



EFFECTS OF CLIMATE CHANGE ON CASSAVA OUTPUT IN NIGERIA

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ABSTRACT

The study examined the effects of climate change on cassava output in Nigeria. The study specifically described crop output trend in Nigeria, determine the relationship between the climatic variables and the selected crop output, analyzed the effect of the climatic variables on the selected crops output and determine the time span for possible disequilibrium adjustment for the changes in the climatic variables. Data were secured from the Food and Agriculture Organization (FAO) and the Nigerian Meteorological Agency (NIMET) from 1981-2018. The effect of climate change was analyzed using Autoregressive Distributed Lag Bound approach, Error Correction Model and Augmented Dickey– Fuller tests for stationarity test. On the effects of climatic variables on cassava output, the coefficient of multiple determination (R^2) 0.6589, shows that about 65.89%, of the variations in maize output was explained by the climatic variables. F-statistics of 4.41 is significantly higher than the lower bound of 2.9 and the upper bound of 3.8 at 5% level. This indicates that there is a long run relationship between maize output and the climatic variables in the model. The ECM value of maize output is -0.213. The magnitude of the coefficient estimate of ECM suggests that 21.3% of the disequilibrium caused by previous years' shocks converges back to the long-run equilibrium in the current year. This reveals that the speed of adjustment will adjust to the long-term equilibrium. The model used in the study was subjected to diagnostic tests such as CUSUM and Ramsey stability test, normality tests, serial correlation tests and heteroscedasticity test. This paper recommends the need for programmes to intimate farmers with modern adaptation strategies especially the use of irrigation facilities to supplement rainfall in the study area. Sensitization of farmers on the importance of weather forecast.

Key words: Climate Change, Cassava, ARDL, Bound, Approach, Nigeria.

DOI:10.5281/zenodo.12779181

Manuscript ID # 158

INTRODUCTION

Climate change is one of the most noticed environmental problems facing mankind worldwide. It also affects agriculture in several ways and has direct impact on food production. Climate change was defined by the Intergovernmental Panel on Climate Change (IPCC, 2014) as statistically significant variations that persist for an extended period, typically decades or longer. It includes shifts in the frequency and magnitude of sporadic weather events as well as the slow continuous rise in global mean surface temperature. Climate change can be seen in different ways. These includes changes in average climatic conditions – some regions may become drier or wetter on average; changes in climate variability – rainfall events may become more erratic in some regions; changes in the frequency and magnitude of extreme weather events and changes in sea levels. Climate change is a process of global warming, in part attributable to the greenhouse gases generated by human activity. These greenhouse gases are generated from the burning of fossil fuels such as coal, oil and gas. These fuels contain carbon and carbon dioxide is one of the gases which contribute to global warming.

Climate change impacts are felt on agricultural production, health, biodiversity, social and economic conditions (Adepoju, 2017, Borokinni, 2016). Climate change has strong impact on health, water resources and land use, coastal Infrastructure, environment and other sectors and even a stronger impact on agriculture especially in developing countries like Nigeria (Onu and Ikehi, 2016). It is predicted to worsen the incidence of drought and desertification and millions of people will become refugees as a result. The impacts of climate change are being felt by both developed and developing countries, and in Nigeria for example, more than two thirds of the country is thought to be prone to desertification. Desert covers about 35 percent of Nigeria's land mass, is advancing at an estimated 0.6 km per annum, while deforestation is taking place at 3.5 percent per annum. An empirical assessment belt has moved from Kebbi, Kano, Maiduguri to new Bussa, Kaduna, Jos, Sheleng while Savannah now interface between desert and forest along Oyo, Osun, Kogi and Benue states. Moreover, the Sudano-Sahelian region of Nigeria has suffered a decrease in rainfall in the range of 3-4 percent per decade since the beginning of the nineteenth century.

The concern with climate change is heightened given its linkage to the agricultural sector and poverty. In particular, it is anticipated that adverse impacts on the agricultural sector will exacerbate the incidence of rural poverty. Impacts on poverty are likely to be especially severe in Nigeria where the agricultural sector is an important source of livelihood for a majority of the rural population. The Nigerian agriculture is rain fed. Also the Nigerian food production system will be adversely affected by the variability in timing and amount of rainfall, frequent outbreaks of crop pests and diseases and heat stress. Although Nigeria has made some efforts to adapt and mitigate climate change risks, the efforts are still rudimentary especially when compared with the impending catastrophe.

Cassava (*Manihot esculentus* Crantz) belongs to the family Euphorbiaceae and was said to originated in Latin America, it was cultivated in every part of the world (Nwaogu *et al.*, 2016, Audu *et al.*, 2018). It is one of the important root crops of the tropics (Lawal *et al.*, 2018). According to the International Fund for Agricultural Development (IFAD, 2013) There is about 600 million people in Africa that depends on Cassava production for their food. Nigerian cassava production according to Elega *et al.*, (2018) is by far the largest in the world with about 45 million metric tonnes, a third more than production in Brazil and almost double the production of Indonesia and Thailand. In Sub-Saharan Africa the per kg/year cassava consumption is 103, which is higher than maize (40), banana/plantain (28), sorghum (23), milk (27), meat (41), yam (28) and millet (11) in the same region (IITA, 2004). Cassava is cultivated in almost all the ecological zones in Nigeria because of its ability to adapt to weather conditions of the country and its ability to be processed into different products, its appropriateness to the prevailing climatic conditions in the areas it's easy to plant and process. In view of the above, cassava is hardy and any extreme weather events that affect cassava will most likely affect many other staple food crops which could lead to food crisis in Nigeria. Therefore, this informed the choice of cassava for the study. Several scholars have studied the effects of climate change on crops but have not attributed it specifically to climatic variables such as temperature, rainfall, pressure, sunshine and carbon dioxide emissions. But the study sought to find out the effects of temperature, rainfall, pressure, sunshine and carbon dioxide emissions on the production of cassava in Nigeria. The main objective of the study is to examine the impact of some climatic variables on crop output in Nigeria. The specific objectives are to: analyze the impact of the climatic variables on the selected crops output and determine the time span for possible disequilibrium adjustment for the changes in the climatic variables.

Methodology

Study Area

The study area is the Federal Republic of Nigeria. It is situated at the western coast of Africa. The Federal Republic of Nigeria, with an area of 923,769 square kilometers (made up of 909,890 square kilometers of land

area and 13,879 square kilometers of water area), is situated between 4° and 14° North Latitude and Longitude 3° and 14° East of the Greenwich meridian (Manufacturing Sector Report, 2015).

This study employed time series data which was obtained from NIMET that spanned from 1981 to 2018. The aggregate national data on the production of cassava was collected from Food and Agriculture Organization Statistical website (FAOSTAT). Data for this study was analyzed using Descriptive statistics; Augmented Dickey Fuller Test, Multiple Regression Analysis, Correlation Analysis, Autoregressive Distributed Lag (ARDL) Bound approach and Error Correction Model.

Source of Data

This study employed time series data which was obtained from NIMET that spanned from 1981 to 2018. The aggregate national data on the production of cassava was collected from Food and Agriculture Organization Statistical website (FAOSTAT).

Method of Data Analysis

Data for this study was analyzed using Descriptive statistics; Augmented Dickey Fuller Test, Multiple Regression Analysis, Correlation Analysis, Autoregressive Distributed Lag (ARDL) Bound approach and Error Correction Model.

Model specification

The long run dynamic relationship between the output of crop and the climatic variables was estimated using Autoregressive Distributed Lag (ARDL) Bound approach. ARDL model was chosen for the study because it used to determine the long-term relationship between variables under study. The relationship used to quash when the series is integrated in different order 2(1) hence showing presence of unit root (Anyaebe, *et al.*, 2023). When the series are integrated in different orders, such as I(0) and I(1), the Bounds Test Co integration and Error Correction Model (ECM) of ARDL becomes appropriate to established a long run relationship in the model. The Johansen Co integration Test is no longer valid in the study because of the combination of I(0) and I(1) order of integration in the series. The unit root test was certain that no variable was integrated at order 2(1) and for ARDL model specification and appropriate interpretation.

The empirical regression model

The model is specified as follows in equations 1 and 2;

$$Y_{it} = f(T_t, R_t, AP_t, SH_t, CO_{2t}) + e_t \text{-----} 1$$

Where Y_{it} = output for crop i at time t (kilogrammes)

T_t = mean annual temperature (degree centigrade)

R_t = total annual rainfall (mm)

AP_t = total annual mean atmospheric pressure (kpa)

SH_t = total annual sunshine (hours)

CO_{2t} = total annual CO_2 eq emission (parts per million)

e_t = stochastic error term

$$Y = \beta_0 + \beta_1 T_{it} + \beta_2 R_t + \beta_3 AP_t + \beta_4 S_t + \beta_5 nCO_{2t} + \varepsilon_t \text{-----} 2$$

Where,

$\beta_0 - \beta_5$ = parameters to be estimated;

ε_t = stochastic error term

Four functional forms of multiple regression that were tried to select the best fit based on statistical, economic and econometric criteria. The functional forms are: linear function, exponential function, semi-log function and double log function as shown in equations 3-6.

$$\text{Linear function: } Y = \beta_0 + \beta_1 T_{it} + \beta_2 R_t + \beta_3 AP_t + \beta_4 S_t + \beta_5 nCO_{2t} + \varepsilon_t \text{-----} 3$$

$$\text{Semi-log: } \ln Y = \beta_0 + \beta_1 T_{it} + \beta_2 R_t + \beta_3 AP_t + \beta_4 S_t + \beta_5 nCO_{2t} + \varepsilon_t \text{-----} 4$$

$$\text{Exponential: } Y = \ln \beta_0 + \ln \beta_1 T_{it} + \ln \beta_2 R_t + \ln \beta_3 AP_t + \ln \beta_4 S_t + \ln \beta_5 nCO_{2t} + \varepsilon_t \text{-----} 5$$

$$\text{Double-log: } \ln Y = \ln \beta_0 + \ln \beta_1 T_{it} + \ln \beta_2 R_t + \ln \beta_3 AP_t + \ln \beta_4 S_t + \ln \beta_5 nCO_{2t} + \varepsilon_t \text{-----} 6$$

3.3.3.2 Unit root test

Testing for the existence of unit root is a key pre-occupation in the study of time series models and cointegration. Generally, time series data contains unit root meaning that these series are not stationary. Augmented Dickey Fuller (ADF) test (1979), generally a popular method, is being applied to test whether the unit root under the hypothesis series has unit root.

The model to check the unit root is as shown in equation 7:

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum Y \Delta Y_{tj} + e_t; \dots \dots \dots 7$$

Where, Y_t = series tested

ΔY_t = first difference of Y_t

δ = test difference coefficient

j = lag length chosen for ADF

e_t = white noise

t = time or trend variable

The significance of δ was tested against null hypothesis (H_0), $\delta=0$ and alternative hypothesis, $\delta<0$. If we do not reject the null hypothesis, the series is non-stationary. Hence the hypothesis of non-stationarity cannot be rejected, each of the variables was differenced until they became stationary (that is significant at 5% level). At this point, the existence of a unit root was rejected. The stationarity test is also known as the unit root test. The unit root test was to ascertain that no variable was integrated at order 2 and for ARDL model specification (Nkoro and Uko, 2016)

3.3.3.4 Co-integration technique

The Bound test ARDL model was adopted in testing the long-run relationship between crop output and the climatic variables and the model to check co integration is presented in equation 8:

$$\ln Y_t = \beta_0 + \sum_{i=1}^p \alpha_1 \ln Y_{t-1} + \sum_{i=0}^{q1} \alpha_2 \ln temp_{1t-1} + \sum_{i=0}^{q2} \alpha_3 \ln rainfall_{2t-1} + \sum_{i=0}^{q3} \alpha_4 \ln pressurs_{3t-1} + \sum_{i=0}^{q4} \alpha_5 \ln sunshine_{4t-1} + \sum_{i=0}^{q5} \alpha_6 \ln co2emissions_{5t-1} \dots \dots \dots 8$$

When the series are integrated in different orders, such as $I(0)$ and $I(1)$, the Bounds Test co integration and Error Correction Model (ECM) of ARDL become appropriate to established a long run relationship in the Model. The Johassen Co integration Test is no longer valid in the study because of a combination of $I(0)$ and $I(1)$ order of integration in the series.

3.3.5 Granger causality test

Granger (1988) showed that in the case of a bivariate system, with time the series X_t and Y_t which are integrated at the same order, when the past and the present value of Y_t provides some useful information to forecast X_{t+1} at time t , it is said that Y_t Granger causes X_t . Granger causality test will be carry out to determine the direction of causality. When two variables are co-integrated and stationary, one can go ahead to carry out the Granger causality test. This is because one granger causal relationship must exist in a group of co-integrated series (Chirwa, 2000). When Granger causality run one way (uni-directional), the variable which Granger-causes the other is tagged the exogenous variable. Exogeneity can be weak or strong. Hendry (1986) observed that weak exogeneity occurs when there is no significant Granger causality from the other variable. It could also be bi-directional which means that both variables influence each other (e.g, X causes Y and Y also causes X). It also shows how much of the current Y can be explained by the past values of Y and then to show whether lagged values of X can improve the prediction of Y , of equivalent if the coefficient on the lagged X s are statistically significant. This test assumes that the information relevant to the prediction of the variables in question is contained solely in the time series data on these variables.

Granger model that was used in this study can be represented by equation 9:

$$\Delta Y_{it} = \sum_{i=1}^m a_i \Delta Y_i (t-1) + \sum_{j=1}^n a_j \Delta Y_j (t-1) + \rho_i \dots \dots \dots 9$$

Where,

m and n = are the numbers of lags determine by suitable information criteria (Akaike).

α = parameter to be estimated

Rejection of the null hypothesis indicates that variable j Granger cause change i . The hypothesis under Granger causality can be stated as follow:

H_0 : Variable j does not cause change in variable i

H_1 : Variable j causes change in variable i

3.3.6 Error correction model

Vector error-correction models (ECMs) ARDL are widely used to model of economic variables that are non-stationary individually but linked by long-run relationships. A “standard” ECM assumes that these variables follow a linear adjustment process towards their long-run equilibrium. The short and long run equilibrium will be investigated with the help of error correction model (ECM) which is an appropriate system of single equation. The error correction model tells us the degree to which the equilibrium behavior drives short run dynamics. Equilibrium relationship in turn have implications for a short run behavior, one or more series move to restore equilibrium. Short and long run equilibrium among the variable Temperature (T), Rainfall (R), Atmospheric Pressure (AP), Sunshine Hours (SH) and Carbon Dioxide (CO₂) in the system will be investigated with the help of ECM as given in equation 10.

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta \zeta_t - \alpha_2 + (Y_t - Z_t)_{t-1} + e_t \dots \dots \dots 10$$

Where,

Z_t= the vector of explanatory variables

Y_t and Z_t= the co integrating variables

α₂=error correction term (ECT)

e_t=error term

In line with some scholars (Edet *et al.*, 2021), the ECM is specified as equation 11:

$$\Delta Y_t = \beta_0 + \sum_{i=0}^p \alpha_1 \Delta Y_{t-1} + \sum_{i=0}^{q1} \alpha_2 \Delta temp_{1t-1} + \sum_{i=0}^{q2} \alpha_3 \Delta rainfall_{2t-1} + \sum_{i=0}^{q3} \alpha_4 \Delta pressure_{3t-1} + \sum_{i=0}^{q4} \alpha_5 \Delta sunshine_{4t-1} + \sum_{i=0}^{q5} \alpha_6 \Delta carbon\ dioxide\ emissions_{5t-1} \dots \dots \dots 11$$

$$\alpha(-temp - rainfall - pressure - sunshine - Carbon\ dioxide\ emissions) + e_t$$

ECM is the speed of adjustment measuring long-run disequilibrium correction. The component displays the rate of convergence to equilibrium in the presence of shocks. With a number less than or equal to 1, it is anticipated that the ECM will be negative. The presence of co integration in the model confirms a long-term relationship.

RESULTS AND DISCUSSION

Unit Root Test

The Augmented Dickey Fuller test (ADF) was used to check the stationarity of the climatic variables and cassava output for the presence of unit root. This is to test whether output of cassava and the climatic variables were stable or not. Unit root test was carried out for the five climatic variables; temperature, rainfall, pressure, sun shine and CO₂ emissions. The result revealed that at Level, all the five climatic parameters with p-values of 0.0007, 0.0000, 0.0000, 0.0603 and 0.030 were significant at 1%, 5% and 10% respectively. The null hypothesis was therefore rejected which means that the climatic variables were stationary at level I (0). The P-value for the output of cassava was insignificant at 1%, 5% and 10%. To make the outputs of the crop attained stationarity, its first difference was taken. And the P-value for the coefficients at First Difference was found to be significant at 1%, therefore, the null hypothesis for the existence of unit root was not rejected for the output of cassava at first difference.

Table 1: Unit Root Results

Variables	Intercept	Trends &	Remarks	FIRST	Intercept	
Trends &	Order of	intercept	DIFFERENCE			
intercept	integration					
	ADF	P-value	ADF	P-value	ADF	P-
value		ADF	P-value			
Temp	-4.316941	0.0015	-5.213318	0.0007	-9.9063709	0.0000
-8.985581		0.0000	I (0)			
Rainfall	-3.309789	0.0214	-4.839453	0.0000	-10.28861	0.0000 -
10.21546	0.0000	I (0)				
Pressure	-6.809579	0.0000	-6.732138	0.0000	-7.820158	0.0000 -
7.721582	0.0000	I (0)				
Sunshine	-3.571423	0.0115	-3.451851	0.0603	-7.069989	0.0000 -
6.972437	0.0000	I (0)				
CO ₂	-3.485668	0.0139	-4.679216	0.030	-9.41490	0.0000 -
9.392250	0.0000	I (0)				
Cassava	-1.194426	0.6669	-1.326745	0.8658	-6.288654	0.0000 -
6.416877	0.0000	I (1)				

Source: Field Survey, 2022

Testing for lag length

The lag selection-order criterion was used to select the appropriate lag length to be included in the co-integration model. Results in Table 2 is the lag selection order for the various information criteria for cassava, cowpea, groundnuts maize, sorghum and soya beans. On the basis of the Akaike's information criterion (AIC), Hannan-Quin information criterion (HQIC) and Schwarz's information criterion (SIC). The appropriate lag order is 1 selected by using Akaike criteria.

Table 2: VAR Lag Order Selection Criteria

Lag	Logl	LR	FPE	AIC	SC	HQ
0	554.1111	NA	2.40e-21		-30.45062	-30.18670 -30.35850
1	643.2728	143.6494		1.29e-22*	-33.40405	-31.55661* -32.75924*
2	680.4912	47.55680		1.44e-22	-33.47173	-30.04078 -32.27424
3	723.7352	40.84153		1.59e-22	-33.87418*	-28.85970 -32.12399

Source: Field Survey, 2022

*indicates lag order selected by the criterion

LR sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Aaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Effects of Climatic Variables on Cassava Output

The results of the effects of climatic variables in Table 3 show considerable similarities in the explanatory power of the independent variables included particularly in terms of the signs, magnitude and levels of significance of the coefficients. However, the semi-log function was chosen as the lead equation based on apriori expectation of fulfilling economic, statistical and econometric. criteria with respect to the signs, magnitude and significance of the regression coefficient. The result in Table: 4.9 shows that, the coefficient of multiple determination (R^2) is 0.7593 indicating that about 76% of the variation in cassava crop output is explained by the climatic variables included in the model. The value of F-statistic shows that the equation has a good fit at 1 percent level of significance, which means that the explanatory variables explains the variations in cassava output in Nigeria. The result reveals that temperature and rainfall had a positive relationship with cassava output and are significant at 5% and 1% level respectively. This implies that increase in the amount of rainfall will positively lead to increase in the output of cassava. Higher temperatures will also result in increase in cassava output. The positive relationship between cassava output and rainfall agrees with the findings of Anyaegbu *et al.*, (2022) which said that rainfall had a long-term significant impact on cassava yield in Nigeria.

Table 3 Coefficient Estimates for cassava output

Variables	Coefficient	Std error	t-statistics	p-values
Cons	-11.59346	7.888661	-1.469636	0.1517
Temp	0.566584**	0.207831	2.726173	0.0104
Rainfall	0.003190***	0.000522	6.114884	0.0000
Pressure	0.003299	0.004084	0.807934	0.4253
Sunshine	0.003299	0.327986	-0.531724	0.5987
CO ₂ emissions	-0.763585	7.888661	-1.326157	0.1517
R^2	0.759836			
R^2 Adj	0.721100			
F-statistics	19.61574			
Prob (F-statistics)	0.000000			
DW	1.49584			

Source: Field Survey, 2022 ***, ** = significant at $p < 0.01$ a

Table 4: Diagnostic Test results for Cassava

Test	Test statistics	P-value	Decision
Breusch – Godfrey Serial Correlation LM Test	0.5129	0.4349	No autocorrelation
Heteroscedasticity Test: Breusc Pagan – Godfrey	0.5344	0.3428	No heteroscedasticity
Jarque – Bera (Normality test)	0.573679	0.750679	Normal

Source: Field Survey, 2022

Co-integration Relationship between the Variables

Table 5 indicates the direction of causality between output of cassava, temperature, rainfall, pressure, sunshine and carbon dioxide emission. The result indicated that there existed interdependent causality among cassava, temperature, rainfall, pressure, sunshine and carbon emission and vice versa. Co – integration between two series implies Granger Causality in at least one direction but the opposite may not be true. The result revealed that four cases of unidirectional relationship and eleven cases of the absence of integration between the pairs of crop and climatic variables. The case of unidirectional relationship indicates that the climatic variable with significant value of probability causes output formation for the crop with no response. The case of lack of integration means that the pair of crop in question has not been influenced by the climatic variables.

Table 5. Granger Causality Co-Integration Relationship Between Cassava Output and Climatic Variables

Null Hypothesis	Obs	f-statistics	p-values	Directionn
Temp does not Granger Cause Cassava	37	0.81755	0.4511	No co - integration
Cassava does not Granger Cause Temp		0.76291	0.4751	
Rainfall does not Granger Cause Cassava	37	0.85280	0.4363	Unidirectional
Cassava does not Granger Cause Rainfall		1.65892	0.020	
Pressure does not Granger Cause Cassava	37	0.36014	0.7006	No co - integration
Cassava does not Granger Cause Pressure		0.71975	0.4951	
Sunshine does not Granger Cause Cassava	37	0.41652	0.6631	No co - integration
Cassava does not Granger Cause Sunshine		0.03516	0.9655	
CO ₂ emissions does not Granger Cause Cassava	37	2.21045	0.1272	No co - integration
Cassava does not Granger Cause Co ₂ emissions		0.79283	0.4618	

Source: Field Survey, 2022

Bounds test for co integration

The decision rule of the co integration is determined by the F statistic value. The tests generate a lower and upper bound critical value. If the F values are higher than the lower and upper values, the null hypothesis of no co integration can be rejected. If the F-value lies between the lower and the upper, then co integration is deemed inconclusive. Table 6 shows ARDL bounds test results. The decision rule of the co integration is determined by the F statistic value. The tests generate a lower and upper bound critical value. If the F values are higher than the lower and upper values, the null hypothesis of no co integration can be rejected. If the F-value lies between the lower and the upper, then co integration is deemed inconclusive.

Table 6 shows that the F-statistics 5.18 is significantly higher than the lower bound of 2.9 and the upper bound of 3.8 at 5% level. This indicates that there is a long run relationship between cassava output and the climatic variables in the model. This also indicates that null hypothesis of no co integration is rejected at 5% level of significance which confirms that there is co integration among the variables.

Table 6: ARDL Bound Test for Cassava

		Critical Values							
		10%		5%		1%			
Lag Length	F-statistics	k	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Lower Bound	Outcome
ARDL (3,1,2,4,4,2)	5.18	5	2.8	3	2.9	3.8	3.06	4.15	Co . integrated

Source: Field Survey, 2022

Long run and Short run impacts of climate change on cassava output

The long run estimates of cassava output presented temperature, rainfall, pressure, sunshine and carbon dioxide emissions as the independent variables while cassava is the dependent variable.

Table 7 revealed that temperature and rainfall has negative coefficient estimates of 0.226 and 0.852 at 5% level of significance. The results indicate that at 1% increase in annual temperature and rainfall will decrease cassava output by 22.6% and 85.2% respectively. An increase in climate change measured by temperature and rainfall decreases agricultural economic growth. This is expected as high temperatures and rainfall negatively affect agricultural productivity in the short run. Although high temperatures are associated with drought, more rainfall will be expected to moderate the impact, however, the results suggest that an increase in rainfall also has negative effects on agriculture. Another plausible reason could be when the rains eventually occur, they do so excessively and mostly during off-seasons. A common problem brought about by climate change. Pressure and carbon dioxide emissions has positive coefficient estimates of 0.324 and 0.166 at 1% and 5% levels of significance respectively. By implication a 1% increase in annual pressure will increase cassava output by 32.4% while a 1% increase in carbon dioxide emissions will increase cassava output by 16.6% and this agrees with the study of Anyaegbu *et al.* (2023) on the impact of climate change on cassava yield in Nigeria.

In estimation of short-run model, optimal lag was determined automatically, and short-run estimates are presented in Table 7. As presented in Table 7, there is statistically significant and positive short-run relationship between cassava output and its two-years lagged value. The result suggests that keeping other variables constant, a 1% increase in the lagged of cassava output results a 0.373% growth of cassava sector. Similarly, cassava output has significant and positive short-run relationship with temperature, rainfall, pressure, sunshine and carbon dioxide emissions. Other variables remain constant, a 1% increase in temperature results a -0.685% decrease in cassava output in the short-run. Concerning rainfall, a 1% increase in annual rainfall its lag value results a -0.103% and decrease in the output of cassava, respectively in the short-run. In the short-run, pressure has negative effect on the output of cassava. The estimated coefficient indicated that other variables kept constant, a 1% increase in pressure and its second lag results a 0.116% and 0.417% increase in cassava output, respectively. In the short-run, sunshine has negative effect on cassava output. That means a 1% increase in sunshine and its lag value results a -0.295%, -0.344%, -0.784% and -0.118% decrease cassava output, respectively. The carbon dioxide emissions also negatively affect the output of cassava in the short-run. The result suggests that a 1% increase in carbon dioxide emissions and its lag value results a -0.027 does not increase or decrease cassava output.

Table 7: Long run (LR) estimate of Cassava Output

Variables	Co integrating Form				
	Coefficient	Std error	t – stat	p - values	
LOG(CASSAVA(-1))	0.373**	0.129	2.898	0.0134	
LOG(CASSAVA(-2))	-0.244**	0.106	-2.308	0.0317	
LOG(TEMP)	-0.685***	0.147	-4.656	0.0006	
LOG(RAINFALL)	-0.103***	0.031	-3.319	0.0061	
LOG(RAINFALL(-1))	-0.151***	0.0215	-7.032	0.0000	
LOG(PRESSURE(-1))	-0.420	0.753	-0.558	0.5866	
LOG(PRESSURE(-2))	-0.116***	0.017	-6.686	0.0000	
LOG(PRESSURE(-3))	0.417***	0.096	-4.329	0.0010	
LOG(SUNSHINE)	-0.295***	0.063	-4.639	0.0006	
LOG(SUNSHINE(-1))	-0.344***	0.070	-4.881	0.0004	
LOG(SUNSHINE(-2))	-0.784*	0.414	-1.892	0.0829	
LOG(SUNSHINE(-3))	-0.118**	0.0497	-2.385	0.0345	
LOG(CO ₂ EMISSIONS)	-0.027	0.092	0.298	0.7709	
LOG(CO ₂ EMISSIONS(-1))	-.664***	0.108	-6.146	0.0000	
Long run Coefficients					
LOG(TEMP)	-0.226**	0.077	-2.911	0.0130	
LOG(RAINFALL)	-0.852**	0.117	-7.267	0.0000	
LOG(PRESSURE)	-0.324***	0.096	3.354	0.0057	
LOG(SUNSHINE)	0.673	2.750	0.244	0.8107	
LOG(CO ₂ EMISSIONS)	0.166**	0.075	2.210	0.0472	

Source: Field Survey, 2022 ***, **, * = significant at $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively

Error Correction Model (ECM) Estimation

The coefficient of Error Correction Term (-0.390) in Table 8 is negative and statistically significant at a 1% level. The negative and significant coefficient estimate of ECM indicates that there is a co-integrating relationship between cassava output and its determinants. In, the magnitude of the coefficient estimate of ECM suggests that 39% of the disequilibrium caused by previous years' shocks converges back to the long-run equilibrium in the current year. This reveals that the speed of adjustment will adjust to the long-term equilibrium. By implication, the independent variables (temperature, rainfall, pressure, sunshine and CO₂ emissions) would take 3 (1/0.390) years to adjust any negative short-run and long-run shocks to the cassava output in the long run.

Table 8: Error Correction Model (ECM) Estimation of Cassava

Variables	Coefficient	Std error	t - stat	p – Values
CoinEq (-1)	-0.390***	0.0068	-5.775	0.0000
Constant	-343.256***	78.143	-4.393	0.0069
R ²	0.8085			
Adj R ²	0.4734			
F – Statistics	2.4128			
Prob (F-Stat)	0.0000			
DW	1.6133			

Source: Field Survey, 2022

Table 9: Diagnostic Test results for Cassava

Test	Test statistics	P-value	Decision
Breusch – Godfrey Serial Correlation LM Test	8.37992	0.15728	No autocorrelation
Heteroscedasticity Test: Breusc Pagan – Godfrey	0.59495	0.7039	No heteroscedasticity
Jarque – Bera (Normality test)	0.38307	0.825689	Normal

Source: Field Survey, 2022

Conclusions

The study examined the effect of climate change on cassava output in Nigeria. Hence, the need to know the relationship existing between temperature, rainfall, pressure, sunshine, carbon dioxide and cassava output in Nigeria; and more so, the effect of temperature, rainfall, pressure, sunshine and carbon dioxide on the output of cassava output in Nigeria. Time series data over the period 1981 – 2018 obtained from NIMET were utilized in this study. The tools of data analysis employed in the study includes ADF test which was used to test for stationarity. ARDL bounds test established that there exists a long run relationship between the climatic variables and cassava output. Findings of the study indicates: (i) annual average temperature contributes significantly and positively to cassava output in Nigeria (ii) annual average rainfall also significantly and positively contributed to the output of cassava (iii) hours of sunshine contribute significantly and negatively to the output of cassava and (iv) carbon dioxide emissions contributed significantly and negatively to the output of cassava. The study generally shows that variation exists in the climatic variables and they significantly impact cassava output in Nigeria.

CONCLUSION AND RECOMMENDATIONS

The study analyzed the effect of climate change on cassava output in Nigeria using the autoregressive distributed lag (ARDL) approach. ARDL bounds test established that there exists a long run relationship between the climatic variables and cassava output. Findings of the study shows that: (i) annual average temperature significantly and positively contributed to the output of cassava (ii) annual average rainfall also significantly and positively contributed to the output of cassava (iii) hours of sunshine contribute significantly and negatively to the output of cassava and (iv) carbon dioxide emissions contributed significantly and negatively to the output of cassava. and (ii) carbon dioxide emissions contributed significantly but negatively to the output of maize. Variation exists in the climatic variables and they significantly impact cassava output in Nigeria. Climate change affects cassava output based on the significance of annual temperature, rainfall, hours of sunshine and CO₂ emissions in cassava output models. This paper recommends the need for governmental policies towards mitigation measures, such as conservation of resources and the development and deployment of alternative energy sources, massive campaign on greenhouse gas emission activities in the country and agricultural innovation that increase soil nutrient and do not contribute to change in climate should be encouraged.

ACKNOWLEDGEMENTS

This research was an excerpt of a Ph.D thesis of the first author. The authors would like to acknowledge Federal University Wukari, TETFUND for the Scholarship and Study leave for the research. All individuals included in this section have consented to the acknowledgement.

References

1. Adepoju, A.A. (2017). Climate Change and Health in Nigeria. Nigerian Tribune. Available from <https://www.tribuneonline.com>. Assessed on 18th July 2021 at 10.00 am
2. Anyaegbu, C.N.; Okpara, K.E.; Taweprada, W.; Akeju, D.; Techato, K.; Onyeneke, R.U.; Poshyachinda, S. and Pongpiachan, S. (2022). Impact of Climate Change on Cassava Yield in Nigeria: An Autoregressive Distributed Lag Bound Approach. *Agriculture* 2023,13,80, pp.1-15
3. Audu, I. A., Filli, F. B., Osayi, C. P. and Ishaya, A. (2018). Diversification of the Nigerian Economy through Cassava Processing in three Local Government Areas of Taraba State: A Profitability Analysis Presented at the 19th Annual National Conference of Association of Agricultural Economist held at the Federal College of Forestry Mechanization, Akafa-Kaduna, Auditorium on Monday 15th-Thursday 18th October, 2018.
4. Ayinde, O. E., Aina, I. V. and Babarinde (2017) Effect of Agricultural growth on unemployment and Poverty in Nigeria: A co-integration approach. *Tropical Agriculture*. Vol.94 No.4 Pp 434-444
5. Bakucs, L.Z. and Ferto, I. (2005): Marketing margins and price transmission on the Hungarian pork meat market. *Journal of Agribusiness* 21(2):273-286.
6. Borokinni, J. (2016). Climate Change and Health Impacts. The Nation Newspaper. <https://www.nationonline.ng.net/climate-change--impacts>. Retrived on 25th Oct. 2019

7. Chirwa, E.W. (2000). *Liberalization of Food Marketing and Market Integration in Malawi*. Final Report of an AERC sponsored Research Work, Presented at the Biannual Economic Research Workshop, Nairobi, Kenya. May 27, 2007.
8. Edet, E.O.; Udoe, P.O.; Isong, I.A.; Abang, S.O.; Ovbiroro, F.O. (2021). Impact of climate variability on yield of maize and yam in Cross River State, Nigeria: An autoregressive distributed lag bound approach. *World News Nat. Sci. Int. Sci. J.* 36, 60–74
9. Elega, J. O., Tanko, I. U. and Ojo, M. A.(2018). Analysis of the Determinants of Cassava and Rice Consumption in Nigeria (1970-2016). Presented at the 19th Annual National Conference of Association of Agricultural Economist held at the Federal College of Forestry Mechanization, Akafa-Kaduna, Auditorium on Monday 15th-Thursday 18th October, 2018.
10. Enete, A.A; Madu, I.I., Josephat C. Mojekwu, J.C; Onyekuru, A.N., Nwubuya, E.A. and Fidelis, E (2011) *Indigenous Agricultural Adaptation to Climate Change: Study of Southeast Nigeria*. Published by the African Technology Policy Studies Network P O Box 10081, 00100 GPO Nairobi Kenya
11. Engle, R. F., and Granger, C. W. J. (1987): Co-integration and error correction: representation, estimation and testing. *Journal Econometrica*, 55, 251-276. <http://dx.doi.org/10.2307/1913236>
12. Farauta, B.K., Idrisa, L. Y., Egbule, C.L and Agu, V.C. (2011) *Farmers' Perceptions of Climate Change and Adaptation Strategies in Northern Nigeria: An Empirical Assessment* Published by the African Technology Policy Studies Network Nairobi Kenya
13. Granger, C.W.J., (1969) Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica* 37 (3), 424–438.
14. Hendry, D.F. (1986). Econometric Modelling with Co-integrated variables: An overview, *Oxford Bulletin of Economic and statistical research*. Vol.48. No.3. Pp201-212
15. Intergovernmental Panel on Climate Change (IPCC,2014). *Climate Change 2014: Synthesis Report*. Contribution of Working Group I, II and III to the Fifth Assessment Report. 9Core Writing Team, R.K. Pachauri and L.A. Meyer). IPCC Geneva, Switzerland.
16. Johansen, S., (1988), “Statistical analysis of cointegration vectors”, *Journal of Economic Dynamics and Control*, 12, pp. 231-254.
17. Lawal , A. T., Mohammed, A. B. and Umar, M. M. (2018). Analysis of Resource Use Efficiency in Cassava Production in Gwarzo Local Government Area of Kano State, Nigeria presented at the 11th Africa Farm Management Association (AFMA) Congress Abuja-Nigeria 2018 held at the NAF Conference Center, 496, Ahmadu Bello Way, Garki 2, Abuja-Nigeria from 4th -9th , 2018.
18. Manufacturing Sector Report, (2015). *Overview of GDP growth in Nigeria; Analysis for Future Improvement through Economic diversification*. National Economic Summit Conference, 2014.
19. Nigerian National Petroleum Corporation (2018) Newsletter.
20. Nkoro, E.; Uko, A.K. (2016). Autoregressive Distributed Lag (ARDL) cointegration technique: Application and interpretation. *J. Stat. Econom. Methods* 5, 63–91
21. Nwaogu, D. C., Echebiri, R. N. and Eluhu, J. (2016). Determinants of Labour Supply and Output of Cassava Farmers in Ebonyi State, Nigeria. Presented at the 50th Annual Conference of Agricultural Society of Nigeria held at the Library Complex of the National Root Crops Research Institute, Abia State, Nigeria on the 3rd – 7th October, 2016.
22. United Nations (2018) *World Urbanization Prospects*. The 2018 Revision
23. www.macrotrends.net. Nigeria Population 1950-2023. (accessed on 26 May, 2023)
24. IFAD 2014
25. IITA 2014