

Climate Change and Crop Production in Nigeria: An Error Correction Modelling Approach

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ABSTRACT: Climate change is termed as one of the greatest challenges of the 21st century and this has posed threat to agricultural dependent economies. In fact report had it that developing economies are at disadvantage as they stand to experience some of the severe effects from climate change. It is against this backdrop that this paper examines the impact of climate change on crop production in Nigeria. Ten crops were selected and three climatic variables were used for the study. Data for the study were extracted from the Food and Agricultural Organisation database, World Development Indicator and the CBN Statistical Bulletin and the data covers the period 1970-2009. Analysis of data was done with cointegration approach. The study revealed that the effect of climatic variables on crop production varies depending on the type of crop and seasonal properties and length of days of the crop. In general, climate change effect was found to be pronounced on the output of the crops. It is therefore recommended that various adaptation strategies necessary for increased output of these crops be adopted by farmers and this can better be achieved with proper enlightenment programmes for the farmers.

Keywords: climate change; global warming; crop production; error correction model

JEL Classifications: Q54; Q56

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) stated that climate change is emerging as one of cardinal challenges of the 21st century (APF, 2007). Human-induced climate change resulting from increase in the concentration of greenhouse gases (GHGs) in the atmosphere and food insecurity are two closely related threats facing mankind in the 21st century. IPCC observed that unrelenting emission of greenhouse gases into the atmosphere between 1970 and 2004 led to a 70% increase of greenhouse gases into the atmosphere (Omojolaibi, 2011). The gases emitted into the atmosphere include Carbon Dioxide (CO₂), methane (CH₄), Nitrous Oxide (N₂O), Hydroflourocarbons (HFCs), Perflorocarbons (PFCs) and Carbon hexafluoride (CF₆). All these gases were unambiguously articulated in the Kyoto Protocol. CO₂ among these gases increased over the per capita income and population and thereby contributes to over 40% of the total emission of the GHGs (Odingo, 2009).

Climate change due to anthropogenic factors has shown that the globe is warming (Odingo, 2009; IPCC, 2007). Scientific accounts on global warming have indicated that the average global temperature has increased by around 0.7⁰C (1.3⁰F) since the advent of the industrial era (Asafu-Adjaye, 2008). Studies have shown that the trend is accelerating such that the average temperature is rising at 0.2⁰C every decade (IPCC, 2007; Ofori-Boateng, 2012). With the rising level in temperature globally, local rainfall patterns are changing, ecological zones are shifting, the seas are warming and ice caps are melting (IPCC, 2007). African countries and other developing countries have been termed to have been at disadvantage as the tropical areas stand to experience some of the most severe effects

from climate change and agriculture which takes a significant part of employment and food provision in Africa is the most sensitive to climate variability.

The challenges of climate change became so pronounced that in 1992, at the Rio Earth Summit Agenda, the United Nations Framework Convention on Climate Change (UNFCCC) was signed as the first commitment of the world to control the emission of GHGs (Redgwell, 2008; Oniemola, 2011). The UNFCCC constitutes the crucial global discussion forum on climate change as to the scope and timing of a potential agreement to combat climate change issues globally. Consequently, the Kyoto Protocol to the UNFCCC concretise the commitment of the world to bring the emission under control by officially setting the standards for GHGs emission in developed countries specifically at least 5.2 below the 1990's level for the 2008-2012 period (Redgwell, 2008). The Kyoto Protocol sets up four mechanisms which Annex 1 parties (developed countries) may use in complying with part of their GHGs emission reduction commitments. These include Carbon Balance, Market for Pollution Permit (Emission Trading), Joint Implementation and Clean Development Mechanism (Glazewski, 2008).

Reports opined that increasing global temperature is likely to boost agricultural production in the temperate regions; it is expected to reduce yields in the tropical regions of the world (WTO -UNEP 2009). It is projected that many African regions will suffer from drought and floods with greater frequency and intensity in the nearest future (IPCC, 2007). The report further observed that the rise in average temperature between 1980/1999 and 2080/2099 would be in the range of 3-4⁰C across the entire African continent which is 1.5 times more than the global level. The report continued that Africa's Mediterranean region will experience a decrease in precipitations during the century. These dry conditions would affect the northern boundary of Sahara and West African coast where Nigeria lies.

Agriculture remains the mainstay of the majority of households in Nigeria and is a significant sector in Nigeria's economy. The significance of the agricultural sector to Nigeria's economy cannot be overemphasized as it is catalyst for food provision, contribution to the gross domestic product, provision of employment, provision of raw materials for agro-allied industries, and generation of foreign earnings. A sectoral analysis in 2006 of the real GDP indicated that the agricultural sector contributed to about 42 percent of the GDP compared with 41.2 percent in 2005 (CBN, 2011). The growth rate of the contribution of the agricultural sector to the GDP at 1990 constant basic prices grew from 4.2 percent in 2002 to 7.2 percent in 2006. The agricultural sector also employed over 60 percent of the total labor force in Nigeria in 1999.

Crop production takes a significant aspect of agricultural production and exports in Nigeria. Generally, there are many factors influencing crop production and these include soil, relief, climate and diseases among others. In relation to climate, rainfall is one of the dominant controlling variables in tropical agriculture since it supplies soil moisture for crops. Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops (Tunde et. al., 2011). Climate is an important resource to crop production in Nigeria especially in the rainforest zone of Nigeria as farmers depend largely on rain for agriculture (Onyeneke, 2010). Studies indicate that Africa's agriculture is negatively affected by climate change (Pearce *et al.*, 1996; McCarthy *et al.*, 2001; Onyeneke, 2010) and that adaptation is one of the policy options for reducing the negative impact of climate change (Adger *et al.*, 2003; Kurukulasuriya and Mendelsohn, 2006).

However, food production could not keep pace with population increase. Food shortage is therefore linked with climate change. Today, climate change and food insecurity are twin devils that have been identified as urgent world problems. This is because food security which is mainly from agriculture threatened by the emergence of climate variability as agriculture serves as one of the sensitive sectors to this threat. Over 60% of the Nigerian populace depends so much on agriculturally related activities for sustenance and crop production takes significant aspect of agricultural related activities in Nigeria. For instance, crop production contributes more than 80% of Agricultural GDP and more than 48% of total non-oil GDP in Nigeria (CBN, 2011). Ayinde et al. (2011) opined that climatic fluctuation is putting Nigeria's agriculture system under serious threat and stress. This implies that rural sustenance and food security in Nigeria is under serious threat as crop production takes significant aspect of agricultural activities in Nigeria. It is against this backdrop that this present study examines the impact of climate change on different varieties of crops in Nigeria.

This study is therefore justified on the basis that empirical studies on the impacts of climate change on long-run crop production in Nigeria are scanty. Few studies that are available never considered econometric methodology and modelling approaches that first consider theoretical link between climatic variables and crop output. The time coverage of these studies is small besides the exclusion of other main climate variables that affect crop production like carbon emission (CO₂) in the atmosphere. Thus, the study bridges these gaps by adopting and applying a coherent and consistent model that explains the relationship between climate change variables and varieties of crops produced in Nigeria.

2. Background Issues

2.1 The Issue of Global Emission and the Nigerian Ecosystem

An understanding of the issue of global emission or climate change issue is germane to the robustness of this paper; hence it is briefly discussed here. At the global level, a country may generate global warming through the emission of industrial pollutants and destroys the ozone layer which might affect other countries that might not be emitting as the emission leads to accumulation of GHGs in the atmosphere that creates concern for the globe. Such pollution is termed trans boundary externality (IPCC, 2000).

In a global context, externalities are specified in terms of distinction between polluting and victim countries. However, the main problem here in the issue of global emission is how to internalize the externality that is the implementation of polluter pays principle, at the global level. This is a case of multilateral externality. This is because global emission involves several polluters and several victims, uncertain on the source and the direction of externalities. This makes it a global concern as each country is termed a polluter and a victim (Odingo, 2009).

In the model of social optimum with externalities, which is the standard model of environmental policy, general equilibrium implies that global emission is the cumulated sum of unitary emissions, independent of the origin and the nature of each unit of emission (Asafu-Adjaye, 2005). The underlying hypothesis is termed uniformly mixing pollutants. This hypothesis is therefore plausible only for the global warming case, as contribution of a unit of CO₂ to the accumulation of GHGs in the atmosphere is the same wherever it was produced. For instance, a unit of CO₂ generated in the polar area or in a tropical area will contribute to same extent to the global warming, but the polar agriculture will benefit from the global warming whereas the African agriculture will likely suffer from it. However, acid rain impacts will differ from one country to another, depending on the soils characteristics, distance from the source of pollution, and the direction of the dominant winds (IPCC, 2000).

Nigeria contains six ecological zones, ranging from a belt of mangrove swamps and tropical forests along the coast to open woodland and savanna on the low plateau which extends though much of the central part of the country, to the semi-arid plains in the north and highlands to the east. The principal food crops are yams, cassava, and maize to the south, and millet, sorghum, and cowpeas in the drier north. Cocoa, rubber, oil palm, groundnuts, and cotton are the main crops which are generally destined for export. Between the arid north and the moist south lies a Guinea Savanna Zone sometimes referred to as the middle belt. This area produces staples such as yams, sorghum, millet, cassava, cowpeas, and corn, with rice an important crop in some places. The middle belt's southern edge represents the lower limits of the northern grain-dominated economy. The most significant commercial crop of the middle belt is sesame (or benniseed).

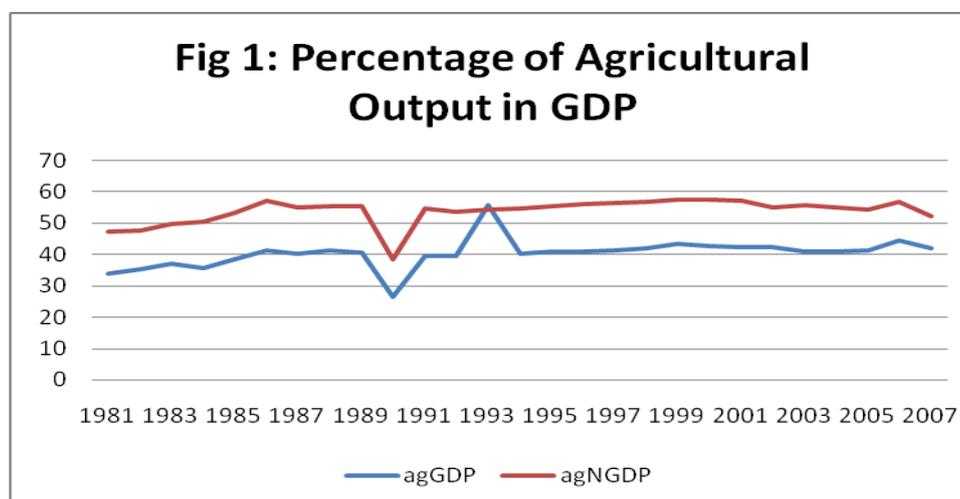
Rainfall is heaviest in the south, where the rain forests and woodlands benefit from abundant precipitation and relatively short dry seasons. Root crops are the staples in the south, including cassava, yams, taro (*cocoyams*), and sweet potatoes. The cash crops in the south are tree crops, which in general are grown on large plantations that include cacao, oil palm, and rubber. However, almost 85 percent of Nigeria's current palm oil production is from unorganized wild groves. The northern third of Nigeria experiences a dry season of five to seven months, and lies mostly in the Sudan and Sahel Savanna zones. Staples in the north are millet, cowpeas, and a drought-resistant variety of sorghum known as guinea corn. Sorghum is Nigeria's most widely cultivated grain, accounting for more than 45 percent of the total area. Sorghum cultivation spans from the north to the middle belt where precipitation and soil moisture levels are low. Corn is also cultivated, as well as rice in suitable lowland areas. Wheat is a *fadama* (lowland) crop, irrigated along broad valley bottoms in the north,

especially in the Lake Chad basin. The north's principal commercial crops are cotton and groundnuts (USDA, 2000).

2.2 Agriculture and the Nigerian Economy

2.2.1 Agricultural Production in Nigeria

A trend analysis of Central Bank of Nigeria statistical data (2007) as shown in Figure 1 indicates that percentage of agricultural contribution to GDP (agGDP) falls below 40% in the early 80s but however, increased to above 40% between 1986 and 1989 but fell to less than 30% in 1990. The agricultural contribution to GDP was above 50% between 1993 and 1994.



The period 1986-1994 was the Structural Adjustment Programme (SAP) period and a closer look at this Figure shows that the programme never had a meaningful impact on the agricultural sector as the contribution to GDP in the post SAP period average just little above 40%. However, agricultural contribution to total non oil GDP (agNGDP) as shown in Figure 1 was less than 50% contribution in 1981-1982 but the contribution increase above 50% from 1983 till 1990 when it fell below 40% contribution. It later bounced back to above 50% contribution from 1991 till date. The advent of oil in the early 1970s made Nigeria highly dependent on oil revenue, with the performance of the agricultural sector adversely affected over years. Though the growth rate in the agricultural sector in Nigeria increased from an average of about 3 percent in the 1990s to about 7 percent in mid 2000, the food security/sufficiency status of Nigerians continued to decline. (CBN Bulletin, 2007).The dismal performance of the agricultural sector in terms of its contribution to Nigeria's yearly total revenue in the last three decades prompted the government to initiate several agricultural schemes and programs to enhance agricultural productivity in Nigeria.

2.2.2 Crop Production in Nigeria

Using same data sources as in Figures 1 and 2, the percentage contribution of crop production to total agricultural production (crpAG) in Nigeria can be shown. It is evident from the figure that crops production to agricultural output takes a significant aspect. This is revealed from the figure that crop production takes above 80% of agricultural output in Nigeria.

This invariably means that Nigeria's agricultural sector is predominantly dominated by crop production. It implies that any adverse effect on crop production will alter the contribution of agriculture to GDP in Nigeria.

Figure 3 shows the percentage contribution of selected crops production to total crop output in Nigeria. The figure indicates that cassava production takes the lead in its production contribution to total crop output in Nigeria. Though, it is evident in the early 80s that cassava production contribution was insignificant as it fell below 2% but increased to above 15% contribution and above 20% contribution in the year 1986 and 1991-1994 respectively. It maintained its lead all through. This is followed by yam and sorghum production respectively. Besides sorghum production that takes the third position in terms of contribution to total crop output in Nigeria, the remaining crops take less than 5% percentage contribution to total crop output. This is also confirmed by Figure 4 that shows the output of the selected crops in Nigeria.

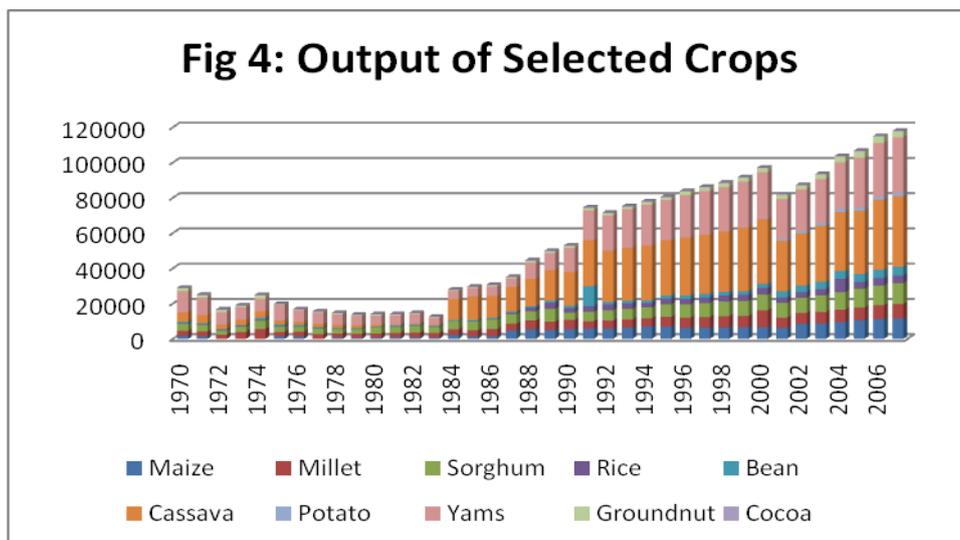
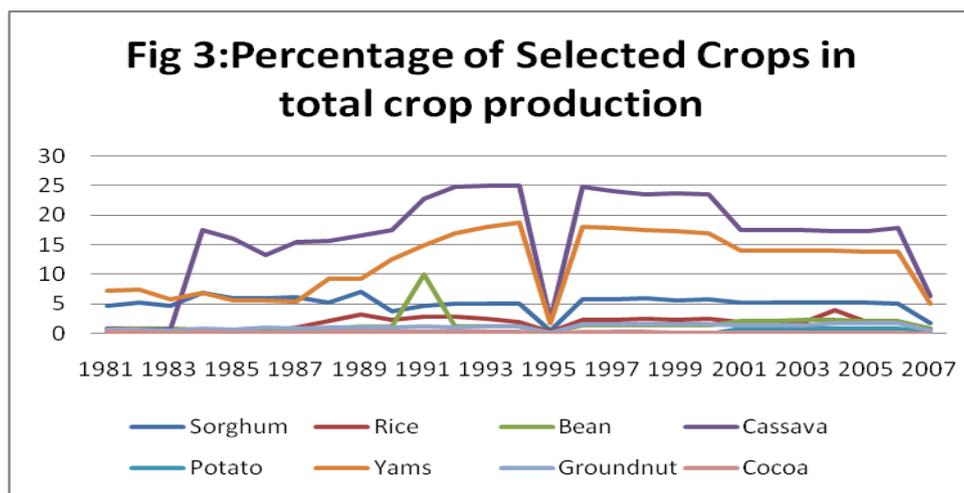
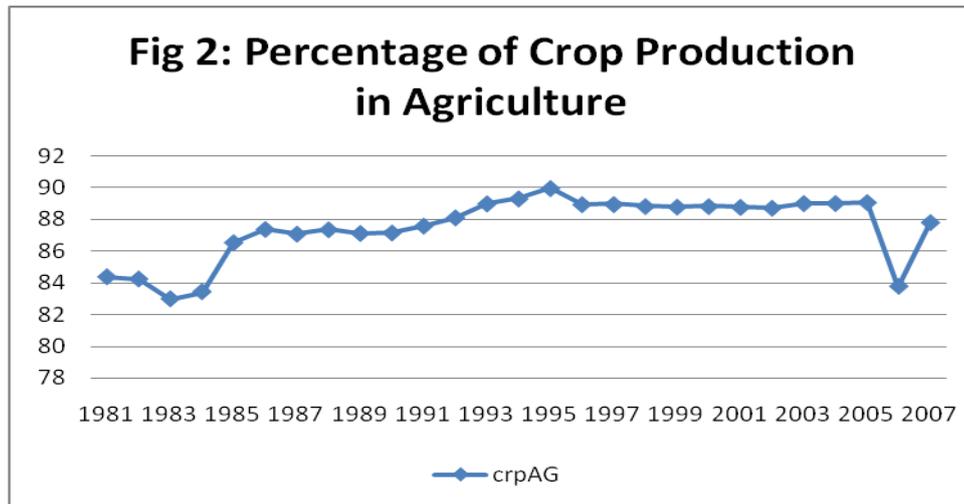


Figure 4 indicates that the output of cassava was insignificant from 1970-1984 but takes the lead from 1985 to date. This is followed by the output of yam production.

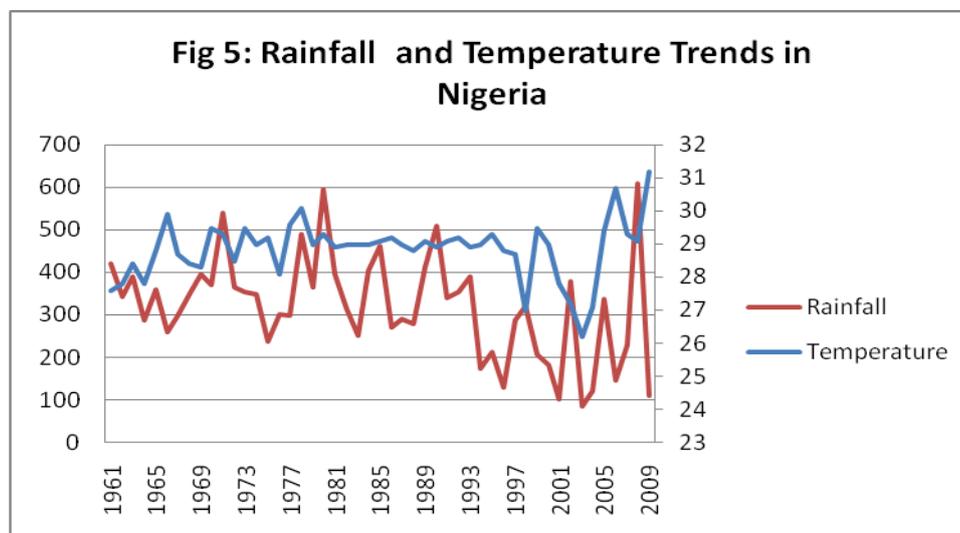
2.3 Climatic Condition and Agricultural Production

2.3.1 Climatic Condition in Nigeria

Figure 5 reports trend analysis of Nigeria's temperature and rainfall situations. The graph indicates that temperature in Nigeria is rising overtime. It is evident from the graph that Nigeria has had a fair

distribution of temperature except for the early part of the 1970's and 2000's. This implies that temperature in Nigeria experienced a dwindling and fluctuating trend in the early 70's and 2000's. And this recent fluctuating trend might have detrimental effect on agricultural production.

In terms of rainfall as shown in Figure 5, there has been declining trend throughout the study period. The rainfall trend shows fluctuating trend throughout the period besides being on a decline trend.



Note: Rainfall (mm); temperature (°C).

2.3.2 Carbon Emission in Nigeria

As earlier stated, among the gases emitted to the atmosphere contributing to GHGs, CO₂ emission contributes more than 40%. It is on this basis that we examine the trend of CO₂ emission in Nigeria in comparison with South Africa being termed as the highest contributor to CO₂ emission in Africa. Table 1 shows CO₂ emission for Nigeria, South Africa, Sub-Saharan Africa and the World.

Table 1: Carbon Emission (Co2) Emission in Nigeria, South Africa (SA) and Sub Saharan Africa (SSA) and the World

Year	Nigeria (Kt)	SA (Kt)	SSA (kt)	World (Kt)
1971-1975	46,594	175153	284546	16340552
1976-1980	58511	208506	337314	18702774
1981-1985	66202	294102	436688	18990602
1986-1990	58282	335511	478023	21474350
1991-1995	50354	345225	484647	22694215
1996-2000	48953	368366	520595	24239605
2001-2008	94037	398569	623816	28787784

Source: World Development Indicator Database, 2012.

It is evident from the table that Nigeria's CO₂ emission is less than half of the emission by South Africa. This is confirmed by the fact that Nigeria's average CO₂ emission for the period 1971-1975 was 46,594 kt compared to South Africa with CO₂ emission of 175,153 kt. Between 1976-1980 the average CO₂ emission for Nigeria and South Africa were 58511kt and 208506kt respectively. The trend of the differences in the two countries remained the same as South Africa proved to emit more than twice the emission of Nigeria. Though, the population of Nigeria is far beyond that of South Africa, it is evident that population increase is not the reason behind the huge differences between these countries emission rate. It is not far from the fact that South Africa engages in more industrial activities than Nigeria and uses more carbon emitting energy than Nigeria.

For instance, Figure 6 shows the trend of the percentages of Nigeria (NigSSA) and South Africa(saSSA) CO₂ emission in total Sub-Saharan African (SSA) CO₂ emission in the world. It is evident from this graph that South Africa contributes to more than 60% of the total CO₂ emission in

SSA. The Sub-Saharan Africa region is made up of over 50 independent countries however it is shown from the above graph than emission from South Africa alone is above 60% on the average during the period under study. Nigeria emits less than 20% on the average to the total SSA CO₂ emission in the world. This is also clearly shown in Figure 7.

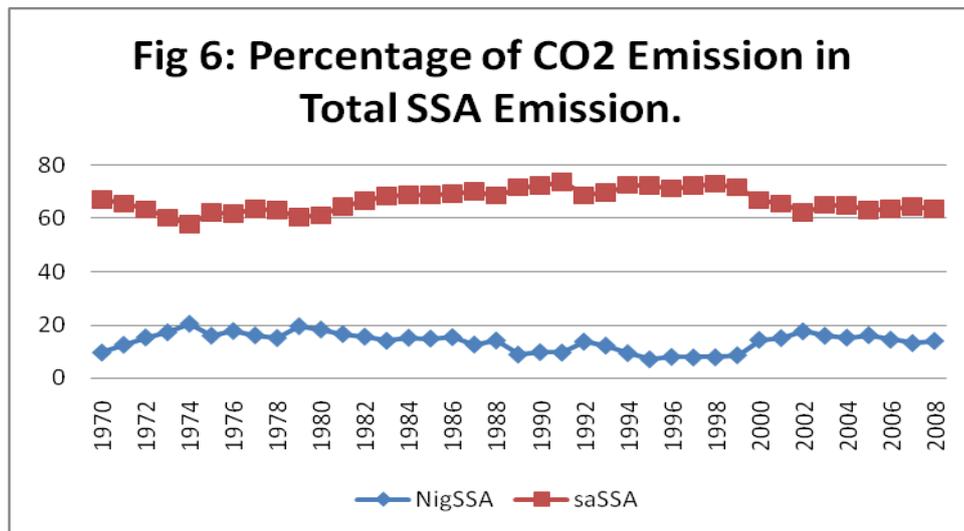
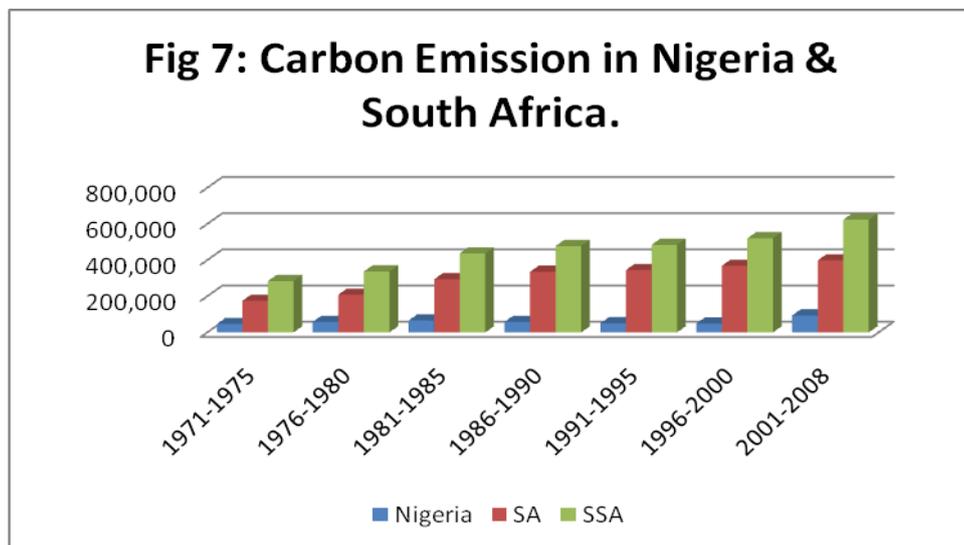
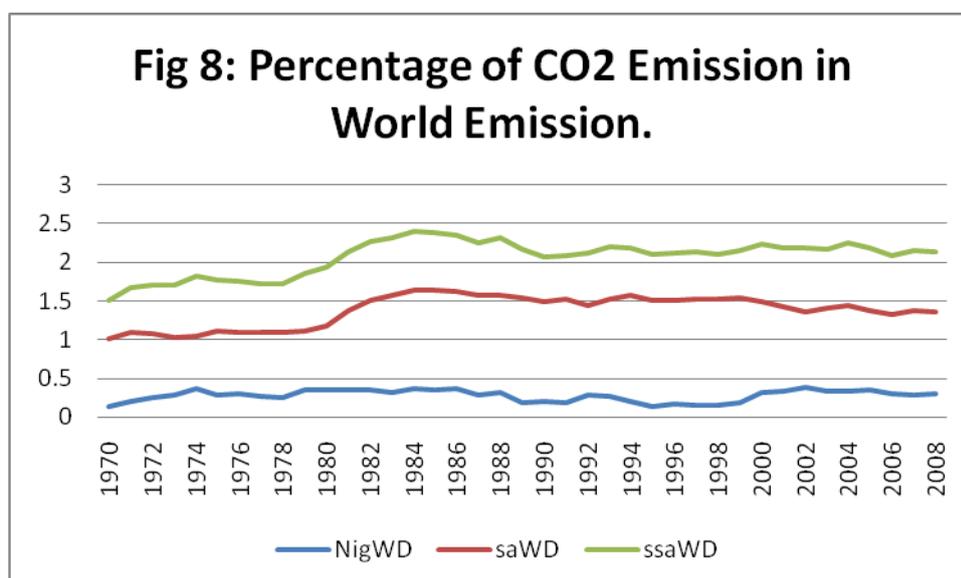


Figure 7 shows the CO₂ emission in kilowatts for Nigeria, South Africa and SSA. It is clearly seen that throughout the 1971-2008 period, Nigeria contributes insignificant amount to total emission in SSA as against South Africa which takes the lion share of CO₂ emission the region.



A cursory look at Figure 8 also indicates that in the world, despite the population of Nigeria, Nigeria contributes to less than 0.5% of total emission in the world during the period under study as against South Africa that around 1.5% emission to world total emission. The graph also shows that SSA region emit less than 2% to total world emission of CO₂ on the average for the sample period. Developed countries of the world take lion share of global emission as against the developing countries that contribute insignificant amount to world CO₂ emission. However, the conflicting and competing issue is that there is need to reduce GHGs emission in the world but developing countries need to meet up with current challenges of development and this cannot happen in isolation of GHGs emission. This is the sticky situation the developing countries of Africa have found themselves.



3. Brief Empirical Literature

Empirical literature on the impact of climate variables on agricultural output has left us with no direction as the results are inconclusive. Previous studies have concluded that temperature and precipitation are appropriate variables for capturing climate change effects on crop yields in the temperate and tropical regions respectively (Mendelsohn et al. 1994, Kurukulasuriya and Mendelsohn 2006, Ofori-Boateng, 2012).

Mendelsohn and Dinar (1999) have examined the impacts of climate change on agriculture in India and Brazil. They employed three different methods for the analysis namely; the Ricardian method, agro-economic model, and agro-ecological zone analysis. Environmental factors such as farm performance, land value or net income and traditional economic inputs which are land and labour, and support systems such as infrastructure were used as explanatory variables in the models. Unlike most studies, this analysis pointed out the significance of the adaptation. They argue that farmers will adapt to new condition due to climate change by making production decisions which are in their own best interests. Crop choice is one of the examples of farmers' adaptation to warmer weather in the paper. Wheat, corn, and rice are three crops as examples since the regions in which they grow depend on the temperature. As temperature gets warmer wheat farmers switch wheat to corn for making profits. Later, if temperature gets warmer again enough to lose profits, farmers adapt to warmer weather thus switch to rice from corn. The results of the Ricardian method, agro-economic model, and agro-ecological zone analysis showed that increase in temperature will decrease the crop production especially the crops grown in cool areas such as wheat. However, the authors argue that the result of the Ricardian method suggests that farmers' ability to adapt to new condition will mitigate the impacts of climate change in the long run while the agro-economic model and agro-ecological zone analysis would be more suitable for short run analysis since the adaptation is not included in the models.

Mathauda et al. (2000) investigated the effects of temperature change on rice yield in the Punjab region in India by using the CERES RICE simulation model between 1970 and 1990. They stratified the weather scenario by 5 different conditions which are normal weather, slight warm (0.5°C increase in temperature), moderate warm (1°C increase), greater warm (1.5°C increase), and extreme warm (2°C increase) in the simulation model. The model predicted that temperature increase decreases rice yield by 3.2% in slight warm, 4.9% in moderate warm, 8.2% in greater warm, and 8.4 % in extreme warm condition compared to normal condition scenario. The result also showed that an increase in temperature negatively affects not only rice production but also other rice attributions such as biomass, crop duration, and straw yield.

Torvanger et al. (2004) analyzed climate change impacts on agricultural production in Norway for the period 1958-2001. The study employed time series data with a biophysical statistical model to examine the dynamic linkages between yields of potatoes, barley, oats, wheat and climate change variables such as temperature and precipitation. The study found that there is a positive impact on yields from temperature in 18% of the crops. The effect is found to be strongest for potatoes.

Regionally, the study revealed that temperature is likely to be a more important limiting factor for crop growth in Northern Norway than other regions. The effect of precipitation found to be negative in 20% of the cases.

Seo et al. (2005) analyzed the climate change impacts on Sri Lankan agriculture using the Ricardian method and five AOGCM experimental models. The model analyzed the net revenue per hectare of the four most important crops (rice, coconut, rubber, and tea) in the country. This paper focused more on the precipitation effect on crop production while most literatures usually analyze the temperature effect. It is mainly due to the greater range of precipitation across the country although the limited range of temperature variation allows only a simple test of temperature impacts in the study. Both the Ricardian method and five AOGCM experimental models revealed that the effects of increase in precipitation are predicted to be beneficial to all crops tested and the benefit ranges from 11 % to 122 % of the current net revenue of the crops in the model. On the other hand, the impacts of increase in temperature are predicted to be harmful to the nation and the loss ranges from -18 % to -50 % of the current agricultural productivity.

Kabubo-Mariara and Karanja (2007) found in Kenya that there is a non-linear relation between temperature and crop revenue on one hand and between precipitation and crop revenue on the other. De (2009) identified temperature and precipitation as significant variables in explaining the impact of climate change in Zimbabwe while Dell et al. (2008) established across several studies of the world that temperature has a large negative effect on growth but only in poor countries. They further show that precipitation has no significant effect on growth in both rich and poor countries.

Basak (2009) analyzed climate change impacts on rice production in Bangladesh by using simulation model. The model is specifically focused on Boro rice production which accounts for 58% of the total rice production during 2008 in Bangladesh to estimate the effects of future climate change. Soil and hydrologic characteristics of the locations, typical crop management practices, and traditional growing period and climate data in 2008 were used for the analysis and temperature and CO₂ levels are controlled in the simulation model called DSSAT (Decision Support System for Agrotechnology Transfer). The simulation results show that rice production varies in different locations for different climatic conditions and hydrological properties of soil although same Boro rice was used in all areas. The model also indicates that rice production decreases drastically from 2.6 % to 13.5 % and from 0.11% to 28.7% when the maximum temperature was increased by 2°C and 4°C. Although the simulation model shows that a drop in minimum temperature also reduces the rice yield, it suggests that increase in maximum temperature causes more damage in the production. The model also found some positive effects of CO₂ concentration on the rice yield but the impact was little compared to that of temperature change.

In Nigeria, Agboola and Ojeleye (2007) examined the impact of climate change on food crop production in Ibadan. The study adopted both primary and secondary data collection procedures. For the secondary source of data, time series data covering 30 years were collected on climate variables and the analysis was done with bivariate Chi-square and ANOVA supported by graphical illustrations. The study revealed that farmers have noted various changes in climate conditions over the last two to three decades. It was further shown that there has been decline in crop yields on food crop production due to reduction in rainfall and relative humidity and as well as increase temperature.

Ayinde et al. (2011) examined the effect of climate change on agricultural production in Nigeria and the study covered the period 1980-2002 and adopted time series data. They analyzed their study with the recent cointegration technique of analysis and revealed that temperature had negative effect on agricultural productivity while rainfall was found to exert positive effect on agricultural productivity. Tunde et al. (2011) also analyzed the effect of climate variables on crop production in Patigi, Kwara State, Nigeria and the study used time series data covering 1999-2008. The analysis was done by correlation and Ordinary Least Square (OLS) methods without examining the time series properties of the data. The study revealed that rainfall highly correlated with maize production but weakly correlated with Millet production and Sorghum. Temperature however was found to correlate with rice and groundnut production negative.

Jidauna et al. (2012) investigated empirically the effect of climate change on agricultural activities in selected settlements in Nigeria specifically, the Sudano-Sahelian Region. The study used a structured questionnaire and focus group approaches for data collection procedures and employed inferential statistical technique for the analysis. The study found that rainfall and temperature have

been on a decline and increase respectively. The effects are decline in crop yield that has attracted the application of fertilizers and abandonment of farmlands.

Sowunmi and Akinola (2010) empirically examined the effect of climate variability on maize production in Nigeria. The study specifically analyzed the dynamic link between changes in climate elements and agronomic parameters for maize production in different ecological zones of Nigeria for the period 1980-2002. They employed the two-way analysis of variance and the coefficient of variation techniques of analyses. It was revealed that there exists a significant difference of annual rainfall, temperature and output of maize in the seven identified ecological zones.

A cursory look at the empirical literatures shows that the studies on the relationship between climate change and crop production in Nigeria are faced with weak methodological issues that might have misleading results. Besides, these studies cover shorter time period and specific region or state in Nigeria that might not give policy recommendation that could be applicable for Nigeria at large.

4. Theoretical Framework and Model Specification

4.1 Theoretical Framework

Our empirical framework follows the derivation in Bond et al. (2007). Though, the derivation of this framework was used for panel study, its theoretical explanation could be used for time series studies as it best fits in explaining the dynamic linkages between climate variables and agricultural crop production. This presented as follows. Consider the following simple economy:

$$y_t = \ell^{\beta T_t} A_t L_t \dots \dots \dots (1)$$

$$\frac{\Delta A_t}{A_t} = g + \gamma T_t \dots \dots \dots (2)$$

where Y is aggregate output, L measures population, A measures labor productivity, and T measures climate. Equation (1) captures the level effect of climate on production; that is, the effect of current temperature or precipitation on crop yields. Equation (2) captures the growth effect of climate; i.e. the effect of climate on features such as institutions that influence productivity growth. Taking logs in the production function and differencing with respect to time, we have the dynamic growth equation:

$$g_t = g + (\beta + \gamma)T_t - \beta T_{t-1} \dots \dots \dots (3)$$

where g_t is the growth rate of per-capita output. The “level effects” of climate shocks on output, which come from equation (1), appear through β . The “growth effects” of climate shocks, which come from equation (2), appear through γ . The growth equation in (3) allows separate identification of level effects and growth effects through the examination of transitory weather shocks. In particular, both effects influence the growth rate in the initial period of the shock. The difference is that the level effect eventually reverses itself as the climate returns to its prior state. For example, a temperature shock may reduce agricultural yields, but once temperature returns to its average value, agricultural yields bounce back. By contrast, the growth effect appears during the climate shock and is not reversed: a failure to innovate in one period leaves the country permanently further behind. The growth effect is identified in (3) as the summation of the climate effects over time. The above reasoning extends to models where climate effects play out more slowly. With more general lag structures in (1) and (2), the growth effect is still identified by summing the lagged effects of the climate shock. For the standard distributed-lag result demonstrated formally (see Bond et al., 2007).

4.2 Model Specification

Based on the above theoretical framework, present below is our empirical model to be estimated:

$$outp_t = \theta_1 + \phi_{11}temp_t + \phi_{12}rain_t + \phi_{13}cab_t + \mu_t \dots (4)$$

Where, Outp=output of selected crops as indicated below
 outp e [gmz, gml, grc, gbn, gcv, gpt, gym, ggn, gcc, gsh]’ (see Table 2)

$\theta_1 = \text{int ercepts}$

$\phi_{11} - \phi_{13} = \text{coefficients}$

$\mu = \text{error - term}$

Temp=temperature (°C) ; rain= rainfall (mm) and cab=carbon emission (Kt)

The dynamic error correction model specification is thus;

$$\Delta outp_t = \alpha_0 + \alpha_1 \sum_{a=\infty}^n \Delta outp_{t-1} + \alpha_2 \sum_{a=\infty}^n \Delta temp_{t-1} + \alpha_3 \sum_{a=\infty}^n \Delta rain_{t-1} + \alpha_4 \sum_{a=\infty}^n \Delta cab_{t-1} + ecm_{t-1} \dots (5)$$

Where, ecm is error correction term (lagged residual of static regression) and ‘Δ’ stands for the first difference.

Equation 5 is estimated for each of the ten selected crops, hence, ten models are estimated. Model 1 examines the effect of climatic variables on beans production, model 2 analyzes the effect of climatic variables on cassava production, model 3 examines the link between climatic variables and cocoa production, model 4 examines climatic variables effect on groundnut production, model 5 analyzes the effect of climate change on maize production, model 6 examines the effect of climate variables on millet production, model 7 analyzes the effect of climatic variables on potato production, model 8 analyzes the impact of climatic variables on rice production, model 9 examines the effect of climatic variables on sorghum production and model 10 analyzes the effect of climatic variables on yam production in Nigeria.

Table 2. Variables Definition

Variable	Definition		
gmz	Maize production	=	Output of Maize Production
gml	Millet production	=	Output of Millet production
grc	Rice production	=	Output of Rice production
gbn	Beans production	=	Output of Beans production
gcv	Cassava production	=	Output of Cassava production
gpt	Potato production	=	Output of Potato production
gym	Yam production	=	Output of Yam production
ggn	Groundnut production	=	Output of Groundnut production
gcc	Cocoa production	=	Output of Cocoa production
gsh	Sorghum Production	=	Output of Sorghum Production
temp	Temperature	=	Temperature in degrees
rain	Rainfall	=	Annual series of rainfall (mm)
cab	Carbon emission	=	Carbon in the atmosphere (Kt)

4.3 Data Source and Analysis

The study extracted annual time series data on temperature and rainfall from the Food and Agriculture Organization Database, 2012; the different crop production data from the CBN Statistical Bulletin, 2011 and the carbon in the atmosphere data from the World Development Indicator Database. The analysis is done with the error correction technique. The data coverage is 1970-2009.

5. Empirical Analysis

5.1 Unit Root Results

The analysis begins by conducting stationarity test to ascertain the stationarity or otherwise of the variables and the appropriateness of the specification of the models. Thus, both the Augmented Dicky Fuller (ADF) and the Philips Perron (PP) tests are employed. The ADF-test and PP-test are reported in Table 3.

The results show that the variables are non-stationary in their levels. The variables only became stationary after first difference except for rainfall, temperature and output of beans production. This is confirmed by both the ADF-test and the PP-test statistics in Table 3 above. Since, most of the variables follow order one [I(1)] process, the next step is to test if there exists a long run relationship (cointegration) among the variables.

5.2 Cointegration Test Result

To ascertain the long run relationship among the variables, we employed the Johansen Maximum-likelihood approach. The number of cointegrating relations from all the models on the basis of trace statistics using critical values at 5% are summarized in Table 4.

Table 3. Unit Root Test Result

Variables	Augmented Dickey Fuller Test				Philips Perron Test			
	Without Trend		With Trend		Without Trend		With Trend	
	Level	1 st Diff.	Level	1 st diff.	Level	1 st diff.	Level	1 st Diff.
gmz	0.68	-6.02*	-2.25	-6.34*	0.94	-6.02*	-2.23	-6.40*
gml	-0.66	-8.99*	-4.11**	-8.94*	-1.09	-13.08*	-4.09**	-18.35*
grc	-0.96	-9.13*	-4.16***	-9.01*	-1.26	-14.74*	-4.16***	-15.88*
gbn	-3.90*		-5.65*		-3.97*		-5.65*	
gcv	0.06	-5.13*	-2.24	-5.12*	-2.66	-7.62*	-2.83	-7.59*
gpt	0.64	4.60	6.65	-6.18*	0.64	-5.70*	-0.74	-6.20*
gym	0.93	-4.33*	-1.77	-4.62*	0.36	-4.30*	-2.46	-4.63*
ggn	-0.45	-8.74*	-2.55	-4.72*	0.01	-8.74*	-2.39	-25.9*
gcc	-2.93	-7.69*	-3.06	-7.63	-2.93	-8.17*	-3.03	-8.06*
gsh	0.91	-8.88*	-3.47***	-9.38*	0.61	-9.68	-3.37***	-10.91
temp	-3.73*		-4.41*		-3.55**		-3.34***	
rain	-4.09*		-5.62		-4.13*		-5.62*	
cab	1.23	-3.64*	-1.19	-3.87*	1.26	-3.69*	-0.57	-3.86*

Note: *, **, ***, indicate 0.99, 0.95 & 0.90 level of confidence respectively.

Source: E-Views Estimation by authors

Table 4. Cointegration Test Result

rank	Trace Stat for Model 1	Trace Stat for Model 2	Trace Stat for Model 3	Trace Stat for Model 4	Trace Stat for Model 5	Trace Stat for Model 6	Trace Stat for Model 7	Trace Stat for Model 8	Trace Stat for Model 9	Trace Stat for Model 10
r≤0	57.68	64.62*	73.56*	75.51*	71.70*	92.05*	75.76*	81.28*	82.03*	67.32*
r≤1	35.66	42.82*	47.28*	38.57*	40.01*	43.97*	41.84*	46.16*	48.87*	36.94*
r≤2	17.3**	22.80*	25.93*	20.14*	19.39*	20.45*	22.91*	23.88*	28.32*	18.53*
r≤3	4.36**	8.65*	8.76*	8.61*	7.20*	8.40**	7.44*	5.67**	9.42*	6.14**

Note: *, ** stand for 0.99 & 0.95 level of confidence

Source: E-Views Estimation by authors

The results of the trace statistics in Table 4 indicate that the hypothesis of no cointegration among the variables can be rejected for all the ten models. The results revealed that at least four cointegrating vectors exist among the variables of interest in all the models. Considering the existence of long run relationship established among the variables as shown in Table 4, the analysis employs an error correction estimation approach which result is presented in the next section.

5.3 The Error Correction Result

As a result of the existence of unit root problem associated with some of the variables and establishment of long run relationship with the Johansen cointegration, we proceed to estimate an error correction model. Table 5 shows the parsimonious error correction result selected based on akaike information criterion and Schwarz criterion.

The parsimonious error correction result shown in Table 5 indicates that almost all the models are devoid of serious econometric problems as their Durbin-Watson statistics indicate absence of serial correlation and their F-statistics also passed the significant test except for models 6 and 9. The value of their coefficient of determinants also exhibited goodness of fit as the explanatory variables explained above 50% of the variation in each the crops used as dependent variable in the models. The value of F-statistics implies that there is a considerable harmony between each of the crops in each model as dependent variable and the explanatory variables put together.

It is evident from the result of model 1 that temperature had significantly negative effect on beans from production while rainfall was found to have a positive impact on beans production in Nigeria. However, carbon emission in the atmosphere was found to impact negatively the production of beans in Nigeria.

This implies that increased temperature and carbon in the atmosphere leads to reduction in the output of beans production in Nigeria. The error correction variable in the model that passed the significant test indicates that about 2% of the deviation of beans production from its long run value will be corrected. In model 2, temperature and rainfall were found to have significantly positive effect

on cassava production in Nigeria under the study period while carbon emission had significantly negative effect on cassava production. The error correction variable which passed the significant test shows that about 16% of the deviation in cassava production from its long run value will be corrected. For model 3, temperature was found to have a significantly negative effect of cocoa production while rainfall and carbon emission in the atmosphere were found to impact positively the production of cocoa in Nigeria. The error correction variable in that model also passed the significant test; hence it will act to correct about 3% of the deviation of cocoa production from its long run value.

Table 5. Parsimonious Error Correction Result

Regressors	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
C	-21.1*	18.58*	-28.5***	300.9	-102.3	28.25	-3.48	85.92	12.57	16.47
Dep Var(-1)	0.79**	0.21**	0.68	-0.21	-1.44***	-0.13	0.83	1.02*	0.03	0.27
Temp	-1.16**	-8.34	-17.85*	110.14**	-22.37***	3.61	-2.26	-14.6**	6.48	19.49
Temp(-1)	0.31	-13.46***	4.71	-150.9**	20.52	-7.96	1.89	-9.55***	-4.99	-10.61
Rainfall	0.05*	-0.33	1.17**	-6.98***	4.24***	-0.87***	-1.78	1.07*	-0.63**	-1.43
Rainfall(-1)	0.20**	1.10***	1.43	-0.35	3.25**	0.82	0.79***	-0.36	-0.15	-1.07**
carbon	1.49		2.29	-8.23***	4.63***	-0.86***	-0.27	-0.45**	-0.41	-0.46**
Carbon(-1)	-0.09**	-0.02**	2.33***	-0.87**	1.56	0.35	1.08	-0.24	-0.14**	-1.61
ecm(-1)	-0.02*	-0.16**	-0.03**	-0.05***	-0.21**	-0.06***	-0.07***	-0.18*	-0.01	-0.08**
R²	0.78	0.68	0.95	0.76	0.65	0.73	0.71	0.98	0.61	0.53
Durbin-Watson	2.25	1.83	2.29	2.05	2.02	2.19	2.35	2.23	2.15	2.04
F-statistics	8.56*	.79***	27.3***	1.59	3.16***	1.02	3.19**	80.42*	0.79	5.58***

Note: *, **, *** stand for 0.99, 0.95 & 0.90 level of confidence respectively.

Source: E-Views Estimation by authors

In model 4, contemporary temperature was found to have positive effect on groundnut production while lagged or previous temperature was found to have negative effect on groundnut production. Rainfall was found to have a significantly negative effect on groundnut production while carbon emission had positive effect on it. The error correction variable also passed the significant test in the model; hence it could rightly act to correct any deviation of groundnut production from its long run value for about 5%. For maize production, the model indicates that temperature and carbon emission had significantly negative effect while rainfall had positive impact on the production of maize in Nigeria. The error correction variable which was significant as deduced from the result could rightly act to correct about 21% of deviation of maize production from its long run value. For millet production as shown from model 6, temperature had negative effect on its production though this was not significant while rainfall and carbon emission that passed the significant test were also found to negatively influence the production of millet production in Nigeria. The error correction variable in this model act to correct about 6% of the deviation of millet production from its long run and this is significant.

For potato production in Nigeria as shown in model 7, carbon emission and temperature were found to have insignificant effect on its production while rainfall was found to have a significantly positive effect on potato production in Nigeria. The error correction variable which is significant implies that any deviation of potato production from its long run value can be corrected for about 7%. Model 8 shows that temperature and carbon emission affect negatively the production of rice in Nigeria, the coefficients are significant. However, rainfall was found to have significantly positive effect on rice production for the period under study. The error correction variable which is significant implies that about 18% of deviation of rice production from its long run value is corrected. For the model of sorghum production which is model 9, the error correction variable never passed the significant test hence it cannot act to correction sorghum production from any deviation in its long run value. However, all the explanatory variables were found to have negative effect on sorghum production in Nigeria. And lastly for yam production as shown in model 10, temperature, rainfall and carbon emission were all found to impact negatively the production of yam in Nigeria. The error correction variable was significant; therefore it could rightly act to correction any deviation of yam production from its long run value.

4. Conclusion

This study attempts to examine the effect of climate change on crop production in Nigeria for the period 1970-2009. The study used three climatic variables namely temperature, rainfall and carbon in the atmosphere. Ten crops were selected which are beans, cassava, cocoa, groundnut, maize, millet, potato, rice, sorghum and yam. The study employed an error correction technique of analysis. The study first examined the stationarity status of the variables with the ADF-test and the PP-test and the results revealed that all the variables became stationary after first difference except for temperature, rainfall and output of beans production. We then proceeded to use the Johansen cointegration test to establish long run relationship before estimating the parsimonious error model. In all, ten models were estimated, one for each crop with the climatic variables included as explanatory variables. Data for the study were extracted from the Food and Agriculture Organization database online and the Central Bank of Nigeria Statistical Bulletin on various issues.

The study revealed that the effect of climatic variables on crop production varies depending on the type of crop and seasonal properties and length of days of the crop. In general, climate change effect was found to be pronounced on the output of the crop. This is deduced from the results that some seasonal crops that are harvested during the raining seasons were found to have been negatively affected by rainfall. Carbon emission in the atmosphere was also found to have affected the output of almost all the crops during the sample period. It is therefore recommended that various mitigation and adaptation strategies necessary for increased output of these crops be adopted by farmers. These include the use of improved crop varieties that survive adverse climatic conditions, intercropping, soil conservation, changing planting dates in line with climate changes, tree planting against harsh temperature and irrigation.

The study suggests further that proper climate forecast is a *sin-quo-non* in guiding farmers. There is also the need for enlightenment programmes such as organized seminars for the farmers to be abreast with modern adaptation strategies.

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