ISSN 1333-2422
UDK = 633.179 : 551.583 (669.1)

ORIGINAL SCIENTIFIC PAPER

The effect of climate change on rice production in Adamawa State, Nigeria

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ABSTRACT

This study analyzes the effect of climate change on rice production in Adamawa State, Nigeria. The study describes the trend in rice production and determines the factors affecting the output of rice in Adamawa. Secondary data from 1990-2015 was used. The analytical tools used were descriptive analysis, unit root and regression analysis. The result of the study reveals that there is variation in the trend of the climatic factors affecting rice production in Adamawa State. The findings reveal that rainfall and minimum temperature are the major climatic factors that affect the rice production; such that 1% increase in rainfall leads to 22.2% increase in rice production and 1% increase in minimum temperature leads to 3.7% reduction in rice production. Therefore rainfall is found to be positively significant to rice output, while minimum temperature is found to be negatively significant. The study therefore recommends that irrigation facilities should be built, especially in the north where drought threatens food production. Also breeders should develop rice varieties that have less gestation period and can survive high temperature.

Key words: Nigeria, climate change, unit root, regression analysis, rice production

INTRODUCTION

Climate change refers to any variation in climate over time, whether due to natural variability or as a result of human activity (Intergovernmental Panel on Climate Change, IPCC, 2001a; 2001b). Climate change in the form of higher temperatures, reduced rainfall and increased rainfall variability, reduces crop yields and net farm revenues, and threatens food security in low income based economies, including African countries (FAO, 2007). At the recently concluded 10th Session of IPCC WG II and 38th Session of IPCC in Yokohama, Japan, the world was warned that climate change impacts are leading to shifts in crop yields, decreasing yields overall and sometimes increasing them in temperate and higher latitudes... In light of these, some indigenous communities are changing seasonal migration and hunting patterns to adapt to changes in temperature

(IPCC, 2014). According to Shah et al (2009) the adverse consequences of climate change will take an irreplaceable toll on food production and food security especially in developing countries which have a low capacity to cope and adapt to these challenges. Evidence from Singh et al (1997) confirmed the effects of climate change on farm net revenue in different parts of the globe through rainfall and temperature variability. These probably underlie the reason why International Food Policy Institute's 2013 Global Food Policy Report observed that current discussions on the post-2015 agenda are emphasizing the need to expand beyond the Millennium Development Goals (MDGs) by incorporating climate change alongside urbanization, conflict, and sustainable consumption and production patterns into the development framework. With nearly 6% of Nigeria's population dependent on agriculture and the sector contributing nearly 40% of the country's GDP, Nigeria remains vulnerable to climatic variability and long term climate change (Ajetomobi et al, 2010). Unfortunately, credible reports from Nigerian Metrological Agency, NIMET (2012a) did not offer much hope. The report indicated that Nigerian climate had shown considerable temporal and spatial shifts in its variability and change, making extreme climate and weather event (drought, flood, heat waves, ocean surges, etc.) a more regular event, exemplified by destructive flood of 2012 which occurred in many parts of Nigeria. Eboh et al (2006) observed that, while data limitations made it difficult to estimate cost of possible crop land degradation, the historic crop yield data showed that economic cost of degradation and poor management of renewable natural resources was at least 6.4% of GDP in Nigeria. They found that the annual cost of yield decline as a result of environmental or land degradation from 1995-2004 in Nigeria was estimated at 1.6 billion dollar. More than 60% of this cost was attributed to roots and tubers. The economic effects of the climate change at the micro enterprise level can be gleaned from effects on farm net revenues which are the focus of this study. In a similar way, IPCC (2014) warned that climate change adaptation could cost $100 billion globally. The emphasis is on smallholder farmers since they dominate the Nigerian agricultural sector, engaging about 65% of the population and contributing between 30-40% of the nations' GDP (Ajetomobi et al, 2010). Morton (2007) noted that although climate change issues were recently receiving a lot of empirical and documentary attention, especially as they affect rural areas of developing countries, there have been relatively insufficient discussions concerning the impact of climate on agriculture, specifically in the area of smallholder and subsistence systems. Most studies that have addressed the issues (e.g. Enete et al, 2011; Umoh and Eketekpe, 2010) were either too location specific, used qualitative approach or just reviewed related literature only. The study's focus on staple crops (especially rice, yam, cassava, cowpea and maize) was instructive. IFPRI and Nigerian Strategy Support Programme's report indicated that despite the fact that cereals, roots and tubers dominated Nigerian crop production at a time when the country was the world's leading producer of cassava, yams and cowpea, their productivities were still below potential yields while profitability varied across three broad agro-ecological zones. IFPRI (2009) also asserted that Nigeria was characterized by high reliance on food imports amidst growing level of malnutrition

across the country, with rural areas being especially vulnerable to chronic food shortages, malnutrition, unbalanced nutrition, erratic food supply, poor quality foods, high food costs and even total lack of food. This situation can be exacerbated by risks of climate change if Nigeria remains aloof.

The variation in weather and climate has led to a lot of devastating consequences and effects in various parts of the country (Kebbeh et al, 2003). These include flooding, deforestation, desertification, erosion, drought, sea level rise, heat stress, pests and diseases, erratic rainfall patterns, and land degradation. More specifically, the South-South geopolitical zone is mainly affected by sea level rise and deforestation induced changes; South-East by erosion, flooding and land degradation; North-Central by changes due to de-vegetation and over-grazing; North-East by drought, desertification and heat stress, and North-West also by drought, desertification and heat stress (Ozor, 2009). The centrality of agriculture to Developing Economies (DEs) is not in dispute (Umoh, 2003). Nigeria, with over 140 million inhabitants, constitutes about a quarter of Africa's total population. Agriculture is the largest sector of economy, providing about two-third of the nation's workforce (NBS, 2007a). In spite of this, Nigeria faces acute shortage of food as a result of its low agricultural productivity (Ukwu et al, 2003). This shortage, which varies seasonally or yearly, is reflected in the quantity of food made available for consumption by Nigerians. Rice remains an important component of that quantity; a major arable crop grown in Nigeria where supply is still considered insufficient to match the consumption increase (NBS, 2007a).

Agriculture had its effect on climate change just as climate change had on agriculture. According to Sauchyn and Kulshreshtha (2008), agriculture sources such as animal husbandry, manure management and agricultural soils account for about 52% of global nitrous oxide (N2O) emissions. Climate change is a global crisis – the inter-governmental panel on climate change estimates that there will be increase in global mean temperature of about 1°C above the present value by the year 2025 and 3°C before the end of next century (IPCC, 2002). Some of the critical challenges that agriculture will face under climate changes are obvious. Many of them are the amplification of the substantial challenges that the current climate already imposes; water availability is at the top of the list. Water is already scarce in many regions, increasing demand and competition for water will combine with changing and less predictable rainfall and river flows (USAID, 2008). In Africa, where so many people rely directly on the rain for their foods and livelihoods, any changes in rainfall present a major risk. Indeed the IPCC's fourth assessment report suggest that some African countries may see yields from rain fed agriculture fall by as much as 50% by 2020, if production practices remain unchanged (IPCC 2002).

The study seeks to achieve the following objectives:

- to examine the trend of climate change in the study area from 1990-2015,
- to describe the rice production trend in Adamawa,
- to analyze the effect of climate change on rice production.

MATERIAL AND METHODS

The study was carried out in Adamawa State of Nigeria. Adamawa is a state in north-eastern Nigeria, with its capital at Yola. It was formed in 1991 from part of Gongola State with four administrative divisions: Adamawa, Ganye, Mubi and Numan.

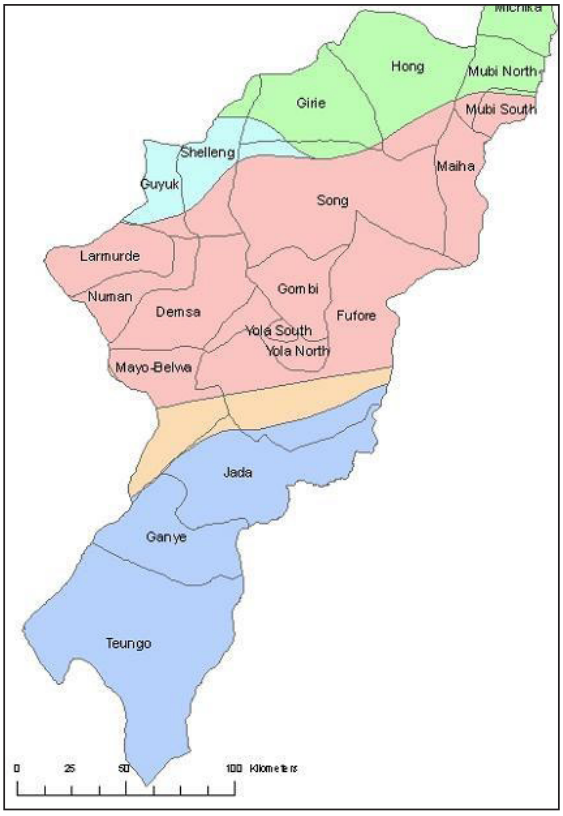


Fig 1: Map of Adamawa State, Nigeria

The set of data for this study were time series data from secondary sources. Secondary data from 1990-2015 were used. The data on climate was collected from National Cereal and Research Institute (NCRI) meteorological station and production data from Food and Agricultural Organization, National Bureau of Statistics and Central Bank of Nigeria. The analytical techniques for this study involved the use of descriptive and inferential statistics; the descriptive statistics involved the use of graphs to examine the movement and trend of various components of rice production. In addition, the production trend (output) of rice in Adamawa State was also described through the graph. Unit root or stationary test was conducted to make decisions on whether the variables were stationary; the Augmented Dickey-Fuller (ADF) test was used for this test. The ADF F-ratio critical value was used to make decision on the unit root of the variables while Regression analysis was used to examine the various climatic component of rice productivity in Nigeria.

MODEL SPECIFICATION

Johansen technique was used not only because it is vector auto-regressive based but because it performs better in Multivariate model.

$$LYt = \beta_o + \beta_1 LX_{1t} + \beta_2 LX_{2t} + \beta_3 LX_{3t} + \beta_4 LX_{4t} + U_t$$

Where
Y_t = Annual Rice output (Kg)
X_1= Annual average Rainfall (mm)
X_2= Annual average Maximum temperature (°c)
X_3= Annual average Minimum temperature (°c)
X_4= Annual average Humidity (Rh)
t = Years
U_t = Error term

RESULTS AND DISCUSSION

A. Descriptive statistics of the yields and other climatic factors

(i) Rice Yield Trends

Adamawa State is one of the major contributors to rice production in Nigeria. Therefore rice yield or output trend was examined to

know the factors responsible for the increase and decrease in the trend of production. As seen in Graph 1 there was a stable production of rice from 1990 to 1994, with total output of about 21000 tons of rice. In the year 1995 there was a decrease in total rice yield by 17000 tons, followed by a rapid increase in 1996 and in 1997. After that there was a general fall or decrease from the year 1998 to 2002. From 2003 to 2006 the state experienced an increase in output by 15000 tons; however from 2007 to 2008 there was yet another fall in output. From 2009 to 2013 there was an increase in output. The highest rice production in Adamawa State was recorded in 2014 (219500 tons) and this might be result of several factors: adoption of improved new technology, favorable climate etc. The year with the lowest output was 2001 with 1200 tons. The increase in output can generally be linked to the policy initiated in 1985, when federal government placed a ban on the importation of rice into the country. In the year 1995, the federal government introduced a 100% tariff on rice which caused a decrease in the total output. The tariff affected the state output that could have encouraged rice farmers in Adamawa State to produce more to add to the country's total rice output.

Graph 1: Graphical Representation of Rice Yield Trend in Adamawa State, Nigeria.
Source: FAO Survey Data (1990-2015) and Own Calculation

(ii) Rainfall Trends Over Years

The graph below shows rainfall trend from 1990 to 2015. It shows that with less than 40 cm, rainfall was at its lowest in Adamawa State in the year 2008. There was an increase in the amount of rainfall in 1991. Rainfall fell below 100 cm from 1990 to 2008. From this, it could be deduced that Adamawa State experienced drought throughout those years. From 2008 to 2010 there was a sudden increase in rainfall, with as much as 100 cm, which is a sure sign of flood in the state. The rainfall amount decreased again to its original level in 2011, maintaining the level it had before, i.e. below 100 cm from 2012 to 2015.

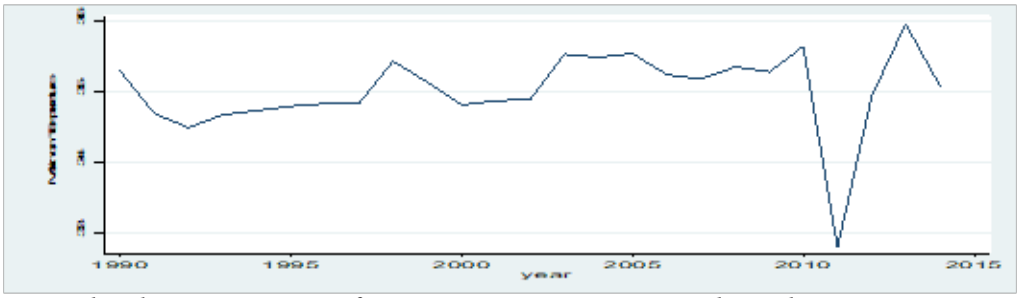
Paddy requires more water than any other crop. As a result, paddy cultivation is done only in those areas where minimum rainfall is 115 cm (although the regions that have average annual rainfall between 175 and 300 cm are the most suitable). Paddy also needs flooded conditions, with the depth of water varying

over 25 mm at the time of transplanting to as much as 150 mm for the 10 weeks of growing period.

(iii) Maximum Temperature Trends Over Years

Graph 3 is a graphical representation of maximum temperature in Adamawa State from 1990 to 2015. The maximum temperature reached its highest in 2013 at 36°C. The increase in temperature may be a result of increase in solar radiation, decrease in humidity and decrease in rainfall; the lower the rainfall the higher the increase in temperature. The state also experienced decrease in maximum temperature in the year 2011, which was below 33°C. In 2011 the state experienced the lowest maximum temperature. Increase in maximum temperature was recorded in 1997, 2003 and 2010 but never reached the highest recorded in 2013. Temperature also varies from place to place and according to season. It has been noted that there are considerable contrasts between the coastal areas and the interior, as well as between the high plateau and the lowlands. On the plateau, the mean annual temperature varies between 21 0C and 27 0C. In the Jos area, temperatures are between 20 0C and 250 C. On the lowlands, such as the Sokoto Plains, the Chad Basin and the Niger-Benue lowlands, the mean annual temperature is 27 0C. The coastal fringes have lower means than the interior. It appears therefore that altitude and proximity to the sea determine to a great extent the distribution of temperature in Nigeria. Generally, temperatures are high throughout the year because Nigeria lies within the tropics and the mean monthly figure can go above 27 0C, while daily maximum temperatures can go between beyond 35 0C – 38 0C, depending on the location (Ayinde et al, 2011).

Graph 2: Graphical Representation of Rainfall Trend in Adamawa State, Nigeria
Source: NIMET Rainfall Data (1990 -2015) and Own Calculation



Graph 3: Graphical Representation of Maximum Temperature Trend in Adamawa State
Source: NIMET Maximum Temperature Data (1990 -2015) and Own Calculation

(iv) Minimum Temperature Trends Over Years

The minimum temperature values recorded from 1990 to 1994 were below 23°C and increased to more than 22.5°C. The drop in temperature may be linked to unsteady weather condition. Rice is a tropical crop and is grown in the areas where the average temperature during the growing season is between 20°C and 27°C. During its four months of growth abundant sunshine is essential. The minimum temperature should not go below 15°C as germination cannot take place below that temperature.

(v) Relative Humidity Trends Over Years

Graph 5 represents trends in relative humidity of Adamawa State. There was a fall in relative humidity in 1991, 1992, and 2009. The drop in temperature may be linked to unsteady weather condition in the state. Increase in relative humidity occurred in 1999 and 2006 but reached its highest in 2007. Relative humidity is a ratio which shows the amount of saturation in the air. In order to change relative humidity, the amount of moisture in the air must change (such as drier winds or more humid air from another place) or the amount of moisture stays the same but the temperature changes.

Graph 4: Graphical Representation of Minimum Temperature Trend in Adamawa State
Source: NIMET Minimum Temperature Data (1990 -2015) and Own Calculation

Graph 4: Graphical Representation of Minimum Temperature Trend in Adamawa State
Source: NIMET Minimum Temperature Data (1990 -2015) and Own Calculation

B. Results of Stationary (Unit Root) Test and Regression Analysis

Table 1 presents the results of the Augmented Dickey-fuller test to show whether variables (rainfall, humidity, maximum and minimum temperature) are stationary. From the equation, almost all variables are significant as climatic factors affecting rice production. Error correction is thus formulated since it has been ascertained that there is a long-run relationship between the variables. The estimations in Table 2 show that the explanatory variables (rainfall, relative humidity, maximum temperature and minimum temperature) have a direct effect on the output or the yield of rice in Adamawa state. Autocorrelation refers to the correlation of a time series with its own past and future values. Autocorrelation is also sometimes called "lagged correlation" or "serial correlation", which refers to the correlation between members of a series of numbers arranged in time. The test statistics above shows that there is (1.46) absence of auto-correlation. Coincidentally, the best fit for the regression remained low after adjusting the degree of freedom as indicated by the adjusted R-squared (0.5550%) i.e. the estimation result reveals that the explanatory variables jointly account for 55.5% changes in production. The result also shows that minimum temperature and rainfall are statistically significant in explaining changes in rice yield or output as a result of climate change. This implies that 1% increase in minimum temperature will cause 3.715% reduction in rice production in Adamawa State, this shows a negative impact. Rainfall on the other hand has a positive impact in that with every 1% increase in amount of rainfall, there is an increase of about 22.28% in rice production. Humidity and maximum temperature are not significant in explaining the effect of climate change on rice production in Adamawa State. This result correlates with the result of Ayinde et al., 2011, where rainfall is also a significant factor in Nigerian agricultural production. In addition to this, in seasons where temperature is high and rainfall is very low and leads to drought, the use of drought resistant variety in the study will keep the production level in a stage where maximum temperature and reduction in rainfall will not be significant. These justify the importance of innovative variety as a way of coping with climate variability.

Table 1. Result of stationary (unit root) test

Variables	ADF-statistics	Critical level	Order of Integration
Yield	1.656	1% = -3.750	Stationary
	(0.4538)	5% = -3.000	
		10% = -2.630	
Maximum	-4.621	1% = -3.750	Stationary
Temperature	(0.0001)	5% =-3.000	
		10% =-2.630	
Minimum	-2.336	1% = -3.750	Stationary
Temperature	(0.0533)	5% =-3.000	
		10% =-2.630	
Rainfall	5.851	1% =-3.750	Stationary
		5% =-3.000	
		10% =-2.630	
Humidity	-5.031	1% = -3.750	Stationary
	(0.0000)	5% =-3.000	
		10% =-2.630	

Table 2. Regression result for effect of climate change on rice production.

Variables	Coefficient	Standard Error	t	VIF
Rainfall	22.289	0.69897	2.90	1.52
Max temp	-0.1238	2.05266	-0.06	1.52
Min temp	-3.7159	1.319323	-2.82	1.49
Humidity	0.3225	0.991427	0.33	1.32
Constant	21.39907	6.682972	3.20	
Number of observation	=25			
F (4, 20)	=3.05			
Probability > F	=0.0408			
R-squared	=0.379			
Adjusted R-squared	=0.555			
Root MSE	=0.14066			

CONCLUSION

The result of the study reveals that there is variation in the trend of the climatic factors and also variation in rice output in Adamawa State, Nigeria. The findings also showed that rainfall and minimum temperature are the climatic factors that affect the rice production of Adamawa State, such that 1% increase in rainfall leads to 22.28903 increase in rice production and 1% increase in minimum temperature leads to 3.715957 reduction in rice production. Therefore, rainfall is found to be positively significant to the research while minimum temperature is found to be negatively significant.

It can be concluded from the results that climate change exits in Adamawa State and it is really affecting the agricultural sector (rice production). Rice production in Adamawa State is adversely affected by this climate changes as shown by the shock that exists in the production trend. The rice production trend in Adamawa State is not stable but had the best rice yield or output in 2014 with 219,500 tons. The result further showed that the major climatic factors affecting rice production in Adamawa State are rainfall and minimum temperature; so much so that the higher the rainfall the higher the rice output and the higher the minimum temperature the lower the rice output.

Based on the results of this study, the following recommendations were made in order to improve the rice production potential of the state and Nigeria at large:

- A research should be conducted to reduce the effect of climate change and thus improve the rice production and agricultural sector of the country. Also, breeders should help to develop rice varieties that can survive drought environment.
- Based on the findings of this study, climate change data management authorities such as NIMET should be encouraged to provide farmers with early warning signals via an organized extension service program, Agricultural Development Programs (ADPs) and the FADAMA III program. Weather stations should be established all over the country to provide farmers with weather data so they can plan their production in a more climate-smart way.
- Irrigation facilities should be built, especially in the north where drought threatens food production. Private investors can delve into such services and allow farmers to pay since government failure had been the bane of agricultural development in Nigerian history.

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Utjecaj klimatskih promjena na proizvodnju riže u Adamawi, Nigerija

SAŽETAK

Ovaj se rad bavi utjecajem klimatskih promjena na proizvodnju riže u Adamawi, Nigerija. Opisuju se trendovi rasta i pada proizvodnje te određuju faktori koji utječu na količinu proizvedene riže. Istraživanje se temelji na sekundarnim podacima iz razdoblja od 1990. do 2015. Za analizu su korištene sljedeće metode: deskriptivna analiza, test jediničnog korijena i regresijska analiza. Rezultati dobiveni istraživanjem pokazuju da klimatski faktori utječu na proizvodnju riže u Adamawi, a kao glavni među njima ističu se količina padalina i minimalna temperatura: porast u količini padalina od 1 % rezultira porastom u proizvodnji riže od 22.2 %, a porast minimalne temperature od 1 % rezultira padom u proizvodnji riže od 3.7 %. Iz toga se može zaključiti da postoji pozitivna korelacija između količine padalina i količine proizvedene križe te negativna korelacija s obzirom na minimalnu temperaturu. S obzirom na dobivene rezultate preporučuje se izgradnja objekata za navodnjavanje, osobito na sjeveru gdje su sušna razdoblja prijetnja proizvodnji hrane. Također, uzgajivačima se preporuča razvoj vrsta riže koje imaju kraći gestacijski period te mogu preživjeti više temperature.

Ključne riječi: Nigerija, klimatske promjene, jedinični korijen, regresijska analiza, proizvodnja riže