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EFFECT OF CLIMATIC CHANGE AND VARIABILITY ON GROUNDNUT (*ARACHIS HYPOGEA*, L.) PRODUCTION IN NIGERIA

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Abstract

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The study examined the effect of climate change and variability on groundnut production in Nigeria. The study specifically analyzed the trend in climatic parameters (temperature, rainfall) in the study area; analyzed the trend in groundnut farmers' output; and determined the long-run as well as the short-run influences of climatic parameters on the farmers' output. The population of the study is the entire Nigeria which is over 160 million persons. No sampling procedure was carried out as the work was entirely based on time series data. The study further used the aggregate domestic groundnut production index from FAO which spanned from 1980–2014. Results showed that within this range of the years (1991 and 2000), there was a slight decrease in the mean temperature and rainfall and yet they did not negatively affect the output of groundnut, instead there was an increase. However, from 2001–2010 and 2011–2014, the mean temperature (27.58°C), mean rainfall (1123.58 mm) and groundnut output (58067.36 metric tonnes), and from 2011–2014 which recorded the mean temperature (27.60°C), mean rainfall (1383.15 mm) and the groundnut output (71484.70 metric tonnes) indicated that there is an increase in mean temperature with a corresponding increase in groundnut output, respectively. Results from the Augmented Dickey Fuller (ADF) test indicated that the temperature, rainfall and groundnut are non-stationary as they do not show a significant negative coefficient; thus, they are further differentiated to attain stationarity. Pertaining to the result, the variables underwent a first order differentiation after which there was non-stationarity. It was recommended that the Nigerian government should organize programmes under the supervision of the Ministry of Agriculture to train groundnut farmers to keep climate and production activity records in other to provide firsthand information when the need arises. More so, climate research centres should initiate, conduct and coordinate research on the on the status of Nigerian environment with emphasis on climate (Rainfall and Temperature). Hence, adequate communication channels that make research result available to the groundnut farmers should be provided.

Key words: climate change; variability; groundnut; production; farmers; Nigeria
Abbreviations: ADF – Augmented Dickey Fuller; CBN – Central Bank of Nigeria; CLIP – Climatic Parameters; ECT – Error Correction Term; DAFF – Department of Agriculture, Forestry and Fisheries; FAO – Food and Agriculture Organization; IPCC – Intergovernmental Panel on Climate Change; MOA – Ministry of Agriculture; NAMC – National Agricultural Market Council; VAR – Vector Autoregressive; VECM – Vector Correction Model

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Introduction

Groundnut (*Arachis hypogaea,* L.), also referred to as peanut, is one of the world's principal oil seed crops, which originated from South America, and is now widely cultivated throughout the tropical, sub-tropical and the warm temperate climatic zones (Sogut et al., 2016). Historically, the production of groundnut in Nigeria started about the year, 1912 in response to its high world prices (Tadesse et al., 2014). Since then, Nigeria has maintained a prominent place amongst the world producers of it. Nevertheless, Nigeria assumed the prominent position of the world's leading exporters of groundnut in the 1950s (Eicher, 1967; NAMC-DAFF, 2016).

As the world's largest groundnut producer and exporter in the 1960s, Nigeria recorded a production of 500 000 metric tons that period (Purseglove, 1968; DFID, 2008). However, the production fell by almost half the 1973 figure in less than a decade, due to a combination of two important factors. Firstly, the drought of 1974/75 production season, which brought with it aphid infestation led to huge losses for both farmers and merchants of more than 750 000 hectares in groundnut fields. Secondly, the incidence of oil boom in Nigeria became a well-known issue about that same time (Ntare et al., 2005). Due to its diverse economic importance and uses, groundnut can be described as an economic crop. The haulms serve as an important fodder for ruminant livestock, especially sheep and goat (Li et al., 2013). The plant, through its biological activities in nitrogen fixation is an important soil fertility conserver (Mofya-Mukuka and Shipekesa, 2013). The nuts are consumed roasted, boiled or processed as confectionary, snack nuts, peanut butter or as cookies. They are therefore consumed primarily when roasted or as oil (Government of Gujarati, 2017).

Groundnut crop which is an aspect of crop agriculture has been observed over time to be sensitive to short-term changes in weather, as well as to seasonal, annual and longer-term changes and variations in climate (Khanal and Mishra, 2017). Climatic risk and variability in weather, is one of the important factors affecting groundnut production and land allocation (Mofya-Mukuka and Shipekesa, 2013). According to Eregha et al. (2014), climate change is regarded as one of the greatest challenges of the 21st century and has posed great threats to agriculturally dependent economies. In fact, report has it that developing economies are at a disadvantage as they stand to experience some of the severe effects of climate change (Li et al., 2013). Importance of studies on impacts of climate change and environmental management are underlined by Bachev (2009, 2010, 2013) and Bachev and Nanseki (2008).

Immediate attention is required to handle the serious problem of climate change and variability (Kasimba, 2012). According to Boko et al. (2007) and IPCC (2007), a recent IPCC report concluded that changing climatic conditions are likely to impose additional pressure on water availability, thereby reducing the length of the growing season and forcing large regions of marginal agriculture out of production. In other words, groundnut crop as a leguminous crop requires few inputs and increases soil fertility by fixing nitrogen, making it an appropriate choice in the low-input agricultural systems that are prevalent among many small-scale farmers in Africa (Okello et al., 2010; Olusina and Odumade, 2012).

Available pieces of evidence show that each day brings fresh proofs of climate change and these effects include increasing temperatures, decreasing rainfall in the continental interiors, drought, desert encroachment, melting ice, extreme weather, floods, sea level rise, sinking of Islands, water scarcity, health and agricultural problems (Colls, 2008). Excessive increases in temperature results in low agricultural productivity and this may lead to depletion of soil nutrients and destruction of soil structure and organisms which contribute to the fertility of the soil. Ordinarily, rainfall can be considered to have positive effect on agricultural productivity except where it leads to flooding, erosion and leaching (Nelson et al., 2009).

Rainfall amount and high temperatures are the most important elements of climate change in Nigeria. As a result of that, the Northeast region of Nigeria is increasingly becoming an arid environment at a very fast rate occasioned by the fast reduction in the amount of surface water, flora and fauna resources on the land (Ayinde et al., 2011). Consistent reduction in rainfall leads to a reduction in the regeneration rate of land resources. The northern zone therefore faces the threat of desert encroachment. The Southern region of Nigeria, which was largely known for high rainfall, is currently confronted by irregular rainfall and high temperatures (Adejuwon, 2004; Obioha, 2008). Furthermore, Iizumi et al. (2014) indicated that climate change and variability has an adverse impact not only on groundnut, but on the global food production and food security, all things remaining equal. Hence, a reduction in yield and increased variability from extreme weather events is likely to increase the long-term mean and volatility of staple food prices (Khanala and Mishra, 2017).

Moreover, as a cash crop, groundnut can give relatively high returns for a limited land area, and is well adapted to the hot semi-arid conditions characterizing many of the regions where it is grown (Wangai et al., 2001; Settaluri et al., 2012). In addition to that, it affects not only the high returns wielded by the groundnut producers and marketers, but the water resources management and the overall economy of the country (Eregha et al., 2014). That food and energy security is crucially dependent on the timely availability of adequate water and ideal climate for farming has been noted (Ewona and Udo, 2011). According to Jain and Kumar (2012), temperature and its changes impact on a number of hydrological processes including rainfall. More so, climate change has direct effects on increasing global temperature, alter precipitation patterns, and alter the pattern of crop agriculture especially that of groundnut production (Karaburun et al., 2012).

Conversely, groundnut production faces several production constraints including droughts and erratic rainfall patterns (Kasimba, 2012). Its productivity is said to be affected by poor local markets, poor pricing structure and lack of lucrative export markets. According to Nelson et al. (2009), the poor price structure is a disincentive to increase production because groundnut production is a labour-intensive crop and the low prices mean that farmers cannot make a profit and therefore, cannot increase their scale of production. The export market creates demand and hence, drives the production (Minde et al., 2008).

This paper reviews the importance of groundnut production to the poor in Nigeria, and outlines the expected consequences of climate change and variability for groundnut production, focusing on the consequences for the rural poor in developing countries. It further offers a comprehensive understanding of how the repercussions of climate change and variability affects both natural and human systems in relation to groundnut production.

The general objective of the study is to analyze the effect of climatic change and variability on groundnut production in Nigeria. Specifically, the objectives:

i. analyzed the trend in climatic parameters (temperature, rainfall)in the study area;

ii. analyzed the trend in groundnut farmers' output; and

iii. determined the long-run and short-run influences of climatic parameters on the farmers' output.

Materials and Methods

Nigeria is situated on the west coast of Africa. It shares a common boundary with Republic of Niger and Chad to the North, Republic of Cameroon to the East, and Benin Republic to the West. The country is bounded by the Atlantic Ocean in the South stretching to 823 km (FMLHUD, 2014). The total area of Nigeria is 923 768 km² of which 910 768 km² is a land, while the rest (13 000 km²) is all water. Nigeria's total boundaries are 4 047 km in length and borders on Benin at 773 km; on Cameroon at 1 690 km; on Chad's at 87 km; and on Niger at 1 497 km, as the case may be. Nigeria's climate is characterized by strong latitudinal zones, becoming progressively drier as one moves north from the coast. Nigeria's climate is marked by two seasons, dry (or harmattan) and rainy (production) seasons (The Library of Congress Country Studies, 1991). The country lies between 4°N and 14°N, and between 3°E and 15°E. Nigeria is located within the tropics and therefore experiences high temperatures throughout the year. The mean for the country is 27°C. Average maximum temperatures vary from 32°C along the coast to 41°C in the far north, while mean minimum figures range from 21°C in the coast to under 13°C in the north. The climate of the country varies from a very wet coastal area with annual rainfall greater than 3 500 mm to the Sahel region in the north western and north eastern parts, with annual rain fall less than 600 mm (Oyinbo et al., 2013).

The population of the study is the entire Nigeria which is over 160 million persons. No sampling procedure was carried out as the work was entirely based on time series data. The study further used the aggregate domestic groundnut production index from FAO which spanned from 1980–2014. It is pertinent to note that rainfall was measured in Millimeters (mm), output in (000'metric tonnes), temperature in degrees centigrade (°C) and trend(s) in the number of years.

Data for the study was analyzed using descriptive and inferential statistics. Objective (i) and (ii) were achieved using descriptive statistics such as means, percentages, standard deviation of the series. Also, graphs were used to describe the trend or movement of the climatic variables and also the trend in Groundnut production (Output) in Nigeria from 1980–2014. To check the stationarity or non-stationarity of the series, the Augmented Dickey-Fuller was used. The Johansen (1991, 1995) Vector Autoregressive (VAR) based co-integration test was used to analyze part of objective (iii) i.e. the long-run relationships, while the VAR Model and Vector Correction Model (VECM) were employed in determining the short-run relationships between the climatic variables on the output of Groundnut. The VAR was used wherever co-integration occurred, while VECM was implemented in the absence of co-integration.

Augmented Dickey-Fuller (ADF) unit root test

In order to establish the stationarity level, unit root tests were carried out so as to avoid the problem of spurious regression as described by Granger and Newbold (1980), and Gogoi (2010). If unit root is found, then the conditions of stationarity are violated. The most commonly used unit-root test is the Augumented Dickey-Fuller Test (ADF). The test equation is given as:

$$\Delta OUTAQ_t = \alpha_0 + \alpha_1 t + \\ + \beta OUTAQ_{t-1} + \sum \delta_1 \Delta OUTAQ_{t-1} + \varepsilon_t, \qquad (2.1)$$

where OUTAQ is the aggregate groundnut production index, α_0 is the constant, α_1 is the coefficient of the trend series;

$OUTAQ_{t-1}$ is the lagged value of the first order; and ε_t is the error term.

Dickey-Fuller adds lagged dependent variables to the test equation to remove distortions to the level of statistical significance thereby lowering the power of the test to detect a unit root when one is present. The null hypothesis can be evaluated by testing whether $\beta = 0$, while the alternative hypothesis tests whether $\beta < 0$ A rejection of null hypothesis implies that the series is stationary.

$$\Delta CLIP_t = \alpha_0 + \alpha_1 t + \beta CLIP_{t-1} + \sum\delta_1 \Delta CLIP_{t-1} + \varepsilon_t, \qquad (2.2)$$

where CLIP is the aggregate of all the climatic parameters, α_0 is the constant, α_1 is the coefficient of the trend series, $CLIP_{t-1}$ is lagged value of the first order and ε_t is the error term.

Co-integration Test

If variables CLIP and OUTAQ have unit roots with some linear combination of them indicating stationarity, the spurious regression which occurs when the variables are non-stationary can be taken care of or avoided due to co-integration (Koop, 2000). According to Engle and Granger (1987), two series are integrated in the same order 1(q) co-integrated, with the linear combination of the two variables generating a stationary series. In other words, a non-stationary series that are co-integrated may diverge in the short run, but must be linked together in the long run. Even though they become attracted in the long run relationship, the co-integrated variables may never move far apart (Koop, 2000). Hence, testing for co-integration implies testing for the existence of such a long-run relationship between the economic variables.

Nevertheless, Johansen Test, which is a VAR-based Co-Integration Test considered a general VAR of order p:

$$y_t = A_1 y_{t-1} + \ldots.. + A_p y_{t-p} + \beta x t_{t-i} + \varepsilon_t, \qquad (2.3)$$

where y_t is a k-vector of non-stationary variables that are for instance integrated of order 1 and commonly denoted as I (1); y_t consists of $CLIP_t$ and $OUTAQ_t$; x_t is a d-vector of deterministic or exogenous variables which are optional, and ε_t is a vector of innovations or random shocks.

$$\Delta y_t = \Pi y_{t-1} + \sum\Gamma_i \Delta y_{t-1} + \beta x_1 + \varepsilon_t \qquad (2.4)$$

where:

$$\Pi = \sum A_i - I,\ \Gamma_i = -\sum A_j \qquad (2.5)$$

Vector Error Correlation Model (VECM)/ Vector Autoregressive (VAR) Model

The co-integration relationship only takes care of the long run relationship regardless of the short run dynamics explicitly. A good time-series model must describe both the long run and short run effects of the individual variables. Hence, it is defined as a dynamic model in the long run equilibrium, and referred to as the speed at which the dependent variable Y, returns to equilibrium after a change in an independent variable X.

The model is often stated as the acronym, VECM. It is therefore, a restricted VAR designed for use with non-stationary series that are known to be co-integrated. Simple formulations of two variable systems are represented as follows:

$$CLIP_t = \beta_1 OUTAQ_t \qquad (2.6)$$

The corresponding VECM is:

$$CLIP_t = \alpha_1(OUTAQ_{t-1} - \beta_1 CLIP_{t-1}) + \varepsilon_{1,t} \qquad (2.7)$$

$$\Delta OUTAQ_t = \alpha_2(OUTAQ_{t-1} - \beta_1 CLIP_{t-1}) + \varepsilon_{2,t} \qquad (2.8)$$

In this simple model, the only right hand side variable is the error correction term. In the long run equilibrium, this term is zero. However, if CLIP and OUTAQ deviates from the long run equilibrium, the error correction term will be non-zero with each variable adjusting to partially restore the equilibrium relationship. The coefficient α_1 measures the speed of adjustment of the i^{-th} endogenous variable towards the equilibrium. If α_1 has a negative sign, this ensures that any disequilibrium will be corrected. If α_1 tends to -1, then a large percentage of the disequilibria is corrected from each period; if tending to 0 then the adjustment will be slow and if the sign is positive, then it will imply that the system diverges from the long run equilibrium path.

However, if the lagged difference terms and constants are included as will be done in this study, equation (3.7) becomes:

$$\Delta CLIP_t = \delta_0 + \sum\varphi_i CLIP_{t-I} + \sum\gamma_i \Delta OUTAQ_{t-i} + \\ + \alpha_1(OUTAQ_{t-1} - \beta_0 - \beta_1 CLIP_{t-1}) + \varepsilon_{1,t} \qquad (2.9)$$

$$\Delta OUTAQ_t = \eta_0 + \sum\lambda_i CLIP_{t-i} + \sum\theta_i OUTAQ_{t-i} + \\ + \alpha_2(OUTAQ_{t-1} - \beta_0 - \beta_1 CLIP_{t-1}) + \varepsilon_{2,t}, \quad (2.10)$$

where δ_0 and η_0 are the constant terms (intercepts) in the climatic parameters and output of groundnut equations respectively. φ_i, γ_i and λ_i; θ_i are the coefficients of the lagged climatic parameters and lagged output of groundnut respectively; β_1 is the co-integrating vector and α_1 and α_2 are the speed of adjustment in the climatic parameters and output of groundnut equations respectively.

If the variables of CLIP and OUTAQ are not co-integrated, the analysis will proceed in a VAR framework.

The empirical model is then specified thus:

$$CLIP_t = \delta_0 + \sum\varphi_i CLIP_{t-I} + \sum\gamma_i OUTAQ_{t-i} + \varepsilon_{1,t}$$

$$OUTAQ_t = \eta_0 + \sum\lambda_i CLIP_{t-i} + \sum\theta_i OUTAQ_{t-I} + \varepsilon_{2,t} \quad (2.11)$$

The formulations above apply irrespective of whether it is aggregate or individual climatic parameter that is being considered.

Results

Trend in climate change parameters (temperature, rainfall and groundnut output) from 1980-2014

As indicated in Table 1 and Figures 1, 2 and 3 below, the result shows the mean of the rainfall, temperature and groundnut output within the ranges in years under study. From 1980–1990, 26.36°C was the mean temperature, 1131.71 mm was the mean rainfall and 1439.46 metric tonnes was the mean output of groundnut within this range of years.

Table 1

Descriptive statistics of trend in climate change parameters (temperature, rainfall and groundnut output) in Nigeria from 1980–2014

Years	Temperature (°C)	Rainfall (mm)	Groundnut Output
1980 – 1990	26.36	1131.71	1439.46
1991 – 2000	26.27	1041.11	2040.20
2001 – 2010	27.58	1123.58	58067.36
2011 – 2014	27.60	1383.15	71484.70

Source: Data Analysis, 2016

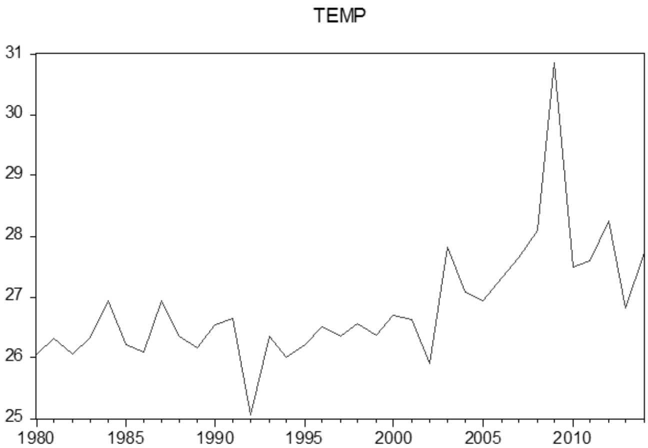

Fig. 1. Trend in temperature in Nigeria from 1980-2014

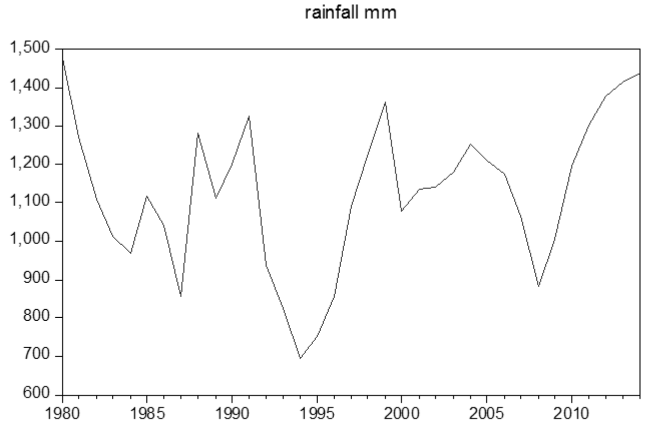

Fig. 2. Trend in rainfall from 1980-2014

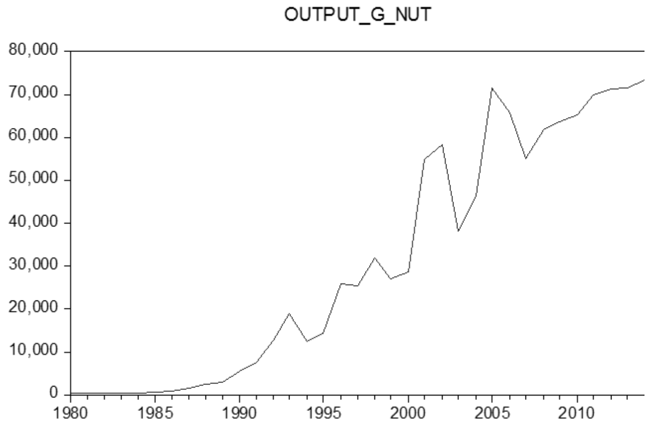

Fig. 3. Trend in groundnut farmers' output in Nigeria from 1980-2014

Augmented dickey fuller's test for stationarity

The Augmented Dickey Fuller's test which is a unit root test was employed to detect if the variable under investigation has a stable mean value (stationarity). This is carried-out mostly when time series data are trended over time and regression may produce high R^2s but may be spurious or meaningless (Granger and Newbold, 1974). The results are seen in Table 2.

Johansen co-integration Test Results

From Table 3, the variables are integrated in the same order representing the Johansen co-integration results, which is based on the findings of Engle and Granger's (1987) submission that long run equilibrium relationships may exist between non-stationary variables.

Table 2
Results of augmented dickey fuller test for stationarity

Parameters	Level				1st differencing			
Variables	ADF	1%	5%	10%	ADF	1%	5%	10%
Temperature	-3.37	-3.64	-2.95	-2.61	-7.40	-3.65	-2.96	-2.62
Rainfall	-2.76	-3.64	-2.95	-2.61	-5.86	-3.65	-2.95	-2.62
Groundnut Output	0.62	-3.65	-2.96	-2.62	-10.63	-3.65	-2.96	-2.62

Source: Computed from Field Survey Data, 2016

Table 3
Results of Johansen co-integration Test of long run relationship between temperature, rainfall and aquaculture output

Eigen Value	Trace Statistic	Critical Value 5%	Hypothesized No. of CE(s)
0.34	23.76	29.80	None*
0.26	9.93	15.49	At most 1
0.00	0.01	3.84	At most 2

(*) indicates significance at 1%
Source: Data Analysis, 2016

Vector error correction model of short run effects of temperature and rainfall on groundnut

The parameter of the long run model showed that long run equilibrium exist between temperature and groundnut output (Table 4). This is based on the fact that the coefficient of temperature is significant in the long run. In addition, the long run coefficient of rainfall on groundnut output was not significant.

Table 4
Vector error correction model test of long and short run relationship among temperature, rainfall and groundnut output

Long-run Estimates	
Regressors	Coint Eq 1
Groundnut output	1
Rainfall (mm)	-9.26 (-0.26)
Temperature	-37852.25 (-5.35*)
Constant	974612.6
Short- run ECM	Groundnut Output Model
Coint Eq 1	0.11 (-1.66) ***
Δ Groundnut t-1	-0.015 (-0.08)
Δ Rainfall t-1	-9.25 (-0.99)
Δ Temperature	-2782.87 (-1.42)
Constant	0.36 (0.00)

(*) indicates significance at 1%; (**) indicates significance at 5%
Source: Data Analysis, 2016

Discussion

Trend in climate change parameters

As shown in Table 1, the range of years from 1991–2000 indicates a mean temperature of 26.27°C, mean rainfall of 1041.11 mm and mean groundnut output of 2040.20 metric tonnes. Within this range of years, there was a slight decrease in the mean temperature and rainfall and yet they did not negatively affect the output of groundnut instead, there was an increase.

From 2001–2010, the mean temperature observed was 27.58°C, mean rainfall of 1123.58 mm and groundnut output of 58067.36 metric tonnes. Here, there was an increase in mean temperature with a corresponding increase in groundnut output.

From 2011–2014, the mean temperature of 27.60°C, mean rainfall of 1383.15 mm and groundnut output of 71484.70 metric tonnes. For this range of years, it had the highest mean temperature, rainfall and groundnut output.

From Table 1, the least recorded of mean temperatures and groundnut output was 1991–2000 and the least recorded of mean rainfall was 1991–2000. The finding here is in line with the work of Odjugo (2010) and Oguntunde et al. (2012) reporting the trend and variations of temperature in Nigeria.

Unit root test for stationarity

As indicated in Table 2, the result revealed that temperature, rainfall and groundnut are not stationary at 1% level of significance as they do not show a significant negative coefficient. Thus, they are further differenced to attain stationarity. Pertaining to the result, the variables underwent a first differencing after there was non-stationarity at level. At first differencing, temperature, rainfall and groundnut attained stationarity. This sign of non-stationarity corroborate the findings by Boubacar (2010) of the effects of droughts on crop yield and yield variability in the Sahel.

Johansen co-integration Test

From the results shown in Table 3.0, it indicated that the independent variable (temperature) significantly affects the dependent variable (output of groundnut). Thus, there exist a long run relationship between the variable leading to the rejection of the null hypothesis of no co-integration and accepting the alternative hypothesis of co-integration. Subsequently, the error correction model was conducted upon detection of long run relationship among the parameters. Amikuzuno and Donkoh (2012) made a similar observation.

Vector error correction model of short run effects of temperature and rainfall on groundnut

This implies that increase in temperature by 1% significantly decreases the long run output of groundnut by 37852.25. .Also, the low and insignificant value of the ECT with a coefficient of 0.11 implies that disequilibrium in the short run to long run relations is not immediately corrected. This is due to the fact that groundnut farmers are constrained by technical factors which limit their ability to adjust to changes in temperature in the short run. Chikezie et al. (2015) made a similar observation in their study on the effect of climate change on the production of some selected food crops in Southeast Nigeria.

Conclusion

The overall purpose of the study assessed the effect of climate change and variability on groundnut production in Nigeria. Hence, the need to know the relationship existing between temperature, rainfall and groundnut output in Nigeria; and more so, the effect of temperature and rainfall on the output of groundnut provided insights on the trend in temperature, rainfall and groundnut output in Nigeria. Time series data over the period 1980 – 2014 obtained from various publications of the CBN and Annual Book of Abstract were utilized in this study.

The tools of data analysis employed in the study included ADF test which was used to test for stationarity. Co-integration analysis established that there exist a long run relationship between temperature and the output of groundnut. The study shows generally, the variability that exists in Nigeria temperature and rainfall (climatic parameters and their effects significantly on groundnut output.

Efforts of policy makers and the government are geared as well as directed towards addressing the imminent climate change issues by developing mitigation and adaptation options with the aim of reducing its adverse effects. In other words, based on the findings of this study, the following recommendations were made:

- The Nigerian government should organize programmes under the supervision of the MOA to train groundnut farmers to keep climate and production activity records in other to provide firsthand information when the need arises.
- Climate research centers should initiate, conduct and coordinate research on the on the status of Nigerian environment with emphasis on climate (Rainfall and Temperature).
- There should be adequate communication channels that make research result available to the groundnut farmers.

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