, crop science, and farming practices have significantly boosted agricultural productivity. However, the sector faces numerous challenges that threaten its sustainability and effectiveness. This section explores the concept of agricultural productivity, the factors influencing it, the challenges it faces, and potential strategies for improving it.

Agricultural productivity is measured as the ratio of agricultural output to the inputs used in production. It can be expressed in various ways, such as yield per hectare or output per unit of labor. High agricultural productivity means that more food or other agricultural products are produced with fewer resources. This is essential for feeding a growing global population and ensuring that resources are used efficiently (Liu, *et al.* 2020) [10]. Agricultural output refers to the total quantity of products produced by 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 critical for assessing the performance and capacity of the agricultural sector (Liu, *et al.* 2020) [10].

Theoretical Review

Structural Change Theory of Agriculture

Both Rostow and the agricultural development stage theorists have emphasized the importance of structural changes during the early stages of economic development. Tenure reform, fiscal policy reform, and others have identified as important factors in reducing the political power of those who have a vested interest in the *status quo*, and releasing the productive energies of the peasants and the emerging middle class. With these reforms agricultural prosperity is expected to stimulate industrial development by providing the mass purchasing power needed to sustain an expanding urban-industrial sector. Since initiation of steps leading to exchange decontrol in the Philippines in 1961, the agricultural and commodity sectors have experienced sustained increases in prices, output, and income. At the same time the sectors producing primarily for domestic consumption have, with the exception of the domestic agriculture and construction industries, failed to share in this growth.

Mellor's Theory of Agricultural Development

In 1966 Mellor posited that "the faster agriculture grows, the faster its relative size declines. Others have dubbed this "Mellor's Law." Mellor's observation stems from the possibility that technological changes can overcome the effects of a growing population, and following Engel's Law, as per capita income increases, the percentage of income spent on food will decline leading to a relative decline in the size of the agricultural sector. Where agriculture represents a large share of total output, structural transformation requires increases in agricultural productivity. In the process, agriculture becomes relatively less important while paving the way for the development of the nonagricultural sector. Nearly 40 years later, leaders in the international development community still hold that this notion "captures the essence of agricultural growth and its causal relationship to the structural transformation and aggregate growth of an economy." Mellor further notes that the relationship described in the above statement "can be illustrated by comparing the agricultural and nonagricultural growth rates of countries in each of the world's three major geographical regions. Mellor's Theory of Agricultural Development provides a comprehensive framework for analyzing 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 address these challenges.

Empirical Review

This section of the study is on reviewing past and related studies on the relationship between climate change and agricultural output. This was divided into foreign and local studies for a comprehensive analysis.

Rezaei, *et al.* (2023) [17] carried out an empirical study on the impact of climate change on crop yields in Australia. The study adopted the Principal Component Analysis (PCA) method. It was 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. In contrast, elevated CO_2 only benefits C4 plants (maize, millet and sorghum) under drought stress. Under the most severe climate change scenario and without adaptation, simulated crop yield losses range from 7% to 23%. The adverse effects in higher latitudes could potentially be offset or reversed by CO_2 fertilization and adaptation options, but lower latitudes, where C4 crops are the primary crops, benefit less from CO_2 fertilization. Irrigation and nutrient management are likely to be the most effective adaptation options (up to 40% in wheat yield for higher latitudes compared with baseline) but require substantial investments and might not be universally applicable, for example where there are water resource constraints. Establishing multifactor experiments (including multipurpose cultivar panels), developing biotic stress modelling routines, merging process-based and data-driven models, and using integrated impact assessments, are all essential to better capture and assess yield responses to climate change.

Abeysekara, Siriwardana, and Meng (2023) uses 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 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. Among 8 out of 9 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 Sichaun 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) [14] 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 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 data base 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 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.

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). Rainfall (coefficient = 0.841).

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.

3. 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 is on the study Oyita (2024) with

strategic adjustments:
In Implicit Form: $AGO = f(MAT, MAR, MARH, SD)$
The econometric specification takes the following form:

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

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

4. Results and Discussion

Empirical Results

Time series data are often assumed to be non-stationary and thus, it is necessary to perform unit root test 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 term. 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 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.

Co-integration Analysis (Johansen Methodology)

Table 2: Co-integration Test Result

Unrestricted Co-integration Rank Test (Trace)				
Hypothesized		**Trace**	**0.05**	
No. of CE(s)	Eigenvalue	Statistic	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 E-views 10

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: 09/10/24 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 E-views 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 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 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 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) [17] 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 aligns with Abeysekara, Siriwardana, and Meng (2023) [1] 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 next few decades. The findings of the study also align with findings of Onyeneke *et al.* (2024) [14] 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.

5. Conclusion and Recommendations

The results indicate that climate change has had a detrimental effect on agricultural output in Nigeria from 2000 to 2023. Factors such as increasing temperatures, erratic rainfall patterns, droughts, and floods have led to reduced crop yields, negatively impacting food security and economic stability. Crop production has been especially vulnerable to changing precipitation levels and extreme weather events, which have disrupted planting and harvesting seasons. Additionally, soil degradation and water scarcity caused by climate fluctuations have further strained agricultural productivity.

In conclusion, the adverse impacts of climate change on Nigeria's agriculture underscore the urgent need for adaptive strategies. Effective measures, such as adopting climate-resilient crop varieties, improving irrigation systems, and implementing sustainable agricultural practices, are crucial to enhancing resilience and ensuring food security amidst ongoing environmental challenges.

Recommendations

1. There is an urgent need to promote the research, development, and distribution of crop varieties that are specifically bred for heat tolerance and drought resistance. These crops can better withstand higher temperatures and changing climate conditions, ensuring stable yields even under stressful environmental conditions.
2. There is need to invest in and promoting the use of irrigation can mitigate the adverse effects of irregular rainfall patterns. Efficient irrigation systems, such as drip and sprinkler irrigation, can help ensure that crops receive adequate water, thereby enhancing agricultural productivity even during periods of low rainfall.
3. Farmers should be encouraged to adopt climate-resilient agricultural practices that can withstand high humidity levels. This could include selecting and planting crop varieties that are more tolerant to humidity and diseases associated with it. Additionally, implementing integrated pest management strategies can help mitigate the adverse effects of increased humidity on crop health.
4. There is an urgent need to promote agroforestry systems where trees and crops are grown together. This approach can provide shade, reduce soil temperature, and conserve 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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