

Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach

O. E. Ayinde^a, M. Muchie^a and G. B. Olatunji^b

^a*Institute for Economic Research on Innovation, Tshwane University of Technology,
159, Skinner Street, Pretoria, South Africa*

^b*Department of Agricultural Economics and Farm Management,
University of Ilorin, Kwara State Nigeria
E-mail: AyindeOE@tut.ac.za*

KEYWORDS Rainfall. Temperature. Co-integration. Agricultural Productivity. Nigeria

ABSTRACT Climatic fluctuation is putting Nigeria's agriculture system under serious threat and stress. The study of the effect of climate change on agricultural productivity is critical given its impact in changing livelihood patterns in the country. Descriptive and co-integration analysis are the techniques used to analyze the Time series data used in this work. The finding demonstrates that the rate in agricultural productivity is persistently higher between 1981 and 1995, followed by a much lower growth rate in the 1996–2000 sub period. There was variation in the trend pattern of rainfall. Temperature was not relatively constant either. The Augmented Dickey-Fuller test for unit root revealed that agricultural productivity is not stationary and likewise the annual rainfall but became stationary after the differencing. Annual temperature on the other hand is stationary at its level. Temperature change was revealed to exert negative effect while rainfall change exerts positive effect on agricultural productivity. However previous year rainfall was negatively significant in affecting current year agricultural productivity. It is recommended that if agricultural productivity was to be increased and sustained, environmentally and agricultural sensitive technologies and innovations that can prevent climate fluctuation should be encouraged.

INTRODUCTION

The agricultural sector has a multiplier effect on any nation's socio-economic and industrial fabric because of the multifunctional nature of the sector (Ogen 2007). It has the potential to be the industrial and economic springboard from which the country's development can take off (Stewart 2000). This sector remains the main source of livelihood for most rural communities in developing countries in general. In Africa, agriculture provides a source of employment for more than 60 per cent of the population and contributes about 30 per cent of Gross Domestic Product (Kandlinkar and Risbey 2000). Rain-fed farming dominates agricultural production in sub-Saharan Africa, covering around 97 per cent of total cropland and exposes agricultural production to high seasonal rainfall variability (Alvaro et al. 2009). In Nigeria, agriculture is the main source of food and employer of labour employing about 60-70 per cent of the population (Mayong et al. 2005). It is a significant sector of the economy and the source of raw materials used in the processing industries as well as a source of foreign exchange earning for the country (Mohammed-Lawal and Atte 2006). Since agriculture in Nigeria is mostly rain-fed, it follows

therefore that any change in climate is bound to impact its productivity in particular and other socio-economic activities in the country. The impact could, however, be measured in terms of effects on crop growth, availability of soil water, soil erosion, incident of pest and diseases, sea level rises and decrease in soil fertility (Adejuwon 2004). The issue of climate change has become more threatening not only to the sustainable development of socio-economic and agricultural activities of any nation but to the totality of human existence (Adejuwon 2004). As further explained by UNFCCC, the effect of climate change implies that the local climate variability which people have previously experienced and adapted to is changing and this change is observed in a relatively great speed.

The threat that climate changes pose to agricultural production does not only cover the area of crop husbandry but also includes livestock and in fact the total agricultural sector. African farmers also depend on livestock for income, food and animal products Nin, Ehui, (Benin 2007). Climate can affect livestock both directly and indirectly (Adams et al. 1999; Manning and Nobrew 2001). Direct effects of climate variables such as air, temperature, humidity, wind speed and other climate factors influence animal

performance such as growth, milk production, wool production and reproduction. Climate can also affect the quantity and quality of feed stuffs such as pasture, forage, and grain and also the severity and distribution of livestock diseases and parasite (Niggol and Mendelsohn 2008). Hence the totality of agricultural sector is considered by examining agricultural productivity.

Rainfall is by far the most important element of climate change in Nigeria and water resources potential in the country (Adejumo 2004). The northeast region of Nigeria is increasingly becoming an arid environment at a very fast rate per year occasioned by fast reduction in the amount of surface water, flora and fauna resources on land (Obioha 2008). Consistent reduction in rainfall leads to a reduction in the natural regeneration rate of land resources (Fasona and Omojola 2005). This makes people to exploit more previously undisturbed lands leading to depletion of the forest cover and increase on sand dunes/Aeolian deposits in the northern axis of Nigeria. Climate change is the most severe problem that world is facing today. It has been suggested that it is a more serious threat than global terrorism (King 2004). The southern area of Nigeria largely known for high rainfall is currently confronted by irregularity in the rainfall and temperature is gradually increasing in the Guinea savannah zone of the country. In addition, the northern zone faces the threat of desert encroachment (FME 2004).

Climate change affects food and water resources that are critical for livelihood in Africa where much of the population especially the poor, rely on local supply system that are sensitive to climate variation. Disruptions of existing food and water systems will have devastating implications for development and livelihood. These are expected to add to the challenges climate change already poses for poverty eradication (De Wit and Stankiewicz 2006). According to Obioha (2009), the sustainability of the environment to provide all life support systems and the materials for fulfilling all developmental aspirations of man and animal is dependent on the suitability of the climate which is undergoing constant changes. The effect of these changes is posing threat to food security in Nigeria. The study examines the trend of agricultural productivity and evaluates the effect of climate change on agricultural productivity.

METHODOLOGY

The study area is Nigeria. The study uses time series data spanning from 1980 to 2005. The data were sourced from Federal Bureau of Statistics, the Central Bank of Nigeria (CBN) bulletin, Food and Agricultural Organization Publication (FAO), and Nigeria Meteorological Agency.

Descriptive statistics and Co-integration analysis were used to analyze the data. The co-integration analysis involve unit roots test performed on both level and first difference to determine whether the individual input series are stationary and exhibit similar statistical properties. It must be noted that regressing a non-stationary time series data over another non-stationary time series data gives a spurious or nonsense regression. To correct for this, a unit root test is performed. A time series data is stationary if the joint distribution of any set of n observations $X_{(1)}, X_{(2)}, \dots, X_{(n)}$ is the same as joint distribution of any set of $X_{(1+k)}, X_{(2+k)}, \dots, X_{(n+k)}$ for all n and k . $Y_t = pY_{t-1} + U_t$, $1 \leq p$
 $p \leq 1$ where U is the white noise error.

If Y_t is regressed on its lagged value of Y_{t-1} and the estimated p is statistically equal to 1 then Y_t is non-stationary that is, it exhibit unit root $I(1)$. On the other if the estimated value of p is not statistically equal to 1, the Y_t is stationary that is, has no Unit root $I(0)$.

Augmented Dickey Fuller (ADF) Test was used to test for the stationarity of the data. The test consists of the following regression:

$$\Delta Y_t = \beta_1 + \beta_2 \tau + \delta Y_{t-1} + \alpha \sum_{\tau=1}^n \Delta Y_t + \varepsilon_t$$

Where,

$$e_t = \Delta Y_{t-1} = (Y_{t-1} - Y_{t-2}), \Delta Y_{t-2} = (Y_{t-2} - Y_{t-3}).$$

The Johansen procedure was used to test for the number of co-integration vectors in the model. Johansen technique was used not only because it is vector auto-regressive based but because it performs better in multivariate model Maddala (2001). If X_t and Y_t are then co-integrated, their short-run dynamics can be described by Error Correction Model (ECM). The theory states that if two variables Y and X are co-integrated, then the relationship between them can be expressed as ECM. The co-integration model is given as:

$$LY_t = \beta_0 + \beta_1 LX_{1t} + \beta_2 LX_{2t} + U_t \dots \dots \dots (1)$$

Where Y_t = Agricultural Productivity index

X_1 = Annual temperature ($^{\circ}\text{C}$),

X_2 = Annual rainfall (mm)

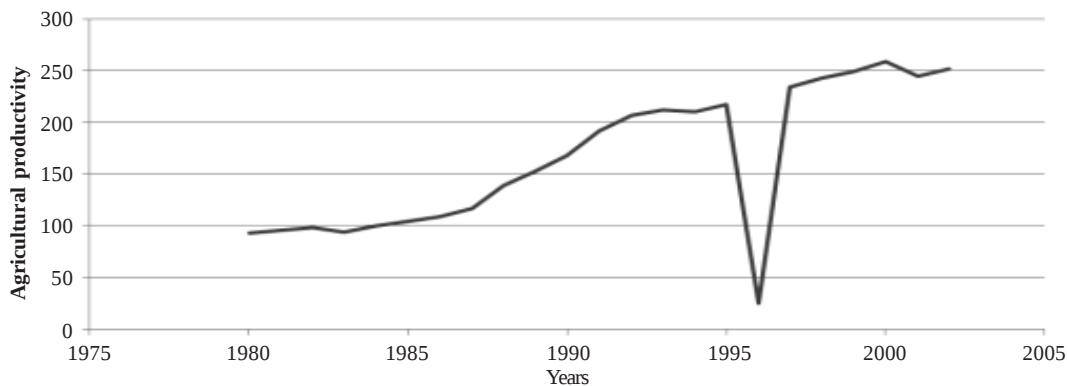


Fig. 1. Agricultural productivity index trend

RESULTS AND DISCUSSION

Trend of Agricultural Productivity

The study reveals that there are persistently higher rates in agricultural productivity between 1981 and 1995 in the study area (Fig. 1). This may be due to the structural adjustment programme (SAP) in Nigeria which started around 1986. This was probably achieved through a more growth rate in capital expenditure towards agriculture than the rate in other sectors of the economy. Figure 1 further reveals that a much lower rate was experienced in agricultural productivity in the 1996–2000 sub period. In fact sharp and great reduction is revealed in 1996. This may be due to a sharp reduction in total labour in agriculture from 59 percent in 1981–1995 sub-period to 45 percent in 1996–2000 sub-period. The maximum index is 258.20 while the lowest is 24.80 during the years under study. The

difference between the highest and lowest index is 233.40. This implies a great variability in the agricultural productivity rate.

Trend of Annual Rainfall

There is an occurrence of rainfall variability (inter-annual) and unreliability in the country especially during the years studied. The period of 1990–1995 experienced the lowest of 693.64 mm while the highest is 1478 mm experienced around 1980. The mean rainfall is 1080.76 mm. This implies there is evidence of climate change especially since 1985. Figure 2 reveals the variability in this climate variable (rainfall).

Trend of Annual Temperature

The average temperature during the study period is 26.3°C, while the maximum and the minimum are 26.94°C and 25.06°C respectively.

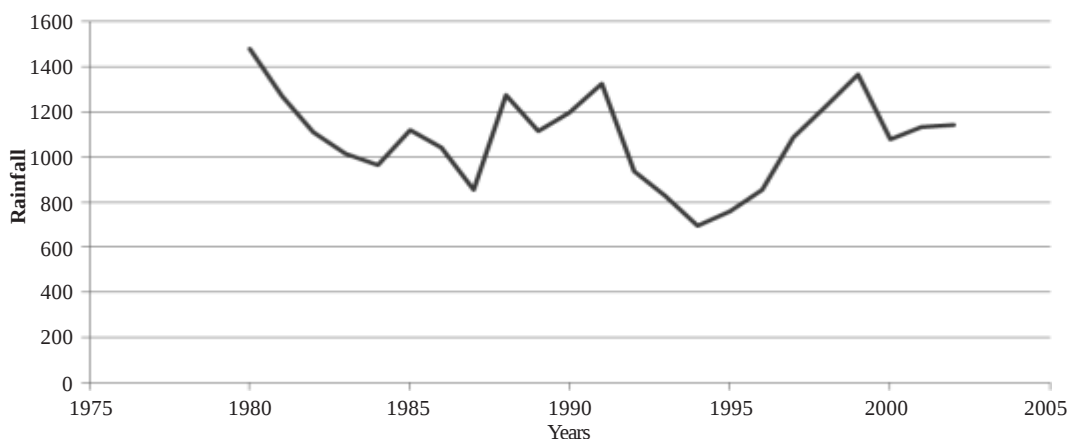


Fig. 2. Rainfall trend

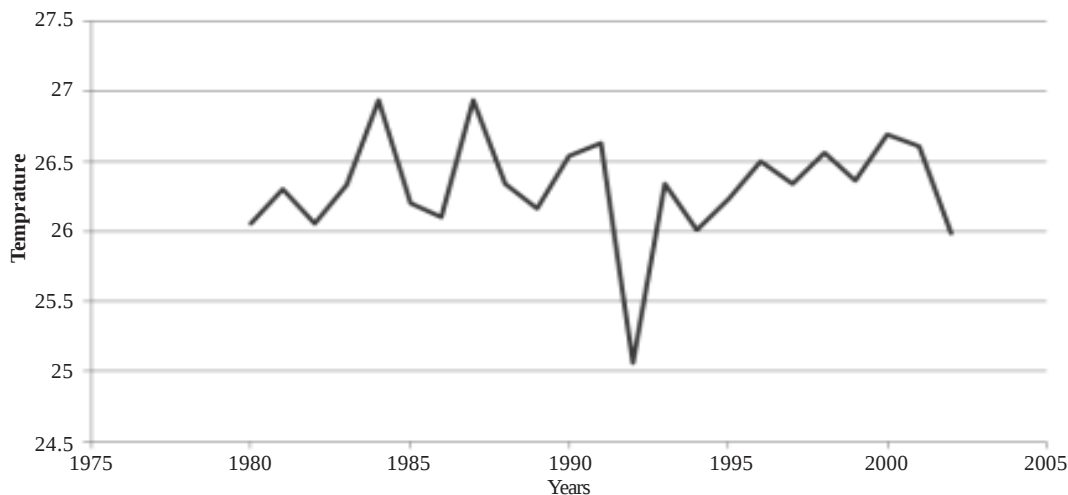


Fig. 3. Temperature trend

Figure 3 shows that temperature is not relatively constant. There is a sharp reduction in the annual temperature in year 1992 and since then it has been experiencing unsteady trend. There is variation in the temperature variable.

Cointegration Test

Table 1 presents the result of ADF test. It is evident that agricultural productivity is not stationary and likewise the annual rainfall but are stationary after the differencing. Annual temperature on the other hand is stationary at the level.

Table 2 presents the Johansen Co-integration result. The likelihood ratio shows that there are three co-integrating (CI) equations in the analysis. Only one of the CI equations was chosen. The CI equation chosen was based on the conformity of the coefficients with economic theory and its statistical significance. From the equation, all the independent variables considered are significantly having effect on agricultural productivity in Nigeria during the period studied.

Since it has been ascertained that the variables exhibit unit root $I(1)$ (non stationary) at their levels but stationary after differencing and there

exist a long run relationship between the variables, error correction model is thus formulated however since temperature variable is stationary at its levels the model will make use of the variable in its level and not lagged whereas only the rainfall will be lagged in error correction model as its only one that exhibit unit root with the dependent variable. This error correction model gives the proportion of disequilibrium error that is accumulated in the previous period, corrected in the current period.

Table 2: Johansen co-integration result

Eigen value	Likelihood ratio	5%	1%	Hypothesized no of CE(s)
0.6824	40.4253	29.68	35.65	None*
0.5301	18.6340	15.41	20.04	At most 1**
0.2019	4.2861	3.76	6.65	At most 2**

** (*) denotes rejection of the hypothesis at 5% (1%) significance level. Likelihood Ratio tests indicates 3 co-integrating equation(s) at 5% significance level

The adjusted R^2 shows that about 98 percent of the variation in agricultural productivity is explained by the combined effect of all variables considered (Table 3). Temperature is revealed

Table 1: Result of stationary test from Augmented Dickey-Fuller Test

Variables	Level	1 st difference	2 nd difference	Order	Decision
LY	-0.9542	-2.9154	-6.3477***	I(1)	Non-stationary
LX ₁	-5.4598***	-7.3439***	-8.8988***	I(0)	Stationary
LX ₂	-2.7435	-4.8160***	-8.0732***	I(1)	Non-stationary

Note: L denotes log. Critical value: 1% = -3.7667

from the result to exert negative effect on agricultural productivity. Committing type II error, it can be considered as an increase in temperature change will likely result in decreasing agricultural productivity. This may be that high temperature depletes soil nutrient making it hard on livestock and agricultural production generally. Naturally speaking rainfall can be considered to have positive effect on agricultural productivity. From Table 3 result, an increase of 0.2 unit of previous year rainfall will decrease agricultural productivity by a unit. The positive effect of rainfall on agricultural productivity is to the extent when rainfall is not over flooding as this is revealed in the negative effect of previous year rainfall on the agricultural productivity. This may implies that heavy rainfall of the previous year could lead to erosion and leaching. Leaching makes nutrient unavailable for the current cropping season and thus decreasing agricultural productivity.

Table 3: Results from the error correction model

Variable	Coefficient	Standard error	T-statistics	Probability
Temperature	-0.9167	0.8130	-1.1276	0.2743
Lag Rainfall	-0.2199	0.0339	28.5829	0.0000
Ecm-1	0.9698	0.0653	-3.3701	0.0034
Constant	4.1807	1.1857	3.5259	0.0024
R ² =0.97		F-statistics=10731.32		

CONCLUSION

The study shows that there is variability in Nigerian rainfall and temperature. The study also shows that the change in climate has significant effect on agricultural productivity. This is clearly revealed in the rainfall variable however temperature seem not an important variable of climate in determinants of agricultural productivity in Nigeria economy.

RECOMMENDATIONS

From the on-going, it could be recommended that Nigerian government needs to give agriculture a serious priority. The current climate change effect can be minimized if policy toward mitigation is geared. Agricultural productivity can be increased and sustained by developing agricultural technologies that are environmentally sensitive. Also agricultural innovation that increase soil nutrient and do not contribute to change in

climate should be encouraged. Furthermore, since previous year's climatic fluctuations affect the current productivity, recycling of this important climate factor (rainfall) should be encouraged in Nigeria in order to maintain a steady supply of agricultural produce.

REFERENCES

- Adams R, McCarl B, Segerson K, Rosenzweig C, Bryant KJ, Dixon BL, Conner R, Everson RE, Ojima D 1999. The economic effect of climate change on United States agriculture. In: R Mendelsohn, J Neuman (Eds.): *The Impact of Climate Change on the United States Economy*. Cambridge, UK: Cambridge University, pp. 18-54.
- Adejuwon SA 2004. Impact of climate variability and climate change on crop yield in Nigeria. *Contributed Paper to Stakeholders Workshop on Assessment of Impact and Adaptation to Climate Change (AIACC)*: 2-8.
- Alvaro C, Tingju Zhu, Katrin R, Richard SJ, Claudia R 2009. Economy-wide Impact of Climate Change on Agriculture in Sub-Saharan Africa International Food Policy Research Institute (IFPRI). *Discussion Paper* 00873:1.
- CGIAR 2008. Consultative Group on International Agricultural Research: "The Challenge of Climate Change; Poor farmers at risk". From <www.cgiar.org/4-6> (Retrieved on 10 February, 2010).
- De Wit M, Stankeiwicz J 2006. Changes in surface water supply across Africa with predicted, climate change. *Science*, 311: 1917-1931.
- Fasona MJ, Omojola SA 2005. Climate Change Human Security and Communal Clashes in Nigeria. *An International Workshop* Holmen Fjord Hotel, Asker, near Oslo, 21-23 June 2005.
- Federal Government of Nigeria (FGN) 1999. *Drought Management in Nigeria; What Can People do to Minimize Its Impact?* Abuja: Federal Ministry of Environment.
- Federal Ministry of Environment 2004: Abuja. From <www.nigeria.com.ngcichng.org./ccinfo.php> (Retrieved on May 20, 2004).
- IFPRI 2009. Climate Change Impact on Agriculture and Costs of Adaptation. *Food Policy Report*. Washington, D.C.: International Food Policy Research Institute (IFPRI).
- Intergovernmental Panel on Climate Change 2007 (IPCC) "Fourth Assessment Report". From <www.ipcc.ch> (Retrieved on July 2 2009)
- Kandlinkar M, Risbey J 2000. Agricultural Impacts of Climate Change; if adaptation is the answer, what is the question? *Climate Change*, 45: 529-539.
- King D 2004. Climate change science: Adapt, mitigate or ignore? *Science*, 303: 176-177.
- Maddala GS 2001. *Introduction to Econometrics*. 3rd Edition. England: John Wiley and Sons Ltd.
- Manyong VM, Ikpi A, Olayemi JK, Yusuf SA, Omonoma BT, Okoruwa V, Idachaba FS 2005. Agriculture in Nigeria: Identifying Opportunities for Increased Commercialization and Investment in USAID/IITA/UI Project Report Ibadan, Nigeria.
- Manning M, Nobrew C 2001. Technical Summary Impact, Adaption and Vulnerability: A Report of Working Group II of the Intergovernmental Panel on Climate Change. In: J McCarthy, OF Canziani, NA Leavy, JD

- Dekken, C White (Eds.): *Climate Change 2001: Impact, Adaption and Vulnerability*. Cambridge: Cambridge University Press, pp. 44-65.
- Mohammed-Lawal A, Atte OA 2006. An Analysis of Agricultural Production in Nigeria. *African Journal of General Agriculture*, 2(1): 1-6.
- Niggol S, Mendelsohn R 2008. Animal Husbandry in Africa: Climate impacts and adaptations. *AfJARE*, 2(1): 66.
- Nin A, Ehui S, Benin S 2007. Livestock productivity in developing countries: An assessment. In: R Evenson, Pingali P (Eds.): *Handbook of Agricultural Economics* (3). North Holland, Oxford Press, pp. 2467-2532.
- Obioha E 2008. Climate change, population drift and violent conflict over land resources in north eastern Nigeria. *Journal of Human Ecology*, 23(4): 311-324.
- Obioha E 2009. Climate variability, environmental change and food security nexus in Nigeria. *Journal of Human Ecology*, 26(2):107-121.
- Ogen O 2007. The agricultural sector and Nigeria's development: Comparative perspectives from the Brazilian agro-industry economy 1960-1995. *Nebula*, 4(10): 184-194
- Stewart R 2000. Welcome Address. *Proceedings of the 7th World Sugar Conference*. Durbar.