Journal of Scientific Research & Reports
3(3): 397-406, 2014; Article no. JSRR.2014.001

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Climate Change and Growth Rate of Food Grain Output in Nigeria (1970-2010)

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Authors' contributions

This work was carried out by author JOU in collaboration between all authors. Guided by the expertise advice of authors KCI, JOU designed the study, wrote the protocol, and wrote the first draft of the manuscript. SAS made editorial contributions to the first draft. Authors KCI and JOU managed the analyses of the study as well as the literature search. All authors made contributions to the work. Authors KCI, JOU and COKI managed the literature searches. However, all authors read and approved the final manuscript.

Original Research Article

Received 2nd April 2013
Accepted 10th October 2013
Published 26th November 2013

ABSTRACT

The study examined climate change and growth rate of food grain output in Nigeria from 1970-2010. Time series data of maize, rice, millet, sorghum, wheat, temperature and rainfall were used for the study. Data analysis involved the use of Descriptive Statistics and the annual additive series (Trend) Analysis measured in years by getting the annual average of parameters which depict the factual position of climate change by variations of the weather parameters over time. Findings showed that the preferred weather parameters (rainfall and temperature), and the food grain (maize, rice, millet, sorghum, wheat) exhibited significant changes in trend of growth during the 1970-2010 period. Rainfall grew at the compound growth rate of 5.3 % more than temperature per annum. The compound growth rate of maize, millet, sorghum, and wheat output were less than the compound growth rate of rice by 0.9%, 6.5%, 5.9% and 6.4% respectively, and the compound growth rate of maize, rice, sorghum, and wheat outputs were more than the

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compound growth rate of millet output by 5.6%, 6.5%, 0.6% and 0.1% respectively. Acceleration was witnessed in the growth rate of temperature, rainfall, sorghum, and millet; deceleration for wheat, while stagnation was witnessed in the growth rate of rice and maize over the 1970-2010 periods. There was significant difference in the average growth rate of rainfall and each of maize, millet, sorghum and wheat yield; and no significant difference between rainfall and rice. There was no significant difference also in the average growth rate of temperature and each of maize, millet, sorghum and wheat yield; but there was significant difference between temperature and rice. The conclusion of the study is that food grain yield was influenced by rainfall and temperature. It is therefore recommended that if increase in food grain production is to be sustained, proper irrigation and drainage should be applied.

Keywords: Climate change, Growth rate, Food grain, Nigeria

1. INTRODUCTION

Climate change is already affecting the natural and managed systems-forests, wetlands, coral reefs, agriculture, fisheries-that societies depend on to provide food, fuel, and fiber and many other services and this scenario will make it harder to produce food for the world's growing population and will also alter the timing, availability and quality of water resources [1].

Climate change has brought with it changes in weather patterns that can have serious repercussions for all of us, upsetting seasonal cycles, harming ecosystems and water supply, affecting agricultural farming systems and food production, and also causing sea-levels to rise [2]. Climate change is now a subject of global concern [3]. Climate change has the potential of affecting all natural and human systems and may be a threat to human development and survival socially, politically and economically. Nigeria has a variety of ecosystems, from mangroves and rain forests on the Atlantic coast in the south to the savannah in the north bordering the Sahara. Whether dry or wet, those ecosystems are being battered by global warming or climate change. Climate change is expected to impact on the agricultural sector in multiple ways, among others through increased variability with regard to temperature, rain, frequency and intensity of extreme weather events, changes in rainfall patterns and in water availability and perturbations in ecosystem [4]. Many countries in the tropical and sub-tropical regions of which Nigeria is included, are expected to be more vulnerable to warming because of additional temperature increases that will affect their marginal water balance and harm their agricultural sector [5]. The problem is expected to be more severe in Africa, where current information is the poorest, technological change has been the slowest and the domestic economies depends heavily on agriculture [6].

The United Nations Framework Convention on Climate Change defines climate change as change of climate which is directly attributed or indirectly attributed to human activity that alters the composition of the global and /or regional atmosphere and which is in addition to natural climate variability observed over comparable time periods [7]. Climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors, for example the soil's moisture and fertility. Climate variability and change has a direct, often adverse effect on the quantity and quality of agricultural production in Nigeria [8]. Climate change affect farming outputs at any stage from cultivation through the final harvest even if there is sufficient rain, its irregularity can affect yields adversely if rain fail to arrive during the crucial growing stages of the crops. It has been noted that temperature trend in Nigeria since 1901 shows increasing pattern- the mean air temperature in Nigeria between 1901 and 2005 was 26.6ºC while the temperature increase for the 105 years was 1.1ºC [9]. This is obviously higher than the global mean temperature increase of 0.74ºC which had been recorded since 1860 when actual scientific temperature measurement started [10, 11]. Rainfall trend in Nigeria between 1901 and 2005 shows a general decline. Within the 105 years that is between 1901 and 2005, rainfall amount in Nigeria dropped by 81mm. Rainfall became worst from the early 1970s, and the pattern has continued till date [9]. This period of sharp drastic rainfall decline corresponds within the period of sharp temperature rise. The trend of temperature in Nigeria is relatively constant, which can also be linked to the irregular movements of rainfall, which regulates the condition of the temperature.

Today, climate change is one of the most crucial environmental challenges with serious negative socio-economic consequences, although, triggered both by natural and human activities such as industrial production, agriculture and transportation which is the major contributor to the concentration of green house gases (GHGs) in the atmosphere which causes climate change [12,13]. Nigeria’s wide range of climate variation allows it to produce a wide variety of food and cash crops. Food shortage is therefore linked with climate change [13]. In contrast, it has been reported that temperature has no linkage with agricultural output [14]. Food shortages as a result of population increases are more obtained in Nigeria than climate change. However, climate change can cause food shortages in the case of flood situation. Using regression analysis to examine drought as factor affecting arable crops output, it has been shown that drought causes decrease in output of food crops [15]. The study established that drought is a major cause of crop failure in rain-fed dependent agrarian community. Severe food shortages due to drought situations have been established in related studies [16].

2. METHODOLOGY

The study was conducted in Nigeria; officially comprising 36 states and the 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 [17]. In Nigeria, demarcation by climate regions proposes that three regions exist: the far south is defined by its tropical rain forest, 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; and the rest of the country is savannah and rainfall is 20-60 inches per year [18]. Nigeria is the most populous country in the Africa (about 150,000,000 people), the seventh most populous country in the world in which the majority of the population is black [7]. It is listed among the next eleven economies and is a member of the fastest growing economies in the world, with the international monetary fund projecting an 8% growth in the economy in 2011 [17].

The research focused on: time series data of maize, rice, millet, sorghum, wheat, temperature and rainfall for a period of forty years (1970-2010) was used for the study. 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). Data Analysis involved the use of Descriptive Statistics and Trend Analysis.

In modeling trend for this study, the exponential trend or log linear trend was employed in line with convention [19] and it is fitted as:

$$\ln Y_{it} = \beta_0 + \beta_1 t + e_{it} \qquad (1)$$
$$\ln Q_{it} = \beta_0 + \beta_1 t + e_{it} \qquad (2)$$

Where,

$\ln Y_{it}$ = climatic parameters (rainfall and temperature) measured in millimeters (mm) and centigrade (^oC) respectively;
$\ln Q_{it}$ = yield of selected food grains (wheat, sorghum, rice, maize and millet) measured in tonnes;
β_0 = the constant in the regression line;
β_1 = the trend coefficients;
t = trend measured in years;
e_{it} = the error term.

The log quadratic trend equation was used to measure the acceleration or deceleration or stagnation in the growth rate and is fitted as;

$$\ln Y_{it} = \beta_0 + \beta_1 t + \beta_2 t^2 + e_{it} \qquad (3)$$
$$\ln Q_{it} = \beta_0 + \beta_1 t + \beta_2 t^2 + e_{it} \qquad (4)$$

Where:

β_2 = estimated parameter.
All variables as previously defined.

A positive significant value of β_2 indicates acceleration while a negative significant value entails a deceleration. Stagnation in the growth process is explained by a non- significant value of β_2. In line with [20, 21], the compound growth rate equation will be given as;

$$r = (e^{\beta} - 1) \times 100 \qquad (4)$$

Where:

e = Euler's exponential constant (2.71828);
β = estimated coefficient in equations (1) and (2) respectively.

In comparing the growth rate between the selected food grains yield and climate parameters,), student's t- distribution was used. A paired sample t-test was employed to test for differences between the average growth rates in the yield of each of the selected food grains (wheat, sorghum, rice, maize and millet) and each of the considered climatic parameters (rainfall and temperature).

The t- statistic is given as;

$$t_{cal.} = \frac{\bar{x}_i - \bar{x}_j}{\sqrt{S_p^2\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}} \qquad (5)$$

Where, S_p^2, is pooled variance given as;

$$Sp^2 = \left. (n_i - 1)S_i^2 + (n_j - 1)S_j^2 \middle/ n_i + n_j - 2 \right. \quad \text{---} \quad \text{---} \quad \text{---} \quad (6)$$

Where:

$\boldsymbol{\bar{x}_i}$ = average growth rates for each of the selected food grains (wheat, sorghum, rice, maize and millet) respectively;
$\boldsymbol{\bar{x}_j}$ = average growth rates for each of the considered climatic parameters (rainfall and temperature) respectively;
$\boldsymbol{n_i}$ = number (years) of yield for each of the selected food grains (wheat, sorghum, rice, maize and millet) respectively;
$\boldsymbol{n_j}$**=** number (years) of change for each of the considered climatic parameters (rainfall and temperature) respectively;
$\boldsymbol{S_i^2}$ = variance of yield for each of the selected food grains (wheat, sorghum, rice, maize and millet) respectively;
$\boldsymbol{S_j^2}$ = variance of change for each of the considered climatic parameters (rainfall and temperature) respectively;
$\boldsymbol{n_i + n_j - 2}$ **=** degree of freedom.

3. RESULTS AND DISCUSSION

3.1 Trend in Growth Rate of Climate Parameters and Output

The estimated experimental growth equation for maize, millet, rice, sorghum and wheat output quantities; and for rainfall and temperature pattern is presented in Table 1. Temperature and rainfall as well as the output quantities of maize, millet, rice, sorghum and wheat exhibited significant growth during the period under review. The coefficient of the time variable is positive and statistically significant with respect to temperature, rainfall and output quantities of maize, millet, rice, sorghum and wheat indicating an increase in the output quantities of maize, millet, rice, sorghum and wheat as well as in the quantity of rainfall and temperature. Table 1 showed further that, the coefficient of multiple determinations is high and statistically significant for both climatic parameters and output quantities of selected food grain crops during the preference period. This implies that, growth in the output quantities of maize, millet, rice, sorghum and wheat; as well as in temperature and rainfall are highly time dependent.

3.2 Acceleration, Deceleration and Stagnation of Output for Selected Food Grains and Climatic Parameters

The estimated quadratic growth equation for maize, millet, rice, sorghum, and wheat output quantities and for rainfall and temperature (climatic parameters considered) are presented in Table 2. The estimated coefficient of time for the quantities of rainfall and temperature was respectively significant and positive in sign. It indicates acceleration in the growth rates of these climatic parameters. This implies that the volume of rainfall and the intensity of temperature in Nigeria increased at an increasing rate within the period under review.

Similarly, the statistically significant and positive values of the coefficient of time for the output quantities of sorghum and millet indicates acceleration in the growth rates of these food grains in Nigeria. This implies that the output quantities of millet and sorghum in Nigeria increased at an increasing rate within the preference period.

The coefficient of time for the output quantities of wheat was statistically significant. It was negative in sign and indicates deceleration in the growth rates of wheat in Nigeria. This implies that, output quantities of wheat in Nigeria increased at a decreasing rate within the preference period. In addition, the statistically non-significant and positive value of time for the output quantity of rice and the statistically non-significant and negative value of time for the output quantity of maize indicate stagnation in the growth rates of these food grains in Nigeria. This implies sameness in the growth of maize and rice output within the period under review (1969/1970 - 2009/2010).

Table 1. Estimated equation for output quantities of selected food grains and climatic parameters

Dependent Variable	B_0	B_1	R^2	Adjusted R^2	F – Ratio
Rainfall	5.272 (23.605)***	0.053 (5.388)***	0.433	0.418	29.035***
Temperature	3.452 (216.010)***	0.001 (2.049)**	0.099	0.76	4.200**
Maize	6.309 (42.380)***	0.087 (13.519)***	0.824	0.820	182.760***
Millet	7.759 (123.160)***	0.034 (12.368)***	0.797	0.792	152.962***
Rice	5.141 (23.078)***	0.095 (9.875)***	0.714	0.707	97.517***
Sorghum	7.844 (142. 089)***	0.040 (16.946)***	0.880	0.877	287.177***
Wheat	3.280 (11.125)***	0.035 (2.753)***	0.763	0.741	7. 583***

*Note: Asterisk *** and ** represent 1% and 5% significant levels respectively. Figures in brackets are t – values.*

Table 2. Estimated quadratic trend model for output of food grain and climatic parameters

Dependent variable	B_0	B_1	R^2	Adjusted R^2	F – Ratio
Rainfall	5.272 (23.605)***	0.053 (5.388)***	0.433	0.418	29.035***
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*Note: Asterisk *** and ** represent 1% and 5% significant levels respectively. Figures in brackets are t – values.*

3.3 Compound Growth Rate of Output and Climatic Parameters

The computed compound growth rates in temperature and rainfall as well as in the output of maize, millet, rice, sorghum and wheat are presented in Table 3. The compound growth rate of the considered climatic parameters was higher in rainfall than in temperature by 5.3% per annum. This result suggests that the production capacity of Nigerian's farmers will be influenced more by the changes in rainfall than to temperature. To this, relatively recent studies in Nigeria established decrease in output of selected arable food crops due to drought [15, 16].The table also showed that the compound growth rate in the output quantities of the selected food grains was highest in rice production and lowest in millet production. The compound growth rate of maize, millet, sorghum and wheat outputs were less than the compound growth rate of rice output 0.9%, 6.5%, 5.9% and 6.4% respectively. The compound growth rate of maize, rice, sorghum, and wheat outputs were more than the compound growth rate of millet output by 5.6%, 6.5%, 0.6% and 0.1% respectively. This result suggests that the production of rice in Nigeria is given more consideration than millet production in Nigeria. This would be informed by the popularity of rice in most Nigerian's household meals and its frequent consumption in ceremonies than millet.

Table 3. Compound growth rates of output and climatic parameters

Variables	Parameters (B_1)	Exponential Growth Rates (%)
Climate parameters		
Rainfall	0.053***	5.4
Temperature	0.001**	0.1
Crop output		
Maize	0.087***	9.1
Millet	0.034***	3.5
Rice	0.095***	10.0
Sorghum	0.040***	4.1
Wheat	0.035***	3.6

****= Significant at 1%, ** = Significant at 5%*

3.4 Confirmation of Variability in the Growth Rates of Food Grain Output and Climate Changes

To examine the assertion that the production of such food grains as maize, millet, rice, sorghum and wheat are influenced by climatic changes such as the change in temperature and rainfall, the mean growth rates in the production of these selected food grains and selected climatic factors were each compared respectively as shown in Table 4. The average growth rate in maize, millet, rice, sorghum and wheat were 10.1%, 107%, 21.4%, 10.9% and 17.2% respectively while the average growth in temperature and rainfall were 1.2% and 31.7% respectively. The difference in the average growth rate between rainfall and each of maize, millet, sorghum and wheat yield was significant (Z= 1.814 for rainfall-maize pair; 4.959 for millet-rainfall pair; 2.853 for rainfall-sorghum pair and 2,221 for rainfall-wheat pair) while the difference in the average growth rate between rainfall and rice was not significant (Z= 0.396). The significance of the difference in the average growth rate of maize, millet, sorghum and wheat with rainfall suggested that, increase in rainfall intensity affects the growth rate of maize, millet, sorghum and wheat. Thus, increased rainfall might not be favourable to maize, millet, sorghum and wheat growth and yield. However, the non-significance of the difference in the average growth rate of rice with rainfall suggested that rice yields more with increase in rainfall and vice versa.

Table 4. Test of significance of the difference between the growth rates of climatic parameters and food grain output

Sample	Mean	Std deviation	Std. Error Mean	DF	Z- Stats
Rainfall $_T^A$	31.693	201.501	31.469		
Rice $_T^B$	21.399	61.714	9.638		
A-B	10.294	166.377	25.984	40	0.396
Maize $_T^A$	10.123	81.069	36.087		
Rainfall $_T^B$	31.693	201.501	31.469		
A-B	18.429	120.432	10.159	40	1.814
Millet $_T^A$	10.735	84.683	35.695		
Rainfall $_T^B$	31.169	201. 501	31.,469		
A-B	-20. 958	116.818	4.226	40	4.959
Rainfall $_T^A$	31.693	201.501	31.469		
Sorghum$_t^b$	10.852	432.464	38.774		
A-B	20.841	431.292	7.305	40	2.853
Rainfall $_+^A$	31.6993	201.501	31.469		
Wheat $_T^B$	17. 180	70.001	24.934		
A-B	14.513	213. 032	6.535	40	2.221
Maize $_T^A$	10.123	81.069	36.087		
Tempt$_t^b$	1.185	9.201	1.438		
A-B	8.938	79.076	35.361	40	0.253
Millet $_T^A$	10.735	84.683	35.695		
Temp $_T^B$	1.185	9.021	1.438		
A-B	9.550	75.760	34.926	40	0.273
Rice $_T^A$	21. 399	61. 714	9. 638		
Temp $_T^B$	1.185	9.201	1.438		
A-B	20.214	58.079	9.070	40	2.229
Sorghum $_T^A$	10.852	432.464	38.77		
Temp $_T^B$	1.185	9.201	1.438		
A-B	9.667	432.254	37.336	40	0.259
Wheat $_T^A$	17.180	70.001	10.934		
Temp $_T^B$	1.185	9.201	1.438		
A-B	15.995	71.171	11.115	40	1.439

*Note: Asterisk ***, **, * represent 1%, 5%.10% significant levels respectively.*
a-b represent paired sample differences

Similarly, the difference in the average growth rate between temperature yield and each of maize, millet, sorghum and wheat yield was not significant (Z= 0.253 for temperature-maize pair; 0.273 for millet- temperature pair; 0.259 for sorghum-temperature pair and 1.439 for temperature-wheat pair) while the difference in the average growth rate between temperature and rice yield was significant (Z= 2.229). The non-significance of the difference in the average growth rate of maize, millet, sorghum and wheat with temperature suggested that these food grains thrive well under increased temperature. Therefore fluctuation in temperature might necessarily reduce the growth in the yield of maize, millet, sorghum and wheat. However, the significance of the difference in the average growth rate of rice with temperature suggested that the increase in temperature did not reduce the rate of growth of rice yield. Thus, the growth in rice yield will continue to increase irrespective of the changes in temperature in Nigeria. Climate variability and change have a direct but often adverse influence on the quantity and quality of agricultural production in Nigeria [8].

4. CONCLUSION

The statistical analysis showed that, temperature and rainfall, as well as the output quantities of maize, millet, rice, sorghum and wheat have significant growth during the period under review (1970 -2010). There was acceleration in growth rates of Average rainfall, temperature, sorghum and wheat and stagnation in the growth rates of rice and maize. The difference in the average growth rate between rainfall and each of maize, millet, sorghum and wheat yield is significant while the difference in the average growth rate between rainfall and rice yield is not significant. The difference in the average growth rate between temperature and each of maize, millet, sorghum and yield is not significant, while the difference in the average growth rate between temperature and rice yield is significant. This shows that, agriculture in Nigeria is highly dependent on climate change.

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, should be applied in rice production. On the other hand, effort should be gear 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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