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Investigation of the Direction of Causality and Effect of Climate Change on Food Grain Output in Nigeria (1970-2010)

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Abstract

Agricultural production in Nigeria is weather dependent; extreme variations in rainfall and temperature have influence on food production. Most of the crops produced in Nigeria are low-technology based and are therefore heavily susceptible to environmental factors. The study analyzed the direction of causality and effect of climate change on food grain output in Nigeria from 1970-2010.Time series data were employed for the study. The data were sourced from the Central Bank of Nigeria and National Bureau of Statistics. Granger causality test analysis and regression analysis were the analytical tools used. The Granger causality approach showed that changes in rainfall and temperature (climatic parameters) positively affect food grain output in Nigeria. While from the regression analysis, most of the food grains were significantly affected by rainfall and temperature. It is, therefore, recommended that for food grain output to increased and sustained; irrigation agriculture as most suitable mode of water provisions should be contemplated for the farmers by government and concerned agencies. Policies and government intervention programmes should aim at increasing the technological capacity for agricultural production and the budgetary allocation to agricultural sector in order to boost the contribution of the industry to the economy.

Keywords: *Causality, Climate Change, Food Grain Output, Nigeria*

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I. INTRODUCTION

Nigeria's economy is predominantly agrarian and the exploitation of natural resources remains the drive for the country's economic development (Nwajiuba and Onyeneke., 2010). Undoubtedly, agriculture sector is extremely vulnerable to climate change mainly due to its higher dependence on climate and weather conditions (OIC Outlook, 2010). Adejuwon (2004) observed that, Nigeria's agriculture depends highly on climate because temperature, sunlight, water, relative humidity are main drivers of crops growth and yield. Climate change as a concept in this case refers to a change that is attributed directly or indirectly to human activities, that alters the atmosphere composition of the earth which leads to global warming (Nasiru, 2009). Agricultural production in Nigeria being weather dependent implicate that climate variability and change has a direct, often adverse influence on the quantity and quality of agricultural production in Nigeria (Sowunmi and Akintola, 2010). Changing climate also comes with it resultant change in land-use and land cover, leading to the decline in crop output. Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops. In spite of this, food production has not kept pace with population increase. Food shortage has therefore been linked with climate change (Adefolau, 2007). Climate change is one of the most serious environmental threats facing mankind worldwide, it affects mankind in several ways, including its direct impact on food production (Enete and Amusa, 2010). Climate change, which is attributed to the natural climate cycle and human activities, has adversely affected agricultural productivity in Africa (Ziervogel *et al.,* 2006). Available evidence shows that climate change is global, likewise its impacts; but the most adverse effects will be felt mainly by developing countries, especially those in Africa due to their low level of coping capacities (Nwafor 2007, Jagtap 2007). Global climate change may impact food production across a range of pathways by changing overall growing conditions (general rainfall distribution, temperature region and carbon); by inducing more extreme weather such as floods, drought and storms and by increasing extent, types and frequency of infestations, including that of invasive alien species (Iheke, and Oliver-Abali, 2011).

Temperature affects cereal production by controlling the rate of physio-chemical reaction and rate of evaporation of water from crops and soil surface (Ismaila *et al*., 2010). Studies have shown that productivity in rice and other tropical crops will decrease with increase in temperatures as a result of global warming. Very high temperature causes large percentage of grain sterility in rice. Effects of heat stress on rice include reduced tillering, reduced height, reduced spikelet number, sterility and reduced grain filling. Effects of heat stress on rice include reduced tillering, reduced height, reduced spikelet number, sterility and reduced grain filling. A significant effect of climate change due to increased levels of CO_2 would be reflected in the production of both C3 crops (wheat and rice, etc) and C4 crops (millet, sorghum, and maize) (Adejuwon, 2004). There is an observed declined in crop yield and food crops production due to reduction in rainfall and relative humidity and increase in temperature in Nigeria (Agbola and Ojeleye, 2007). Estimated by FAO (2005) is that by 2100, Nigeria and other west African countries are likely to have agricultural losses of up to 4% due to climate change.

II. METHODOLOGY

The study was conducted in Nigeria. Officially the Federal Republic of Nigeria is a federal constitutional republic comprising of 36 states and its federal capital territory, Abuja. The country is one of the sub-Saharan African nations in the western part of Africa and shares land border with the republic of Benin to the west, Chad and Cameroon to the Gulf of Guinea on the Atlantic Ocean (Wikipedia, 2011). In Nigeria, demarcation by climate regions proposes that three regions exist: the far south is defined by its tropical rain forest climate, where annual rainfall is 60 to 80 inches per year. The far north is defined by its almost desert-like climate, where rainfall is less than 20 inches per year. The rest of the country, everything in between the far-north and far- south is savannah and rainfall is 20-60 inches per year (Nation Master, 2009). Nigeria is the most populous country in the Africa (149,000,000), the seventh most populous country in the world in which the majority of the population is black (UNFCC, 2007). It is listed among the next eleven economies and is a member of the fastest growing in the world, with the international monetary fund projecting an 8% growth in the economy in 2011 (Wikipedia, 2011).In carrying out this research work, time series data of maize, rice, millet, sorghum, wheat, temperature and rainfall were used for the study. Focus was on direction of causality and effect of climate change on the food grain yield for a period of forty one year's interval (1970-2010). The data were obtained from secondary sources of several issues of the production year book published by the National Bureau of statistics (NBS), Annual abstract of statistics and several issues of the central bank of Nigeria (CBN), Annual Reports and statement of Accounts, food and Agriculture organization (FAO), and the Nigerian Meteorological Agency (NIMET). In order to avoid spurious effect of the regression of the data, transformation into stationary was done using Augmented Dickey- Fuller test. Data analysis involved the use of Granger Causality test analysis and Regression Analysis.

The Granger Causality test, according to Granger (1969), involved the estimation of the following pairs

$$W_t = \sum_{t-1}^{n} \propto_1 Z_{t-1} + \sum_{j-1}^{n} \beta_1 W_{t-1} + U_{1t} \quad \ldots \quad (1)$$

$$Z_t = \sum_{t-1}^{n} \propto_1 Z_{t-1} + \sum_{j-1}^{n} \delta_1 W_{t-1} + U_{2t} \quad \ldots \quad (2)$$

Where,

W_t = climatic elements at time t;

Z_t = selected food grains (wheat, sorghum, rice, maize and millet) output at time t;

t-1= lag variables; and

α_1 and β_1 = parameters to be estimated;

U_{1t} and U_{2t} = error term.

By this model, a variable that causes the order was identified.

The regression model that was formulated below was applied in estimating yield for each of the selected food grains (wheat, sorghum, rice, maize and millet) respectively. A regression model for the estimation of the effect of climate change parameters on yield of selected food grains (wheat, sorghum, rice, maize and millet) was specified in its implicit form as;

$TQ_t = f(RAIN_t, TEMPt, TRENDt, AHCROPt, REXR_t, GCEAt, LFA_t)$ **…** (3)

Where:

TQ_t = yield quantity of wheat or sorghum or rice or maize or millet (tonnes) in period t;

$RAIN_t$ = average annual rainfall (mm) in period t;

$TEMP_t$ = average annual temperature (^{0}C) in period t;

$TREND_t$ = linear trend time (T = 0, 1...41), a proxy for technology, which measures productivity effect;

$AHCROP_t$ = area harvested of crop;
$REXR_t$ = real exchange rate;
$GCEA_t$ = government capital expenditure on agriculture;
LFA_t = labour force in agriculture.

It should be noted that selection of either rainfall or temperature or both in the final estimation of effect of climate change parameters on yield of selected food grains was depended on the outcome of the granger causality test.

III. RESULTS AND DISCUSSION

3.1 Direction of Causality between Climate Change and Food Grain Output in Nigeria

The dynamic pair wise Granger causality test was undertaken to establish the link as well as measure the effect of past changes in the climate on the yield performance of maize, millet, rice, sorghum and wheat in Nigeria at least in the short-run. The dynamic pair wise Granger causality test results between climate change and food grain yield are presented in Table1. The test was computed with two lags of the variables in the model. The first groups of hypothesis tests for causality were between rainfall and the selected food grains yield. The results as shown in Table 1, reveals that a unidirectional relationship existed between changes in rainfall and the yield of maize, millet, rice, sorghum, and wheat and grain respectively. Therefore Granger causality runs one way from rainfall to yield level for maize, millet, rice, sorghum, and wheat grain respectively. By implication, historical and current level of changes in rainfall clearly predict the level of yield witnessed for maize, millet, rice, sorghum, wheat and aggregate food grain yield in Nigeria respectively. This suggests that for increased level of yield to be obtained for the selected food grains in Nigeria.

Effort must be made to moderate the influence of climatic parameters like the rainfall on these crops. Furthermore, the second group of hypotheses test for causality was between temperature and the selected food grains yield. However, the result obtained was robust to reject the null hypotheses because of the high F-statistic for each pair of variables with a low probability values. This indicates that statistical evidence was obtained to reject the null hypotheses. This implies that climate changes in the form of temperature significantly influences maize, millet, rice, sorghum, and wheat food grain yield in Nigeria at least in the short-run. These results showed a two-way relationship between temperature and millet as well as temperature and sorghum in Nigeria with short-run influence. Similarly a unidirectional relationship existed between changes in temperature and the level of yield of maize, rice, wheat and aggregate food grain in Nigeria with at least short-run effect respectively. Therefore, climate changes in the form of rainfall or temperature clearly predict the level of yield of such food grains like maize, millet, rice, sorghum and wheat in Nigeria.

3.2 Influence of Climate Changes on Food Grain output in Nigeria

The estimated multiple regression result of the effect of climate changes on food grain yield in Nigeria in the long-run is presented in Table 2. The result showed that the coefficient of multiple determinations (R^2) of maize, rice, millet, sorghum and wheat yield was 0.821, 0.910, 0.820, 0.911 and 0.781. It indicates that the regressors explained 82.1%, 91%, 82%, 91.1% and 78.1% of the variations in maize, rice, millet, sorghum and wheat yield in the long-run respectively. The F-statistics for all the grains considered was significant and confirms the significance of the entire models. The Durbin-Watson (DW) value of 1.950, 1.960, 1.862, 1.994, 2.140 and 1.820 for maize, rice, millet, sorghum and wheat indicates that, auto-correlation is not a problem in the models respectively. Rainfall, temperature, technological changes and government capital expenditure on agriculture were the significant factors that influenced maize yield in Nigeria in the Long-run.

Rainfall and temperature were indirectly related to maize yield. This an indication that maize yield decreases as rainfall and temperature intensifies increase. Maize required a moderate level of rainfall and temperature to increase yield. Thus, very intense rainfall affects maize yield especially from the time it starts flowering and fruiting as it destroys the maize's inflorescence and thereby reduce maize yield. The elasticity of response of maize yield relative to changes in rainfall and temperature is elastic (ER= -1.225 for rainfall and -5.804 for temperature) with a negative sign. This result suggest that a unit change in rainfall and temperature leads to about 1.23% and 5.8% decrease in maize yield respectively. Technological changes and government capital expenditure on agriculture were directly related to maize yield, an indication that maize yield increases as technology in maize production and government capital expenditure on agriculture increases. A change in current level of technology (total factor productivity) is brought about by such factors as increased knowledge about production methods and education. An increase in the adoption of new methods of production by maize farmers will lead to an increase in maize yield. An increase in government capital expenditure on agriculture will increase the share of maize subsector of total government capital expenditure on agriculture. This will create an enabling environment for maize production to strive through a reduced cost of production. Similarly, rainfall, temperature; technological changers and government capital expenditure on agriculture were the significant factors that influence rice yield in Nigeria in the long-run within the period under investigation. Rainfall, temperature, technological changes and government capital expenditure on agriculture were directly related to rice yield, an indication that rice yield increases as rainfall, temperature, technological changes and government capital expenditure on agriculture increases. The elasticity of response of rice yield relative to rainfall, temperature, technological changes and government capital expenditure on agriculture were elastic and suggests that a 10% increase in rainfall, temperature intensity, technological changes and government capital expenditure on agriculture will probably lead to about 36.7%, 14.6%, 11.3% and 27.8% increase in rice yield. In the long-run, rainfall, temperature, technological changes, real exchange rate and government capital expenditure on agriculture were the significant factors that influences millet yield in Nigeria within the period under review. Temperature, technological changes, real exchange rate and government capital expenditure on agriculture were significant and directly related to millet yield, an indication that millet yield increases as temperature; technological changes real exchange rate and government capital expenditure on agriculture increases. Millet production in Nigeria is temperature dependent. Increases in annual temperature enables millet to fruit and mature and for the grains to be stored at moderate humidity content. Increase in fruit production by millet as well as in storability will likely lead to an increase in millet yield and ensure for its seed continuous availability for planting. As a result, millet yield increase as temperature increase. An increase in the adoption of new methods of millet production by farmers will lead to an increase in millet yield. An increase in the domestic prices of imported millet will serve as an incentive for millet farmers to increase millet production since the domestic market for millet will strive through increased demand for the crop in the face of increasing population in the country.

As a result, millet production will increase as real exchange rate increases. An increase in government capital expenditure will create an enabling environment for millet production to strive through a reduced cost of production. Rainfall was significant and negatively related to millet yield. This implies that millet yield decreases in the face of increased rainfall. Excess, too heavy and untimely annual rainfall prevents millet stands to grow and produce fruit. Decrease in fruit production by crops and damage of crop's stands by heavy rainfall will likely lead to a decrease in crop yield. As a result, millet yield decreases as annual rainfall increased. In the long-run, rainfall, temperature, technological changes, area harvest of crops, and government capital expenditure on agriculture were the significant factors that influenced both sorghum and wheat yields in Nigeria within the 1970 to 2010 period. Rainfall was significant and negatively related to sorghum and wheat yields, an indication that sorghum and wheat yields decreases as the intensity of rainfall increases. Excess, very intense and untimely annual rainfall hinders cereals crops to stand, grow and produce fruit. Damage of cereal crops in the forms of washing away of the crops stands and decreases in fruit production occasioned by heavy and untimely rainfall will likely lead to a decrease in cereal crops yield. As a result, sorghum and wheat yield decreases as annual rainfall increased. Temperature, technological changes and area harvested of either sorghum or wheat were significant and positively related to both sorghum and wheat yields. This indicates that sorghum and wheat yields increases as temperature, technological changes and area harvested of these crops increased. Adequate temperature will ensure that sorghum and wheat production are never reduced. In the presence of improved technologies, a farm firm will innovate to increase subsistence production (Nnamerenwa, 2012).

An increase in the rate of adoption of improved systems of farming wills likely lead to an increase in sorghum and wheat yield. The extent of access to land a farmer has will influence his farming business. According to Onyebinama (2004), limited access to land limits the size and scale of the farm business. Crop planted is likely to increase as the area of land increases. As the area planted of sorghum or wheat increased, sorghum and wheat yield increased. Government capital expenditure on agriculture was significant and positively related to sorghum yield but negatively related to wheat yield. This indicates that sorghum yield increases as government capital expenditure on agriculture increased but wheat yield decreases as government capital expenditure on agriculture increased. The relationship between sorghum conforms to a prior expectations but the relationship between wheat yield and government capital expenditure on agriculture is in misalignment with a prior expectation. It may likely mean that the share of the wheat subsector in the total government capital expenditure on agriculture is so insignificant to influence a significant increase in wheat yield or that the funds made available by the government for wheat production are diverted to other agricultural subsectors production.
The coefficients of the regression which indicate the elasticity of response of sorghum yield relative to rainfall, temperature, and technological changes, area harvested of sorghum and government capital expenditure on agriculture were 0.860, 1.870, 0.402, 0.220 and 0.130 respectively. This indicates for example that a 10% increase in rainfall or temperature will decrease and increase sorghum yield by 8.6% and 18.7% respectively. Also the elasticity of response of wheat yield relative to rainfall and temperature are inelastic (ER = -0.750) for

rainfall and elastic (ER = 6.040) for temperature. This result suggest that a 10% increase in rainfall will decrease wheat yield by 7.5% while a 10% increase in temperature will favour wheat yield by 60.4%.

Table 1: Result From the Dynamic Granger Causality Tests

Null Hypothesis	Observations	F-statistics	Probability
Rainfall does not Granger cause maize	39	2.493	0.090^{x}
Maize does not Granger cause rainfall	39	1.412	0.260
Temperature does not Granger cause maize	39	3.445	0.044^{xx}
Maize does not Granger cause temperature	39	1.550	0.221
Temperature does not Granger cause millet	39	2.410	0.098^{x}
Millet does not Granger cause Temperature	39	2.570	0.092^{x}
Millet does not Granger cause rainfall	39	0.722	0.493
Rainfall does not Granger cause millet	39	3.931	0.030^{xx}
Rainfall does not Granger cause sorghum	39	2.841	0.073^{x}
Sorghum does not Granger cause rainfall	39	1.390	0.263
Temperature does not Granger cause sorghum	39	2.850	0.073^{x}
Sorghum does not Granger cause temperature	39	4.550	0.020^{xx}
Rainfall does not Granger cause wheat	39	2.720	0.080^{x}
Wheat does not Granger cause rainfall	39	0.120	0.890
Temperature does not Granger cause wheat	39	2.672	0.084^{xx}
Wheat does not Granger cause temperature	39	0.094	0.910
Rainfall does not Granger cause rice	39	8.710	0.005^{xxx}
Rice does not Granger cause rainfall	39	2.310	0.115
Temp does not Granger cause rice	39	5.674	0.007^{xxx}
Rice does not Granger cause temp	39	1.921	0.163

Source: Computed by Authors, 2012

Table 2: Regression Result of the Effect of Climate Changes on Food Grain Yield in the Long-run.

Variables	Maize	Rice	Millet	Sorghum	Wheat
Rainfall $_t$	- 1.225	3.670	- 0.090	- 0.860	- 0750
	(- 3.149)***	(2.141)***	(-1.920)*	(- 1.920)*	(- 2.450)^{xx}
Temp$_t$	- 5.804	1.460	1.605	1.870	6.040
	(- 2.470)**	(1.733)*	(3.660)***	(2.520)**	(1.771)^{x}
Trend $_t$	0.910	1.130	0.31	0.402	1.170
	(3.646)***	(5.050)***	(3.195)***	(4.970)***	(2.960)^{xxx}
AH crop $_t$	- 0.019	1.720	- 0.222	0. 220	0. 506
	(- 0.090)	(9.611)	(- 1.040)	(3.310)***	(2.665)^{xxx}
REXR $_t$	1.173	- 0151	0.260	0.010	0.320
	(1.050)	(-1.190)	(3.124)***	(1.310)	(1.662)
GCEA $_t$	0.720	2.780	0.630	0.130	- 0.450
	(2.071)**	(3.210)***	(2.362)**	(5.190)***	(- 3.340)^{xxx}
LFA $_t$	- 0.060	1.028	- 1092	- 0.040	- 0.180
	(- 0.199)	(0.270)	(- 0.610)	(- 0.410)	(-0. 444)
Constant	16. 801	4.206	10.820	17.920	24.430
	(2.182)**	(0.270)	(1.410)	(33.743)***	(1.513)
R^2	0.821	0.910	0.820	0.911	0.781
Adjusted R^2	0.782	0.890	0.780	0.892	0.762
F – statistics	20. 960***	44. 122***	19.910***	46.822***	5.664^{xxx}
DW- Test	1.950	1.960	1.862	1.944	1.820

Note: Asterisks ***, ** and * represent 1%, 5% and 10% significance levels respectively. Figures in brackets are t-value.

IV. CONCLUSION

Temperature and rainfall were shown from the study to exhibit variability. The granger causality approach showed that, there is a relationship between changes in a temperature and rainfall (weather parameters) and food grain output. In the long–run, rainfall, temperature, technological changes and government capital expenditure on agriculture were the significant factors that influenced maize yield in Nigeria within the year under review. Rainfall, temperature, technological changes and government capital expenditure on agriculture were significant factors that influenced rice yield in Nigeria. Significant factors that influenced millet yield in the long –run however were rainfall, temperature, technological changes, real exchange rate and government capital expenditure on agriculture. Rainfall, temperature, technological changes, area harvested of crops, and government capital expenditure on agriculture significantly influenced both sorghum and wheat yield in Nigeria within the period under review. From the result of the analysis, it can be seen that, rice yields more with increase in rainfall while the growth rate of maize, millet, sorghum and wheat was affected by increase in rainfall intensity- showing that, increase in rainfall might not be favourable to maize, millet, sorghum and wheat growth and yield. It is therefore recommend that, if rice yield will be increased and sustained, irrigation, as a constant water supply measure for the farmers should be applied in their rice production. On the other hand, effort should be geared towards providing drainage facilities in order to adjust any unfavourable influence of increase in rainfall on maize, millet, sorghum and wheat growth and yield in Nigeria. In the long-run, technological changes, government capital expenditure on agriculture significantly influenced food grain yield. So, policies and government intervention programmes should aim at increasing the technological capacity for agricultural production and the budgetary allocation to agricultural sector in order to boost the industry. There should be implementation of state forest plantation program. Carbon sequestration by forests is acknowledged to be an effective way of reducing the high concentration of Co_2 in the atmosphere which is the cause of climate change through global warming.

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