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# CLIMATE CHANGE AND AGRICULTURAL PRODUCTION TRENDS IN NIGERIA: IMPLICATION FOR SUSTAINABLE FOOD PRODUCTION

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## ABSTRACT

Climate change variability is a threat to agricultural production at both global scales. The present study evaluates the link between climate change and food security in Nigeria which is a pointer to sustainable food production. Secondary data were extracted from the database of FAO and World Bank development indicator were used to assessed the staple crops such as casaba, cowpea, maize, rice and yam. The descriptive statistics (mean standard deviation and coefficient of variation) and correction model coupled with co-integration approach were used to analyse the data. The finding revealed an inconsistency in temperature and rainfall pattern which is an evident of changing climate. The average value of 11.4 tones/hectare, 0.85tons/ha, 0.25tons/ha, 0.30tons/ha and 1.83 tons/ha for cassava, cowpea, maize, rice and yam respectively were all lower than the expected global average. The result of unit root test showed that cassava and maize output are non-stationary at their level form but stationary after differencing and there is long run relationship between the variables. The result of error correction model revealed that rainfall ($\beta$ = -0.263, $p<0.01$) and temperature ($\beta$ = -0.083, $p<0.01$) exert positive effect on cassava and maize respectively. However, estimated parameters ($\beta$ = 0.046, $p<0.01$), ($\beta$ = 0.081, $p<0.01$) and ($\beta$ = 0.328, $p<0.01$) obtained for cowpea, rice and yam respectively showed negative relationship. Temperature showed significant and negative effect on rice and yam output. This implied that temperature and rainfall are important climatic factors that determine the growth of agricultural food crops in different ecological zones of Nigeria. The study therefore recommends environmental policies that are beneficial to crop production and facilitate climate change adaptation strategies.

**Keywords: Climate change, Food security, Correction model, Co-integration, Agricultural production**

## INTRODUCTION

Climate change remains a major threat facing human survival especially developing countries such as Nigeria (Hulme *et al*., 2001; Nicholson, 2014). Additionally, climate change serves as a stressor which affects the ecosystems functions and quality, although, the causes or its implications can be traced to anthropogenic activities such as deforestation, uncontrolled bush burning and deposition or discharged of waste effluents.

Despite technological advances such as irrigation systems to increase food production, climate change remains a prevailing challenge if sustainable agriculture is desired. Adoption of irrigation systems and use of genetically modified crops, climate change is still a determining factor of productivity in agriculture. Several reports have been produced by Intergovernmental Panel on Climate Change (IPCC) showing that there will be reduction in crop yield of most tropical and subtropical regions (IPCC, 2021; IPCC, 2021). In Africa for example some crops such as maize, cassava, and cowpea are already at their maximum tolerance for temperature. Nevertheless, Smith et al. (2014) and IPCC (2014) opined that uncontrolled human activities such as extensive bush burning will leads to food insecurity especially in spatial environment of today. Climate change has been predicted to affect African agriculture in a range of ways leading to an overall reduction in productivity and loss in GDP between 2% to 7% in 2100 in the sub-Sahara and about 2 to 4% in Western Africa (Enete and Amusa, 2010).

Agriculture which is the main stay of many household economies and significant sector of most developing economies is more vulnerable to climate change because agricultural productivity depends largely on environmental conditions (Eregha *et al*., 2014). Climate is an important factor in crop production among many countries. Particularly in Nigeria most farmers are climate dependant such as temperature and rainfall (Onyeneke, 2010). Although, decline in agricultural production can be traced to climate change and is of great concern if optimum crop production is desired (Pearce *et al.*, 1996; McCarthy *et al.*, 2001; Onyeneke, 2010). However, to achieve this, there is need to acquire up to date information about drivers of climate change.

Food production shortage is associated with climate change problem. Food insecurity and climate change are twin devils that have been identified as urgent problems limiting socio economic development. Food production shortage has been linked with climate change. Today, climate change and food insecurity are twin devils that have been identified as urgent problems limiting socio economic development. Sustainable food availability depends on efficient agriculture and this is threatened by the emergence of climate variability. For example, more that 60% of Nigerian households depend on agriculture production for their survival (Eregha *et al.*, 2014). Nigeria is marked as the hot spot of climate change. The predicted effect on the economy was estimated at 6 – 30% of its GDP by 2050 which worth between $100billion and $460 billion to climate change (Ebele and Amodi, 2016).

Many areas in Nigeria with major agricultural activities are facing one problem or the other due to climate change. The arid zone is currently faced with severe heath stress and rainfall shortage while the Sahel zone receives less than 10 rainfall inches a year with 25 percent less than that of thirty years ago (Sayne, 2011). Going by the IPCC prediction, the situation may get worse by 2100 when global rainfall would have dropped below 10% with projected decline of 2-7% in the contribution of agriculture to country's total GDP (Enete and Amusa, 2010; Chukwuezie *et al.*, 2016). Crop failure and declining yields in some part of the country are linked to higher temperatures and drought (Chukwuezie *et al.*, 2016; Eze *et al.*, 2018). The unpredictable and irregular rainfall seasonality to more torrential rainfall, adverse wind storms and flooding in many areas are the signs of climate change in southern part of Nigeria. Ayinde *et al.* (2011) noted that fluctuation in climatic variables is putting Nigeria's agriculture system under serious threat and stress. Agricultural production system in Nigeria is under threat and stress. The implication of this is that households in Nigeria are prone to food insecurity and livelihood problem. The implication of this is that households in Nigeria are vulnerable to food insecurity and livelihood problem. This study evaluates the trends of climate change in order to provide policy information for possible strategy towards climate adaptation and increased agricultural productivity.

## METHODOLOGY

Description of the study area

The study area is Nigeria. Nigeria, with a total land area of 923,768km$^2$ is situated between the Sahel to the north and the Gulf of Guinea to the south in the Atlantic Ocean. The estimated population is about 218 million. This makes the country the most populous country in Africa, and the world's sixth-most populous country. Nigeria borders Niger in the north, Chad in the northeast, Cameroon in the east, and Benin in the west. The country initially relies on agriculture as the principal foreign exchange earnings. However, Agriculture has failed to keep pace with Nigeria's rapid population growth, and Nigeria now relies upon food imports to sustain itself. The country relies on importation in order to meet up with wide gap between food supply and demand. Agricultural problems thereby complicated with climate change issue and poor agricultural technologies.

Data collection

The study involved the use of time series data from 1998 to 2018. The data were sourced from Food and Agricultural Organization Publication (FAO) and World Bank. These data include crop output of selected five staple foods these were: cassava, cowpea, maize, rice, and yam. Also data were collected on weather variables such as rainfall and temperature.

Data analysis

Data were subjected to descriptive statistics such as mean, standard deviation and coefficient of variation, seemingly unrelated regression analysis. The co-integration analysis involves unit roots test performed on level and first difference. The co-integration was used to determine the individual input series which exhibit similar properties and stationary. Co integration test is necessary to determine whether any changes in the data will adjust or not to short run interaction. If the data is static OLS would be used to estimate the long run model where variables are neither lagged nor differenced. There are three likelihood outcomes after performing stationary analysis. the times series are order 0, that is stationary in level. Series are integrated of order 1 i.e. stationary after first order. Series are integrated of different order. i.e. having a combination of I(0) and I(1) series. A time series data is stationary if the joint distribution of any set of *n* observations.

$Xt_1, Xt_2, \dots \dots \dots \dots \dots \dots \dots .. Xt_n$---------------------------------------------------------1

Equation 1 is the same as joint distribution of any set of equation 2

$Xt_{1+k}, Xt_{2+k}, \dots \dots . Xt_{n+k}$-----------------------------

for all n and k $Y_i = PY_{t-1} + U_t \; 1 \le P$ if $Y_i$ -----------------------------------------3

Equation 3 is regressed on its lagged value of $Y_{i-1}$ and the estimated P is statistically equal to 1 then $Y_i$ is non-stationary. However, if the estimated value of P is not statistically equal to 1 the $Y_i$ is stationary.

Augmented Dickey Fuller (ADF) test is a popular approach used for testing the unit root null hypothesis. In this study unit root was used to ensure that the dependent variable is of I(1) in the level and none of the variables is of I(2) of the higher order. If the dependent variables are co-integrated, their short run dynamics can be described by Error Correction Model (ECM). This study used Johansen Cointegration test. This was performed on the level form of the variables not on the first difference.

Seemingly unrelated regression approach: This was used in the estimation. The model allows for different regressors metrics in each equation e.g. $X_i \neq X_j$ and account for contemporaries' correlation. The model is specified below

$Y_{ti} = \alpha_i + \beta_{i1}X_1 + \beta_{i2}X_1 + \beta_{i3}X_3 + \varepsilon$ -----------------------------------------------------------4

Where,

$Y_{ti}$ = crop yield and $i$ represent the five major staple crops grown in Nigeria (maize, rice, beans, yam and cassava) and $t$ refers to sample years from 1998-2018 the explanatory variables $X_1$, $X_2$ and $X_3$ are temperature, rainfall and humidity

The error correction model is specified as

$\Delta Y_t = \propto_0 + \propto_1 \sum_{a-\infty}^{n} \Delta Y_{t-1} + \propto_2 \sum_{a-\infty}^{n} \Delta X_{1t-1} + \propto_2 \sum_{a-\infty}^{a} \Delta X_{2t-1} + ECM_{t-1}$----------------5

Where,

Where, ECM is error correction term (lagged residual of static regression) and '$\Delta$ ' stands for the first difference.

Equation 5 is estimated for each of the five selected crops, (cassava, cowpea, maize, rice and yam) hence, five models were estimated.

## RESULTS AND DISCUSSION

### Trends of selected crop outputs and weather elements in Nigeria

The results in Table 1 present the summary statistics of variables used in this study. The crop outputs are the major staple crops produced by farmers and their contribution to household food security in Nigeria. The average value of 11.14 tonnes/hectare obtained for cassava was lower than the global average value of 12.8ton/ha.

According to FAO (2013) cassava can reach 80 tonnes per hectare under optimal conditions. Other crops considered in this study are also less than the expected yield. Although, the trends is not consistent but a decreasing trend were observed in recent years that is year 2012 especially cassava and yam compared to earlier period (Figure 1-4). There was a rise in temperature since 2013 and inconsistent rainfall pattern. This is an evidence of changing climate.

**Table 1: Summary statistics of crop outputs in Nigeria and weather element**

| | Crop output (tones/hectare) | | | | | Weather variables | |
|---|---|---|---|---|---|---|---|
| Year | Cassava | Cowpea | Maize | Rice | Yam | Rainfall (mm) | Temperature Degree Celsius |
| 1998 | 11.845 | 0.450 | 1.455 | 1.766 | 10.400 | 95.211 | 27.522 |
| 1999 | 10.581 | 0.661 | 1.7634 | 1.648 | 10.914 | 102.969 | 27.062 |
| 2000 | 10.692 | 0.661 | 1.433 | 1.653 | 10.911 | 93.270 | 26.868 |
| 2001 | 10.583 | 0.661 | 1.543 | 1.433 | 10.801 | 91.528 | 27.055 |
| 2002 | 10.914 | 0.694 | 1.642 | 1.477 | 11.011 | 90.481 | 27.238 |
| 2003 | 11.466 | 0.727525 | 1.653 | 1.554 | 11.575 | 112.247 | 27.373 |
| 2004 | 12.126 | 0.727 | 1.763 | 1.565 | 12.346 | 93.569 | 27.343 |
| 2005 | 12.114 | 0.749 | 1.829 | 1.576 | 12.674 | 94.609 | 27.608 |
| 2006 | 13.228 | 0.760 | 2.004 | 1.635 | 13.336 | 97.902 | 27.464 |
| 2007 | 12.348 | 0.736 | 1.879 | 1.432 | 10.989 | 97.090 | 27.361 |
| 2008 | 13.007 | 0.749 | 2.157 | 1.933 | 12.676 | 101.589 | 27.064 |
| 2009 | 12.971 | 1.126 | 2.420 | 2.128 | 11.551 | 94.400 | 27.755 |
| 2010 | 13.465 | 1.298 | 2.039 | 2.026 | 14.342 | 101.722 | 27.857 |
| 2011 | 12.357 | 0.599 | 1.793 | 2.240 | 8.161 | 80.453 | 27.434 |
| 2012 | 8.772 | 1.629 | 1.666 | 2.091 | 7.938 | 100.756 | 27.248 |
| 2013 | 7.751 | 1.420 | 1.611 | 1.813 | 7.716 | 79.923 | 27.507 |
| 2014 | 9.614 | 0.636 | 1.747 | 2.147 | 9.331 | 92.173 | 27.584 |
| 2015 | 10.221 | 0.699 | 1.719 | 2.209 | 9.341 | 81.177 | 27.798 |
| 2016 | 10.646 | 0.917 | 1.934 | 2.226 | 9.403 | 103.035 | 27.886 |
| 2017 | 9.868 | 0.996 | 1.756 | 2.201 | 9.046 | 81.1770 | 27.986 |
| 2018 | 9.566 | 1.007 | 2.306 | 2.243 | 8.746 | 103.035 | 27.996 |
| Mean | 11.149 | 0.852 | 1.815 | 1.857 | 10.629 | 94.682 | 27.477 |
| St.Dev | 1.5418 | 0.296 | 0.257 | 0.302 | 1.835 | 8.630 | 0.323 |
| CV | 13.828 | 34.711 | 14.16514 | 16.269 | 17.272 | 9.114 | 1.178 |

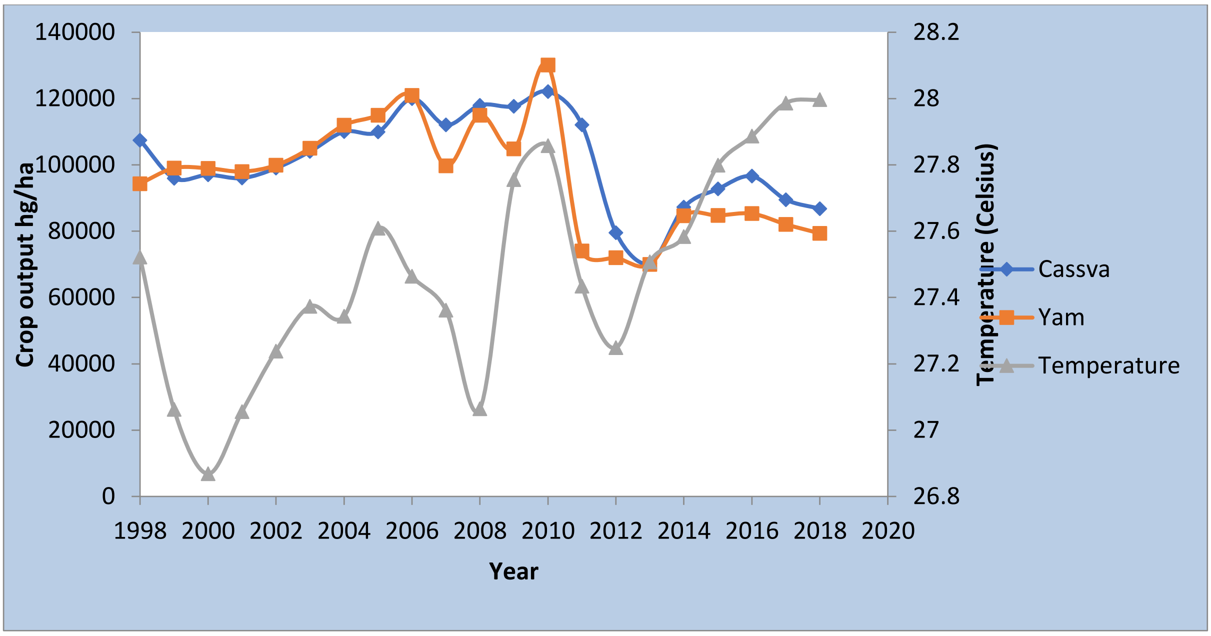


**Figure 1: Nigeria Annual average Output of Cassava and Yam in relation to annual temperature**

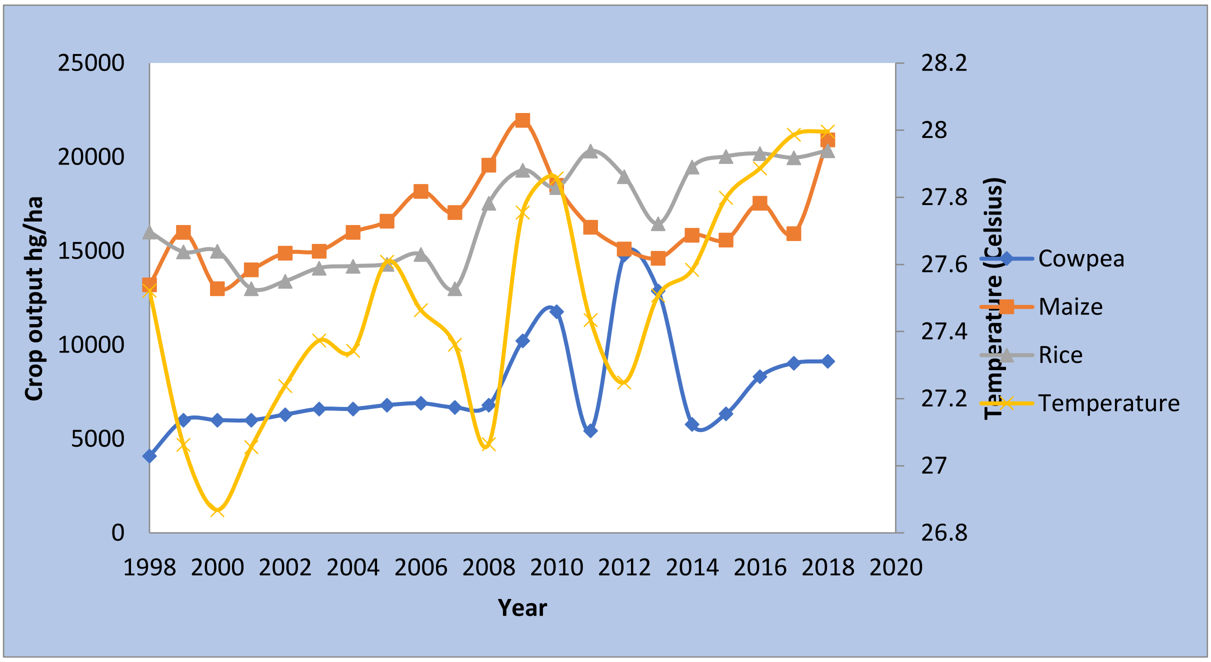


**Figure 2: Relationship between crop output (cowpea, maize and rice) and temperature**

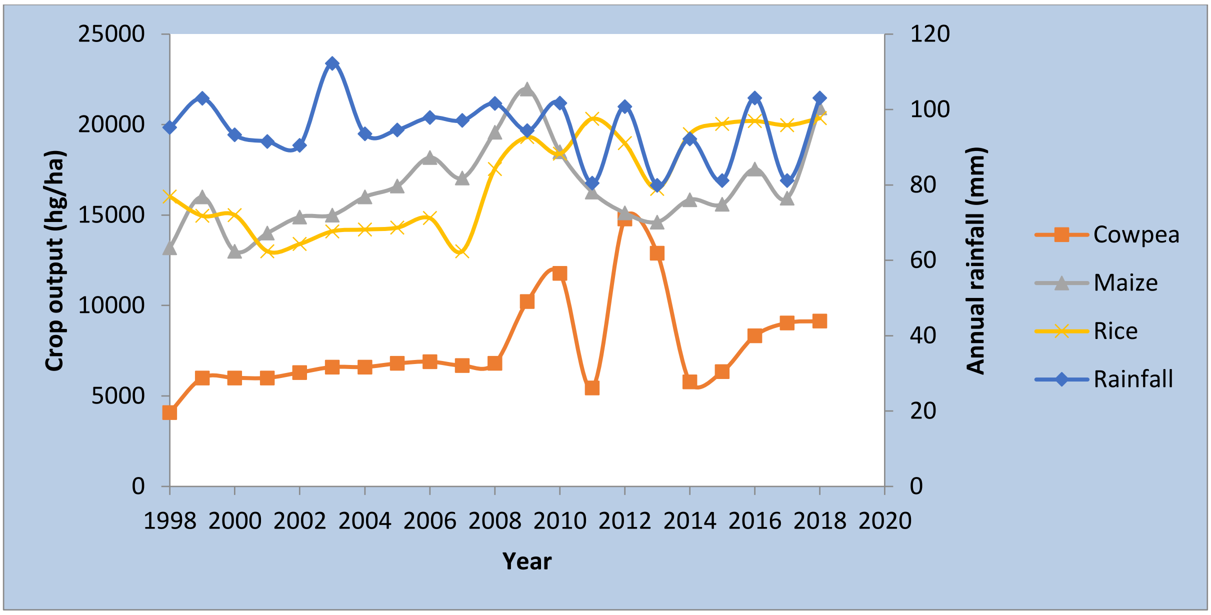


**Figure 2: Relationship between crop output (cowpea, maize and rice) and rainfall**

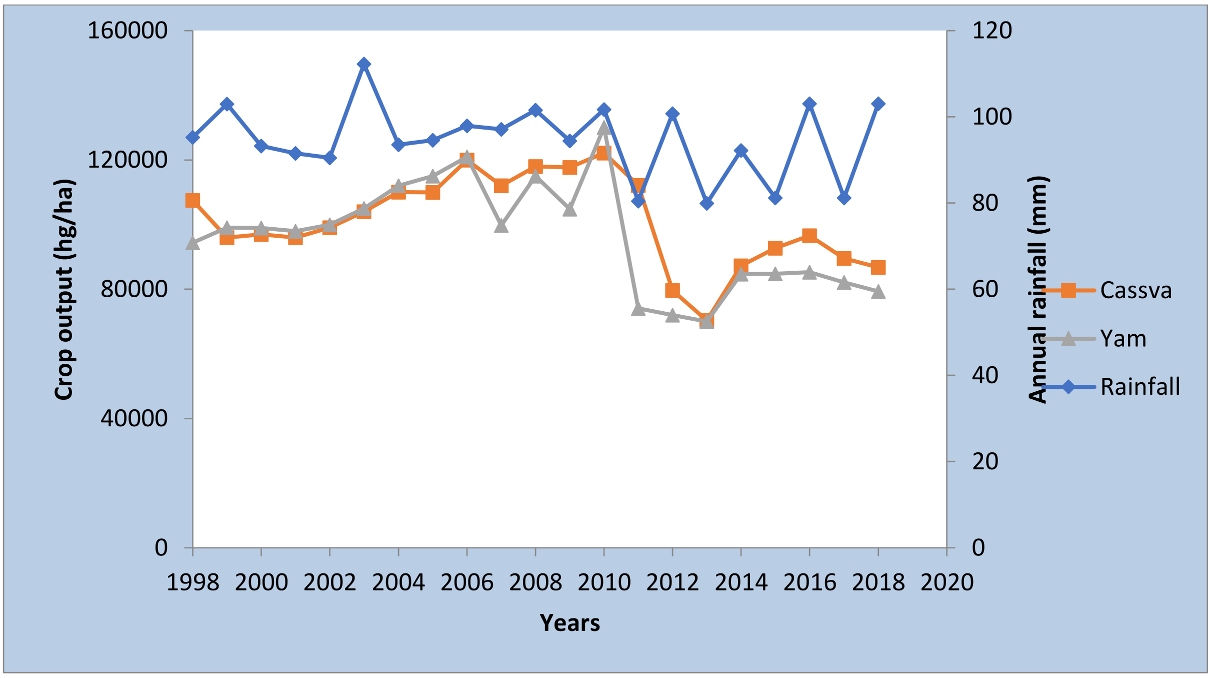


**Figure 4: Nigeria Annual average Output of Cassava and Yam in relation to annual rainfall**

## Co-integration Test

The result of unit root test using Augmented Dickey-Fuller approach is presented in Table 2. As shown in the results yam, rice, cowpea, temperature and rainfall are stationary while maize and cassava are non stationary. This indicates that the data generated for this study evolved around zero at level. The co-integration test revealed that maize and cassava are stationary after the first difference. It was revealed that most of these variables are stationary at level. Cassava and maize output are non stationary at their level form but stationary after differencing and there is long run relationship between the variables, error correction model is necessary. The variables that are stationary at their level therefore required no lag variables. The data series for cassava and maize are lagged in error correction model as there variables exhibit unit root with independent variables.

**Table 2: Augmented Dickey-Fuller unit root test**

| Variable | Level | 1st difference |
|---|---|---|
| Cassava | -2.497 | -3.238*** |
| Cowpea | -3.458*** | -5.952*** |
| Maize | -1.622 | -2.489*** |
| Rice | -2.836*** | -3.964*** |
| Yam | -1.993*** | -2.953*** |
| Rainfall | -2.623*** | -4.101*** |
| Temperature | -4.189*** | -4.752*** |

***** =P<0.01**

The results presented in Table 3 showed the effect of seasonal fluctuation of temperature and rainfall on output of selected agricultural crops. It was revealed that the estimated coefficients obtained for all the crops were significant at 1% level of probability. The parameters were negative for cassava and maize which implied a positive relationship while the coefficients were positive in the case of cowpea, rice and yam. These indicate a negative relationship since the sign of coefficients are reversed in the long run. The positive relationships with maize and cassava showed inadequate rainfall and increased rainfall would have resulted to increased output. Olaniyan (2015) noted that decreased level of precipitation could cause serious decrease in crop yield especially maize is sensitive to moisture stress around the time of tasselling and cob formation. The crop needs optimum moisture condition at the time of planting. More so, the impact of rainfall on all the selected crops is due to the fact that majority of farmers in Nigeria are practicing rain fed agriculture. This renders Nigeria agriculture vulnerable to climate change (Agboola and Fayiga, 2016).

Temperature changes were found influencing maize, rice and yam. The estimated parameter was negative for maize and positive for all other crops. The positive coefficients implied that as the temperature increases the output decreases and vice versa since the reverse is the sign in the long run. The implication of these findings is that it is only maize production with minimal temperature and higher temperature was found influencing the production of cassava, cowpea, rice and yam. The significant coefficients of temperature in relation to crop output is evident that temperature is the most important climatic factors that determines the growth of agricultural crops in different ecological zones of Nigeria (Olaniyan, 2015).

**Table 3: Vector Error Correction Result**

| Variable | Cassava | Cowpea | Maize | Rice | Yam |
|---|---|---|---|---|---|
| Rainfall | -0.263*** | 0.046*** | -0.083*** | 0.081*** | 0.328*** |
| | (0.058) | (0.014) | (0.019) | (0.020) | (0.058) |
| Temperature | 1.655 | 0.013 | -1.187*** | 0.049*** | 2.485*** |
| | (1.202) | (0.234) | (0.355) | (0.358) | (1.000) |
| R-square | 0.64 | 0.42 | 0.76 | 0.83 | 0.65 |
| Ch2 | 25.51 | 10.31 | 2.72 | 68.67 | 26.85 |
| Log likelihood | -25.51 | -60.23 | -51.21 | -50.86 | -83.41 |

***P<0.01 Figures in parentheses are percentages

## CONCLUSION AND RECOMMENDATION

This study examines the effect of climate change on crop output in Nigeria. Two climatic variables (temperature and rainfall) and five crops were selected. Decreasing trends were observed in the output of the selected agricultural crop with seasonal variation in rainfall and rising temperature over the period under consideration. Data obtained for crop output and climatic variables were stationary. However, data obtained for cassava and maize were stationary after first difference. The observed climatic variables were found affecting agricultural crops. Rainfall decrease showed a decreasing effect on crop output while increasing temperature exerts a decreasing effect on crop output. The result established that changes in climatic variables are responsible for changes in the output of agricultural crops. The study recommends environmental policies that are beneficial to crop production and facilitate climate change adaptation strategies. Also, farm practices that will not contribute to climate change should be embraced by the farmers.

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