Effects of Climate Change on Rice and Maize Production in Nigeria from 1970 - 2012

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Abstract

Rice and maize are two important crops that play significant roles in food security and building Nigeria's foreign reserves. Threats to these crops have national security implications. Several studies have confirmed the threat that weather variability and climate change pose to the agriculture sector in Nigeria, which is largely weather dependent. This paper reports the effect of climatic variables on the output of these two important staples, rice and maize, in Nigeria.

Secondary data for a 43-year period, 1970 – 2012, were used for the study. Data were collected on climatic variables such as mean annual rainfall and average daily temperature.

The time trend analysis was used to examine the trends in the movement of climate variables and crop output, while, co-integration analysis was used to understand the relationship between the output of the selected crops and climatic variables.

Further, a long-run equilibrium relationship was observed between the mean annual rainfall and the average annual temperature for the rice model. Thus, mean annual rainfall positively affected rice output while mean daily temperature negatively influenced it. For the maize model, a long-run equilibrium relationship was observed amongst maize, rainfall and temperature. The resulting Error Correction

Model indicated that the previous year's mean rainfall and mean temperature values had a strong positive influence on maize output.

Efforts at controlling the emission of greenhouse gases should be sustained globally to reduce the adverse impact of temperature rise for crops like maize. Investment in irrigation projects should be top priority to make water availability constant for farm use nationally to significantly increase the output of these important crops. Rice production can be concentrated in the southern and middle belts and maize in the northern part of the country to take advantage of the differences in the temperature requirements for the production of these crops.

Keywords: Arable crops, Climatic variables, Maize, Rice, Climate change

Introduction

Climate change is a serious environmental threat to food security and it worsens poverty because of its impact on agricultural productivity. Almost all the sectors of agriculture depend on weather and climate, whose variability have meant that rural farmers who implement their regular annual farm business plans encounter total failure due to climate change effects (Ozor et al., 2010). Local climate variability influences people's decisions, with consequences for their social, economic, political and personal conditions (UNFCCC, 2007). The Intergovernmental Panel on Climate Change (IPCC, 2001)) stated that climate change is emerging as one of the cardinal challenges of the twenty-first century (APF, 2007). Human-induced climate change resulting from increase in the concentration of greenhouse gases (GHGs) in the atmosphere and food security are two closely related threats facing mankind in the twenty-first century. The challenges of climate change became so pronounced that in 1992, at the Rio Earth Summit, the international environmental treaty, 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).

Agricultural production in Nigeria is mostly weather dependent, thus climate variability and change have direct, often adverse influence on the quantity and quality of agricultural production in the country (Adejuwon, 2004, and Sowunmi and Akintola, 2010). In Nigeria, between 2000 and 2005, there was a decline in crop yield and food crop production due to reduction in rainfall, relative humidity and increase in temperature in Nigeria (Agbola and Ojeleye, 2007). Like in other developing countries, the challenges of climate change and global warming in Nigeria are enormous due to widespread poverty. The problem is expected to be more severe in Africa where current information on climate change is limited; technological change is low and the domestic economy depends heavily on agriculture (Action Aid, 2008). There is growing consensus in the scientific literature that over the coming decades, higher temperature and changes in precipitation levels caused by climate change will be unfavorable for crop growth and yield in many regions and countries, including Nigeria (Yesuf et al., 2008). Interests in these issues have motivated a substantial body of research on climate change and agriculture over the past decade (Lobell et al., 2008; Wolfe et al., 2005; Fischer et al., 2002). Though climate change is a threat to agriculture, non-agricultural and socio-economic development, agricultural production activities are generally more vulnerable than other sectors (Ajetumobi and Abiodun, 2010). Thus, in the long run, agriculture and agricultural practices will have to adapt to these changes to ensure food security for human survival.

Maize (*Zea mays*) and rice (*Oryza sativa*) are grown in different agro-ecological environments throughout the world. They are important cereal crops in sub-Saharan Africa (SSA) and important staple crops in Nigeria. Africa produces 6.5 percent of maize worldwide. Nigeria with nearly 8 million tons emerged as the largest producer in Africa. Agricultural production in general and maize production in particular are rain-fed. The implication of this is that irregular rainfall can trigger famine during occasional droughts (IITA, 2005). The importance of the maize crop cannot be over-emphasized. It has been put to a wider range of uses than any other cereal: as human food, feed grain, and fodder crop and for hundreds of industrial purposes, because of its broad global distribution. Its low price relative to other cereals; diverse grain types, and wide range of industrial and biological properties also contribute to the importance of maize.

Rice is an important crop consumed as a healthy and staple food. It is relatively easy to produce and is grown both for sale and home consumption. The crop can grow on different types of soil provided there is adequate supply of moisture. However, it grows best on rich loamy to clayey soils that are able to retain water with adequate humus. It requires an annual rainfall of 120-175 cm, which should be evenly distributed. Various reasons have been attributed to the wide gap between demand and supply in Nigeria, which includes an aging farming population, improper production techniques, scarcity and high cost of inputs, rudimentary post-harvest and processing methods, inefficient milling methods, poor or low mechanization on rice farms and low competitiveness with imported rice (Daramola, 2005). Nguyen (2004) submitted that rice farming is being affected by increasing temperatures and irregularity in rainfall patterns, which have been attributed to climate change.

Climate change refers to a significant and persistent change in the distribution of weather pattern. Scientific evidence shows that the earth's climate has continuously changed throughout history but recent climate change effects show an unusual trend which is attributed to the emission of greenhouse gases by humans, mainly from the transport, agriculture, manufacturing, energy and other critical sectors of the economy. This human-induced climate change is commonly referred to as global warming. Agriculture and climate change take place on a global and regional scale. They are inter-related processes. In spite of the uncertainties about the precise magnitude of climate change on a regional scale, an assessment of the possible impacts of climate change on agricultural resources under varying conditions is important for formulating response strategies, which should be practical, affordable and acceptable to farmers.

Furthermore, the accelerating pace of climate change combined with global population and income growth threatens food security everywhere. The overall impacts of climate change on agriculture are expected to be negative and thereby threatening to global food security. It is important to note that most of the crops produced in Nigeria are low technology based and are therefore heavily susceptible to environmental factors and climate change, which are problems to farmers (Obioha, 2008). Farmers face challenges of tragic crop failures, reduced agricultural productivity, increased hunger, malnutrition and diseases due to the adverse effect of climate change (Zoellick, 2009). These problems hamper agricultural output and the contribution of the agricultural sector to the Nigeria's Gross Domestic Product (GDP). This study therefore investigated the effect of climatic variables on the output of two important staples – rice and maize, in Nigeria.

Materials and Method

The study utilized secondary data for a 43-year period (1970 – 2012). Data on climatic variables such as mean annual rainfall and average daily temperature were collected from the Nigerian Meteorological Agency (NIMET) while data on annual output of rice and maize were obtained from the National Bureau of Statistics (NBS), Nigeria.

The time trend analysis was used to examine the trends in the movement of climate variables and crop output while, co-integration analysis was used to understand the relationship between the output of the selected crops and climatic variables. The error correction model employed in the study is represented thus:

$$Y = b_0 + b_1X_1 + b_2X_2 + ecm$$

where:

Y = output in maize and rice production (tonnes)

X_1 = rainfall (mm)

X_2 = temperature (°C)

b_{is} = regression coefficients

ecm = error correction term

Results and Discussion

Trends in annual rainfall

Average annual rainfall fluctuated over the period of the study, alternately falling and rising over the sub-periods, ranging from a low of 88.55mm to a highest of 95.94mm (Table 1). From 92.07 mm in the 1970 – 1979 sub-period, it dropped to 88.55mm in the 1980 – 1989 sub-period, then rose to 96.54mm in the 1990 – 1999 sub-period. It decreased slightly to 95.94mm in the 2000 – 2009 sub-period, but increased again to 96.40mm in the 2010 – 2012 sub-period. The average annual rainfall over the study period was 93.09mm. The intra sub-period annual percentage change in the annual rainfall was 1.34 percent, 3.26 percent, 1.03 percent per year in the 1970 -1979, 1980 – 1989 and 2000 – 2009 sub-periods, respectively. However a negative growth of 8.99 percent per year and 0.48 percent per year were recorded in the 1990 – 1999 and 2010 – 2012 sub-period. The average annual growth rate of rainfall for the period covered by the study was 1.88 percent. There was a degree of instability in the average annual rainfall with the coefficients of variation ranging from 11.12 percent to 13.40 percent, with an average of 13.23 percent over the study period.

Table 1: Trends in annual rainfall

Year	Mean (mm)	Annual percent change	Coefficient of variation
1970-79	92.07	1.34	11.12
1980-89	88.55	3.26	12.43
1990-99	96.54	-8.99	12.30
2000-09	95.94	1.03	11.23
2010-12	96.40	-0.48	13.40
Total	93.09	1.88	13.23

Source: Authors' computation, 2016.

Trends in annual temperature

Average annual temperature rose consistently over the period of the study though in varying degrees. It rose from 26.63^{0}C in the 1970 – 1979 sub-period, to 27.44^{0}C in the 2010–2012 sub-period (Table 2). The average annual temperature over the study period was 27.03^{0}C. The intra sub-period annual percentage changes in the annual temperature were 1.34 percent, 0.34 percent, 2.34 percent, 0.97 percent and 0.56 percent per year in the five sub-periods respectively. The average annual growth rate of temperature for the period covered by the study was 1.24 percent. There was a degree of instability in the average annual temperature with the coefficients of variation ranging from 11.34 percent to 14.44 percent, with an average of 13.12 percent over the study period.

Table 2: Trends in annual temperature

Year	Mean (°C)	Annual percent change	Coefficient of variation
1970-79	26.63	1.34	11.34
1980-89	26.99	0.34	12.32
1990-99	27.07	2.34	14.44
2000-09	27.31	0.97	12.38
2010-12	27.44	0.56	11.36
Total	27.03	1.24	13.12

Source: Authors' computation, 2016.

Trend of changes in annual output of maize

The average annual output of maize fluctuated over the period of the study, with alternately rising and falling (Table 3). It rose from 1.01 thousand metric tonnes in the 1970 – 1979 sub-period to 1.33 thousands metric tons in the 1980 – 1989 sub-period, but fell to 1.26 thousand metric tonnes in the 1990– 1999 sub-period and later increased to 1.67 and 1.73 thousand metric tonnes in the 2000-2009 and 2010–2012 sub-periods respectively. The average annual output ranged from 1.01 thousand metric tonnes in 1970 – 1979 to the highest of 1.73 thousand metric tonnes in 2000 – 2009. The average annual output of maize over the study period was 1.34 thousand metric tonnes. The intra sub-period annual percent growth rate of maize output was between 0.22 percent and 0.97 percent. The average annual growth rate of output of maize for the period covered by the study was 0.78 percent. There was a degree of instability in the average annual output of maize with the coefficients of variation ranging from 11.14 percent to 12.38 percent, with an average of 12.38 percent over the study period.

Table 3: Trends in annual output of maize

Year	Mean (000 metric tonnes)	Annual percent growth rate	Coefficient of variation
1970-79	1.01	0.34	12.21
1980-89	1.33	0.97	11.18
1990-99	1.26	0.22	12.22
2000-09	1.67	0.34	11.14
2010-12	1.73	0.23	12.09
Total	1.34	0.78	12.38

Source: Authors' computation, 2016.

Trends in annual output of rice

Table 4 presents the trend of annual output of rice over the study period. The average annual output fluctuated, rising from 1.70 thousand metric tonnes in the 1970 – 1979 sub-period to 2.07 thousands metric tonnes in the 1980 – 1989 sub-period. It fell to 1.75 thousand metric tonnes in the 1990 – 1999 sub-period and further to 1.48 thousand metric tonnes in the 2000 – 2009 sub-period, before rising to 1.75 thousand metric tonnes in the 2010 – 2012. The average annual output of rice ranged from a low of 1.48

thousand metric tonnes in the 2000 – 2009 sub-period to the highest of 2.07 thousand metric tonnes in the 1980-89 sub-period. The average annual output of rice over the study period was 1.75 thousand metric tonnes. The intra sub-period annual percent growth rate of rice output was 0.75 percent, 0.97 percent, -0.76 percent, -0.67 percent and 0.99 percent per year in the 1970 – 1979, 1980 – 1989, 1990 – 1999, 2000 – 2009 and 2010 – 2012 sub-periods respectively. The average annual growth rate of output of rice for the period covered by the study was 1.97 percent. There was a degree of instability in the average annual output of rice with the coefficients of variation ranging from 10.34 percent to 14.44 percent, with an average of 10.74 percent over the study period.

Table 4: Trend of changes in annual output of rice

Year	Mean (000 metric tonnes)	Annual percent growth	Coefficient of variation
1970-79	1.70	0.75	10.34
1980-89	2.07	0.97	11.28
1990-99	1.75	-0.76	14.44
2000-09	1.48	-0.67	12.32
2010-12	1.80	0.99	11.56
Total	1.75	1.97	10.74

Source: Authors' computation, 2016.

Results of Time Series Analysis

Unit root test

The result of the Augmented Dickey-Fuller (ADF) unit root tests for the non-logged variables used in the study (Table 5) show that annual output of maize (Y_1), annual rainfall (X_1), and annual temperature (X_2) are not stationary at their original values but, stationary at first difference, showing that using their original values for regression analysis will give spurious results.

Table 5: Results of ADF unit root test for variables

Variables	Augmented Dickey Fuller (ADF) values (Level)	Augmented Dickey Fuller (ADF) values (First difference)	Order of integration
Maize	-1.771	-4.507	1
Rain	-2.464	-4.411	1
Temp	-2.476	-3.762	1
Critical values			
1%	-4.265	-2.373	
5%	-2.953	-3.568	
10%	-2.613	-3.723	

The result of Augmented Dickey-Fuller (ADF) unit root tests for non-logged variables used in the study, presented in Table 6, shows that annual output of rice (Y_1), annual rainfall (X_1), and annual temperature (X_2) are not stationary at their original values but are stationary at first difference, showing that using their original values for regression analysis will give spurious results.

Table 6: Results of ADF unit root test for variables

Variables	Augmented Dickey Fuller (ADF) Values (Level)	Augmented Dickey Fuller (ADF) Values (First difference)	Order of integration
Rice	-1.772	-4.508	1
Rain	-2.463	-4.412	1
Temp	-2.477	-3.763	1
Critical values			
1%	-4.265	-2.373	
5%	-2.953	-3.568	
10%	-2.613	-3.723	

Source: Author's computation.

Co-integration tests

The result of the co-integration analysis for the regression equation used in the study for the non-logged variables shows two co-integrating variables (Table 7). The variables are the output of maize (Y_1), annual temperature (X_1) and annual rainfall (X_2),confirming a long-run relationship among the variables.

Table 7: Result of co-integration analysis of non-logged variables for regression equation

Eigen Value	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)	Co-integrating Variables
0.649	127.380	94.250	104.180	None **	maize
0.613	86.527	68.420	77.070	At most 1 **	temp
0.459	50.441	47.310	54.460	At most 2 *	rain

CE(s) means Co-integration(s)

* and** denotes rejection of hypothesis of no co-integration at 1% and 5% significance level respectively.

Similarly, the result of the co-integration analysis for the regression equation used in the study for the logged variables (see Table 8) shows two co-integrating variables. The variables are annual output of maize (Y_1), annual rainfall (X_1) and annual temperature (X_2) confirming a long-run relationship among the variables.

Table 8: Result of co-integration analysis of logged variables for regression equation

Eigen Value	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)	Co-integrating Variables
0.659	128.380	94.150	103.180	None **	maize
0.623	87.527	68.520	76.070	At most 1 **	temp
0.449	50.441	47.210	54.460	At most 2 *	rain

CE(s) means Co-integration(s)

* and** denote rejection of hypothesis of no co-integration at 1% and 5% significance levels respectively.

The result of the co-integration analysis for the regression equation used in the study for the non-logged variables shows two co-integrating variables (Table 9). The variables are output of rice (Y_1), annual temperature (X_1) and annual rainfall (X_2), confirming a long-run relationship among the variables.

Table 9: Results of co-integration analysis of non-logged variables for regression equation

Eigen Value	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)	Co-integrating Variables
0.658	128.381	94.151	103.181	None **	rice
0.624	87.528	68.521	76.071	At most 1 **	temp
0.448	50.442	47.211	54.461	At most 2 *	rain

CE(s) means Co-integration(s)

* and** denote rejection of hypothesis of no co-integration at 1% and 5% significance level respectively.

Similarly, the result of the co-integration analysis for the regression equation used in the study for the logged variables presented in Table 10 shows two co-integrating variables. The variables are annual output of rice (Y_1), annual rainfall (X_1) and annual temperature (X_2) confirming a long-run relationship among the variables.

Table 10: Result of co-integration analysis of logged variables for regression equation

Eigen Value	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)	Co-integrating Variables
0.648	127.381	94.251	104.181	None **	rice
0.614	86.528	68.421	77.071	At most 1 **	temp
0.458	50.442	47.311	54.461	At most 2 *	rain

CE(s) means Co-integration(s)

* and** denote rejection of hypothesis of no co-integration at 1% and 5% significance level respectively.

Results of Correction Analysis

Table 11 presents the results of the error correction analysis. The coefficient of determination (R^2) is 0.890. The F-value is significant at 1% level, showing that the model has a good fit. The coefficient of the error correction factor is negative and significant at 11% level. The significance of the error correction term supports co-integration and suggests the existence of a long-run equilibrium steady state between the output of maize, rainfall and temperature. The coefficient of annual rainfall (X_1) lagged by one year is positive and significant at 1% level. This result implies that the current output of maize is dependent on the previous year's amount of rainfall.

Similarly, the coefficient of annual temperature is positive and statistically significant at 1% level, indicating that the level of output of maize is positively affected by the previous year's annual temperature. In summary, the results show that annual rainfall (X_1) and annual temperature (X_2), lagged by one year, positively affect the output of maize.

Table 11: Results of error correction analysis

Dependent variable Ln Y(Maize output)

Variable	Coefficient	t-statistics
ECMt(-1)	-0.907	6.021*
LnX_1	0.033	-0.396
LnX_1(-1)	0.298	3.940*
LnX_2	0.227	0.242
LnX_2(-1)	0.281	4.932*
C	0.005	1.172
R^2	0.890	
Adjusted R^2	0.794	
T-statistics	9.364*	
Log likelihood	107.384	
Durbin Watson	1.930	
Akaike (AIC)	-4.707	
Schwarz (SC)	-3.929	
Mean dependent	0.011	
S D dependent	0.043	

* Coefficient significance at 5% level

The results of the regression analysis are presented in Table 12 . The coefficient of multiple determinations (R^2) is 0.720. The F-value is statistically significant at 1 percent level, showing that the models fitted the data well. Table 12 reveals that the coefficient of annual temperature (X_1) is negative and statistically significant at 5 percent level. The result shows that there is an inverse relationship between the annual temperature and the output of rice. A one percent rise in annual temperature will lead to a 0.64 percent fall in the output of rice. This implies that a rising annual temperature would stimulate a reduction in the output of rice and will lead to significant reduction in the rice farmers' income from rice production. As shown in Table 12, the coefficient of annual rainfall (X_2) is positive and statistically significant at 5 percent level, implying a direct relationship between this variable and the output of rice. A one percent increase in annual rainfall will induce a rise of 0.19 percent in the output of rice. This result suggests that expansion in the domestic production of rice can be achieved by augmenting annual rainfall with irrigation. In summary, the result shows that annual temperature (X_1) negatively affects the output of rice, while annual rainfall (X_2) positively affects the output of rice.

Table 12: Result of error correction analysis

Dependent Variable = LnY(Rice output)

Variables	Coefficients	t-value
ECMt(-1)	-0.707	6.221*
LnX_1	-0.499	-0.642**
LnX_1(-1)	0.298	3.940*
LnX_2	0.192	0.482**
LnX_2(-1)	0.281	4.932*
C	0.565	0.383
R^2	0.720	
Adj. R_2	0.728	
Sum sq resid	1.576	
S.E. equation	0.288	
F-statistic	3.812*	
Log likelihood	5.884	
Durbin Wat.	1.761	
Akaike AIC	0.654	
Schwarz SC	0.439	
Mean Dep	0.020	
S.D. Dep.	0.274	

** Coefficient significant at 5% level.

Conclusion and Recommendations

Based on the findings from the study, it is concluded that climate change significantly affects the output of maize and rice crops in Nigeria. Thus, the following recommendations are made:

1. Efforts to control the emission of greenhouse gases should be sustained globally to reduce the adverse impact of temperature rise for crops like maize.

2. Investment in irrigation projects should be top priority to make water constantly available for farm use nationally to significantly increase the output of these important crops.

3. Rice production can be concentrated in the southern and middle belts and maize in the northern part of the country, to take advantage of the differences in temperature required for their production.

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