Journal of Agriculture and Social Research (JASR) Vol. 15, No. 1, 2015

FOOD GRAIN YIELD RESPONSE TO CLIMATE VARIABILITY IN NIGERIA: AN EMPIRICAL ANALYSIS

C.A KALU,[1]AND J.A MBANASOR[2]
[1]National Root Crops Research Institute (NRCRI) Umudike, P.M.B 7006 Umuahaia
[2]Department of Agribusiness and Management,
Micheal Okpara University of Agriculture Umudike, Nigeria
Corresponding author Email : confidence.kalu@gmail.com

ABSTRACT

The effect of variability of climate parameters on grain yield and the proportion of change in production that is due to impact of climate variability demands urgent attention. This study looks at the consequences of climate variability on grain yield in Nigeria within 1970-2012.The result revealed that the yield of rice was negatively affected by rainfall (p=0.1) and (p=0.05) for fertilizer quantity. Maize yield was observed to be influenced negatively by area harvested (p=0.1). Based on these findings, the use of improved high yielding varieties, availability of more input supplies, introduction of improved farming techniques and cultural practices are necessary to increase the yield of these grains.

Keywords: climate variability, yield and grain, cultural practices

INTRODUCTION

There is sufficient evidence that the world has been witnessing long term changes in climate patterns and variability with rapid acceleration in recent decades. Considerable shifts in long term temperature and rainfall averages, sea levels, frequency and intensity of droughts and floods, and their variances have been observed (IPCC, 2007).

Agricultural production depends on climate variables such as temperature, precipitation and light. Farm households' ability to grow enough food to feed themselves and their animals is determined to a large extent by these climate variables. Dowing (1992) asserted that change in global climate variables may present risk to future livelihoods. Many African countries, whose economy is largely based on weather sensitive agricultural production systems like Nigeria, are particularly vulnerable to climate change (Dinar *et al.*, 2006)The vulnerability of Nigeria agricultural sector to climate variability is of particular interest and has been a natural focus for research because agriculture is a key sector in the economy accounting for between 60%-70% of the labour force and contributing between 30%-40% of the of nation GDP (Ajetomobi et al; 2011). Food grain production is essential in developing countries, especially Sub Saharan Africa (SSA) where agriculture is the main source of food and livelihood (Badiane and Delgado, 1995).

The synthesis Report of the forth assessment of Intergovernmental Panel on Climate Change (IPCC) states with high confidence that agricultural production and food security in many African countries and regions are likely to be severely affected by climate variability and change (IPCC, 2007a). Also according to Food and Agricultural Organization, it was reported that extremes of heat and cold, droughts and floods, and various forms of violent weather phenomena have wreaked havoc on the agricultural systems in African region (FAO, 2000). Climate variability contributes immensely to vulnerability to economic loss, hunger and famine. Hence, it is imperative that these aspects are well understood in order to formulate more sustainable policies and strategies to promote food production in Nigeria. The important research question that remains therefore as to what proportion of change in production that is due to impact of climate variability? Studying the effect of climate variability and change on agricultural production is especially important for agricultural sector in Nigeria, which is heavily dependent on rainfall due to the country's limited irrigation capacity. Climate variability may also undermine attempts to reduce poverty, since majority of Nigeria's population live in rural area and depends heavily on agricultural incomes(Ajieroh, 2010). Climate change causes a challenge to maintaining agricultural growth, significantly reducing poverty and achieving the millennium Development goals (MDGs)

The two main techniques mostly used in evaluating the effect of climate change on yields include: (1) crop growth models and (2) regression analyses. (Subervie, 2008) Crop growth models are widely used and produce precise crop yield responses to weather events. However crop growth models require daily weather data and are calibrated under experimental conditions. Alternatively, regression analyses allow the quantification of weather changes on crop yields in an actual cropping context. The study will apply the econometric approach totwo staple grain crop (maize and rice)productions in Nigeria.

MATERIALS AND METHODS

Data Source and Collection Procedure

This study was based on time series data obtained from various sources spanning from 1970 to 2012. The aggregate national data on production of selected grains like maize and rice were collected. The sources of the data collected include various editions of the Bureau of statistics (NBS), Central Bank of Nigeria statistical bulletin, Food and Agricultural Organization statistical website (FAOSTAT), United Nations and World Bank climate data bases. The study made use of agronomic, input, and climate data. The input and agronomic data were obtained from FAOSTAT and NBS while climate data was gotten from UNDP and World Bank Climate data base. Aggregate annual data on production, yield, Area harvested and Planted, and fertilizer quantity applied were collected from FAOSTAT. The data were analysed using Fully Modified Ordinary Least Square Regression approach which is specified following Philips and Hansen (1990). Which is formulated and expressed as

$y_{it} = f\ (A_{it}, T_t, P, CO_2, \text{fert}\ )$ …………………………..1

Where

$y_{it=}$ yield for crop i at time (tonne/hectare)

Ait= Area harvested for crop i at time t (hectare)

T = mean annual temperature (O^c)

P= total annual rainfall (mm)

CO_2 = total annual CO_2 emission (k_t)
Fert = fertilizer applied (tonne)

RESULTS AND DISCUSSION

Preliminary tests (stationarity test)

Prior to the estimation of the impact of climate variability on grain yield, the variables to be used were subjected to stationarity tests. Philips-perron (PP) unit root test was used in determining the stationarity of the variables under consideration and the results were presented in Table 1

From Table 1, the entire test variable for determining impact of climate variability and change on grain yield were not stationary at levels but became stationary in difference on the basis of the pp probability. As such, the null hypothesis of non-stationarity was rejected .

Table 1: Unit Root Test Result

	Intermediate Phillips-Perron test results for unit root					
Series	***Prob.***		***Bandwidth***		***Obs***	
	Level	**1st Difference**	**Level**	**1st Difference**	**Level**	**1st Difference**
CO2	0.3613	0.0000	2.0	0.0	42	41
FERT	0.1870	0.0000	1.0	7.0	42	41
LNCO2	0.1083	0.0000	2.0	4.0	42	41
LNFERT	0.1156	0.0000	7.0	7.0	42	41
LNMZA	0.6132	0.0032	3.0	1.0	42	41
LNMZSP	0.5747	0.0000	4.0	4.0	42	41
LNMZYD	0.0415	0.0000	6.0	39.0	42	41
LNPESTCD	0.5851	0.0000	1.0	5.0	42	41
LNPMZ	0.9761	0.0000	1.0	2.0	42	41
LNRA	0.5589	0.0002	1.0	2.0	42	41
LNRAIN	0.0001	0.0000	9.0	25.0	42	41
LNRP	0.8547	0.0001	4.0	4.0	42	41
LNRSP	0.6300	0.0000	0.0	3.0	42	41
LNRYD	0.0406	0.0000	4.0	2.0	42	41
MZA	0.7847	0.0017	3.0	2.0	42	41
MZSP	0.6890	0.0004	3.0	2.0	42	41
MZYD	0.0342	0.0000	3.0	40.0	42	41
PESTCD	0.9178	0.0000	1.0	8.0	42	41
PMZ	0.3631	0.0000	5.0	9.0	42	41
RA	0.1549	0.0000	0.0	1.0	42	41
RAIN	0.0001	0.0000	11.0	23.0	42	41
RP	0.9717	0.0000	2.0	27.0	42	41
RSP	0.1019	0.0000	1.0	6.0	42	41
RYD	0.0569	0.0000	4.0	2.0	42	41
TEMP	0.9995	0.0000	2.0	3.0	42	41

Estimation of impact of climate variables on grain yield using fully modified ordinary least squares (FM-OLS)

The parameter estimates of the cointegration regression model (Fully Modified Ordinary Least Squares, FMOLS) applied in analysing the climate variables alongside CO_2 emission and fertilizer input application to ascertain their effects on grain yields intwo staple grain crops in Nigeria over the period of study are summarized in Table 1. The trend variable was significant in all the models, thus confirming that a linear trend exists in the models.

The results indicated that natural logs of rainfall, temperature, fertilizer quantity applied in the farms and land area harvested to rice significantly influenced the yield of rice in Nigeria at 10%, and 5% level of significant respectively. The slope coefficients of the mentioned variables included were -2840.450 ($p<0.10$); 45916.830 ($p<0.01$), -449.167($p<0.01$), 2786.095 ($p<0.01$) and 3347.204 ($p<0.01$). While it could be inferred from the results that climate variation (proxy by rainfall and temperature variability) significantly determined the variability in yield of rice over the period of study, temperature and precipitation changes do not have expected effect on rice yields. While rainfall increase resulted in decrease of yield of rice during the review period, it was observed that rice yields responded positively to increase in temperature in the study. A percentage increase in the volume of rainfall resulted in a decrease in yield of the farms by 2,840.45 tonnes per hectare; while a percentage rise in temperature resulted in an increase in yield of rice farms by 45,916.83 tonnes per hectare. The result is inconsistent with the findings of Lloh*et al*. (2014) and Ayinde*et al*. (2013) that had a positive and negative coefficient for temperature and rainfall on a similar study in Nigeria. It is an accepted fact that high temperature greatly affects the growth and productivity of plants. However, the extent to which this occurs in specific climate zones depends on the probability and period of the increased temperature and on the diurnal timing of it too. (Meehl et al; 2007). For instance Ayinde et al (2013) in their work evaluated the impact of climate change on rice production in Niger state Nigeria found out that the minimum temperature has a positive effect on rice production.

Table 1: Results of FMOLS parameter estimates to model the impact of climate variables, CO_2 emissions and fertilizer input utilization on yields of rice and maize in Nigeria (1970-2012)

Dependent variables:	**Rice Yield**			**Maize Yield**		
Independent variables	***Coefficient***	***Standard error***	***t-Statistic***	***Coefficient***	***Standard error***	***t-Statistic***
Lnrain	-2840.450 (-2.074)*	1369.410	-2.074*	175.330 (0.125)	1399.790	0.125
Lntemp	45916.830 (4.811)***	9544.114	4.811***	5564.166 (0.663)	8393.594	0.663
lnco2	-449.167 (-0.382)	1175.035	-0.382	335.634 (0.277)	1212.809	0.277
Lnfert	2786.095 (6.975)***	399.445	6.975***	56.629 (0.143)	397.012	0.143
Lnarea	3347.204 (2.818)**	1187.631	2.818***	-1628.142 (-2.563)*	635.252	-2.563**
C	-186271.700 (-3.856)**	48302.010	-3.856***	7025.109 (0.189)	37126.870	0.189
@TREND	-493.686 (-5.149)***	95.886	-5.149***	251.885 (4.710)***	53.483	4.710***
R-squared	0.51			0.66		
Adjusted R-squared	0.43			0.60		
JarqueBera Statistic	2.308			2.086		
Engle-Granger tau-statistic	-6.984***			-5.655**		
Mean VIF	7.924			3.096		
Remark on Correlelogram of Residuals Squared	Not Significant at 10%			Not Significant at 10%		
Mean dependent var	17458.95			13552.26		

Source: Output of analysis from E view

Note: "*' = Figures significant at 1% level; "**' = Figures significant at 5% level and "*' = Figures significant at 10% level.**

The implication of the findings is that other parameters may be needed in explaining yield changes. Sometimes, climate change or variability can result in opportunities for increase in yield or productivity of crops depending on the agronomic requirements of the particular crop under a particular, prevailing climate. It can also be deduced from the findings that temperature appeared to exert larger impact on rice yield when compared to rainfall. The increase in yield of 45,916.83 far offset the reduction in yield brought about by a percentage decrease in rainfall in the study.

It was observed that yield of rice was positively influenced on a significant proportion (at 1% statistical significance level) by quantities of fertilizer applied to the crop in each year. The high value of increase (2,786.095 tonnes per hectare) recorded as resulting from an increase of fertilizer application by one percent in study enabled us to infer that fertilizer application as well as intensification of rice farms could support improving yield of rice in Nigeria. It also underlies the need to step up fertilizer access to farmers in Nigeria as a way of improving yields and profitability of rice farms (since profitability can be attained if there is higher yield).

The results also indicate that land area expansion exerted a positive influence on the yield of rice in the study. Increase in land area by rice farmers was accompanied by increase in yield by 3347.204 tonnes per hectare. This result was not consistent with Elodie (2011) who found out that increase in area planted causes a yield decrease for maize. In effect it is against the *apriori* expectation that yield decrease as the area cropped increases due to decreasing marginal land productivity. The increase could be possibly associated with the tendency of the rice farms to benefit from proper spacing which could have some agronomic advantage that could moderate yield of the crop. It is also possible that as more farmers enter into rice farming, possibly coming with new technologies and techniques of farming, the yield of rice responded positively. These farmers who come in and contribute to increasing land area planted to rice, may tend to be more receptive to adoption of innovative technologies such as use of high yielding and disease resistant varieties which contributes to increase in rice yield.

In terms of the diagnostic statistics, the results from such diagnosis validated the use of the model. For instance, the R Square of the model was 0.51 indicating that 51 percent of the variation in the yield over the period in review was explained by the variations in the independent variables included in the model. This is an evidence of a fairly good fitting of the model. The assumption of normality of the residuals of the modified OLS used was violated as the JarqueBera statistics estimated was 2.308 (at $p = 0.32$, i.e. $p>0.10$), implying that the residuals were normally distributed and not badly skewed. Besides, the series recorded an Engle-Granger tau-statistic of -6.984 at $p<0.01$ implying that the null hypothesis of the series not being cointegrated was rejected at 5 percent level. This means that our series were cointegrated and we do not risk working with a spurious regression model. This impressive performance attributes of the model is further boosted by the absence of severe multicolliearity in the model as vindicated by the low variance inflation factor (VIF) recorded for the independent variables' slope coefficients' diagnosis. The presence of serial correlation in the model was rejected by the result of the tests for serial correlation done using the Correlogram of residuals squared which indicated that none of the lags included in the analysis had p values below 10 percent (p>0.10). The foregoing indicates that our model had all the desirable properties of an OLS.

With respect to maize grains, it was observed from results in Table 1 that only one variable, land area harvested, exerted a significant influence on its yield. The slope coefficient of this variable was -1628.142 (p<0.02) indicating that a unit increase (one percent increase) of land area apportioned to maize farming in the country over the period in review resulted in a decrease in yield by 1,628.142 tonnes per hectare. Similar result was reported by Elodie (2011). Who found out that maize yield decrease as the area cropped increase due to decreasing marginal land productivity. This result contrasts with that of rice where the increase in land area brought about increase in yield instead. It thus appears that maize crops possibly would benefit more from a programme of land intensification than rice farms. None of the climate change variables (neither rainfall nor temperature variability) exerted any significant impact on yield of maize so far in the country within the period under study. However, this result does not necessarily indicate that temperature and rainfall does not affect maize yields. Instead, climate variability over the study period may not have been large enough to affect maize yields. . According to Winch (2006) adequate rainfall help maize to produces large yield than any other grains. However, even in drier areas, where yields are more variable is often planted for its higher quality compared to sorghum or millet.

Also, other parameters may be more important in explaining yield changes, such as management practices, but were not included in the regression due to data limitations. According to the test diagnosis statistics, the test for model fitness gave an R squared value of 0.66, which implies that 66% of the variations in yield were actually accounted for by variability in the independent variables included in the regression model. The model also had residuals which was normally distributed with a JarqueBera statistic of 2.086 at p = 0.352 (i.e. p>0.10), thus enabling us to accept the null hypothesis of no significant skewness in the distribution (normal distribution). Similarly, the cointegration test using Engle-Granger Tau statistic recorded a value of -5.655 (p<0.03) enabling us to reject the null hypothesis which held that "series are not cointegrated". The series are therefore accepted as cointegrated and could be reliably used for forecasting.

CONCLUSION AND POLICY IMPLICATION

The results obtained from the regression analyses on impact of climate variability on yield reveals that climate variables has impact on the productivity of grain under study, implying that attention should be paid to different grain varieties that suit the various agro climatic regions in Nigeria . Upland varieties should be made available to farmers in such areas as well swamp varieties too. The application of fertilizer to improve soil fertility, the use of modern agricultural techniques to boost grain yield, introduction of improved crop varieties and high crop yield, application of pesticides to reduce the effects of pests on crops should also be encouraged as it will help to increase the yield of the gains under study.

REFERENCES

Ajetomobi,J., Abiodun,A and Hassan, R. (2011). Impacts of Climate Change on Rice Agriculture in Nigeria.*Tropical and Subtropical Agroecosystems, No. 14.pp20-30*

Ajieroh, V. (2010).A quantitative analysis of determinants of child and maternal nutrition in Nigeria, International food policy research institute/Nigerian Strategy Support Programme Brief No. 11.

Ayinde O. E., Ojehomon, V. E. T., Daramola, F. S. and Falaki, A. A. (2013).Evaluation of the effects of climate change on rice production in Niger State, Nigeria.*Ethiopian Journal of Environmental Studies and Management, Vol. 6 pp. 763-773*

Badiane, O. and Delgado, C. (1995).A 2020 vision for food, agriculture, and the environment in Sub-Saharan Africa.Food, Agriculture, and the Environment Discussion Paper 4. Washington, DC, International Food Policy Research Institute.

Dinar, A., Hassan R., Kurukulasunya, P., Benhin, J. and Mendelsohn, R. (2006). The policy Nexus between agriculture and climate change in Africa. A synthesis of the investigation under the GEF/WB project: Regional climate, water and agriculture: impacts on adaptation of agro-ecological systems in Africa, CEEPA discussion paper No 39. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Downing, T. E. 1992. Climate change and vulnerable places: Global food security and country studies in Zimbabwe, Kenya, Senegal and Chile", Research Paper No. 1, Environmental Change Unit, University of Oxford.

Elodie .B (2011) The Impact of Climate on Crop Production in Sub-Saharan Africa. A Ph.DDessertation submitted to the Department of Economics University of Otago, Dunedin New Zealand.

FAO (2000). The state of food and agriculture: Lessons from the Past 50 years. Rome, Italy, Food and Agricultural Organization of the United Nations.

Intergovernmental Panel on Climate Change (IPCC) (2007).Climate change 2007 - IPCC Fourth assessment report. Cambridge, UK: Cambridge University Press.

Iioh,A.C; Omatta,G; Ogbadu,G.H;andOnyenekwwe,P.C (2014) Effect Of Elevated Temperature On Seed Germination And Seedling Growth On Three Cereal Crops In Nigeria *.Scientific Research And Essays Vol. 9(18) PP 806-813*

Meehl,G.A., Stocker, T. C., Collins, W.D., Fried-lingstein, P., Gate A.T.,Gregory J.M.,Kitoh.A,Knulti.R.,Murphy.J.M., Noda,A.,(2007).Globalclimate Projections, in solomon,S., Qin, .D., Manning, M.,Chen,Z.,Marquis,M.,Averyt, K.B.,Tignor,M., Miller, H.l (Eds). Climate Cambridge university press: Cambridge, UK, 2007, PP 749-845.

Subervie, J. (2008). The variable response of agricultural supply to world price instability in developing countries. *Journal of Agricultural Economics 59(1): 72-92.*

Winch, T. (2006). Growing food: A guide to food production, Springer.