International Journal of Agriculture, Environment and Bioresearch

Vol. 10, No. 02; 2025

ISSN: 2456-8643

EFFECT OF CLIMATE CHANGE ON CASSAVA PRODUCTIVITY IN NIGERIA: LONG- AND SHORT-TERM EFFECT

Anarah, Samuel Emeka, Ahaneku Chinwendu Evangel, Ositanwosu Chukwunonso.O, Ogulewe Divine Onyema and Ezeude Nwando Assumpta

Department of Agricultural Economics and Extension, Nnamdi Azikiwe University

https://doi.org/10.35410/IJAEB.2025.5970

ABSTRACT

This study analyzed the effects of climate change on cassava productivity in Nigeria from 1991 to 2022. It assessed how climate variables such as rainfall, temperature, sunshine duration, carbon dioxide emissions, and relative humidity influenced cassava productivity. The research utilized secondary data analyzed through econometric models, including the Autoregressive Distributed Lag (ARDL) model, and the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The findings revealed in the long-run, Average Annual Rainfall (LNARF), Average Annual Carbon Dioxide Emissions (LNDACDE), a lagged value of Average Annual Temperature (LNDATEMP (-1)), a lagged value of Average Annual Carbon Dioxide Emissions (LNDACDE (-1)), and Average Annual Sunshine Duration (LNASUN) exhibit significant impacts on cassava productivity. Average Annual Inflation Rate (LNDINFR) were the significant variables that influenced cassava productivity between 1991 and 2022. In the short run, the ARDL model shows that among the climate variables, the current values of average annual rainfall (DLN(ARF)), average annual temperature (DLN(DATEMP)), average annual relative humidity (DLN(DARELH)), average annual sunshine duration (DLN(ASUN)), and the area of land under cassava cultivation (DLN(DALUC_CASSAVA)) exhibit significant impacts on cassava productivity in Nigeria.

Keywords: Climate Change, Cassava, Productivity, Nigeria.

1. INTRODUCTION

In Nigeria, the impacts of climate change are already being felt across various agroecological zones. The variability in temperature, rainfall, and relative humidity has disrupted traditional farming practices, leading to significant declines in the productivity of staple food crops such as cassava, maize, and yam (Oyinloye et al., 2018; Diagi et al., 2020). The Sahel and Sudan savannah belts, for instance, have experienced increased aridity and desertification, while the southern rainforest zones have seen alterations in rainfall patterns, with delayed onset and cessation of rains, leading to shorter growing seasons (Ughaelu.2017). These climatic changes have not only reduced crop yields but also increased the vulnerability of farming communities, exacerbating economic disparities and food insecurity (Ughaelu, 2017).

The economic consequences of these climatic disruptions are profound. As agricultural productivity declines, the incomes of farmers, who constitute a significant portion of Nigeria's labor force, are adversely affected. This reduction in income exacerbates existing income inequalities, as those who are already economically marginalized are hit hardest by the decline in agricultural outputs (Ayinde et al., 2011). Moreover, the rising costs of food due to decreased supply further strain the purchasing power of low-income households, deepening the divide between the rich and the poor (Ayinde et al., 2020).

2. MATERIALS AND METHODS

The Study Area

This study was carried out in Nigeria, The population of Nigeria in 2023 was approximately 223,804,633, based on World meter's elaboration of the latest United Nations data, with a population density of 226 per km² and a total land area of 909,890 square kilometers (NBS, 2018).

Model Specification

According to Pesaran *et al*. (2001), the dependent variable must be I(1), while the exogenous variables can be either I(1) or I(0). Based on empirical literature, theories of interest, and diagnostic tests, the long run relationship between climate change and cassava productivity is given as:

$InAPR_t = \lambda_0 + \lambda_1 InARF_t + \lambda_2 InATEMP_t + \lambda_3 InARELH_t + \lambda_4 InACDE_t + \lambda_5 InASUN_t + \lambda_7 InAFDI_{t-1} + \lambda_8 InDIA_t + \lambda_9 InGCEA_t + \lambda_{10} InINFR_t + \lambda_{11} InRER_t + \varepsilon_t$ …... (1)

Where,

λ's = Long run coefficients

In= Stands for Natural Logarithm,

APR_{it} = Value of Cassava productivity in period t

ARF_t = Average annual rainfall (millimetres) in period t

$ATEMP_t$= Average annual temperature (°C) in period t

$ARELH_t$ = Average annual relative humidity (%) in period t

$ACDE_t$ = Average annual carbon dioxide (CO_2) emissions (Metric tons per year) in period t

$ASUN_t$= Average annual sunshine (hours) in period t

$AFDI_t$ = Agricultural foreign direct investment in period t

DIA_t = Total domestic private investment in agriculture (₦'Billion) in period t,

$GCEA_t$ = Government capital expenditure on agriculture (₦' Billion) in period t,

$INFR_t$ = Inflation rate (%) in period t,

RER_t = Real exchange rate (₦/$) in period t,

ε_t = Stochastic disturbance term.

Diagnostic Tests: Stationary Properties of the Variable used in the Analysis

Estimation of the various economic models used in this study was preceded by an examination of the statistical properties of the series, specifically the stationarity of the individual variables. Table 4.6 presents the results of the stationarity tests conducted using the Augmented Dickey–Fuller (ADF) test (1979) and the Phillips–Perron (PP) test (1988). The results indicate that some variables were stationary at level I(0), while others became stationary after first differencing, I(1). This differentiation in stationarity is crucial for selecting appropriate econometric techniques.

Gujarati (2003) emphasized the importance of using the ARDL (Auto-Regressive Distributed Lag) approach to co-integration, particularly in cases where the data exhibit mixed integration orders (I(0) and I(1)). The ARDL approach, developed by Pesaran and Shin (1999), has significant advantages over the Johansen co-integration method. It is versatile, allowing for the analysis of data that is purely I(0), purely I(1), or a mix of both. This flexibility is particularly beneficial in the context of this study, where the stationarity tests reveal a mix of I(0) and I(1) variables. The variables were first logged to their natural logarithms before subsequent unit root test.

3. RESULTS AND DISCUSSION

Table 1: Result of unit root test of logged variables used in the analysis

Variable	Augmented Dickey-Fuller Test			Phillips-Perron Test		
	Level	1st Difference	IO	Level	1st Difference	IO
Average annual CO_2 emission ($ACDE_t$)	-1.599	-4.349 **	I(1)	-1.348	-4.431**	I(1)
Agricultural foreign direct investment ($AFDI_t$)	-1.516	-6.197**	I(1)	-1.339	-6.835**	I(1)
Area of land harvested of cassava ($ALUCC_t$)	-1.624	-5.551**	I(1)	-1.301	-11.043**	I(1)
Value of cassava productivity ($APFCC_t$)	-2.675	-6.114**	I(1)	-2.689	-8.185**	I(1)
Average annual relative humidity ($ARELH_t$)	-2.770	-6.373**	I(1)	-2.667	-8.511**	I(1)
Average annual rainfall (ARF_t)	-10.122**	-	I(0)	-6.228**	-	I(0)
Average annual sunshine hours ($ASUN_t$)	-5.042**	-	I(0)	-8.195**	-	I(0)
Average annual temperature ($ATEMP_t$)	-4.331*	-	I(0)	-1.909	-4.411**	I(1)
Total domestic investment in agriculture (DIA_t)	-4.588**	-	I(0)	-4.526**	-	I(0)
Food security index (FSI_t)	-2.847	-7.439**	I(1)	-2.847	-10.953**	I(1)
Govt. capital expenditure on agric. ($GCEA_t$)	-2.130	-6.816**	I(1)	-1.893	-9.373**	I(1)
Average annual inflation rate ($INFR_t$)	-2.667	-5.335**	I(1)	-2.882	-8.421**	I(1)
Average annual real exchange rate (RER_t)	-0.308	-4.251*	I(1)	-0.444	-4.131*	I(1)

Note: For ADF test at level, critical value at 1% = - -4.297, and at 5% = -3.568; at first difference, critical value at 1% = -4.297, and at 5% = -3.568. For PP test at level, critical value at 1% = -4.285, and at 5% = -3.563; at first difference, critical value at 1% = -4.297, and at 5% = -3.568. Asterisks * and ** represent 5% and 1% significance levels, respectively. These tests were performed by including a constant and trend in the regressions. IO = integration order.

The results in Table 1 show that the average annual rainfall (ARFt), average annual sunshine hours (ASUNt), average annual temperature (ATEMPt), and total domestic investment in agriculture (DIAt) were stationary at level I(0) using the Augmented Dickey Fuller (ADF) test. Similarly, the Phillips–Perron (PP) test confirmed the stationarity of ARFt, ASUNt, and DIAt at level I(0). The majority of the other variables, such as average annual CO2 emission (ACDEt), agricultural foreign direct investment (AFDIt), and areas of land harvested for various crops, were found to be stationary at order one, I(1), indicating that they require differencing to achieve stationarity.

The consistency between the ADF and PP tests in identifying the stationarity of key variables such as ARFt and ASUNt provides confidence in the robustness of the results. However, slight differences between the tests were noted, particularly in the stationarity of the average annual temperature (ATEMPt), which was stationary at level I(0) according to the ADF test but required

differencing according to the PP test. Given these nuances, the PP test was ultimately adopted for this study, as it provided a more comprehensive insight into the stationarity properties of the variables.
The difference-stationary values of the variables that were found to be stationary at order one, I(1), were then generated and used in subsequent analyses. This approach ensures that the models are not biased by non-stationary data, which could lead to spurious regression results. Furthermore, the study employs bounds testing to investigate co-integration relationships, as recommended by Pesaran et al. (2001). This method is particularly well-suited to the ARDL framework, enabling the study to capture both the short- and long-term dynamics between the dependent and independent variables.
Therefore, the stationarity tests and subsequent differencing ensured that the data used in the ARDL models were appropriately treated for non-stationarity, allowing for robust and reliable estimation of the relationships between the variables. The adoption of the PP test provided an additional layer of validation, reinforcing the credibility of the findings and supporting the use of the ARDL approach in this context.

Effect of Climate change on Cassava Productivity in Nigeria (1991-2022)

The effect of climate change on cassava productivity in Nigeria from 1991 to 2022 is analyzed below, considering both long-run and short-run effects. This comprehensive assessment examines how climate variables have shaped cassava production over time, with selected macroeconomic variables included in the model as controls. A bounds test was performed to investigate the presence of a co-integration relationship, ensuring that the analysis captures the dynamic interplay between these variables across different time frames.

Bounds Test

The result of the bounds test performed to investigate the presence of a co-integration relationship between climate change indicators and cassava productivity in Nigeria withing the study period is presented in Table 2.

Table 2: Bounds test result of the presence of a co-integration relationship between climate change indicators, as well as macroeconomic indicators and cassava productivity in Nigeria.

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	4.522	10%	1.98	2.97
k	11	5%	2.21	3.25
		2.5%	2.42	3.52
		1%	2.68	3.84

Source(s): Author Construction from EViews 13 computation, 2024

The bounds test results reveal that the F-statistic of 4.522 is significantly higher than the upper bounds critical values at the 1% level (3.84) and 5% level (3.25). This implies that the test statistic exceeds the critical values for both significance levels, thereby allowing us to reject the

Vol. 10, No. 02; 2025
ISSN: 2456-8643

null hypothesis of no co-integration at the 1% level. This strong evidence suggests the existence of a long-run co-integration relationship among the variables under consideration.

Consequently, the results confirm that there is a stable long-term equilibrium relationship between the variables in the model. This co-integration relationship indicates that the variables, while potentially exhibiting short-term fluctuations, move together in the long run, reinforcing the robustness of the model in explaining the dynamics of cassava productivity. This indicates that the interplay between climate change variables, macroeconomic factors, and cassava productivity in Nigeria is underpinned by a statistically significant long-run equilibrium. The intricate effects of these critical climate and macroeconomic indicators on cassava productivity will be rigorously explored through long-run estimation tests presented in the subsequent analysis.

ARDL Long-run Coefficients

Table 3 presents the ARDL long-run coefficients, detailing the effect of climate change on cassava productivity in Nigeria from 1991 to 2022. In Table 3, the R^2 value of 0.990725, accompanied by an adjusted R^2 of 0.955171, indicates that the independent variables collectively account for 99.1% of the variation in Nigeria's Cassava productivity within the period under study. This high explanatory power demonstrates that the model effectively captures the dynamics of cassava productivity in Nigeria. The null hypothesis of no model significance is unequivocally rejected, as evidenced by the F-statistic of 27.86548, which is highly significant at the 1% level, given the p-value of 0.000240, well below the 0.05 threshold. Additionally, the Durbin-Watson statistic of 1.636854 falls within the acceptable range, suggesting the absence of serial autocorrelation and further validating the robustness of the model. Model selection for estimating the effect of climate change, along with selected macroeconomic variables, on cassava productivity in Nigeria was guided by the Akaike Information Criterion (AIC). The AIC indicated that the ARDL(1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1) model was optimal for this analysis. This model configuration best captures the dynamics between the independent variables and cassava productivity over the study period.

Table 3: Results of the ARDL Long-Run Coefficients for the Effect of Climate Change on Cassava Productivity in Nigeria (1991–2022), with Control for selected Macroeconomic Variables

Dependent Variable: LNAPFC_CASSAVA
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (1 lag, automatic): LNARF LNATEMP(-1) LNACDE(-1) LNARELH(-1) LNASUN LNALUC_CASSAVA(-1) LNAFDI(-1) LNDIA LNGCEA(-1) LNINFR(-1) LNRER(-1)
Selected Model: ARDL(1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNAPFC_CASSAVA(-1)	0.474599	0.211585	2.243067*	0.0661
LNARF	-0.075117	0.023640	-3.177566**	0.0191
LNARF(-1)	-0.032736	0.020005	-1.636337	0.1529
LNATEMP	6.308784	13.75469	0.458664	0.6626
LNATEMP(-1)	63.84915	16.12163	3.960466***	0.0074

Vol. 10, No. 02; 2025

ISSN: 2456-8643

LNACDE	-0.003569	0.001204	-2.965262**	0.0251
LNACDE(-1)	-0.004418	0.001190	-3.711224***	0.0100
LNARELH	0.418399	0.284196	1.472222	0.1914
LNARELH(-1)	-0.757052	0.423536	-1.787455	0.1241
LNASUN	14.07960	4.087959	3.444163**	0.0137
LNASUN(-1)	8.586635	2.829281	3.034918**	0.0230
LNALUC_CASSAVA	-4.41E-06	2.30E-06	-1.915194	0.1040
LNALUC_CASSAVA(-1)	1.11E-05	3.27E-06	3.410079**	0.0143
LNAFDI	0.001810	0.000713	2.539532**	0.0441
LNAFDI(-1)	0.000367	0.000398	0.922453	0.3919
LNDIA	-0.000729	0.000209	-3.481108**	0.0131
LNDIA(-1)	-4.52E-05	6.56E-05	-0.688968	0.5166
LNGCEA	0.000603	0.000182	3.311248**	0.0162
LNINFR	-0.303312	0.147789	-2.052337*	0.0860
LNINFR(-1)	0.081164	0.085653	0.947592	0.3799
LNRER	0.043108	0.068480	0.629504	0.5522
LNRER(-1)	-0.145063	0.108766	-1.333721	0.2307
C	152.3845	44.84127	3.398309**	0.0145
@TREND	0.715893	0.497718	1.438350	0.2004
R-squared	0.990725	Mean dependent var		76.89100
Adjusted R-squared	0.955171	S.D. dependent var		19.87616
S.E. of regression	4.208341	Akaike info criterion		5.702576
Sum squared resid	106.2608	Schwarz criterion		6.823534
Log likelihood	-61.53864	Hannan-Quinn criter.		6.061180
F-statistic	27.86548	Durbin-Watson stat		1.636854
Prob(F-statistic)	0.000240			

Source(s): Author Construction from EViews 13 computation, 2024. (***), (**) and (*) denote 1%, 5% and 10% significance level

To refine the model, dynamic regressors were incorporated with a one-period lag, ensuring that the model automatically adjusted to include only relevant variables. The selection process adhered to the guidelines suggested by the Phillips-Perron unit root test, which was employed to verify the stationarity of the variables, thereby ensuring robust and reliable estimation.

The lag value of cassava productivity is integrated into the model to capture the effects from previous years. At the 10% significance level, a 1% rise in the previous year's cassava productivity results in a 47.5% increase in the current year's cassava productivity. This suggests a strong positive persistence in cassava productivity from the previous period.

Among the climate variables, Average Annual Rainfall (LNARF), Average Annual Carbon Dioxide Emissions (LNDACDE), a lagged value of Average Annual Temperature (LNDATEMP(-1)), a lagged value of Average Annual Carbon Dioxide Emissions (LNDACDE(-1)), and Average Annual Sunshine Duration (LNASUN) exhibit significant impacts on cassava productivity.

Average Annual Rainfall (LNARF) is significant but negatively affects cassava productivity with a coefficient of -0.075117 (p = 0.0191). This indicates that higher levels of LNARF are

Vol. 10, No. 02; 2025

ISSN: 2456-8643

associated with a reduction in cassava productivity. Increased average annual rainfall can lead to decreased cassava productivity in Nigeria due to waterlogging, which suffocates the roots and causes root rot, as well as soil erosion that depletes nutrients. Excess moisture also promotes fungal and bacterial diseases, increases pest pressure, and can delay planting and harvesting, all of which negatively effect yield. Empirical studies indicate that increased rainfall can negatively effect cassava productivity in Nigeria. Osuji et al. (2024) found that insufficient or irregular rainfall was a significant constraint on cassava production, leading to decreased yields and reduced income for farmers. Similarly, Ogbuene et al. (2023) utilized a predictive model and highlighted that rainfall anomalies, including late onset and early cessation of rains, adversely affected cassava yields. Furthermore, Anyaegbu et al. (2022) revealed that rainfall, alongside other climatic variables, had a long-term significant negative effect on cassava yield.

A lag value of Average Annual Temperature (LNDATEMP(-1)), with a coefficient of 63.84915, was significant and positively related to cassava productivity in Nigeria at the 1% level of significance ($p = 0.0074$). This indicates that higher levels of temperature are associated with an increase in cassava productivity. Higher temperatures are beneficial for cassava as it thrives in warm climates. Optimal temperatures between 25°C and 29°C enhance physiological processes such as photosynthesis and respiration, leading to improved growth and starch accumulation in the roots. Warm temperatures also accelerate crop development, allowing for quicker maturation and potentially more frequent harvests. Additionally, higher temperatures can reduce the prevalence of certain diseases that thrive in cooler, wetter conditions, further boosting productivity. This finding aligns with Anyaegbu et al. (2022) and Sowunmi (2020), who noted that climatic variability, including temperature fluctuations, significantly influences cassava output, emphasizing the need for adaptive strategies in response to climate change.

Current and previous year's Average Annual Carbon Dioxide Emissions (LNDACDE and LNDACDE(-1)) were significant and negatively affect cassava productivity in the long run at the 5% and 1% levels of significance, respectively. This implies that increases in the current and previous year's carbon dioxide emissions are associated with a reduction in cassava productivity in Nigeria. Elevated CO_2 levels contribute to climate change effects such as global warming, which exacerbates extreme weather phenomena like extended droughts, irregular and intense rainfall, and temperatures exceeding optimal thresholds for cassava cultivation. These climatic disruptions induce physiological stress in cassava plants, impairing growth and reducing yields. Moreover, elevated CO_2 can increase the prevalence of pests and diseases, further compromising cassava productivity. Additionally, the alteration in the biochemical composition of crops under higher CO_2 conditions may diminish both nutritional quality and yield, undermining agricultural sustainability. Recent empirical studies indicate a significant link between increased carbon dioxide emissions and reduced cassava productivity in Nigeria. Oyeranti (2024) found that a 1% increase in CO_2 emissions correlates with a 2% decrease in agricultural output, highlighting the detrimental effect of carbon emissions on productivity across various crops, including cassava. Amaefule et al. (2023) confirm that carbon emissions negatively affect agricultural productivity, with a long-run relationship established between CO_2 emissions and crop production indices. Osuji et al. (2024) also emphasize that climate change, driven by increased CO_2, has led to decreased cassava yields and economic returns for farmers.

Current and previous year's Average Annual Sunshine Duration (LNASUN and LNASUN(-1)) were significant and positively affect cassava productivity in the long run at the 5% level of significance. This implies that increases in the current and previous year's sunshine duration are associated with an increase in cassava productivity in Nigeria. Longer sunshine duration enhances cassava productivity as the crop requires ample sunlight for optimal photosynthesis, which drives growth and starch accumulation in the roots. Extended sunshine also helps maintain warmer soil temperatures, promoting root growth and nutrient uptake, and reduces the risk of diseases that thrive in shaded, humid conditions. This finding aligns with Osuji et al. (2024), who identified that increased sunshine hours positively effect cassava production in Ebonyi State, Nigeria. It also supports Ogbuene et al. (2023) and Omodara et al. (2023), who found that higher sunshine hours positively correlate with increased cassava yield.

Macroeconomic variables such as the previous year's area of land under cassava cultivation (LNDALUC_CASSAVA(-1)), current value of Agricultural Foreign Direct Investment (LNDAFDI), current value of Private Domestic Investment in Agriculture (LNDIA), current value of Government Capital Expenditure in Agriculture (LNDGCEA), and Average Annual Inflation Rate (LNDINFR) also exhibit notable effects.

LNDALUC_CASSAVA(-1) shows a positive and significant effect on cassava productivity, suggesting that an increase in the area of land under cassava cultivation in the previous year positively influences cassava productivity in Nigeria. Expanding the area of land dedicated to cassava cultivation enhances overall production capacity, allowing for economies of scale in agricultural practices. This expansion facilitates better allocation of resources such as labor, machinery, and fertilizers, leading to more efficient cultivation processes. Additionally, with larger cultivation areas, there is potential for the implementation of improved farming techniques and crop management practices, which enhance yield per hectare. This finding aligns with the works of Agom and Inyang (2024), Nwakpu (2024), and Omoikhoje & Bigirimana (2022), who found that expanding the land area dedicated to cassava cultivation positively impacts productivity.

The current value of Agricultural Foreign Direct Investment (LNDAFDI) demonstrates a positive and significant effect (coefficient = 0.001810, p = 0.0441), indicating that foreign direct investment (FDI) substantially enhances cassava productivity. FDI enhances productivity by injecting capital that supports advanced agricultural technologies, such as high-yield seed varieties and mechanized farming techniques. This capital also aids in modernizing infrastructure and bringing technical expertise, which facilitates the adoption of best practices. By integrating local production into global value chains, FDI promotes increased productivity and sustainable practices, driving sectoral growth. This aligns with Ayuba et al. (2021), who observed that greater foreign direct investment and public agricultural spending significantly boost cassava productivity in Nigeria.

Conversely, the current level of Private Domestic Investment in Agriculture (LNDIA) reveals a negative and significant effect on cassava productivity at the 5% significance level. This suggests that increased LNDIA leads to decrease in cassava productivity. This paradox may arise if investments are diverted to more lucrative sectors, leading to a misallocation of resources away from cassava cultivation. As a result, this misdirection may reduce focus on cassava farming and its specific needs. The complex relationship between private investment and productivity is noted by Agunannah et al. (2023) and Ukpe et al. (2023), who highlight that without adequate public investment and supportive policies, private investment alone may not improve cassava yields.

Government Capital Expenditure in Agriculture (LNDGCEA) positively influences cassava productivity at the 5% level of significance. This indicates that heightened government capital

ISSN: 2456-8643

expenditure on agriculture is associated with increased cassava productivity. Government investments bolster productivity by funding critical infrastructure, such as irrigation systems, roads, and storage facilities, which enhance farming efficiency and reduce post-harvest losses. Additionally, such expenditures support research and development, leading to the dissemination of improved cassava varieties and farming techniques that boost yields. Government investment in extension services and farmer training further empowers local farmers with the necessary knowledge and tools to adopt best practices. By improving market access and ensuring a stable supply of essential inputs like fertilizers and pesticides, government capital expenditure plays a pivotal role in enhancing productivity. This finding is reinforced by Abubakar (2023), Patrick (2023), and Utuk (2022), who stated that increased government spending positively impacts agricultural output, including cassava productivity.

The Average Annual Inflation Rate (LNDINFR) exhibits a negative and significant relationship with cassava productivity (coefficient = -0.303312, p = 0.0860). Rising inflation rates escalate the costs of essential inputs such as seeds, fertilizers, and machinery, thereby diminishing farmers' purchasing power and increasing production expenses. This surge in input costs can curtail investment in productivity-enhancing practices and technologies. Furthermore, inflation can foster economic instability, complicating long-term planning and investment in cassava farming. High inflation also erodes the profitability of cassava cultivation, discouraging investment and diminishing overall productivity. This finding aligns with Okafor & Isibor (2021), who reported that escalating inflation rates adversely affect cassava productivity in Nigeria, underscoring the negative effect of inflation on agricultural performance and economic stability.

ARDL Error Correction Regression Estimated Short-run Coefficients

Table 4.9 presents the result of the ARDL error correction regression estimated short-run coefficients for effect of climate change on cassava productivity within the study period, with selected macroeconomic controls.

The ECM results of the short run indicate that not all climate change indicators and macroeconomic determinants have a significant effect on cassava productivity in the short run. In the short run, the immediate effects of certain climatic variables, such as average annual rainfall (DLN(ARF)) and carbon dioxide emissions (DLN(DACDE)), show a deflationary impact, both at a 1% significance level.

Table 4. Results of the ARDL Error Correction Regression Estimated Short-run Coefficients for the Effect of Climate Change on Cassava Productivity in Nigeria (1991–2022), with Control for selected Macroeconomic Variables

ARDL Error Correction Regression
Dependent Variable: DLN(APFC_CASSAVA)
Selected Model: ARDL(1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1)
Case 4: Unrestricted Constant and Restricted Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	153.1004	15.24473	10.04284***	0.0001
DLN(ARF)	-0.075117	0.009829	-7.642338***	0.0003
DLN(DATEMP)	6.308784	3.056748	2.063887*	0.0846

Vol. 10, No. 02; 2025

ISSN: 2456-8643

DLN(DACDE)	-0.003569	0.000358	-9.955172***	0.0001
DLN(DARELH)	0.418399	0.106158	3.941273***	0.0076
DLN(ASUN)	14.07960	1.660614	8.478552***	0.0001
DLN(DALUC_CASSAVA)	-4.41E-06	6.17E-07	-7.145047***	0.0004
DLN(DAFDI)	0.001810	0.000200	9.030513***	0.0001
DLN(DIA)	-0.000729	7.17E-05	-10.16595***	0.0001
DLN(DINFR)	-0.303312	0.051731	-5.863288***	0.0011
DLN(DRER)	0.043108	0.025831	1.668874	0.1462
ECM(-1)	-0.525401	0.052976	-9.917636***	0.0001
R-squared	0.893375	Mean dependent var		1.838000
Adjusted R-squared	0.828215	S.D. dependent var		5.862168
F-statistic	13.71056	Durbin-Watson stat		1.636854
Prob(F-statistic)	0.000001			

Diagnostic test

Test statistics	***F-statistic***	***P-value***	***Interpretation***
Heteroskedasticity test: Breusch-Pagan-Godfrey	0.711014	0.7454^{ns}	No heteroskedasticity
Breusch-Godfrey Serial Correlation LM Test	0.531324	0.6243^{ns}	No Serial Correlation
Ramsey RESET stability	0.092726	0.5427^{ns}	Model correctly specified
Jacque-Bera test	0.588258	0.7696^{ns}	Normal distribution

Source(s): Author Construction from EViews 13 computation, 2024. (***), (**) and (*) denote 1%, 5% and 10% significance level. (^{ns}) denote not significant.

Conversely, average annual temperature (DLN(DATEMP)) at a 10% significance level, relative humidity (DLN(DARELH)) at a 1% significance level, and sunshine duration (DLN(ASUN)) at a 1% significance level exhibit a positive and significant influence on cassava productivity. The ARDL results for cassava productivity in Nigeria during the study period suggest that, in the short term, achieving positive and meaningful cassava productivity necessitates strategic mitigation efforts to control variations in rainfall patterns and reduce carbon dioxide emissions. To this end, it is imperative that the Nigerian government implements robust climate change policies that proactively address the effects of rainfall variability and carbon dioxide emissions on cassava production.

Additionally, the ARDL error correction regression's estimated short-run coefficients for the effect of climate change on cassava productivity indicate that the area of land under cassava cultivation (DLN(DALUC_CASSAVA)) at a 1% significance level has a negative and significant effect on cassava productivity in the short run. This finding suggests that an increase in the land area under cassava cultivation leads to a reduction in productivity, which deviates from theoretical expectations and can be attributed to several underlying factors. Firstly, the expansion into less fertile or marginal lands may negatively affect productivity due to suboptimal soil conditions. Additionally, the increased demand for inputs such as labor and fertilizers may not be efficiently met, potentially diluting productivity per hectare. Furthermore, newly cultivated areas may experience a lag in reaching optimal productivity levels due to initial inefficiencies or inadequate management practices. These factors collectively contribute to a temporary decline in cassava productivity, illustrating the complex dynamics between land expansion and cassava output. This finding aligns with the studies by Abubakar (2023) on cassava production in Marga Tiga Sub-District, which found that land area under cultivation negatively affected cassava productivity, and Abubakar (2023), who reported similar findings in Nigeria during the period TB 1996–TTE 2017.

Moreover, the ARDL error correction regression's estimated short-run coefficients for the effect of climate change on cassava productivity indicate that macroeconomic indicators such as private domestic investment in agriculture (DLN(DIA)) and the inflation rate (DLN(DINFR)), both at a 1% significance level, have a deflationary effect, while agriculture foreign direct investment (DLN(DAFDI)) at a 1% significance level has a positive and significant effect on cassava productivity. These results suggest that, in the short term, improvements in private domestic investment in agriculture and better management of the inflation rate are necessary for achieving positive and meaningful cassava productivity. To support this, the Nigerian government should implement strong economic policies that address these challenges proactively.

The adjustment speed to equilibrium, as indicated by the Error Correction Model (ECM), is negative and significant at the 1% level, confirming the model's long-term stability. With an ECM coefficient of -0.525401, which is negative and lies between zero and one, the speed of adjustment to long-run equilibrium is approximately 52.5% annually. Ehirim et al. (2017) indicated that an ECM that is negative and significantly different from zero justifies long-run adjustment with a speed of less than 100%. The results, therefore, indicate that the stochastic error (residuals) processes generated and their movements over time in the model can be corrected, with the speed of adjustment back to equilibrium in the long run being 52.5 percent. Consequently, the short-run analysis suggests that while average annual temperature, average annual sunshine duration, and foreign direct investment in agriculture positively and significantly influence cassava productivity, annual rainfall, average annual carbon dioxide emissions, the average annual area of land under cassava cultivation, private domestic investment in agriculture, and the average annual inflation rate contribute to a slowdown in cassava productivity.

Diagnostic tests for serial autocorrelation, heteroskedasticity, and model stability were conducted to assess the model's robustness. The Breusch-Pagan-Godfrey correlation and heteroskedasticity tests, along with the Breusch-Godfrey serial correlation LM test and the Ramsey RESET stability test, confirm the absence of serial autocorrelation, homoscedasticity, and model instability issues. The Breusch-Pagan-Godfrey test for heteroskedasticity yields an F-statistic of 0.711014 with a p-value of 0.7454, indicating that there is no evidence of heteroskedasticity in the model's residuals, meaning the variance of the errors is constant. The Breusch-Godfrey Serial Correlation LM Test shows an F-statistic of 0.531324 and a p-value of 0.6243, suggesting that there is no serial correlation in the residuals, implying that the errors are independent over time. Lastly, the Ramsey RESET test for model specification returns an F-statistic of 0.092726 with a p-value of 0.7696, confirming that the model is correctly specified without any omitted variables. The p-values for these tests exceed the 5% significance level, indicating that the relationship between the dependent and independent variables is accurately defined. Overall, these diagnostic tests validate the robustness and adequacy of the model. Additionally, the CUSUMSQ tests demonstrate that all parameters maintain long-run stability at the 5% significance level, as illustrated in Figure 4.1.

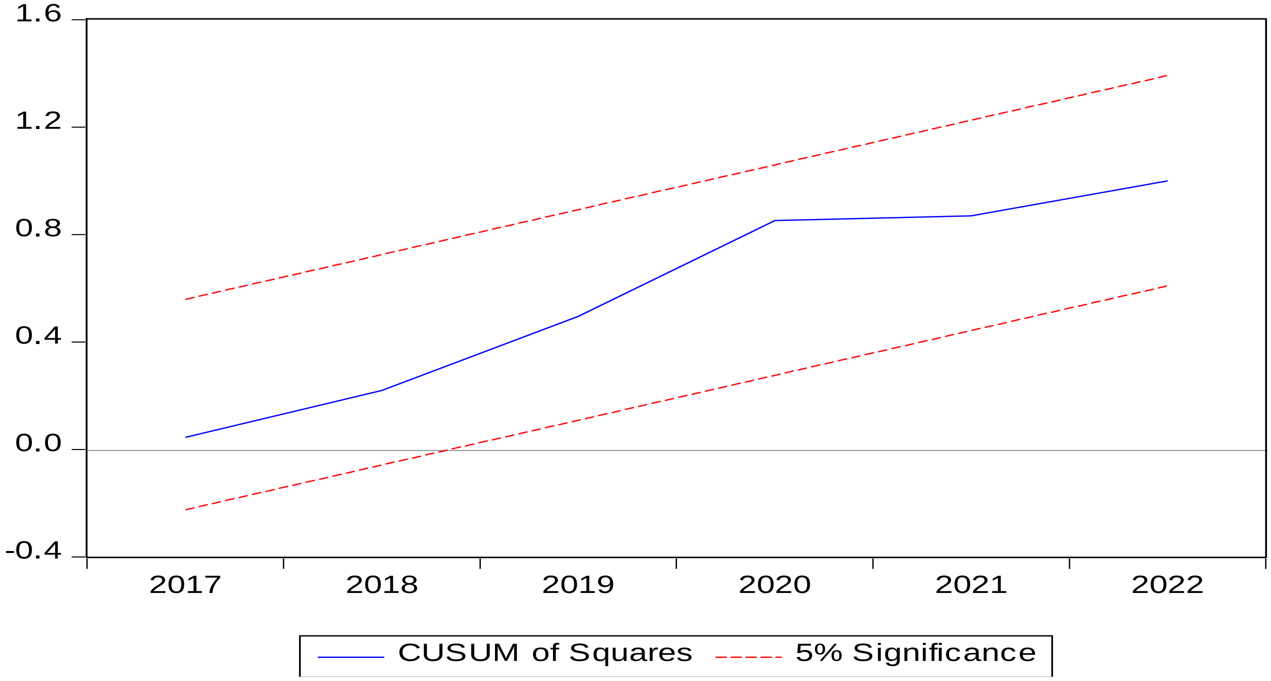

Figure 4.1 CUSUM of Squares (CUSUMSQ) plot for the ARDL model analyzing cassava productivity from 1991 to 2022

The CUSUM of Squares (CUSUMSQ) plot for the ARDL model analyzing cassava productivity from 1991 to 2022 indicates that the model's parameters are stable, as the blue line (representing the cumulative sum of squared residuals) remains within the 5% significance boundaries throughout the period. This stability suggests that the relationship between cassava productivity and its determinants is consistent over time, making the model reliable for forecasting and policy analysis.

4. CONCLUSION AND RECOMMENDATIONS

In the long-run, Average Annual Rainfall (LNARF), Average Annual Carbon Dioxide Emissions (LNDACDE), a lagged value of Average Annual Temperature (LNDATEMP (-1)), a lagged value of Average Annual Carbon Dioxide Emissions (LNDACDE (-1)), and Average Annual Sunshine Duration (LNASUN) exhibit significant impacts on cassava productivity. Also, Macroeconomic variables such as the previous year's area of land under cassava cultivation (LNDALUC_CASSAVA (-1)), current value of Agricultural Foreign Direct Investment (LNDAFDI), current value of Private Domestic Investment in Agriculture (LNDIA), current value of Government Capital Expenditure in Agriculture (LNDGCEA), and Average Annual Inflation Rate (LNDINFR) were the significant variables that influenced cassava productivity between 1991 and 2022. In the short run, the ARDL model shows that among the climate variables, the current values of average annual rainfall (DLN(ARF)), average annual temperature (DLN(DATEMP)), average annual relative humidity (DLN(DARELH)), average annual sunshine duration (DLN(ASUN)), and the area of land under cassava cultivation (DLN(DALUC_CASSAVA)) exhibit significant impacts on cassava productivity in Nigeria. Specifically, DLN(ARF) and DLN(DACDE) negatively effect cassava productivity, while DLN(DATEMP), DLN(DARELH), and DLN(ASUN) positively influence it. Among the controlling macroeconomic variables, the current values of foreign direct investment in agriculture (DLN(DAFDI)), domestic investment in agriculture (DLN(DIA)), and the inflation rate (DLN(DINFR)) were significant. The error correction term (ECM (-1)) was also significant, indicating a strong correction of disequilibrium in the short run. These variables were key in influencing cassava productivity in Nigeria during the period under study.

REFERENCES

Ayuba, A., Dzever, D. D., Raoul, C., Frimpong, E., & Obekpa, H. O. (2021). Can Foreign Direct Investment Complement or Substitute Public Agricultural Spending for the Sustainability of the Agricultural Sector in Nigeria? Empirical Evidence Using Monte Carlo Simulation. *Journal of Applied Economic Sciences (JAES)*, *16*(16), 302–302. https://doi.org/10.57017/jaes.v16.3(73).05

Abubakar, S. (2023). Effect of Government Expenditure on Agricultural Productivity in Nigeria. *Gusau Journal of Economics and Development Studies*, *3*(1), 15–15. https://doi.org/10.57233/gujeds.v3i1.16

Agunannah , M. U., Njoku , K. N., Ikechukwu , C. E., & Anyim , E. I. (2023). Analysis of the determinants of investment among the Pro-Vitamin-A cassava farming household in southeast Nigeria. *GSC Advanced Research and Reviews*, *17*(1), 032–037. https://doi.org/10.30574/gscarr.2023.17.1.0380

Amaefule, C., Shoaga, A., Ebelebe, L.O., & Adeola, A.S. (2023). Carbon emissions, climate change, and Nigeria's agricultural productivity. *European Journal of Sustainable Development Research*, *7*(1), em0206–em0206. https://doi.org/10.29333/ejosdr/12572

Anyaegbu, C. N., Okpara, K. E., Taweepreda, W., Akeju, D., Techato, K., Onyeneke, R. U., Poshyachinda, S., & Pongpiachan, S. (2022). Effect of Climate Change on Cassava Yield in Nigeria: An Autoregressive Distributed Lag Bound Approach. *Agriculture*, *13*(1), 80. https://doi.org/10.3390/agriculture13010080

Ayinde .O.E., M. Muchie and G.B. Olatunji (2011). Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach. J Hum Ecol, 35(3): 189-194.

Agom D. I., & Inyang, N, N. (2024). Analysis of Technical Efficiency of Cassava Farmers in Abak Local Government Area of Akwa Ibom State, Nigeria. *AKSU Journal of Agricultural Economics Extensin and Rural Development/Aksu Journal of Agricultural Economics Extension and Rural Development*, *7*(1), 115–125. https://doi.org/10.61090/aksujaeerd.2024.013

Ayinde, A.S., Folorunsho, R. and Oluwaseun A.E. (2020), "Sea surface temperature trends and its Relationship with precipitation in the Western and Central Equitorial Africa", Climate Change, Vol. 6 No. 21, pp. 36-51.

Chikezie C, Ibekwe U. C, Ohajianya D. O, Orebiyi J. S, Ehirim N. C, Henri-Ukoha A, Nwaiwu I.U.O, Ajah E. A, Essien U. A, Anthony G and Oshaji I.O (2015) Effect of Climate Change on Food Crop Production in Southeast, Nigeria: A Co-Integration Model Approach. International Journal of Weather, Climate Change and Conservation Research Vol.2, No.1, pp.47-56.

Okafor, O., & Isibor, A. (2021). Macroeconomic Variables and Nigerian Agricultural Sector Development. *British Journal of Management and Marketing Studies*, *4*(4), 9–20. https://doi.org/10.52589/bjmms-ttly6klr

Oyinloye, O.D., Akinola, O.O., Akande, Y.O., Akinyele, A.A. and Mosimabale, M.M. (2018), "Food insecurity in Africa", Journal of Humanities and Social Science, Vol. 23 No. 9, pp. 68-75.

Ughaelu, C.M. (2017), "Contemporary environmental issues respect to food production in Nigeria", Journal of Environmental Management, Vol. 41 No. 2, pp. 108-117.

Nwakpu, C. C. (2024). Resource productivity and allocative efficiency in improved cassava (Manihot esculenta) -based mixed cropping system in Ebonyi State, Nigeria. *Farming and Management*, *9(1)* 2024). https://doi.org/10.31830/2456-8724.2024.fm-136

Osuji, Orji, N., Anyanwu, Umeh, H., Eze, & A, O. E. (2024). Effect of Climate Change on Sustainability of Cassava Production in Ebonyi State, Nigeria. *Sumerianz Journal of Agriculture and Veterinary*, *72*, 5–14. https://doi.org/10.47752/sjav.72.5.14

Ogbuene, E.B., Nwobodo, T.N., Aloh, O.G., Okolo, O.J., Ozorme, V.A., Achoru, F., & Ogbuka, J. C. (2023). Application of Predictive Model for Efficient Cassava (ManihotEsculanta) Yield in the Face of Climate Variability in Enugu State, Nigeria. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-3481238/v1

Omodara, O. D., Ige, O. A., Oluwasola, O., Oyebanji, A. T., & Afape, O. O. (2023). Factors influencing cassava farmers' choice of climate change adaption practices and its effect on cassava productivity in Nigeria. *Heliyon*, *9*(3), e14563. https://doi.org/10.1016/j.heliyon.2023.e14563

Sowunmi, F. A. (2020). Effects of Climatic Variability on Cassava Production in Nigeria. *Journal of Agribusiness and Rural Development*, *57*(3). https://doi.org/10.17306/j.jard.2020.01373

Oyeranti, O. A. (2024). Effect of Carbon Footprint on Agricultural Productivity in Nigeria: An Empirical Analysis. *International Journal of Social Science and Economic Research*, *09*(05), 1518–1535. https://doi.org/10.46609/ijsser.2024.v09i05.013

Oyeranti, O. A. (2024). Effect of Carbon Footprint on Agricultural Productivity in Nigeria: An Empirical Analysis. *International Journal of Social Science and Economic Research*, *09*(05), 1518–1535. https://doi.org/10.46609/ijsser.2024.v09i05.013

Ogbo, A., Ebele, N. and Ukpere, W. (2019), "Risk management and challenges of climate Change in Nigeria", Journal of Human Ecology, Vol. 41 No. 3, pp. 221-235.

Omoikhoje, I. D., & Bigirimana, E. (2022). Economic and Environmental Factors that Influence the Productivity of Cassava Production in Nigeria. *Journal of Basic and Applied Research International*, 51–59. https://doi.org/10.56557/jobari/2022/v28i37805