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ANALYSIS OF CLIMATE-RELATED RISK AND MAIZE PRODUCTION IN SOUTHWEST, NIGERIA

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Abstract

One of the consequences of climate change in Sub-Saharan Africa is that farmers would be more exposed to production risk. Therefore, it is imperative to analyse the climate-related risk and maize production in Southwest, Nigeria. Secondary data between 1981 and 2012 were collected on relevant variables and analysed using Growth Function, Co-integration Model (Autoregressive Distributed Lag Approach) and J-P Model. The results confirmed the presence of long-run equilibrium between maize production and temperature, rainfall and relative humidity. The Error Correction Model (ECM) value was -0.0238 for the enterprise. The results of the analysis on the climate-related risk indicated that temperature increased the production risk of maize farmers. It can be concluded that farmers face climate-related risk as temperature increased the production risk of maize farmers. Therefore, stakeholders should create more awareness on the need to always practice eco-friendly activities and put in place coping strategies against the menace of climate change.

Key words**:** *Climate, co-integration, maize, Nigeria, risk*

INTRODUCTION

Maize (*Zea mays*) is known to be an important cereal crop being planted in the rainforest and derived Savannah zones of Nigeria. Maize cultivation was at subsistence level after which it later became more important food crop which has now grown to commercial level. It is largely depended on as raw materials to many agro-based industries [14]. Also, [20] stated that maize undoubtedly remains an important crop for rural food security. As a result of this fact, production of maize must be stepped up in order to ensure food security, which would translate to increased level of income of the farmers. This could be achieved through the development of improved maize varieties and technologies in Nigeria.

According to [34], about 80% of maize produced is consumed by man and animals, while the remaining 20% is used in various agro-based industries where starch, corn sweetener, ethanol, cereal, alkaline, etc are produced. Rainfall (intensity and duration), relative humidity and temperature constitute important climatic factors that influence maize yield and its inconsistency.

Climate change is one of the greatest challenges facing human existence on the surface of earth in this century. It is a process of global warming attributable to the 'greenhouse gases' generated by human activities. Climate change impacts are not only felt by developing countries but also developed countries, which tells us how serious it is to human race. However, the impacts are likely to be greatly felt by developing countries than developed ones. This is not necessarily attributable to the level of contributions of developing countries to climate change but lack of infrastructures (economic, social and political) to sufficiently address effect of climate change [8]. Weather and climate cannot be separated from agriculture because of existence of deep nexus amongst them. Also, climate and weather are dominant factors that influence the overall unpredictability of food production [43] and ongoing source of disturbance to ecosystem services [11].

Efficacy of rainfall in crop production depends on the temperature values which affect evaporation and transpiration, thereby making climate a dominant role in agriculture as it has direct impact on the productivity of physical production factors. Farming output can be adversely affected by climate change at any stage of agricultural production process up till harvesting. Sufficient rainfall is not only needed for good yield but also regular rainfall because its irregularity can adversely affect yields especially when rains fail to arrive during the crucial growing stage of the crops [26].

According to [16], it is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the twenty-first century over many areas of the globe; and there is medium confidence that droughts will intensify in the twenty-first century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration.

Government policies, economic factors, availability of farm supplies, weather and climate variability constitute part of diverse pressures which influence agricultural production. This is the reason why farming business is inherently a risky business as a result of uncertainty relating to all these factors [44]. It is no more new that weather and climate variability affect farm revenue through some other factors, but only its influence on yield is given serious attention because it is the yield that translates to revenue. This indicates the importance of climate variables to agricultural production. [5] explained that increased temperature during growing season can drastically affect productivity in agriculture, farm revenue and food availability.

[30] stated that the sustainability of the environment to provide materials needed for life in order to achieve all planned developments of man and animal depends on the favourable climate which is undergoing changes.

The effect of these changes is posing threat to food security in Nigeria. As explained by [51], literatures have it that adverse weather conditions significantly contribute to continuous inherent uncertainties that lead to crop yield variation. [23] also acknowledged the fact that climate variability causes production risk through its impacts on resources, pests and diseases.

It is predicted that climate change (CC) will cause reduction in areas appropriate for cultivation of many crops in Sub Saharan Africa, unlike Europe and North America which would have an increase in area appropriate for cultivation as they have the greatest capacity and resources to manage CC impact [15]; [50].

Several studies on climate change indicated that climate variability is expected to be on the increase in the next few decades, which is expected to be severe for tropical regions. There will be increase in the frequency of extreme events, such as floods and droughts, thereby increasing the likelihood of revenue shocks with a larger impact on the poor [46]; [45]; [21]; [17]; [48].

The impacts of CC on water and agriculture on the African continent can be very calamitous as agriculture constitutes approximately 30% of Africa's GDP and contributes about 50% of the total export value, with 70% of the continent's population depending on the sector for their livelihood [24]; [7].

Despite the fact that climate change poses serious threat to agricultural production, little is known about climate related risk and maize production in Nigeria. This is the motivation for this study with the following specific objectives of examining the growth rate of maize production between 1980 and 2012, analysing the relationship that exists among the selected climate variables and maize production and identifying the determinants of climate risk in maize production between 1980 and 2012.

This study would help identify factors that determine climate risks in maize production in the study area. The findings from this study would also assist policy makers in formulating policies targeted at adaptation and coping strategies that would reduce climate risks drastically. It will also show how climate change as well as its risks affects food crop production and the need to proffer solutions to the problems emanating from it.

MATERIALS AND METHODS

Study Area

The study area is Southwest Nigeria comprising of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti States. The area lies between longitude $2^0\ 31^1$ and $6^0\ 00^1$ East and Latitude $6^0\ 21^1$ and $8^0\ 37^1$N [1] with a total land area of 76,852km^2 and a population of 27,722,432 [28]. The study area is bounded in the East by Edo and Delta States, in the North by Kwara and Kogi States, in the West by the Republic of Benin and in the South by the Gulf of Guinea. The vegetation in Southwest Nigeria is made up of fresh water swamp and mangrove forest, the low land forest stretches inland to Ogun State and part of Ondo State while secondary forest is towards the northern boundary where derived and southern Savannah exist [1]. Southwest Nigeria is within the tropical rainforest, the area has bimodal rainfall distribution. There are distinct dry and rainy seasons. The wet season is associated with the Southwest monsoon wind from the Atlantic Ocean while the dry season is associated with the northeast trade wind from the Sahara desert. The region has an average annual rainfall and temperature of 1486mm and 26.70C respectively [33]. The region has high density of human population with rain-fed agriculture as primary occupation of the people. The states are known for the cultivation of food crops such as maize, cocoyam, cassava, vegetable and yam [37].

Data Collection and Analytical Techniques

Secondary data on maize output, temperature, relative humidity and rainfall were collected from the National Bureau of Statistics (NBS), Nigerian Meteorological Agency (NIMET) and Agricultural Development Programme (ADP). Two out of the six States in the region were randomly selected and the selected States are Ondo and Oyo. Growth Function Analysis, J-P (Just and Pope) Production Function Model and Co-integration Model Analysis (Bounds Test Approach) were used to achieve the objectives of the study.

Empirical Specifications

Growth Function Model

The growth rate was computed following [3] and [32] by fitting exponential function in time to the data. Normal economic, econometric and statistical criteria were used to select the lead equation which was subsequently used for further analysis. According to [32], this measure takes into account the entire observations, which has proven it to be more realistic in the computation of growth rates. There are other alternative methods of computing compound growth with some shortcomings and one of these methods is the use of data at the beginning and at the end of a period which has been shown to ignore important information. The compound growth rate is computed by fitting the exponential function in time to the data by using the following formula;

$$Y = b_0e^{bt} \quad (1)$$

After linearizing in logarithm, equation 1 turns to:

$$LogY = b_0 + b_1t \quad (2)$$

where:

Y= Output

t = Time trend variable

b_0, b_1, = Regression parameters to be estimated

The growth rate (r) is given by

$$r = (e^{b}{}_1 - 1) \times 100$$

where e is Euler's exponential constant (e = 2.7183).

Data were fitted to the above function in estimating production between 1980 and 2012. The study further investigated the existence of acceleration, deceleration or stagnation in growth rate of maize output. Quadratic equation in time variables was fitted to the data for the period (1980-2012) following [42]; [35]; [2]as follows:

$$LogY = \beta_0 + \beta_1T + \beta_2T^2 \quad (3)$$

The quadratic time term T^2 allows for the possibility of acceleration or deceleration or stagnation in growth during the period of the study. Significant positive value of the coefficient of T^2 confirms significant acceleration in growth, significant negative value of T^2 confirms significant deceleration in growth while non-significant coefficient of T^2 implies stagnation or absence of either acceleration or deceleration in the growth process.

J-P Model

A J-P approach is used to estimate the risk effects of a production function, since it relaxes the second moment of the production restrictions. The approach also aids econometric testing of risk related hypotheses directly [49]. According to [10]; [18], J-P model is based on the principle that the variance of the production function error may be related to some or all explanatory variables, implying that it is a multiplicative heteroskedastic model. The J-P model used in this study is in line with [22], which is as follows;

$Y_i = f(X_i, \beta) + g(X_i , \alpha)\varepsilon_i$ (4)

where Y_i is the yield or mean response output, and X_i is a vector of explanatory variables, β and α are parameter vectors, and ε_i is a random variable with zero mean. The mean output of production is a function of the explanatory variables and is given by the function $f(X_i, \beta)$. The variance of output is related to the explanatory variables by the function $g(X_i , \alpha)\varepsilon_i$. [19] proposed a three stage estimation method which include estimation of the mean output function with fixed effects, estimation of the risk function with fixed effects model; and re-estimation of the mean output function with the method of generalized non-linear OLS.

The general model is;

$Y_i = X'_i \beta + e_i$, where i = 1, 2, ...N (5)

$E(e_i^2) = \sigma_i^2 = \exp[Z'_i \alpha]$ (6)

where $Z'_i = (z_{1i}, z_{2i}, ... z_{ki})$ is a vector of observations for K explanatory variables, $\alpha = (\alpha_1\ \alpha_1\ \alpha_1 .....\alpha k)$ is a (K x 1) vector of unknown coefficients, and $E(e_i) = 0$, $E(e_i e_s) = 0$ for $i \neq s$.

Using the natural log transformation, equation (6) can be rewritten as In $\sigma_i^2 = Z'_i\ \alpha$. Since σ_i^2 is unknown, the least square residuals from equation (5) can be used to replace σ_i^2 in equation (6) which then becomes

$Ine_i^{*2} = Z'_i\ \alpha^* + u_i$ (7)

where $u_i = In(e_i^{*2}/ \sigma_i^2)$.

The u_i will be asymptotically independent with a mean of $E[u_i] = -1.2704$, and with an asymptotic covariance matrix $\Gamma = 4.9348\ (Z'Z)^{-1}$. This result is asymptotically valid in hypothesis tests for the risk effects. To obtain efficient coefficients the predicted values of equation (7) are used as weights for equation (4) [22].

In this study, quadratic functional form, being the best functional form using statistical and economic criteria, was used for the variance (risks effects) of the crop yield, and is given in equations 8. The relationship is as follows;

$lne_{mi}^2 = \alpha_1 X_1 + \alpha_2 X_1^2 + \alpha_3 X_2 + \alpha_4 X_2^2 + \alpha_5 X_3 + \alpha_6 X_3^2$ (8)

where; lne_{mi}^2 = Variance of maize yield, (X_1) = Amount of rainfall, $(X_1)^2$ = Amount of rainfall squared, (X_2) = Temperature, $(X_2)^2$ = Temperature squared, (X_3) = Relative humidity and $(X_3)^2$ = Relative humidity squared.

Autoregressive Distributed Lag (ARDL) Co-integration Model

Autoregressive Distributed Lag (ARDL) is a recent but widely used approach to co-integration. The approach is not as popular as Vector Autoregressive (VAR) Model employed in co-integration studies to establish multivariate relationship. The bounds testing (Autoregressive Distributed Lag (ARDL) Model) co-integration procedure as used by [36]; [38]; [9] empirically analysed the long-run relationships and dynamic interactions among the variables of interest. It has some advantages compared to other co-integration procedures which include the following;

(a) Endogeneity problems and inability to test the hypothesis on the coefficients that are estimated in the long run with the method of Engel-Granger are solved using bounds approach [25].

(b) It is not compulsory that the variables of interest should be integrated of the same order in bounds approach unlike other techniques such as the Johansen co-integration approach. The ARDL bounds testing approach is applicable whether the variables (regressors in the model) are purely I(0), purely I(1), or mutually co-integrated.

(c) It is found that bounds approach is suitable for small sample which makes it more superior to that of multivariate co-integration [27] and [25].

(d) Using bounds test approach, co-integration relationship can be estimated by OLS once the lag order of the model is identified, which makes it simple.

(e)Long and short run parameters are estimated separately in a single model using bounds test approach.

(f)Different variables can be assigned different lag-lengths as they enter the model.

The presence of long-run relationship among variables of interest is tested using an F-test of the joint significance of the coefficients of the lagged levels of the variables. Two asymptotic critical values bounds provide a test for co-integration when the independent variables are I(d) (where 0≤d≤1): a lower value assuming the regressors are I(0), and an upper value assuming purely I(1) regressors. Once the upper critical value is less than the F-statistic, the null hypothesis of no long-run relationship can be rejected regardless of the orders of integration for the time series. Conversely, if the lower critical value is greater than the test statistic, the null hypothesis cannot be rejected. Lastly, if the statistic is between the lower and upper critical values, the result is inconclusive [39].

The null hypothesis of no co-integration (no long-run relationship) among variables of interest is given as:

$$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$

The alternate hypothesis (there is long-run relationship or co-integration exists) among variables of interest is given as:

$$H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$$

This approach to co-integration procedure is used to empirically analyse the long-run relationships and dynamic interactions among maize production, annual temperature, annual rainfall and relative humidity. This study followed [41]and [12] who related crop yield with some climate variables such as temperature and rainfall.

The relationship between maize production and the selected climate variables are as follows;

$$\text{MAIZ} = f(\ln\text{Temp}, \ln\text{Rain}, \ln\text{Hum}) \quad (9)$$

According to [39], the ARDL model specification of equation (9) is expressed as unrestricted error correction model (UECM) to test for co-integration between the variables under study:

$$\Delta\ln\text{MAIZ}_t = \beta_0 + \sum_{i=1}^{q} \beta_1 \Delta\ln\text{MAIZ}_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta\ln\text{Temp}_{t-i} + \sum_{i=0}^{q} \beta_3 \Delta\ln\text{Rain}_{t-i} + \sum_{i=0}^{q} \beta_4 \Delta\ln\text{Hum}_{t=i} + \omega_1 \ln\text{MAIZ}_{t-1} + \omega_2 \ln\text{Temp}_{t-1} + \omega_3 \ln\text{Rain}_{t-1} + \omega_4 \ln\text{Hum}_{t-1} + e_t \quad 10$$

Once co-integration is established, the long run relationship is estimated using the conditional ARDL model specified as:

$$\ln\text{MAIZ}_t = \beta_0 + \omega_1 \ln\text{MAIZ}_{t-1} + \omega_2 \ln\text{Temp}_{t-1} + \omega_3 \ln\text{Rain}_{t-1} + \omega_4 \ln\text{Hum}_{t-1} + e_t \quad 11$$

The short run dynamic relationship is estimated using an error correction model specified as:

$$\Delta\text{MAIZ}_t = \beta_0 + \sum_{i=1}^{q} \beta_1 \Delta\ln\text{MAIZ}_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta\ln\text{Temp}_{t-i} + \sum_{i=0}^{q} \beta_3 \Delta\ln\text{Rain}_{t-i} + \sum_{i=0}^{q} \beta_4 \Delta\ln\text{Hum}_{t-i} + \delta\text{ecm}_{t-1} + e_t \quad 12$$

where:

MAIZ = Maize Output (kg), Temp = Temperature (degree celcius), Rain = Rainfall (mm), Hum= Relative humidity (%), β_0 = Constant term, et = White noise, $\beta_1 - \beta_4$ = Short run elasticities (coefficients of the first-differenced explanatory variables), $\omega_1 - \omega_4$ = long run elasticites (coefficients of the explanatory variables), ecm_{t-1} = Error correction term lagged for one period, δ = Speed of adjustment, Δ = First difference operator, $\ln$ = Natural logarithm and q = Lag length.

RESULTS AND DISCUSSIONS

Trend Analysis and Growth Rate of Maize Output (1980-2012)

The results of trend analysis and growth rate of maize output as presented in Table 1 shows that maize output had a positive trend. The coefficient of the trend variable in maize enterprise was positive and highly significant at 1% level of significance. The positive trend suggests a positive and increasing relationship between time and outputs in the enterprise in the period under study. This implies that maize output increase with time probably because of new technologies being introduced into the agricultural sector from time to time.

The growth rate of maize output as shown in Table 1 reveals that maize output had a positive growth rate of 7.6% in the period under consideration. This is an indication that various agricultural programmes of different governments have positively influenced maize enterprise. Findings from this study reveal that maize growth rate is higher than the average growth rate of 3.25% in maize between 1983 and 2008 in Nigeria as reported by [47].

Table 1. Estimated Trend Equations and Growth Rate for Maize Yield (1980-2012)

Dependent Variable (Yield)	b_0	b_1	R^2	Growth Rate (%)
Maize	-1.1037 (-5.9605)	0.0733*** (7.7077)	65.7	7.6

Source: Computed from ADP data of various years.
Figures in parenthesis represent t-value, *** = 1% significant levels.

Acceleration, Deceleration or Stagnation in the Movement of Growth Rate of Maize Yield.

Quadratic equations were estimated in time variables to determine whether there was acceleration, deceleration or stagnation in the movement in growth rates of maize outputs. Table 2 shows that the coefficients of t^2 for maize output were negative but significant at 1% indicating deceleration in the growth of maize yield during the period under consideration.

Table 2. Quadratic Equations in Time Variables for Maize Yield (1980-2012).

Dependent Variable (Yield)	b_0	b_1	b_2	R^2
Maize	-2.0195 (-10.2655)	0.2303*** (8.6308)	-0.0046*** (-6.0664)	84.6

Source: Computed from ADP data of various years.
Figures in parenthesis represent t-value, *** = 1% significant levels.

This implies that the movement in the growth of maize was not as fast as expected. This scenario could be attributed to poor implementation and monitoring of some of the agricultural programmes put in place by various governments in the study area. This is in conformity with the findings of [29] who reported deceleration in maize output between 1980 and 2010 when maize production in Nigeria as a whole was considered.

Estimated Results for the Variance Response Functions for Maize Yield Using Climate Variables (1980-2012).

The estimated coefficients for the variance of maize yield using climate variables are shown in Table 3.

Temperature and Relative Humidity had significant influence on the variance of maize yield in the study area. The direct relationship that existed between temperature and variance of the maize yield is an indication that climate change poses serious risk to the maize enterprise because of the reduction in the output. Also, the positive relationship between relative humidity and variance of maize yield could lead to disease infestation which could bring about reduction in the maize yield.

Table 3. Estimated Coefficients for the Variance of Maize Yield Using Climate Variables

Variable	Variance of Yield
Intercept	61.6331 (0.2922)
Rainfall	-0.3383 (-0.6459)
Rainfall Squared	0.0010 (0.4702)
Temperature	1.1064*** (-7.3122)
Temperature Squared	1.0605 (0.3939)
Relative Humidity	8.5103** (2.0053)
Relative Humidity Squared	-0.0622 (-0.9564)
R^2	40.4%
Number of Years	33

*Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level; Values in parenthesis represent t-value.
Source: Computed from Field Survey Data, 2015.

F-test Results of the Hypothesis for Maize Enterprise Using Climate Variables

The F-test that the coefficients of Temperature and Temperature squared were equal to zero ($b_3 = b_4 = 0$) was rejected (F-value of 2.90), indicating that Temperature affected the variance of maize yield (Table 4). This scenario shows that Temperature increased the production risk of the maize farmers in the study area. The results show that variability in maize yield may be adversely impacted by variability in Temperature. The F-tests for other climate variables were not rejected because they were not affecting the variance of maize yield and the risk of producing maize in the study area.

Table 4. The F-test results for Maize Using Climate Variables

Null Hypothesis	**Parameter Restriction**	**F-Value**	**Remark**
Variance is not influenced by Rainfall	$b_1 = b_2 = 0$	1.99	Accept H_0
Variance is not influenced by Temperature	$b_3 = b_4 = 0$	2.90**	Reject H_0
Variance is not influenced by Relative Humidity	$b_5 = b_6 = 0$	1.36	Accept H_0

*Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level
Source: Computed from Field Survey Data, 2015.

Relationship Among the Selected Climate Variables and Production of Maize for the Period of 1980 to 2012

Unit Root Tests Analysis

The standard Augmented Dickey-Fuller (ADF) unit root test was employed to check the order of integration of the variables included in the analysis. This is done in order to ensure that the assumption of ARDL stated by [39] is respected in spite of the fact that ARDL co-integration technique does not require pre-testing of variables included in the empirical model for the order of integration [31].

Table 5. Results of Unit Root (ADF) Test for Maize Enterprise

Variables	**Level [I(0)]**		**First Differences [I(1)]**	
	Constant	**Constant and Trend**	**Constant**	**Constant and Trend**
MAIZ	-0.5063 (0)	-1.7290(2)	-5.3127 (0)***	-2.3987 (1)
RHUM	-4.3682 (0)***	-4.2864 (0)***	-5.8029 (1)***	-4.1148 (8)***
TEMP	-1.6481 (2)	-6.0628(0)***	-7.5204 (1)***	-7.4396 (1)***
RAIN	-4.9149 (1)***	-4.8789 (1)***	-7.0084(2)***	-7.0692(2)***

Source: Computed from NIMET and ADP Data, 2015.
Notes:
***, **, * imply significance at 1%, 5%, 10% level respectively.
The figures in parentheses for the ADF (Dickey-Fuller, 1979) statistic represents the lag length of the dependent variable used to obtain white noise residuals.
The lag length for the ADF was selected using Automatic-based on AIC, max lag = 8

As shown in Table 5, the ADF test statistic revealed that Maize output was stationary at first difference *I(1)*, while Relative Humidity, Temperature and Rainfall were stationary at level *I(0)*. The combination of *I(0)* and *I(1)*can be used under ARDL unlike Johansen procedure and this is the justification for using bounds test approach in this study.

Co-integration Test Based on ARDL Bounds Testing Approach

OLS regression was estimated from equation (9) and then tested for the joint significance of the parameters of the lagged level variables when added to the regression analysis. The results from OLS regression are of "no direct interest" to the bounds testing approach to co-integration test. The F-statistic tests the joint null hypothesis that the coefficients of the lagged level variables are zero (i.e. no long-run relationship exists between the variables in question). Wald Test of coefficients in the ARDL-OLS egression was used to estimate the F-statistic. Table 6 reveals the value of calculated F-statistic for F_{MAIZ}(MAIZ | TEMP, RAIN, RHUM) to be 4.36. Since the value is higher than the upper bound critical value of 4.35 at the 5% level, the null hypothesis of no co-integration was rejected.

Table 6. Results of Co-integration Test Based on ARDL Bounds Test Approach

Critical Value	**Critical value Bounds of the F-statistic**	
	Lower bound I(0)	**Upper bound I(1)**
1%	4.29	5.61
5%	3.23	4.35
10%	2.72	3.77

Computed F – Statistic : F_{MAIZ}(MAIZ | TEMP, RAIN, RHUM) = 4.36
Note: Critical Values are cited from Pesaran *et al.* (2001), Table CI (iii), Case 111: Unrestricted intercept and no trend, Number of regressors (K) = 3.

This indicates that there is a long-run co-integration relationship among the variables when maize output was regressed against explanatory variables of average temperature, rainfall and relative humidity.
The result of this study is in conformity with the findings of [4] who reported a long run association between climatic variables (rainfall and temperature) and crop productivity in Nigeria using Johansen test of co-integration.

Analysis of Long Run Estimates

The long run coefficients of ARDL (1,0,0,0) are presented in Table 7. The results revealed temperature and rainfall had positive and negative significant influence, respectively, on maize output in the long run. The inverse relationship that existed between rainfall and maize output could be traced to excessive rainfall that resulted to erosion and leaching. Leaching makes nutrient unavailable for the maize plant and thus decreasing maize output. This is in conformity with the findings of [13] who reported inverse relationship between rainfall and maize yield. Also, findings from this study support [12] who reported that rainfall and agricultural output are inversely related. The direct relationship between maize output and temperature could be linked to the usefulness of temperature in the growth of maize plant but it would get to a stage where increase in temperature becomes hazardous to maize plants. This could be due to the fact that maize is seen as C4 and C3 pathway plant i.e sun-loving plant.

Table 7. Estimated Long Run Coefficients Using the ARDL Approach for Maize Enterprise

Regressor	Coefficient	T-Ratio
TEMP	0.21846**	3.55798
RAIN	-0.10057**	-2.21520
RHUM	-0.37258	-0.24191
INPUT	43.6582	1.97322

Note: *, **, ***, significant at 10%, 5%, 1% respectively.
Maize: ARDL(1,0,0,0) selected based on Schwarz Bayesian Criterion

Analysis of Short Run Estimates – Vector Error Correction Model (VECM)

The analysis of Error Correction Model (ECM) based on ARDL bounds test approach was used to obtain the short run dynamic coefficients associated with the long-run co-integration relationships. The results of the short run coefficients of ARDL (1,0,0,0) model are presented in Table 8. Both temperature and rainfall had direct and inverse relationships respectively with maize output in the short run. The statistically significant negative coefficient of ECM(-1) for maize enterprise verified the long run relationship among the variables in the enterprise. ECM measures how quickly the endogenous variable adjusts to the changes in the independent variables before the endogenous variable converges to the equilibrium level [52]. Negative and statistically significant ECM demonstrates that adjustment process is effective in restoring equilibrium. Negative and low ECM in absolute value points out a slow adjustment. It is, therefore, clear that ECM in this study is statistically significant at 1% level and had a value of -0.0238. The implication of this is that about 2.38% of disequilibrium in maize enterprise from the previous year's shock converge to the long-run equilibrium in the current year. The positive effect of temperature on maize output is when high temperature has not led to soil nutrient depletion and extreme heat that is unfavourable to maize production. Inverse relationship that existed between rainfall and maize output could be as a result of heavy rainfall that caused storm, erosion and leaching. This is in conformity with the findings of [4] who reported a negative and significant effect of rainfall on agricultural productivity.

Table 8. Results of the ARDL Short-run Relationship for Maize Enterprise

Regressor	Coefficient	T-value
ΔTEMP	0.005206***	5.721
ΔRAIN	-0.002397**	-3.751
ΔRHUM	-0.008879	-0.381
ΔINPUT	1.0404	0.194
ecm(-1)	-0.023831***	-2.954

R-Squared = 0.039890 R-Bar-Squared = -0.10782
S.E. of Regression = 0.33668 F-stat. = F(4, 26)2.27006[.058]
Residual Sum of Squares = 2.9471 Equation Log-likelihood = -7.5131
Akaike Info. Criterion = -12.5131 Schwarz Bayesian Criterion= -16.0981
DW-statistic = 1.9425
Note: **,***, significant at 5%, 1% respectively.

Analysis of ARDL Diagnostic Tests

Table 9 shows that the F-test failed to reject the null hypotheses of no serial correlation, homoscedasticity and normal distribution at 5% significant level. Also, stability tests using the cummulative sum of recursive residuals (CUSUM) and cummulative sum of squares of recursive residuals (CUSUMq) plots of Brown *et al*. (1975) [6] for the ARDL model as shown in Figures 1a, 1b, show the movement of the CUSUM or CUSUMq outside or within the critical lines of 5% significant level, which indicates parameter instability or stability. From the Figures, CUSUM statistic lies within the 5% critical lines, meaning that the model coefficients are stable in the short run. On the other hand, CUSUMq statistic for the model coefficients crosses the critical value line, indicating some instability in the ARDL model in the long run for the enterprise.

Table 9. Results of Diagnostic Tests

Test	χ^2 statistic	Probability
Breusch-Godfrey Serial Correlation Test	1.5767	0.2313
White Heteroskedasticity	1.1069	0.3959
Jarque-Bera test (Normality)	1.1845	0.3727

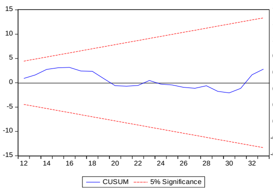

Figure 1a

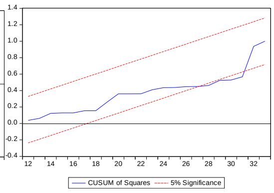

Figure 1b

Fig. 1. Plot of the Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Recursive Residuals of Square (CUSUMq) Tests for ARDL Model.

CONCLUSIONS

Based on the findings of this study, it can be concluded that the growth of maize output experienced deceleration in the period under consideration in the study area. Also, Temperature increased the production risk of the maize farmers in the study area. Temperature, rainfall and relative humidity were important climate factors that influenced the output of maize in the long and short run in the area. Therefore, individuals, government and non-governmental organizations should create more awareness on the need to always practice eco-friendly activities such as afforestation and put in place coping strategies against the menace of climate change on the production of food crops. Climate change issue can also be mitigated by encouraging carbon trading in Nigeria as it is in some advanced countries of the world. Agricultural insurance industry in Nigeria should be further strengthened and empowered to service risky farm businesses. The impact of Agricultural Insurance Industry still needs to be felt more in order to encourage farmers during the period of shocks. Policies that are geared towards the attainment of accelerated growth in maize output should be formulated in Nigeria such as making credit facilities available and accessible to the farmers.

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