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Climate Change and Food Production in Nigeria: Implication for Food Security in Nigeria

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Abstract

Food production in Nigeria is largely dependent on natural environmental resources like rainfall, temperature and relative humidity. This study examined the impact of some of these climatic variables on food production in Nigeria from 1975 to 2010. Secondary time series data obtained from FAOSTAT (Food and Agriculture Organization statistics) and Nigerian Meteorological Agency were used for the study. The data were analyzed using some econometric tools such as Augmented Dickey Fuller (ADF) test, Johansen Test and Vector Error Correction (VEC) Estimates. The ADF test reveals that relative humidity integrated at order zero level while rainfall and temperature and agricultural output were stationary after differencing at level 1 thus showing that the variables had relationship. The results of the Johansen co-integrated test revealed that there is one co-integrating equation at 5% showing a co-integrating relationship between agricultural output and the climatic variables. The Vector Error Correction Estimates indicated that rainfall was positively significant at 5% to food production on the short run indicating that vagaries in climate especially rainfall affected food production and output in Nigeria. It was recommended, therefore, that measure that could help to mitigate the adverse effects of inadequate rainfall e.g. irrigation, drought resistant crops varieties among others should be put in place by the government. Farmers should equally be sensitized and trained in the area of adaptation and mitigation of the effect of climate change as this will go a long way to ameliorate large scale failure in food production in the country.

Keywords: food security, agricultural output, climatic variables, adaptation

1. Introduction

Food production system generally depends on a number of factors which include human, technological and natural elements. The natural elements consist of land and water resources as well as climatic variables comprising of temperature, rainfall, relative humidity, etc. There can be no successful food production if any of these factors are out of balance both in quality and quantity at any given time period. Over the years, there have been vagaries of the climatic variables globally which have given rise to the current climate change phenomenon that has become a recurring decimal in local, national and international discourse. This has become a major source of concern because of their impact on food security especially in the developing countries.

There is no internationally agreed definition of the term “climate change”. Intergovernmental Panel on Climate Change (2007) in her Fourth Assessment Report (AR4) defined climate change as “a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period typically decades or longer”. Climate refers to the characteristic conditions of the earth’s lower surface atmosphere at a specific location; weather refers to the day-to-day fluctuations in these conditions at the same location. The variables that are commonly used by meteorologists to measure daily weather phenomena are air temperature, precipitation (e.g., rain, sleet, snow and hail), atmospheric pressure and humidity, wind, and sunshine and cloud cover (FAO, 2008).

Climate change has generated a global issue and has become more threatening to the sustainable development of agriculture in Nigeria. Adejuwon (2004) observed that Nigerian agriculture depends highly on climate because temperature, sunlight, water, relative humidity are the main drivers of crop growth and yield. Climate is also a major driver of food system performance at the agriculture end of the food chain. It can affect the quantities and types of food produced as well as production-related income. Gregory et al. (2005) reported that dynamic interactions between and within the bio-geophysical and human environments lead to the production, processing, preparation and consumption of food, resulting in food systems that underpin food security. Thus, there is a palpable misapprehension and trepidation that climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It is envisaged that change in climate will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows.

It is also anticipated that the climate change phenomenon will affect agriculture in a number of ways. For example, uncertainties in the onset of the farming season, due to changes in rainfall characteristics (early rains may not be sustained, and crops planted at their instance may become smothered by heat waves) can lead to an unusual sequence of crop planting and replanting which may result in food shortages due to harvest failure. Extreme weather events such as heavy winds, and floods, devastate farmlands and can lead to crop failure. Availability of agricultural products is affected by climate change directly through its impacts on crop yields, crop pests and diseases, and soil fertility. Already climate change is creating increased uncertainty about future temperature and precipitation regimes which makes investments in agriculture and other weather-dependent livelihoods inherent more risky and has increased the burden on food security and income among many farmers in the region (FAO, 2008).

Climate variability and change have a direct, often inverse influence on the quantity and quality of agricultural production (Sowunmi & Akintola, 2010). Evidences from literature and past studies have revealed that the recent climate change has influenced agricultural productivity leading to declining global food production (Kurukulasuriya & Mendelsohn, 2006; IISD, 2007; Lobell et al., 2008). A negative and unfavourable climate change could engender adverse climatic conditions like drought, flooding that would result into food shortage and food insecurity like is being experienced in countries like Somalia, Sudan and other countries within the borders of the arid zones. Nigeria is not left out of this environmental quagmire. During the flooding in the country in 2013, for example, several hundred of thousands of farmland/crops were destroyed. Extreme and adverse environmental condition will also trigger price increases and food import to augment local production. Extreme weather events can damage or destroy transport and distribution infrastructure and affect other non-agricultural parts of the food system adversely.

2. Literature Review

The reality of the impact of climate change on agricultural development has been shown in a number of studies (Fischer et al., 2002; Spore, 2008). A substantial body of research has documented these wide-ranging effects on many facets of human societies (Wolfe et al., 2005; ODI, 2007; Apata et al., 2009). Rough estimates suggest that over the next 50 years or so, climate change may likely have a serious threat to meeting global food needs than other constraints on agricultural systems (IPCC, 2007; BNRCC, 2008). Odjugo (2008) and Rahman (2014) predicted that changes in the world’s climate will bring major shifts in food production increase in temperatures and rainfall in some places and decrease in others while, coastal flooding will reduce the amount of land available for agriculture. It is estimated that by 2100, Nigeria and other West African countries are likely to have agricultural losses of up to 4% of GDP due to climate change (Mendelsohn et al., 2000). This is based on the assumption that parts of the country that experienced soil erosion and operate rain-fed agriculture could have decline in agricultural yield of up to 50% between 2000-2020 due to increasing impact of climate change (Agoumi, 2003; IPCC, 2007). Although previous studies have examined the impact of climate change on food security, more need to be known on the impact of variation in climate on the output of agricultural crops and its long run effect on food security in the country. Hence, there is the need to examine the impact of climatic trends in Nigeria as it affects the output and yield of some major agricultural crops in Nigeria.

Several studies have been conducted in Nigeria to determine farmers’ vulnerability, perception and responses to climate change (e.g. Oyekale, 2012; Salau et al., 2014; Orebiyi et al., 2014; Nwosu et al., 2014) with appreciable results. Some other studies have equally been done to determine the effects of climate change on the production of some major food crops in some parts of the country. For example, Henri-Ukoha et al. (2014) examined the effects of climate change in rice farmers in South East, Nigeria; Sanusi and Oladejo (2014) also looked at the impact of climate change on cocoa production in Nigeria while Akinbola and Imoudu (2014) studied the effect of climate change on cassava production in Ondo State, Nigeria. One common result reported in these studies is that climate change had adversely affected the production of these crops one way or the other prompting the need to take necessary measure to mitigate it effects. Most of the previous studies, however, focused on the effects of climate change on individual crops. This present study, however, focuses on the effects of the variation in climate on the aggregate of agricultural output in Nigeria over a period of time (1975-2010). The objectives of this study are (1) to determine if there is any increase or otherwise in agricultural (crop) output as a result of change in climate, (2) to estimate the climatic factors affecting some food crops output, (3) to proffer policy recommendations based on the results of the study.

3. Methodology

3.1 Data

The data used for this study were secondary data (time series) obtained from FAOSTAT (Food and Agriculture Organization statistics) and climatic data from 1975 to 2010 obtained from the Nigerian Meteorological Agency. The data include annual agricultural output, annual mean temperature in ^{o}C, annual mean rainfall in millimeter and average mean relative humidity.

Augmented Dickey Fuller (ADF) test was used to examine the stationarity of the dataset in order to overcome the problem of spurious regression that is common in time series analysis of nonstationary variables. The model of the ADF test with the constant term and trend is as follows:

$$\Delta Y_t = a_1 + a_{2t} + \beta\gamma_{t-i}\sum_{i=1}^{n}\gamma_i \Delta Y_{t-i} + \varepsilon_i \quad (1)$$

Where,

ΔY_t = First difference of Y_t;

Y_{t-1} = Lagged difference of Y_t;

β = Test coefficient;

α_1 = Constant;

α_2 = Coefficient of variable;

ε_i = Gaussian white noise error term.

ADF is one-sided test whose null hypothesis is H_0: δ = 0 which implies that the series has unit root (non-stationary or integrated of order zero) and the alternative hypothesis (H_0: δ < 0) indicates that he series is stationary. The decision rule is to accept the null hypothesis if the calculated ADF statistic is less than the Makinnon critical values; otherwise the null is hypothesis is rejected. Under the null, Y_t must be differenced to achieve stationarity whereas under the alternative, Y*t* is already stationary and no differencing is required. The ADF unit root test is employed to test the level of integration and the possibility of integration among the variables. If the data set revealed integration property for the employed variables, test of co-integration among the variables following Johansen test techniques (Johansen, 1988, 1991).

3.2 Co-Integration Test

According to Kasidi and Mwakanemala (2010) two variables are said to be co-integrated if they have a short run or long run equilibrium relationship between them. If two variables dependent and an independent are individually non-stationary but their residual (combination) stationary, those variables are co-integrated on the long run. To test for co-integration in the study, Johansen (1988) approach was adopted to test the presence of co-integrating vectors and estimation of long-run relationship if the data set contains two or more time series as well as gives the maximum rank of co- integration(Ssekuma, 2011). According to Hjalmersson and Osterholm (2007), Johansen's methodology takes its starting point in the vector regression (VAR) of n order given by,

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{k-1}\Gamma_i \Delta y_{t-1} + \mu + \varepsilon_i \quad (2)$$

Where,

Δy_{t-1} = First difference of an (n × 1) vector of the n variables;

∏= (n × n) Coefficient matrix;

y_{t-1} = Lagged values of Y_t;

Γ = (n × (k-1)) Matrix of short run coefficients;

μ = (n × 1) Vector of constant;

ε_i = (n × 1) Vector of white noise residuals.

The underlying principle of the Johansen co-integration test is that if the coefficient matrix(∏) has reduced rank (r < n), it can be decomposed into a matrix (n × r) of loading coefficients (α) and a matrix (n × r) of co-integrating vectors (β) such that $\prod = \alpha\beta$ (Oyinbo et al., 2012). R is the number of co-integrating relations (the co-integrating rank). The loading coefficients (α) indicate the co-integration relationships in the individual equations of the system and of the speed of adjustment to disequilibrium and therefore, determines the causality in the system and the direction of causality flows while the co-integrating vectors (β) represent the long-run equilibrium relationship.

Johansen (1988) presented two likelihood ratio tests namely: the Trace and Maximum Eigen value statistic tests which are used to determine the number of co-integrating equations given by the co-integration rank(r). The Trace statistic test equation is shown as follows:

$$Wtrace = -T\sum^{P}\ln\left(1-\delta i\right) \tag{3}$$

The Trace test (*Wtrace*) tests the null hypothesis that there are at most r co-integrating vectors against the alternative hypothesis that there are *r* or more co-integrating vectors (Mafimisebi, 2008). The Maximum Eigen-value (*Wmax*) tests the null hypothesis that there are at most *r* co-integrating vectors against the alternative of r + 1 co-integrating vector and is represented by the equation as follows:

$$Wmax = -T \cdot ln\ \left(1-\lambda r+1\right) \tag{4}$$

3.3 Model Specification

The explicit model for long run relationship among variables was given as,

$$\ln AGRIC\ OUTPUT = \beta_0 + \beta_1\ lnTEMP_t + \beta_2 lnRAINFALL_t + \beta_3 lnRELHUM_t - \mu t \tag{5}$$

In order to examine the short-run relationship among the variables, the corresponding error correction equation was estimated as,

$$\Delta ln\ AGRIC\ OUTPUTt = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta ln\ TEMPt + \sum_{i=1}^{p}\beta_1\Delta ln\ RAINFALLt + \sum_{i=1}^{p}\beta_1\Delta ln\ RELHUMt + \omega ECMt - 1 + \mu t \tag{6}$$

Where,

AGRIC OUTPUT = Agricultural Output (million tonne);

TEMP= Temperature;

RAINFALL = Rainfall (mm);

RELHUM = Relative humidity;

ECM= Error Correction term;

ln = Natural logarithm;

Δ = Difference operator;

The a priori expectations are β_1, β_2, β_3, < 0.

4. Results and Discussion

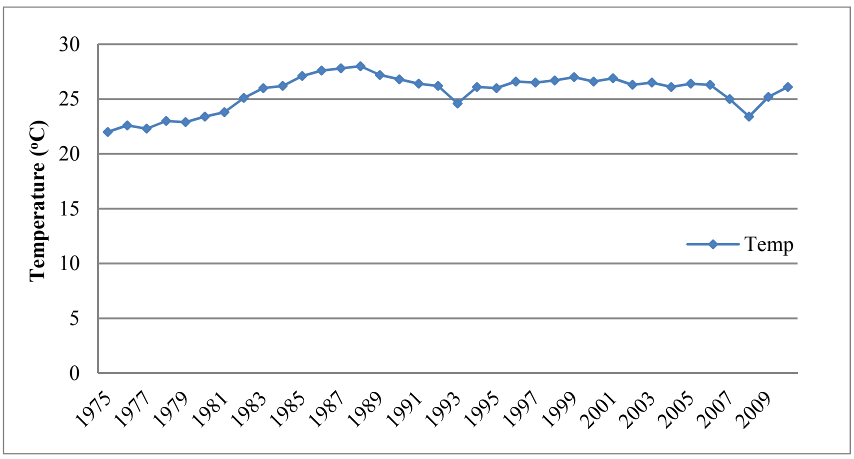

Figure 1. Annual mean temperature in Nigeria (1975-2010)

Figure 1 shows the trend of annual mean temperature in Nigeria between 1975 and 2010. The result showed a gradual rise in temperature between 1975 to mid 1990s with a slight drop in 1994 and subsequent increase till late 2000. The mean temperature between 1975 and 1992 was 25.2 ^{o}C while the mean between 1993 and 2010 was 27.1 ^{o}C. This reveals an overall mean increase of 1.9 ^{o}C.

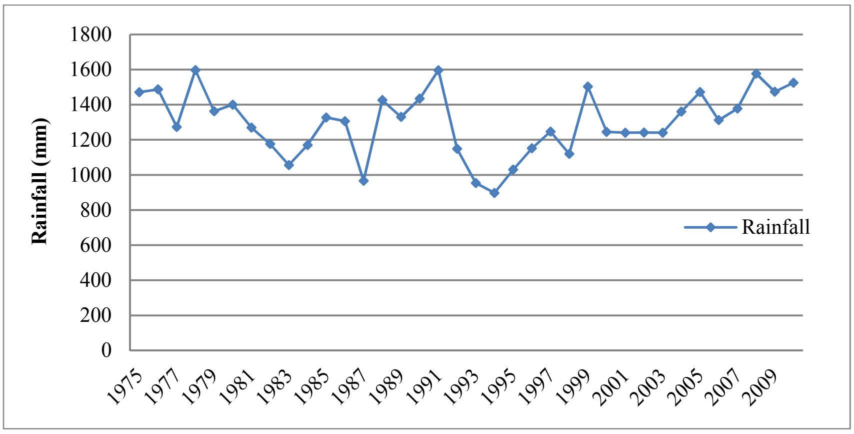

Figure 2. Annual mean rainfall in Nigeria (1975-2010)

The study reveals an irregular rainfall pattern as shown in Figure 2. The highest rainfall was experienced in 1991 and 2008 while lowest rainfall was observed in 1994, which was followed by a gradual increase; it also corresponds with the period of low output. This marked the beginning of changes in climatic factor in Nigeria. Although the increase and decrease in rainfall pattern does not show a corresponding fluctuation in agricultural output that does not suggest that it did not affect agricultural output as food production in Nigeria is largely dependent on natural rainfall. However, 4.2mm increase change in rainfall will likely result into a change in agricultural output and vice versa.

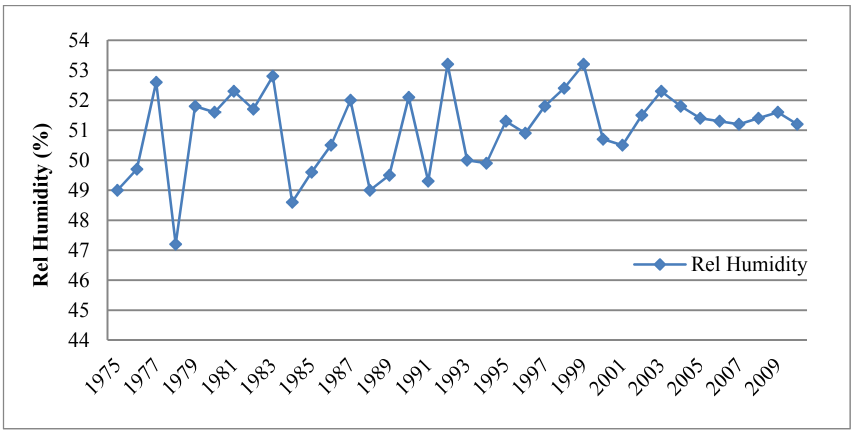

Figure 3. Annual mean relative humidity in Nigeria (1975-2010)

Figure 3 shows the trend of relative humidity in Nigeria. It reveals a slight decrease in relative humidity during the study period. However, there was a direct effect of the relative humidity of the atmosphere on agricultural product. For instance, the mean relative humidity between 1975 and 1992 was 50.7% at 25.2 ^{o}C temperature which means that every kilogram of the air contains 50.7% of the maximum amount of water that it can hold at that that temperature. While the relative humidity between 1993 and 2010 is 51.4% at 27.1 ^{o}C. It is noticed that the study period experienced dry air in the early period and moist air towards the later period. This observation coincides with the period of increased rainfall within the study period.

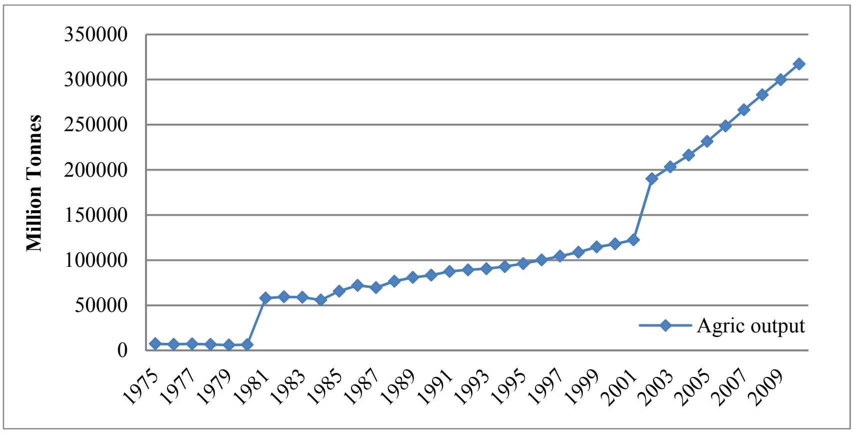

Figure 4. Annual trend of agricultural output in Nigeria (1975-2010)

Figure 4 shows the trend of agricultural output in Nigeria. In this study the lowest agricultural output was observed in the year 1975-1980 with a sharp rise in 1981. However, there was a slight drop in the year 1984 and 1987; this can be traced to the changes in climatic factors. However, there are persistently higher rate in agricultural productivity from 1988-2000 with a sharp rise in 2001. This increment observed can be linked to government policies aimed at improving agriculture and also climatic variables because temperature, sunlight, water, relative humidity are the main drivers of crop growth and yield in Nigeria.

4.1 ADF Test

Table 1. Augmented Dickey Fuller (ADF) Test result

Variable	**Level**	**t-statistics**	**1% level**	**Probability**	**Remarks**
Temp	D(0)	-2.382431	-3.632900	0.1538	**NS**
	D(1)	-5.523519	-3. 639407	0.0001	**S**
Rainfall	D(0)	-3.530388	-3.632900	0.0003	**NS**
	D(1)	-8.274938	-3.639407	0.0000	**S**
Relhum	D(0)	-6.667657	-3.632900	0.0000	**S**
	D(1)	-4.325393	-3.661661	0.0019	**S**
Agric output	D(0)	1.783480	-3.632900	0.9996	**NS**
	D(1)	-5.175658	-3. 639407	0.0002	**S**

Note. * NS = Non stationary, S = Stationary; D(0) = zero level, D(1) = Differencing at level 1.

Source: Computed from Data Analysis.

The result of the ADF test in Table 1 shows that only relative humidity integrated at order zero level while rainfall, temperature and agricultural output were non stationary at zero level; however, after differencing at level 1 all the variables became stationary. Therefore, the null hypothesis of having a unit root is rejected and the alternative is accepted.

4.2 Johansen Test

Table 2. Johansen Co-Integration Test result (Trace Test)

CE(s)	Eigen value	Trace statistics	0.05 critical value	Prob.**
None*	0.559503	49.76571	47.85613	0.0327
At most 1	0.305658	21.89073	29.79707	0.3046
At most 2	0.198460	9.487869	15.49471	0.3222
At most 3	0.056196	1.966381	3.841466	0.1608

Note. * Significant at 5% level.

Source: Computed from Data Analysis.

Table 3. Johansen Co-Integration Test result (Max-Eigen Test)

CE(s)	Eigen value	Max-Eigen statistics	0.05 critical value	Prob.**
None*	0.559503	27.87496	27.58434	0.0459
At most 1	0.305658	12.40286	21.13162	0.5084
At most 2	0.198460	7.521488	14.26460	0.4294
At most 3	0.056196	1.966381	3.841466	0.1608

Note. ** Significant at 5% level.

Source: Computed from Data Analysis.

The results of the Johansen co-integration test(Trace and Max-Eigen) as shown in Tables 2 and 3 indicate that there is one co-integrating equation at 5% level and this implies that the null hypothesis of not having a co-integrating equation($r = 0$) is rejected and the alternative hypothesis of having one co-integrating equation($r = 1$) is accepted.

4.3 Vector Error Correction Estimates

The existence of co-integrating relationship between the dependent and independent variables as indicated by Johansen co-integration test necessitated examining the short run dynamics between the variables in the co-integrating equation by estimating the error correction model.

Table 4. Vector error correction estimates of agricultural output in Nigeria

Variable	Coefficient	Standard Error	t-statistics
Long run			
Constant	305.8684		
ln Agric output(-1)	1.00000		
ln Temp(-1)	-30.77433	8.74862	-3.51762***
ln Rainfall(-1)	-15.97979	4.94900	-3.22890***
ln Relhum(-1)	-127.4561	32.3996	-3.93388***
Short run			
Constant	-0.001416	0.00230	-0.53531
Δln Agric output(-1)	0.006678	0.01299	0.51395
Δln Agric output(-2)	0.020274	0.01371	1.47913
Δln Temp(-1)	0.007326	0.16921	0.04330
Δln Temp(-2)	-0.252650	0.17640	-1.143224
Δln Rainfall(-1)	0.113295	0.04140	2.73638**
Δln Rainfall(-2)	0.121548	0.03943	3.08288**
Δln RelHum(-1)	-0.273357	0.24586	-1.11185
Δln RelHum(-2)	-0.016377	0.18007	-0.09095
ECM(-1)	0.005371	0.00222	2.42450**

Note. ** 5%, *** 1% level of significance.

Source: Computed from Data Analysis.

Diagnostic Statistics:

R-squared	0.669253
Adj. R-squared	0.539830
Sum sq. resids	0.00332
S.E. equation	0.012018
F-statistic	5.171065
Log likelihood	105.0351
Akaike AIC	-5.759700
Schwarz SC	-5.306213
Mean Dependent	**-0.000355**
S.D. Dependent	**0.017717**

The result of the vector error correction as shown in Table 3 contains the long- run estimates, short- run estimates and diagnostics statistics. The long run estimates show that *RAINFAL*, *TEMP* and *RELHUM* are negatively related to *AGRIC OUTPUT* in the long run and is consistent with a priori expectation. However, only *RAINFALL* is positive both in the short but negative in the long run and this gives support to the fact that climate change revealed through the vagaries of these climatic variables will have negative effects on food production and by extension availability, affordability, accessibility and quality in Nigeria both in the near and far future. The error correction coefficient of -0.005371 of the model had the expected positive sign and was significant at 1% confirming the existence of long run relationship between the dependent and independent variables(temperature, rainfall), all things being equal. This shows a feedback of about 0.5% of the previous year disequilibrium from the long run value of the independent variables and shows that food production in Nigeria has a response to rainfall, temperature and relative humidity like in all other tropical countries.

5. Conclusion

This study examined the short run and long run relationship between some climatic variables namely: rainfall, temperature and relative humidity and agricultural output in Nigeria using some time series data from 1975 to 2010. The study has been able to establish that climatic data are related to food production both in the short run and long run. Results indicated that all the variables- rainfall, temperature and relative humidity had negative and significant effects at 1% probability level on agricultural output while only rainfall was positively related to food production on both short run indicating that vagaries in climate affected food production and output in Nigeria. The results showed the strong influence of rainfall as a key determinant of the level of agricultural production and by extension on food security attainment in Nigeria. This implies that vagaries in climate will negatively impact on food production and output in Nigeria in both short and long run, hence the need for timely policy intervention by the government to mitigate the adverse effects of inadequate rainfall or too much rainfall that are likely to result in drought and flooding/ erosion respectively. Farmers should equally be sensitized and trained in the area of adaptation and mitigation of the effect of climate change as this will go a long way to ameliorate large scale failure in food production in the country.

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