



**CLIMATE CHANGE EFFECTS ON MAIZE OUTPUT IN NIGERIA: AN
AUTOREGRESSIVE DISTRIBUTED LAG BOUND APPROACH**

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ABSTRACT

The study examined climate change effects on maize output in Nigeria. 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) 0.6434, shows that about 64.34%, 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. 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: Approach, Bound, Change, Climate and Maize

INTRODUCTION

Agriculture remains the backbone of most African economies and is a major contributor to the gross domestic product (GDP) of the region. It accounts for about a third of Africa's GDP, employs in many countries about 60 – 90 percent of the total labour force and is the main source of livelihood for the poor (CBN, 2019). Agriculture has a multiplier effect on any nation's economy and industrial development because it is a multifunctional sector (Ogen, 2007). It also remains the most important source of livelihood for most rural communities in developing countries in general (Onwutuebe, 2019). In Africa, agriculture is a source of employment for more than 60 per cent of the population and contributes about 30 per cent of the Gross Domestic Product (Kandlinkar and Risbey, 2000).

Rain-fed farming is the most practiced agricultural production system in sub-Saharan Africa, covering about 97 per cent of total cropland and agricultural production is prone to high seasonal rainfall variability (Adisi and Oluks, 2018). In Nigeria, agriculture remains a crucial sector in the Nigerian economy, being a major source of raw materials as well as food and foreign exchange; employing over 70 percent of the Nigerian labor force, and serving as a potential vehicle for diversifying the economy (Onogwu *et al.*, 2017; Solomon and Edet, 2018; Ogbulabor and Ekwuchukwu, 2017; FAO, 2018). It is a significant sector of the economy and the source of raw materials used in the processing industries as well as a source of foreign exchange earnings for the country.

Since agriculture in Nigeria is mostly rain-fed, it follows therefore that any change in climate is bound to impact its production in particular and other socio-economic activities in the country (Ibrahim *et al.*, 2014). Farmers in Nigeria enormously rely on what nature provides, such as the volume of rainfall, intensity of the sun and other climate characteristics for their crop cultivation activities. The impact could, however, be measured in terms of effects on crop growth, availability of soil water, soil erosion, incident of pest and diseases, sea level rises and decrease in soil fertility (Ayinde *et al.*, 2020; Wossen *et al.*, 2018). The issue of climate change has become more threatening not only to the sustainable development of socio-economic and agricultural activities of any nation but to the totality of human existence.

The threat that climate changes pose to agricultural production does not only cover the area of crop husbandry but also includes livestock and in fact the whole agricultural sector (Ani *et al.*, 2022). African farmers also depend on livestock for income, food and animal products. Climate can affect livestock both directly and indirectly. Direct effects of climatic variables like air, temperature, rainfall, sunshine and other climate factors influence animal performance such as growth, milk production, wool production and reproduction. Climate can also affect the quantity and quality of feed stuffs such as pasture, forage, and grain and also the severity and distribution of livestock diseases and parasite (Idumah *et al.*, 2016). Rainfall is by far the most important element of climate change in Nigeria and water resources potential in the country. The northern region of Nigeria is increasingly becoming an arid environment occasioned by fast reduction in the amount of surface water, flora and fauna resources on land. Consistent reduction in rainfall leads to a reduction in the natural regeneration rate of land resources (Fasona and Omojola, 2005).

Climate change is caused by the change in each component of the climate system such as atmosphere, hydrosphere, biosphere, cryosphere and lithosphere or by complicated interactions among those components. The causes of climate change are largely divided into natural causes and artificial causes. Natural causes include the change in solar activity, volcanic eruption, sea water temperature, ice cap distribution, westerly waves and atmospheric waves. On the other hand, artificial causes include carbon dioxide emission from industry and agricultural production activities, deforestation, acid rain and the destruction of the ozone layer by Freon gas, with global warming by the increase of greenhouse gases.

Maize exploration has been high from its point of origin in Central American tropics and Mexico (Adiaha and Agba, 2016; Adiaha, 2016) to all parts of the globe, with its uses/utilization doubling as the day counts, and as Science attention has been on the crop for ages. Corn belongs to the grass family known as Poaceae. Maize is one of the crops modified to adapt to areas of cultivation, resulting in its subspecies, which are identified and classified depending on the extent of starch each possess (Piperno *et al.*, 2001).

Maize contains protein, crude fibre; ether extract and carbohydrate. Maize provides a large amount of energy in the diet of Man and animal (livestock). The crop provides the body with amino acid, although it is deficient in some essential amino acids like lysine and tryptophan. IITA (2001) reported 80% of carbohydrate, 10% protein, 3.5% fibre, in addition to 2% mineral and vitamin content in maize. Maize starch has been utilized in various ways, including the production of noodles. Edible oil which is obtained from maize grain has a low level of saturated fatty acids compared to other protein sources especially animal sources. Khawar *et al.* (2007) reported high-fructose content of corn syrup and sweetener, which can be added to food to preserve its moisture content. Dilip and Aditya (2013) findings show that maize contains selenium that stimulates the

thyroid gland and improve the immunity of humans. Maize silk has served as a source of treatment material in herbal medicine (Oladejo and Adetunji, 2012). About 34-98.3m or 48% hectares of land is cultivated to Nigerian maize production. Maize grain produced in Nigeria are sold as a commercial crop for industrial, agro-based, medical, pharmaceutical and other related uses (Iken and Amusa, 2004).

Despite its high yield potential, maize production is however faced with numerous constraints. One of the major constraints is intermittent drought during the growing season, which, significantly reduce maize yield. Declining agricultural productivity in the face of rapid population growth as a result of climate change is worrisome and cause for a great concerned. Given that different crops have different climate requirements necessitate the need for specific crop analysis which has not been adequately explored in Nigeria. Hence the effect of climate change on notable food crop like maize which has long term implication for food security. Specifically, the study sought to determine the time span for possible disequilibrium adjustment for the changes in the climatic variables

MATERIALS AND METHODS

The 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.

Analytical Techniques

The long run dynamic relationship between the output of crop and the climatic variables was estimated using Autoregressive Distributed Lag (ARDL) Bound approach. When the series are integrated in different orders, such as I(0) and I(1) (Anyaebe, *et al.*, 2023), the Bounds Test Co integration and Error Correction Model (ECM) of ARDL becomes appropriate to established a long run relationship in the model.

The empirical regression model

The model is specified as in equation (1);

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

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

$$Y = \beta_0 + \beta_1 T_{it} + \beta_2 R_t + \beta_3 AP_t + \beta_4 S_t + \beta_5 nCO_{2t} + \varepsilon_t \quad \dots(2)$$

Where,

$\beta_0 - \beta_5$ = parameters to be estimated as seen in equation (2);

ε_t = stochastic error term

Unit root test

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 shown in equation (3):

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum Y \Delta Y_{tj} + e_t; \quad \dots(3)$$

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)

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 (4):

$$\ln Y_t = \beta_0 + \sum_{i=1}^p \alpha_{1i} \ln Y_{t-i} + \sum_{i=0}^{q1} \alpha_2 \ln temp_{1t-i} + \sum_{i=0}^{q2} \alpha_3 \ln rainfall_{2t-i} + \sum_{i=0}^{q3} \alpha_4 \ln pressure_{3t-i} + \sum_{i=0}^{q4} \alpha_5 \ln sunshine_{4t-i} + \sum_{i=0}^{q5} \alpha_6 \ln CO_2 emissions_{5t-i} \quad \dots(4)$$

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.

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 was carry out to determine the direction of causality. 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. It could also be bi-directional which means that both variables influence each other (e.g, X causes Y and Y also causes X).

Granger model that was used in this study can be represented by equation (5):

$$\Delta Y_{it} = \sum_{i=1}^m a_i \Delta Y_i(t-1) + \sum_{j=1}^n a_j \Delta Y_j(t-1) + \rho_i \quad \dots(5)$$

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

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 was investigated with the help of error correction model 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 was investigated with the help of ECM as given in equation (6);

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta Z_t - \alpha_2 + (Y_t - Z_t)_{t-1} + e_t \quad \dots(6)$$

Where,

Z_t = the vector of explanatory variables

Y_t and Z_t = the co integrating variables

α_2 =error correction term (ECT)

e_t =error term

In line with some scholars (Edet *et al.*, 2021), the ECM is specified as equation (7):

$$\begin{aligned} \Delta Y_t = & \beta_0 + \sum_{i=0}^p \alpha_1 \Delta Y_{t-1} + \sum_{i=0}^{q1} \alpha_2 \Delta temp_{1t-1} + \sum_{i=0}^{q2} \alpha_3 \Delta rainfall_{2t-1} + \\ & \sum_{i=0}^{q3} \alpha_4 \Delta pressure_{3t-1} + \sum_{i=0}^{q4} \alpha_5 \Delta sunshine_{4t-1} + \\ & \sum_{i=0}^{q5} \alpha_6 \Delta carbon\ dioxide\ emissions_{5t-1} \quad \dots(7) \\ & \alpha(-temp - rainfall - pressure - sunshine - Carbon\ dioxide\ emissions) + e_t \end{aligned}$$

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 be negative. The presence of co integration in the model confirms a long-term relationship.

RESULTS AND DISCUSSIONS

Unit Root Test

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 maize 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 maize at first difference.



Table 1: Unit Root Test Results

Variable	Intercept		Trends and Intercept		Remarks	First Difference	Intercept		Trends and Intercept		Order of Integration
	ADF	P-values	ADF	P-values			ADF	P-values	ADF	P-values	
Temp	-4.3169	0.0015	-5.2133	0.0007	Stationary		-9.9063	0.0000	-8.9855	0.0000	I (0)
Rainfall	-3.3097	0.0214	-4.8394	0.0000	Stationary		-10.288	0.0000	-10.9855	0.0000	I (0)
Pressure	-6.8095	0.0000	-6.7321	0.0000	Stationary		-7.8201	0.0000	-7.7215	0.0000	I (0)
Sunshine	-3.5714	0.0115	-3.4518	0.0603	Non-stationary		-7.0699	0.0000	-6.9724	0.0000	I (1)
CO₂	-3.4856	0.0139	-4.6792	0.0300	Stationary		-9.4149	0.0000	-9.3922	0.0000	I (0)
Maize	-3.5661	0.0113	-2.5055	0.3239	Stationary		-3.8705	0.0052	-4.1910	0.0109	I (0)

Source: Field Survey (2022)

Effects of climatic variables on maize output

The result in Table 3 shows that, the coefficient of multiple determination (R^2) is 0.6434 indicating that 64.34% of the variation in maize 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 maize output in Nigeria. The result reveals that rainfall had a positive relationship with maize and it will lead to the increase in the output of maize and it corroborates with the findings of Olountuyi and Adigu (2017) that rainfall exhibits positive relationship with agricultural output, while it has an inverse relationship with CO₂ emission which means that increase in the concentration of CO₂ emission will bring about a decrease in the output of maize

Table 3: Multiple regression results for Maize output

Variables	Coefficient	Std error	t-statistics	p-values
Cons	6.735591	13.51933	0.498219	0.6218
Temp	0.268860	0.356174	0.754857	0.4560
Rainfall	0.003409***	0.000894	3.813696	0.0006
Pressure	-0.003604	0.006999	-0.514998	0.6102
Sunshine	0.231017	0.562092	0.410995	0.6839
CO ₂ emissions	-2.386309**	0.986766	-2.418312	0.0217
R^2	0.643428			
R^2 Adj	0.585916			
F-statistics	11.18780**			
Prob (F-statistics)	0.000003			
DW	1.686406			

***, ** = significant at $p < 0.01$ and $p < 0.05$ level respectively

Granger Causality Co-Integration Relationship Between Maize Output and Climatic Variables

The result in Table 4 revealed that two cases of unidirectional relationship and three cases of 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 pair of crops in question has not been influenced by the climatic variables.

Table 4: Granger Causality Co-Integration Relationship Between Maize Output and Climatic Variables

Null Hypothesis	Obs	F-statistics	p-values	Direction
Temp does not Granger Cause Maize	37	0.65274	0.5274	No co – integration
Maize does not Granger Cause Temp		1.15397	0.3282	
Rainfall does not Granger Cause Maize	37	0.79283	0.4613	Unidirectional
Maize does not Granger Cause Rainfall		7.90987	0.0016	
Pressure does not Granger Cause Maize	37	2.44032	0.1032	No co – integration
Maize does not Granger Cause Pressure		0.31567	0.7315	
Sunshine does not Granger Cause Maize	37	2.11544	0.1371	No co – integration
Maize does not Granger Cause Sunshine		0.47783	0.6245	
CO ₂ emissions does not Granger Cause Maize	37	0.21549	0.8073	No co – integration
Maize does not Granger Cause CO ₂ emissions		1.91468	0.1639	

Source: Field Survey (2022)

Bounds test for co- integration

Table 5 shows that the F-statistics 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. 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 5: ARDL Bound Test for Maize

Lag Length	F-statistics	K	Critical Values		5%		1%		Outcome
			10%	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	
ARDL (4,3,4,4,4,0)	4.41	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 crop output

The results of Table 6 reveals that temperature has positive coefficient estimates of 0.673 at 5% level of significance. This means that higher temperatures will bring about higher output of maize which did not agree with the findings of Tagwi (2022) which states that 1% increase in annual temperature will bring about a decrease in the output of crops. Rainfall has negative coefficient estimate of 0.463 at 5% level of significance. 1% increase in rainfall will bring about 46.3% decrease in Maize output. Pressure also has positive coefficient estimates at 10% level of significance.

As presented in Table 6, there is statistically significant and negative short-run relationship between maize output and its first-year lagged value. The result suggests that keeping other variables constant, a 1% increase in the lagged of maize output results a -0.369% decrease in the output of maize. Similarly, maize output has significant and negative short-run relationship with temperature, rainfall, pressure, sunshine and carbon dioxide emissions. Other variables remain constant, a 1% increase in temperature results a -0.731% decrease in maize output in the short-run. Considering rainfall, a 1% increase in annual rainfall and its two years lag value results a -0.217% and -0.941% decrease in the output of maize, respectively in the short-run. In the short-run, pressure has negative effect on the output of cowpea.

Table 6: Long run (LR) estimate of Maize Output

Variables	Co integrating Form			
	Coefficient	Std error	T – stat	p – Value
LOG(MAIZE(-1))	-0.369**	0.170	-2.171	0.0455
LOG(MAIZE(-2))	-0.640	0.154	-3.764	0.6862
LOG(TEMP)	-0.731**	0.307	-2.376	0.0194
LOG (RAINFALL)	-0.217***	0.060	-3.578	0.0059
LOG(RAINFALL(-1))	-0.941**	0.365	-2.577	0.0355
LOG(PRESSURE(-1))	-0.264**	0.086	-3.053	0.0137
LOG(PRESSURE(-2))	-0.232***	0.064	-3.653	0.0053
LOG(PRESSURE (-3))	-0.127**	0.059	-2.139	0.0611
LOG(SUNSHINE)	-0.686**	0.271	-2.524	0.0325
LOG(SUNSHINE(-1))	-0.931**	0.376	-2.476	0.0352
LOG(SUNSHINE(-2))	-0.315	1.752	-0.180	0.8609
LOG(SUNSHINE(-3))	-0.488**	0.165	-2.958	0.0160

LOG(CO ₂ EMISSIONS)	0.177***	0.045	-3.925	0.0035
Long run Coefficients				
LOG(TEMP)	0.673**	0.210	3.193	0.0142
LOG(RAINFALL)	-0.463**	0.160	-2.883	0.0106
LOG(PRESSURE)	0.138*	0.068	2.015	0.1292
LOG(SUNSHINE)	0.266	0.293	0.772	0.4598
LOG(CO ₂ EMISSIONS)	-0.705**	0.257	-2.745	0.0226

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

Error Correction Model (ECM) Estimation of Maize

The coefficient of Error Correction Term (-0.213) in Table 7 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 maize output and its determinants. 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. The independent variables (temperature, rainfall, pressure, sunshine and CO₂ emissions) would take 5 (1/0.213) years to adjust any negative short-run and long-run shocks to the maize output in the long run.

Table 7: Error Correction Model (ECM) Estimation of Maize

Variables	Coefficient	Std error	t – stat	p – Values
CoinEq (-1)	-0.213***	0.0047	-4.481	0.0015
Constant	-117.003**	668.516	-1.758	0.0127
R ²	0.7216			
Adj R ²	0.5342			
F – Statistics	10.99*			
Prob (F-Stat)	0.0031			
DW	2.3662			

Source: Field Survey (2022)

Diagnostic Test

Table 8 presents the diagnostic test assumptions of the ARDL model of the estimate. These diagnostic test assumptions include stability test, normality test, serial correlation test and heteroscedasticity test.

Table 8: Diagnostic Test results for Maize

Test	Test statistics	P-value	Decision
Breusch – Godfrey Serial Correlation LM Test	3.531823	0.4015	No autocorrelation
Heteroscedasticity Test: Breuse Pagan – Godfrey	2.694497	0.3804	No heteroscedasticity
Jarque – Bera (Normality test)	1.782037	0.410238	Normal

Source: Field Survey (2022)

CONCLUSION AND RECOMMENDATIONS

Findings of the study shows that annual average rainfall significantly and positively contributed to the output of maize and carbon dioxide emissions contributed significantly but negatively to the output of maize. The study generally shows that variation exists in the climatic variables and they significantly impact maize output in Nigeria. In general, climate change was found to affect maize output based on the significance of annual rainfall and CO₂ emissions in maize output models. This paper suggests the need for programmes and seminars 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 is also advocated.

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