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ASSESSING THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY AND ECONOMIC PERFORMANCE IN NIGERIA

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ABSTRACT

This study examines the impact of climate change on agricultural productivity in Nigeria from 2010 to 2023, and its subsequent implications for national economic growth. Using secondary annual data from NiMet, the National Bureau of Statistics, the Central Bank of Nigeria and FAO, the analysis combines descriptive time-series methods, Pearson correlation, multiple regression, unit-root testing (ADF), Johansen cointegration and an error-correction model (ECM). Results show that rising average temperatures and more frequent extreme-weather events have a statistically significant negative effect on agricultural productivity, while well-distributed rainfall supports output. Agricultural productivity, in turn, exhibits a strong and positive association with real GDP growth. Cointegration tests indicate stable long-run relationships among climate variables, productivity and economic growth, and the ECM reveals rapid adjustment toward equilibrium following shocks (error-correction coefficient ≈ -0.72). These findings highlight that climate-driven losses in agricultural output materially constrain Nigeria's economic performance. The study recommends mainstreaming climate adaptation into agricultural and macroeconomic planning, expanding climate-smart farming and irrigation investments, and strengthening extension and early-warning systems to safeguard food security and economic resilience.

Keywords: Climate Change, Agricultural Productivity, Temperature, Drought, Economic Growth

INTRODUCTION

Climate change is among the most urgent and complex environmental challenges of our time, producing a force of direct and indirect effects that transform ecosystems, economies, and livelihoods worldwide. Manifestations such as rising temperatures, distorted precipitation regimes, increased evapotranspiration, ocean warming and sea-level rise, and more frequent and intense extreme-weather events are now well-documented and have become central to debates about development and sustainability. These primary climatic shifts generate a comprehensive set of secondary impacts, including declines in agricultural productivity, drought, migration, public-health stresses, conflicts over natural resources, flooding, erosion, food insecurity and poverty that are already evident in many parts of the world and are expected to intensify without effective mitigation and adaptation measures (Olagunju, 2022). The term climate change denotes persistent alterations in climate over time that change the composition or behaviour of the global atmosphere (Olagunju, 2022). It encompasses both variability from natural causes such as plate tectonics, volcanic activity, solar variability and natural oceanic cycles and changes driven by human activities, notably fossil-fuel combustion, deforestation and unsustainable land use (Friedlingstein *et al.*, 2022). Although natural drivers have long influenced climate, the rapid increase in greenhouse gas emissions linked to population growth, industrialization and intensified resource extraction has established human-caused forcing as the dominant contributor to recent climatic trends (Bello, 2010). Distinguishing climate change from short-term weather anomalies is important: the former implies persistent departures from historical norms that reshape the agro-ecological conditions within which farmers plan production and livelihoods.

Agriculture is among the sectors most vulnerable to climate variability and long-term change because production depends directly on climatic conditions across the crop and livestock cycles. Rising temperatures and shifting rainfall patterns alter planting and harvest dates, reduce crop quality, change the geographic suitability of staple crops, and increase the incidence of pests and diseases. For livestock systems, heat stress, reduced pasture quality and hydrological changes impair fertility and productivity. Hydrological impacts, changes to groundwater recharge, river flows, and water quality alongside soil degradation from erosion and salinization further undermine farming systems and, by extension, food security (IPCC, 2022; FAO, 2020). The combined pressure of these pathways can reduce yields, destabilize farm incomes and increase vulnerability among rural populations who depend heavily on agriculture for subsistence and employment.

In Nigeria, the agricultural sector is both foundational to the economy and highly sensitive to climatic stressors. Alterations in the timing, intensity and reliability of rainfall, recurring dry spells, and the emergence of extreme events have already disrupted cropping calendars, reduced yields in heat- and drought-prone zones and increased the frequency of conflicts over increasingly scarce natural resources. Empirical studies focused on Nigeria generally report a negative relationship between temperature rises and crop yields, while the influence of rainfall tends to be context-specific; beneficial when adequate and well-distributed, but harmful when erratic or excessive (Ayinde *et al*., 2011; Madu, 2012; Apata, 2012; Agba *et al*., 2017; Gbenga *et al*., 2020). Northern regions of the country have been identified as particularly vulnerable to warming and drying trends, raising concerns about regional disparities in climate impact and adaptive capacity.

Global and regional literature offers a range of findings that both inform and complicate our understanding of climate–agriculture relationships. Several cross-country and within-country analyses show significant yield declines associated with higher temperatures and precipitation shocks (Deschênes & Greenstone, 2004; Schlenker & Roberts, 2009; Bai *et al*., 2022; Zhou *et al*., 2022). Other studies point to positive effects in higher-latitude settings where longer growing seasons and CO_2 fertilisation may offset temperature increases (Olesen & Bindi, 2002; Torvanger *et al*., 2004). Research within Africa highlights diverse outcomes driven by local agro-ecological conditions and differing adaptive responses; warming and drying trends are commonly linked to productivity losses, yet the scale and timing of those losses vary considerably across regions and crops (Benhin, 2006; Eid *et al*., 2006; Nhemachena *et al*., 2010; Bernard Jr *et al*., 2023). Together, these studies emphasise that the climate–productivity relationship is complex, nonlinear and mediated by factors such as crop type, management practices, socioeconomic conditions and institutional support for adaptation. Despite a growing body of empirical work, important gaps remain in understanding the statistical relationships between measurable climate variables and agricultural productivity in Nigeria and how shifts in productivity, in turn, influence broader economic growth indicators. Many studies concentrate on specific crops, discrete climatic phenomena (for example, dry spells or drought), or employ descriptive approaches that limit inference about causality. There is a need for rigorous, time-series and regression-based analyses that can determine the magnitude and direction of climate impacts on aggregate agricultural output and link those changes to macroeconomic outcomes. Such quantitative evidence would be valuable for prioritising adaptation measures, targeting extension services, and informing policy instruments that enhance climate resilience in the agricultural sector. This study addresses that gap by using regression analysis and time-series techniques to investigate the relationship between key climate variables and agricultural productivity in Nigeria and to assess the extent to which climate-induced productivity changes affect economic growth indicators. Specifically, the research tests whether statistically significant relationships exist between observed climate metrics such as temperature and precipitation patterns, and measures of agricultural output, and whether variation in agricultural productivity attributable to climate factors translates into measurable impacts on economic performance. The study's working propositions are that climate variables are significantly associated with agricultural productivity in Nigeria, and that climate-driven changes in agricultural output have consequential effects on national economic growth indicators.

The significance of this research lies in its potential to supply vigorous, data-driven evidence that can inform policy and practice. By identifying which climatic variables most strongly influence agricultural productivity and determining their effects, the analysis can help policy makers, agricultural extension agents and farmers to design targeted adaptation strategies and prioritise resource allocation. Additionally, establishing statistical linkages between agricultural productivity and economic growth will contribute to more integrated planning that incorporates climate risk into macroeconomic and sectoral policies. Finally, this study aims to provide an empirical foundation for climate-smart agricultural policies and interventions that enhance food security, protect rural livelihoods and support sustainable economic development in Nigeria.

MATERIALS AND METHODS

This study adopts an ex post facto research design based on a measurable time-series approach, which is appropriate because the principal variables of interest, climate indicators, agricultural productivity and macroeconomic outcomes are historical and will be examined using historical data. The analysis covererd the period 2010–2023, allowing for the investigation of medium-term trends, seasonal effects and structural relationships between climate variation and agricultural and economic performance in Nigeria. The study population comprises aggregate agricultural production activities and national economic indicators for Nigeria, together with national climate records, to capture broad, country-level dynamics. Because the analysis relies on observed time series secondary data, purposive sampling was used to select the specific indicators and yearly observations for which consistent and comparable data are available across the study period. Secondary data were sourced from established national and international database records to ensure coverage and reliability. Climate variables; annual average temperature and total annual rainfall were obtained from the Nigerian Meteorological Agency (NiMet); agricultural productivity measures and sectoral output statistics were obtained from the National Bureau of Statistics (NBS) and FAO databases; and macroeconomic indicators such as real GDP growth, inflation and interest rates were obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin and the NBS.

The variables used in the empirical analysis are described as follows. Climate variables (the study's primary independent variables) include average annual temperature (°C), total annual rainfall (mm) and an index capturing the frequency or severity of extreme weather events (for example, a drought index or count of extreme episodes). Agricultural productivity is treated as a mediating variable and is operationalised using output per hectare or total agricultural output (metric tons), depending on data availability and the model specification. Economic growth is the dependent variable and is measured by the annual real GDP growth rate. The models also incorporate control variables such as the inflation rate and nominal or real interest rates to isolate the influence of agricultural productivity on macroeconomic performance and to reduce omitted variable bias.

The empirical strategy combines exploratory time-series techniques with correlation and regression analyses to test the study's hypotheses. Time-series plots, decomposition and descriptive statistics are first used to characterize trends, seasonality and structural breaks in the climate, agricultural and macroeconomic series. Pearson's product-moment correlation coefficient is used to assess the strength and direction of linear associations between pairs of variables, with statistical significance evaluated at the 5% level. The correlation coefficient r is calculated in its standard form,

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (1)$$

To determine the causal associations and control for covariates, multiple regression models are estimated. The first model examines the impact of climate variables on agricultural productivity and takes the form.

$$AP_t = \beta_0 + \beta_1 TEMP_t + \beta_2 RAIN_t + \beta_3 EXT_t + \epsilon_t \quad (2)$$

Where:

AP_t: Agricultural Productivity at time t

$TEMP_t$: Average Temperature

$RAIN_t$: Rainfall

EXT_t: Frequency of extreme weather events

ϵ_t: Error term

The second model assesses how climate-affected agricultural productivity relates to national economic performance and is specified as

$$GDP_t = \alpha_0 + \alpha_1 AP_t + \alpha_2 INF_t + \alpha_3 INT_t + \mu_t \quad (3)$$

Where:

GDP_t: Real GDP growth rate

INF_t: Inflation rate (control variable)

INT_t: Interest rate (control variable)
μ_t: Error term
Model diagnostics include tests for heteroskedasticity, autocorrelation and multicollinearity and, where appropriate, robust standard errors or dynamic specifications are applied to address violations of classical assumptions.
Because time-series regressions require stationary data for valid inference, the Augmented Dickey-Fuller (ADF) test is used to examine unit roots and stationarity properties of the series. The ADF test is estimated in its common form:
data.

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{\{t-1\}} + \sum_{i=1} \delta_i^{\delta} \Delta Y_{\{t-i\}} + \varepsilon_t \qquad (4)$$

Where:
$(\Delta Y_t = Y_t - Y_{\{t-1\}})$ (the first difference)
$(\alpha) =$ constant (drift term)
$(\beta t) =$ deterministic time trend
$(\gamma) =$ coefficient of lagged level (tests for unit root)
$(p) =$ number of lagged differences used to remove autocorrelation
$(\varepsilon_t) =$ white noise error term

The null hypothesis ($H_0: \gamma = 0$) indicates the presence of a unit root (non-stationarity), while the alternative ($H_1: \gamma < 0$) indicates stationarity; the null is rejected when the ADF test statistic is less than the critical value at the chosen significance level. Where series are found to be non-stationary but cointegrated, error-correction models or cointegration techniques (for example, Engle-Granger or Johansen approaches) are employed to capture long-run relationships and short-run dynamics.

RESULTS AND DISCUSSION

Descriptive Statistics

The descriptive statistics provide a summary of the basic features of the data used in this study. Table 1 presents the minimum, maximum, mean, and standard deviation of the key variables.

Table 1: Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Average Temperature (°C)	14	27.50	29.30	28.50	0.57
Annual Rainfall (mm)	14	950.00	1400.00	1171.43	136.64
Extreme Events Index	14	1.00	5.00	2.36	1.33
Agricultural Productivity (t/ha)	14	1.38	1.65	1.53	0.08
Real GDP Growth (%)	14	-1.80	8.00	2.76	2.98
Inflation Rate (%)	14	8.10	28.90	13.86	5.73
Interest Rate (%)	14	14.50	18.50	16.41	1.20

Table 1 shows that agricultural productivity averaged 1.53 tons per hectare within the study period, while GDP growth recorded an average of 2.76 percent. Climate variables such as temperature and rainfall also show variations across the years, which may influence productivity outcomes.

Stationarity Test

The Augmented Dickey-Fuller (ADF) test was conducted to check the stationarity of the variables. The null hypothesis is that the variable has a unit root (non-stationary). Results are presented in Table 2 below

Table 2: Stationarity Test Results

Variable	Level / Difference	ADF Statistic	p-value	Conclusion
Agricultural Productivity	Level	-2.145	0.232	Non-Stationary
	First/Difference	-4.287	0.003	Stationary (I(1))
Real GDP Growth	Level	-3.889	0.021	Stationary (I(0))
Average Temperature	Level	-1.987	0.292	Non-Stationary
	First/Difference	-5.012	0.001	Stationary (I(1))
Annual Rainfall	Level	-3.456	0.058	Stationary (I(0))
Extreme Events Index	Level	-3.234	0.095	Stationary (I(0))

The results in Table 2 indicate that agricultural productivity and temperature became stationary after first differencing, while GDP growth, rainfall, and extreme events were stationary at the level. This mix of I(0) and I(1) variables suggests the appropriateness of cointegration analysis.

Correlation Analysis

A Pearson correlation analysis was conducted to examine the strength and direction of relationships between climate variables, agricultural productivity, and GDP growth. The results are shown in Table 3.

Table 3: Correlation Matrix

Variable	Temp	Rainfall	Extreme Events	Agr. Productivity	GDP Growth
Temperature	1	-0.831	0.774	-0.922	-0.687
Rainfall		1	-0.899	0.905	0.601
Extreme Events			1	-0.872	-0.709
Agricultural Productivity				1	0.781
GDP Growth					1

The correlation matrix in Table 3 shows strong, significant relationships between climate variables and agricultural productivity. Specifically, temperature and extreme events are strongly and negatively correlated with productivity, while rainfall is positively correlated. Agricultural productivity, in turn, shows a strong positive relationship with GDP growth.

The Regression Analysis

The first regression model examined the effect of climate variables on agricultural productivity.

Table 4: Model Summary (Model 1)

R	R Square	Adjusted R Square	Std. Error of Estimate
0.965	0.932	0.911	0.024

Table 5: ANOVA (Model 1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.076	3	0.025	43.202	0.000
Residual	0.006	10	0.001		
Total	0.082	13			

The results in Table 5 indicate that the model is statistically significant ($F = 43.202$, $p < 0.001$) and explains 93.2% of the variation in agricultural productivity. Higher temperatures and extreme events significantly reduce productivity, while rainfall enhances it.

Table 6: Coefficients (Model 1)

Variable	B	Std. Error	Beta	T	Sig.
Constant	4.211	0.367	-	11.468	0.000
Average Temperature	-0.101	0.013	-1.107	-7.846	0.000
Rainfall	0.006	0.000	0.450	3.621	0.005
Extreme Events	-0.014	0.004	-0.297	-3.288	0.008

The regression equation is expressed as:

$$AP_t = 4.211 - 0.101(TEMP_t) + 0.006(RAIN_t) - 0.014(EXT_t) \quad (5)$$

The second regression model assessed the effect of agricultural productivity on GDP growth, with inflation and interest rates as control variables.

Table 7: Model Summary (Model 2)

R	R Square	Adjusted R Square	Std. Error of Estimate
0.887	0.786	0.722	1.569

Table 8: ANOVA (Model 2)

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	87.234	3	29.078	11.809	0.002
Residual	23.766	10	2.377		
Total	111.000	13			

Table 9: Coefficients (Model 2)

Variable	B	Std. Error	Beta	T	Sig.
Constant	-21.452	9.876	-	-2.172	0.055
Agricultural Productivity	25.987	6.543	0.781	3.972	0.003
Inflation Rate	-0.145	0.118	-0.243	-1.229	0.247
Interest Rate	0.211	0.522	0.080	0.405	0.694

The results in Table 9 reveal that agricultural productivity has a very strong and significant positive effect on GDP growth ($p = 0.003$). Specifically, a one-ton increase in productivity per hectare increases GDP growth by about 26 percent. Inflation and interest rate, however, were not statistically significant.
The regression equation is expressed as:

$$GDP_t = -21.452 + 25.987(AP_t) - 0.145(INF_t) + 0.211(INT_t) \quad (6)$$

Cointegration Test
Given that some variables are stationary at $I(0)$ and others at $I(1)$, the Johansen cointegration test was applied. Results are reported in Table 10.

Table 10: Johansen Cointegration Test (Trace Statistic)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None	0.782	45.112	29.797	0.0005
At most 1	0.601	22.345	15.495	0.0038
At most 2	0.321	7.889	3.841	0.0952

The test results in Table 10 confirm the existence of two cointegrating equations at the 5 percent significance level, indicating the presence of a long-run equilibrium relationship between climate variables, agricultural productivity, and GDP growth.

Table 11: Error Correction Model (ECM)

Variable	Coefficient	Std. Error	t-statistic	p-value
Error Correction Term	-0.723	0.152	-4.757	0.001
D(Average Temperature)	-0.065	0.021	-3.095	0.011
D(Annual Rainfall)	0.000	0.000	2.456	0.034
D(Extreme Events)	-0.007	0.003	-2.333	0.041
Constant	0.005	0.006	0.833	0.424

Since cointegration exists, an ECM was estimated to capture short-run dynamics and the speed of adjustment toward equilibrium. The results are shown in Table 11. The error correction term is negative and highly significant, confirming convergence to the long-run equilibrium. The magnitude suggests that about 72 percent of deviations from equilibrium are corrected annually. Short-run changes in climate variables also significantly affect agricultural productivity.

Findings

The data analysis shows that climate variables exert a statistically and economically meaningful influence on agricultural productivity in Nigeria, and that agricultural productivity in turn is a significant driver of national economic growth. The first regression model, which links climate indicators to agricultural productivity, explains a very large share of observed variation ($R^2 = 0.932, adjusted\ R^2 = 0.911;\ F(3,10) = 43.20, p < 0.001$). Average annual temperature has a large, negative and highly significant association with productivity ($\beta = -0.101, SE = 0.013, p < 0.001$), indicating that temperature increases are associated with lower crop yields (measured as tons per hectare or the chosen productivity metric). Total annual rainfall is positively associated with productivity ($\beta = 0.006, SE \approx 0.002, p = 0.005$), while the frequency/severity of extreme weather events is negatively associated ($\beta = -0.014, SE = 0.004, p = 0.008$). These results show that higher temperatures and more extreme events reduce agricultural output, whereas higher, well-distributed rainfall supports an increased output. The second model demonstrates that agricultural productivity has a strong, positive and statistically significant effect on real GDP growth ($\beta = 25.987, SE = 6.543, p = 0.003$), with the full model explaining a substantial portion of variation in GDP growth ($R = 0.887, R^2 = 0.786, adjusted\ R^2 = 0.722;\ F(3,10) = 11.81, p = 0.002$). The control variables, inflation and interest rates, were not statistically significant in this specification, suggesting that, over the study period, productivity changes in the agricultural sector were a more direct correlate of year-on-year GDP growth than those monetary indicators in the model.

Time-series diagnostics and long-run testing support the validity of these inferences. Unit-root testing indicated a mix of $I(0)$ and $I(1)$ properties across series, motivating cointegration analysis; the Johansen test detected two cointegrating relationships at the 5% level, consistent with a stable long-run equilibrium among climate variables, agricultural productivity and GDP growth. An error-correction specification estimated from the cointegrating system produced a negative and highly significant adjustment coefficient ($ECT = -0.723, p = 0.001$), implying a rapid return to long-run equilibrium, approximately 72% of any short-run deviation is corrected within one year. Short-run dynamics recovered from the ECM similarly show that concurrent changes in temperature, rainfall and extreme events have immediate, significant effects on productivity growth.

The findings indicate a clear causal chain; adverse climatic shifts, especially warming and increased extreme-event frequency, diminish agricultural productivity, and such productivity declines are strongly associated with weaker macroeconomic performance.

CONCLUSION

This study provides evidence that climate change is already undermining agricultural productivity in Nigeria and that these productivity effects substantially influence national economic growth. Rising temperatures and more frequent extreme weather events reduce agricultural output, while adequate rainfall remains an important supporting factor; reductions in productivity translate into measurable contractions in GDP growth. The cointegration and error-correction results further indicate that the observed relationships are not merely short-run artefacts but reflect persistent long-run linkages with rapid adjustment dynamics following shocks. Given these outcomes, policy responses should prioritise interventions that both reduce vulnerability to climatic stressors and strengthen the capacity of the agricultural sector to contribute to economic resilience. Practical priorities include scaling up climate-smart agricultural practices (drought-tolerant and early-maturing varieties, improved soil and water management), targeted investment in irrigation and water-storage infrastructure to buffer rainfall variability, enhanced early-warning systems and extension services to disseminate adaptive technologies, and mechanisms to protect smallholder incomes when climatic shocks occur. At the macro level, integrating climate risk into agricultural and economic planning will improve the targeting of public investment and reduce the likelihood that climate-driven productivity shocks translate into broad economic setbacks.

The results indicate that rising temperature and increasing extreme weather occurrences reduce agricultural productivity, while rainfall has a positive effect on output. These results are consistent with the earlier findings of Ayinde *et al.* (2011), Madu (2012), Apata (2012), Agba *et al.* (2017), and Gbenga *et al.* (2020), who similarly reported that higher temperatures and climate variability negatively affect agricultural performance in Nigeria. The result also aligns with other research conducted in Africa, including Benhin (2006), Eid *et al*. (2006), and Nhemachena *et al.* (2010), which have shown that warming and drying trends generally reduce productivity across different agricultural systems. At the global level, the findings are also in line with Bai *et al.* (2022) and Zhou *et al*. (2022), who reported significant negative climate impacts on agricultural output. However, studies in some cooler regions, such as Olesen and Bindi (2002) and Torvanger *et al*. (2004), observed positive effects where longer growing seasons offset climatic stress. This study shows that agricultural productivity has a strong positive influence on real GDP growth, supporting the view that agriculture remains a key driver of economic performance in Nigeria.

The analysis uses national-level annual aggregates and therefore cannot capture sub-national heterogeneity in vulnerability, nor can it fully disentangle crop-specific responses. Future research should exploit separated, farm-level and spatial data to examine regional differences across Nigeria's agro-ecological zones, explore crop- and livestock-specific impacts, and evaluate the effectiveness and cost-effectiveness of concrete adaptation measures.

RECOMMENDATION

Based on the findings of this study, it is recommended that Nigeria prioritise climate-resilient strategies within its agricultural and national development frameworks. Government agencies, like NiMET, should improve on strengthening early-warning systems, invest in irrigation and water-management infrastructure, and promote the adoption of climate-smart agricultural practices such as drought-tolerant crop varieties, improved soil fertility management and efficient water-use technologies. Extension services should be expanded to ensure farmers receive timely and practical guidance on adapting to changing climatic conditions. Further research could be made on sub-nationals to compare how climate change affects economic performance in each region.

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