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RETROSPECTIVE STUDY OF CAUSAL RELATIONSHIP BETWEEN CLIMATE VARIABILITY AND CROP PRODUCTION IN NIGERIA

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Abstract
This study was carried out to examine the causal relationship between climate variability and crop production in Nigeria using time series data covering 1970 to 2008. The data utilized in the study were obtained from various publications of the Central Bank of Nigeria and the Nigerian Meteorological Agency. The data include data on rainfall variability as proxy for climate variability and index of crop production as proxy for crop production. Augmented Dickey Fuller (ADF) test, Vector Autoregression (VAR) lag order selection test and granger causality test were employed in the data analysis. The F statistic of 19.57 and 27.48 from the granger causality test were significant at 1% probability respectively and the results indicated a bidirectional relationship between climate variability and crop production in Nigeria. This implies that variability of climate was significant in influencing crop production and the activities of crop production were significant in influencing the variability of climate over the data period of the study. It is recommended as a matter of urgency that agricultural intensification should be advocated to stem down agriculture related green house gas emissions and farmers should be properly sensitized on coping strategies for adapting to climate variability so as to ensure sustainable crop production in line with the agricultural transformation agenda of Nigeria.
Keywords: Climate variability, Rainfall, Granger causality, Crop production

Introduction
Current trend in population growth suggests that global food production is unlikely to satisfy future demand under predicted climate change scenarios and the situation is generally more serious in less developed countries where agrosystems are already fragile, investment in agriculture is limited and climate change is predicted to have its most devastating effects (Reynolds, 2010). As climate is a primary determinant of agricultural productivity, any significant changes in climate in the future will influence crop and livestock productivity, hydrologic balances, input supplies and other components of managing agricultural systems (Knox *et al.*, 2011). IPCC (2007) has evolved its own usage of the term climate change as any change in climate over time whether due to natural variability or as a result of human activity. Over the years, the change becomes more pronounced and significant as a result of earth's natural variations and man's activities which cause emissions of green house gases thereby increasing global warming which is what actually induces the change in climate (Ifeanyi-obi *et al.,* 2012). Agbola and Ojeleye (2010) were of the view that climate change results from such factors as changes in orbital elements, natural internal processes of the climates system or anthropogenic such as increasing atmospheric concentration of carbon dioxide and green house gases.

Crop production in sub Saharan Africa is directly affected by many aspects of climate change stemming primarily from average increases in temperature, change in rainfall amount and duration, rising atmospheric concentration of carbon dioxide, sea water rise and change in climatic variability and extreme events (Chijioke *et al.*, 2011). Agricultural practice in the country is dominantly rain-fed and therefore particularly vulnerable to the impacts of climate change (FME, 2010). Climate change affects crop production directly through its impact on biophysical factors such as plant and animal growth and the physical infrastructure associated with food processing and distribution (Schmidhuber and Tubiello, 2007). Climatic variability in the context of severe flooding and drought has been directly linked to declines in economic activities (Brown *et al.*, 2008). This was further emphasized by Ibrahim *et al.* (2010) who noted that increased rainfall variability would lead to frequent floods and drought resulting in variability in crop yields in different ecological zones and higher rainfall in the southern part of the country coupled with sea-level rise would lead to crop losses due to water logging, loss of arable land and increased pest infestation.

FAO (2008) posited that climate change affects food security through its impact on all components of global, national and local food systems. Climate change will impact agriculture and food production around the world due to; the effects of elevated carbon dioxide in the atmosphere, higher temperature, altered precipitation and transpiration regimes, increased frequency of extreme events, and modified weed, pest and pathogen pressure (Easterling *et al.*, 2007). Crop productivity will not only be affected by changes in climatically related abiotic stresses(i.e increasing temperature, decreasing water availability increasing salinity and inundation) and biotic stresses(such as increases in pests and diseases)but also changes in atmospheric concentration of carbon dioxide, acid deposition and ground level ozone. Climate change has the potential to irreversibly damage the natural resource base on which agriculture depends and in general adversely affects agricultural productivity (Reynolds, 2010).

Despite the myriads of existing literature on climate change agriculture nexus in Nigeria stemming from the importance of climate to agricultural production and the need for increased food production to meet the food demand of the over one hundred and sixty million population of Nigeria, an in-depth understanding of the causal link between climate variability and crop production has not been properly addressed and therefore, this study was designed to fill the existing gap by providing empirical information on the existence and direction of relationship between climate variability and crop production in Nigeria and make relevant policy implications in the light of the agricultural transformation agenda of Nigeria.

Materials and Methods

Description of data: This study employed time series data on climate variability given by mean annual rainfall in millimetre and crop production given by the index of crop production spanning a period of 1970 to 2008. The data period was chosen because it is the period for which reliable data were available. The data were sourced from various publications of the Central Bank of Nigeria (CBN) statistical bulletin and the Nigeria Meteorological Agency (NIMET).

Analytical Framework: Pairwise granger causality test was the principal analytical tool utilized in this study. Prior to the granger causality analysis, the stationarity of the variables under study were determined to avoid spurious regression which is a common problem in time series analysis. This study used the Augmented Dickey-Fuller (ADF) test to examine each of the variables for the presence of a unit root (an indication of non-stationary). The null hypothesis of the Augmented Dickey Fuller unit root test is $H_0: \delta = 0$ and the alternative hypothesis is $H_a: \delta < 0$. The Granger causality test assumes that the information relevant to the prediction of the respective variables, X and Y, is contained solely in the time series data on these variables. The test involves estimating the following pair of regressions:

$$X_t = \beta_0 + \sum_{i=1}^{p} \beta_i X_{t-i} + \sum_{j=1}^{p} \alpha_j Y_{t-j} + \mu_{1t} \quad \ldots \ldots (1)$$

$$Y_t = \gamma_0 + \sum_{i=1}^{p} \gamma_i Y_{t-i} + \sum_{j=1}^{p} \delta_j X_{t-j} + \mu_{2t} \quad \ldots \ldots (2)$$

It is assumed that the disturbances μ_{1t} and μ_{2t} are uncorrelated. Thus there is unidirectional causality from X to Y if $\alpha_i = 0$ and $\delta_i \neq 0$. Similarly, there is unidirectional causality from Y to X if $\delta_i = 0$ and $\alpha_i \neq 0$. The causality is considered as mutual (bilateral causality) if $\delta_i \neq 0$ and $\alpha_i \neq 0$. Finally, there is no link between X and Y (independence) if $\delta_i = 0$ and $\alpha_i = 0$.

Model Specification: The empirical model employed in examining the presence of causality and the direction of causality of climate variability and crop production was specified as follows:

$$CV_t = \alpha_0 + \sum_{i=1}^{n} a_i CV_{t-i} + \sum_{j=1}^{n} \delta_j CP_{t-j} + e_{1t} \quad \ldots\ldots (3)$$

$$CP_t = b_0 + \sum_{i=1}^{n} b_i CP_{t-i} + \sum_{j=1}^{n} \gamma_j CV_{t-j} + e_{2t} \quad \ldots\ldots (4)$$

Where: CV = Climate variability; CP = Crop production; α_0, b_0 = Constant terms

a_i, δ_j, b_i, γ_j = estimated coefficients of CV and CP; e_{1t}, e_{2t} = Error terms; n = Optimal lag length

Results and Discussion

Unit Root Test: Augmented Dickey Fuller (ADF) unit root test was used to examine the presence of stationary in the variables employed in this study. The result of ADF test as presented in Table 1 indicates that CV and CP were non-stationary at level (integrated of order one) and needed to be differenced once to make them stationary leading to the acceptance of the null hypothesis of the ADF test. The ADF test at first difference form indicates that all the variables become stationary after differencing them once leading to the acceptance of the alternative hypothesis of the ADF test.

Table 1: Augmented Dickey Fuller Unit Test Result

Variables	ADF Test Statistics (Level Form)	Inference	ADF Test statistics	Inference (First Difference)
CV	-1.4237	NS	-5.8653	S
CP	-1.6178	NS	-6.7356	S

NS = Non-stationary, S = stationary, Test critical (5%) = -3.690814

Causality Test: Estimation of pairwise granger causality test is sensitive to lag length and therefore, the optimal lag length utilized in the granger causality test was determined using three criteria (likelihood ratio, final prediction error and akaike information criterion) produced from an unrestricted Vector Autogression (VAR). An optimal lag length of 2 was employed in the granger causality test and the result is presented in Table 2. The F statistic of 19.56981 was significant at 1% probability level and also, the F statistic of 27.48333 was equally significant at 1% probability level. The result indicates that there is bilateral causality between climate variability and crop production over the data period of the study. This implies that variability of climate was significant in influencing crop production and the activity of crop production was significant in influencing the variability of climate over the data period of the study. The observed influence of climate variability on crop production is not far fetched as agricultural production is dependent on climatic variables such as rainfall, temperature, relative humidity. The influence of crop production on the variability of climate could be attributed to the environmental unfriendly activities(bush burning, deforestation, application of agrochemicals, land extensification) of agricultural production that leads to the emission of green house gases such as carbon dioxide($C0_2$), methane(CH_4), Nitrous oxide(N_20) and this agrees with Ogundele and Jegede (2011) who posited that agriculture plays an important role in climate change, both as a contributor in emitting green house gases and as a potential reducer of negative impacts. The build up of green house gases contributes to climate change and therefore, agricultural related green house gas emissions should be minimized through increased agricultural productivity using improved farming technologies/practices and this is in consonance with Burney *et al.* (2010), who noted that investments in yield improvements compare favourably with other commonly proposed climate change mitigation strategies.

Table 2: Result of Granger causality between climate variability and crop production

Null Hypothesis	*Obs.*	*F statistic*	*Prob.*
CV does not granger cause CP	36	19.56981*	0.0016
CP does not granger cause CV	36	27.48333*	0.0074

NP: * P < 0.01

Rainfall variability and index of crop production are retrospectively shown graphically in Figures 1 and 2, respectively.

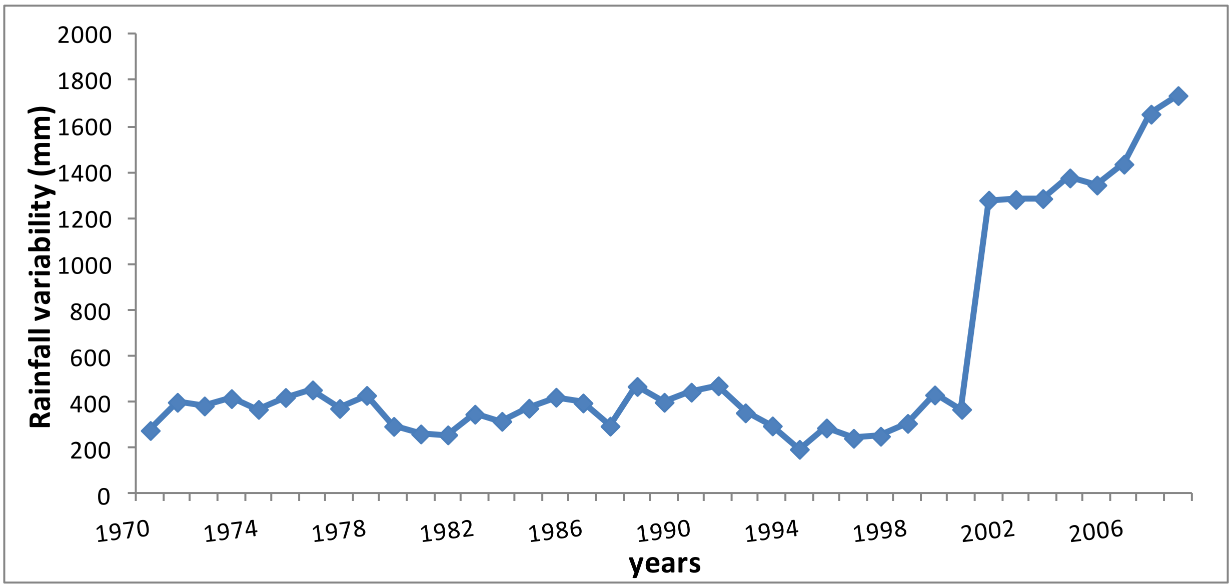

Figure 1: Rainfall variability (1970 to 2008)

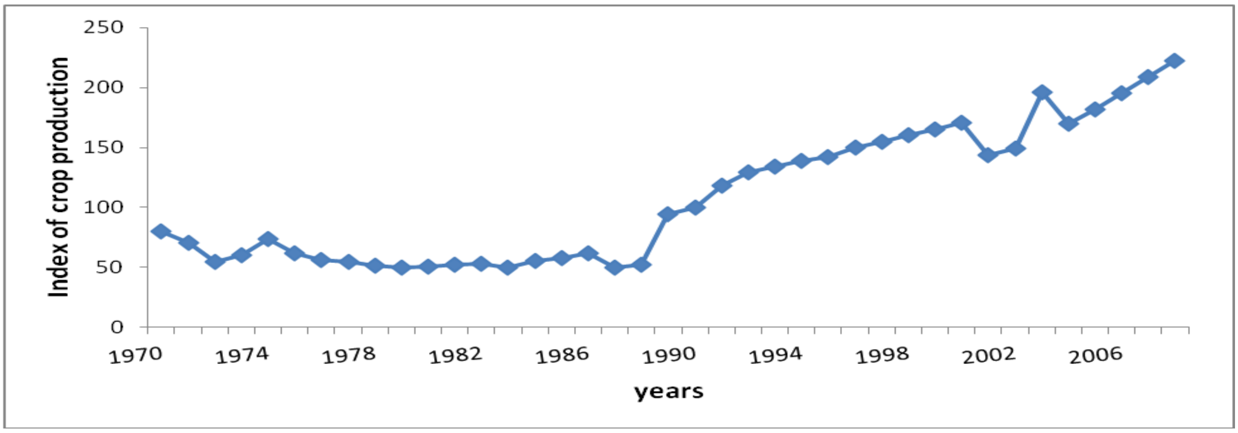

Figure 2: Index of crop production (1970 to 2008)

Conclusion and Recommendations

This study lend credence to the popular view on the significance role of climate on agriculture and also, the influence of agriculture on climate in Nigeria from an econometric perspective using time series data on mean annual rainfall and index of crop production over the period of 1970 to 2008. The key findings established in this study was that climate variability was significant in influencing crop production and also, crop production was significant in influencing climate variability (bidirectional relationship). Based on the existence of bidirectional relationship of climate variability and crop production established in this study, the following recommendations were put forward:

1. Policy framework on agricultural intensification should be pursued rather than agricultural extensification in a bid to increasing food production alongside ensuring sustainability of the environment. This is necessary to stem down the adverse influence of agriculture on the environment via green house gas emission.
2. Policy framework should be set up on proper sensitization of farmers on the coping strategies for adapting to climate variability so as to ensure sustainable crop production towards achieving the goals of the agricultural transformation agenda of Nigeria.

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