JOURNAL OF METEOROLOGY AND CLIMATE SCIENCE
J. Met & Clim. Sci. 19(1): 77-85 (June, 2021)

N.Met.S
Nigerian Meteorological Society

Climate Change and Rice Production in Anambra State

*[1]Ejike-Alieji, Adaeze, [2]Onyeneke, Robert Ugochukwu and [3]Ekpoh

[1]U.P .Department of Geography, Alex Ekwueme Federal University Ndufu- Alike, Ebonyi State, Nigeria.
[2]Department of Agriculture, Alex Ekwueme Federal University Ndufu- Alike, Ebonyi State, Nigeria.
[3]University of Calabar, Calabar, Cross River State, Nigeria
*Corresponding Author: adaeze.ejike-alieji@funai.edu.ng; 08037578694

ABSTRACT: *Rice is an important staple food crop to most households in Nigeria. This crop is affected by climate change and variability because of its sensitivity to changing precipitation and temperature conditions. Therefore, attention must be paid to the production of rice in the face of climate vagaries if the food security objectives of the nation must be achieved. This study therefore used available primary data from climate elements such as rainfall, temperature, relative humidity and wind speed to study the effect of climate change on Production in an agricultural community in Anambra State from 1985–2014. Climate data for 30- year period was obtained from the Nigerian Meteorological Agency (NIMET), and the data for 3 consecutive years obtained usingquestionnairefrom116Rice farmers. The Coefficients of variation, seasonality index and precipitation periodicity index were used to study variability in the climate data. The Mann-Kendall's and Sen.'s tests were used to examine the presence of significant trends in the climate variables. The results show that among all the studied climatic factors, only rainfall had considerable variability and significant trend during the study period While rainfall had a significant negative trend, relative humidity had a significant positive trend (Z = +0.38; α > 0.1). Temperature and wind speed had no significant trend.*

INTRODUCTION

Changing climatic conditions are intricately linked to agricultural productivity. It is estimated that by 2050, climate change will result in reductions of 3.2 percent in global food availability, per-person (Springmann, Mason-D'Croz, Robinson, Garnett, Godfray, Gollin, Rayner, Ballon, and Scarborough, 2016). This largely be due to poor yields of the major staple foods. Chief among such staple food crops is rice. Maize, wheat and rice however, together, account for 87 percent of all grain production worldwide and 43 percent of all food calories (Dyson, 1996). In fact, it is projected that over 116,000,000 tons of rice will be needed by the year 2035 to feed the growing population of the world (Seck, Diagne, Mohanty and Woperis, 2012).

Rice consumption is nonetheless highest in tropical Africa and Asia where increase in temperature variability are more likely. In Africa alone, for example, rice is the major food for over 30,000,000 people (Seck, Diagne, Mohanty and Wopereis, 2012).In Nigeria, the demand for rice as grown steadily at about 5.6 percent *per annum* since 1961 (Osiname, 2002). Its consumption is estimated to be currently rising at 11 percent per annum (Mbam and Edeh, 2011). Rice is nonetheless a staple food for both the rich and the poor. The rainy season and the availability of rains determine when crops are planted and the length of time available for growth. This in turn bears heavily and negatively on crop yield. Rainfall variability is very common and therefore important in the tropics because temperature and the other climatic do not vary as precipitation (Ekpoh 2014). Temperature does not exceed 5 percent coefficient of variation whereas that of rainfall is rarely less than 20 percent even in the same month (Adejuwon, 2005). Among the elements of whether and climate, rainfall and temperature are usually the most important parameters required in estimating variability and yield (Peng, Tang and Zou, 2009).

An estimated 800,000,000 people globally (17 percent of the world's population) are food-insecure. Thirty five percent of these reside in South Asia; 30 percent in East Asia; 22.5 percent in sub-Saharan Africa; and the other 12.5 percent live in Latin America, Middle East and North Africa (Pinstrop-Andersen, Pandy-Lorch and Rosegrant, 2001). This does not augur well for development especially when placed in context with data from future population growth dynamics, where the bulk of population growth is projected to occur in developing countries (Evans, 2009). The challenges of this confluence of pressures on agriculture require that the way crops are raised be improved. Studying the effect of variability in relevant climatic parameters on the yield of key food crops is an important step in that direction. Unfortunately, response to climate change in Nigeria has been reported to be slow (Ekpoh, 2014).

It will also help improve rice yield and encourage maximum production especially for small scale farmers in remote areas who form the bulk of the farming population of Nigeria and sub-Saharan Africa in particular [where they represent 80 percent of all farmers (AGRA, 2014)]. Deliberate research in agrarian areas such as Ayamelum Local Government Area (LGA), where 65.4 percent of the population are reported to be poor subsistent farmers, (Nwalieji and Uzuegbunam, 2012) will help increase the rice yield of farmers despite the apparently precarious ecosystem available for rice farming. Improved yields come with food sufficiency, economic stability, employment generation and all the positive economic down-stream triple effect.

In Nigeria, crop production is a very important part of agriculture and it contributes significantly to the economy. Agriculture employs about 60 percent of the Nigerian workforce and contributes an estimated 41 percent of GDP (Aye and Ater, 2012). Rice production in sub-Saharan Africa is weather-dependent and therefore relies largely on precipitation (the rain-fed system) as against irrigation in many parts of Asia. Unfortunately the average growth rate of irrigated areas in sub-Saharan Africa in the last 30 years was a paltry 2.3 percent and even this has slowed to a meagre 1.1 percent between 2000 and 2003 (You, Ringer, Nelson, *et al.*, 2010).

Rice as a pseudo-aquatic plant requires ample water from precipitation. Without prejudice to the above assertion, flooding may cause rice plants to be completely submerged in water and this could result in the death of the plants if they remain submerged for more than one week (Sark, Reddy, Sharma and Ismail, 2006). Rice grows optimally at a temperature range of 25 to 30ºC (Le Houerou, Popov and See, 1993; Seck *et al,* 2012). Increasing temperature during the heading and ripening period has been shown to result in poor grain quality of harvested rice. This may consistently cause ripped rice grains with visible defects which also contribute to poor yield. In fact, a 2–4ºC increase in temperature above the optimal has been shown to reduce rice yields by 6–16 percent (Seck *et al.,* 2012). Exposure to high temperatures for only a few hours (especially at night) is sufficient to reduce pollen viability, cause spikelet sterility and ultimately poor yields (Kukla and Karl, 1993).

Based on the above argument, the impact of the climate variability on rice yield, and using climate data, in Ayamelum LGA,a major rice producer of Anambra State.Such understanding would help in devising appropriate adaptation strategies and the development of protocols that can help prevent the destructive effects of future climate change events thereby helping farmers overcome the economic losses that may result from such variability in climate variables. Ultimately, since smallholder farmers constitute 80 percent offarmers, improving the yield of important crops such as rice would improve the economic position of many poor farming families (Anambra state government 2011)

Motivation of the Study

The changes observed with respect to the climate parameters, especially with variability in temperature and rainfall have been shown to affect agricultural productivity in different climatic zones of the world (Kuiper 1993). The impact of these factors on rice yield in Ayamelum LGA of Anambra State has not been studied; as such evidence-based adaptation strategies cannot be developed. This knowledge-gap implies that poor farmers in the said area may remain vulnerable to the vagaries of climate variability and change.Given that the rice farmers in Ayamelum LGA depend on the rice yields from typically rain-fed systems to sustain their families, and that increased productivity would in addition to ensuring food security for such families also increase the nation's Gross Domestic Product (GDP), any effort geared towards improving rice yields is important and laudable. Also high cost of rice today for both imported and domestic, this study is more significant especially now that the country is planning to diversify the Economy. it is in this light that this study on the impact of climate variability on rice yield in Ayamelum LGA of Anambra State, finds its significance.

METHODOLOGY

Data for climate variables were aggregated into 5-year periods thus: 1985-1989, 1990-1994, 1995-1999, 2000-2004, 2005-2009, 2010-2014 and the means calculated to reflect monthly variations. The Questionnaires structured to capture 3 consecutive years after the 2012 flooding, wasdistributed among the 116 farmers in various Agricultural communities within the study area.Ayamelum is made up of eight towns namely Anaku, Ifite-Ogwari, Igbakwu, Omasi, Omor, Umerum, Umueje and Umumbo was all part of the study.

Data Analysis

Plots for climate variables were generated using Microsoft Excel. The plots included values for the means, and mean plus or minus one standard deviation, for each climate variable. Values exceeding mean plus or minus one standard deviation were interpreted as varying considerably from the mean as they are outliers to 68 percent of the entire dataset as seen from a normal distribution curve.

In addition to the above, the coefficients of variation were calculated using the formula:

$$CV = \left[\frac{\delta}{\bar{x}} \right] \times 100$$

Where CV is coefficient of variation,
δ is standard deviation, and
$\bar{X}$ is the mean.

CV values ≥ 25percent indicate significant variability in the climate variable studied (Ekpoh and Nsa, 2011).

Furthermore, the rainfall seasonality index was calculated using the formula:

$$SI = \sum_{n-1}^{n=12} [\overline{X}_n - \frac{\overline{R}}{12}]$$

Where SI is seasonality index,
$\bar{X}_n$ is the mean rainfall of month *n*
$\bar{R}$ is the mean annual rainfall.
The rainfall seasonality index is interpreted using the Table below as described by Walsh and Lawler (1981).

Table 1: Interpretation of rainfall seasonality index data

Seasonality Index (SI)	Interpretation
≤ 0.19	Very equable
0.20 – 0.39	Equable with a definite wetter season
0.40 – 0.59	Rather seasonal with a short drier season
0.60 – 0.79	Seasonal
0.80 – 0.99	Markedly seasonal with a long drier season
1.00 – 1.19	Most rains in 3 months or less
≥ 1.20	Extreme, almost all the rains in 1 or 2 months

Source: Walsh and Lawler (1981)

In addition to the above, the precipitation periodicity index, used to determine the magnitude of zonal rainfall variability, was also calculated using the equation:

$$PP = [(A/Y) - (B/Y)] \times 100$$

Where PP is precipitation periodicity,
A = the highest monthly rainfall
B = the lowest monthly rainfall
Y = the total annual rainfall

The following interpretations for the precipitation periodicity index were adopted:

PP < 20percent indicates uniform distribution of rainfall;
PP ≥ 20percent < 30percent indicates slight periodicity;
PP ≥ 30percent indicates excessive periodicity (Hassan and Adefolalu, 2003).

Calculations for these factors and indices were performed using a Microsoft Excel with the appropriate formulae properly inputted.
To test for the existence of a significant trend for the studied climate variables, the Mann-Kendall test, a non-parametric test, was used. It was calculated using the formula:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k)$$

$$sgn\,(x_i - x_k) = \begin{cases} 1 & if\, x_i - x_k > 0 \\ 0 & if\, x_i - x_k = 0 \\ -1 & if\, x_i - x_k < 0 \end{cases}$$

Where x_j and x_k are the annual values years j and k, $j>k$, respectively, and

If n is ≥ 10, the variance of S above is computed using the equation:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5) \right]$$

Where

q is the number of tied groups

t_p is the number of data values in the p^{th} group.

The values of S and $VAR(S)$ are used to compute the test statistic Z as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & \text{if} S > 0 \\ 0 & \text{if} S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & \text{if} S < 0 \end{cases}$$

A positive value of Z indicates an upward trend (conversely, a negative value of Z indicates a downward trend) estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method (Gilbert, 1987) was used as follows:

$$Q_i = \frac{x_j - x_k}{j - k}$$

where $j>k$, and Q is the Sen's estimate.

Because there are many values for x_j, the Sen’s estimator is the median of all the possible values of Q_i, calculated as:

$Q = Q_{[(N+1)/2]}$, if N is odd;

Or if N is even, as:

$$Q = \frac{1}{2}\left(Q\left[\frac{N}{2}\right] + Q\left[\frac{N+2}{2}\right]\right)$$

The above analyses were done using the MAKESENS program developed by Salmi and colleagues of the Finnish Meteorological Institute (Salmi *et al.,* 2002).

Rice Yield

The rice yield [that is quantity of rice (kg) produced per land area (m^2)] for each year was determined using the formula:

Rice Yield = [Quantity of produced] ÷ [farm area cultivate

Ayamelum LGA is one of the 21 LGAs in Anambra State.

RESULTS

Climate Variables and Climate Variability

It is seen that for the 30 year period studied, wind speed was higher in the dry seanson compared to the rainy season. Other than a few spikes above the mean plus one standard deviation values in January (1990-1994), July (1995-1999) and September (1985-1989), the wind speed values were all lower than the upper limit set for considerable variation.

Mean relative humidity was higher than the mean plus one standard deviation limit for considerable variation only in February of the 2010-2014 period. Other than 3 months in the 1990-1994 period (May, June and October), two months in the 2005-2009 period (January and August) and February of the 2000-2004 period, the mean relative humidity values were all higher than the mean minus one standard deviation limit for considerable variation. Relative humidity essentially did not vary a lot during the period under review (Figure 1).

Mean temperature values were lower than the mean plus one standard deviation limit for all the years except for the 2010-2014 period when values higher than the said upper limit were found in January, March, April, June, July, October and November. All the recorded values were higher than the mean minus one standard deviation limit, with the exception of February and September (1990-1994), April, July and December (1985-1989) , November (1995-1999). Clearly the 2010-2014 period was the warmest period and the only period with considerable variation (Figure 2)

From figure 3, The mean rainfall values exceeded the mean plus one standard deviation limit only in July (1990-1994), October (1995-1999), January and May (2005-2009), and May and June (2005-2009). Other than these periods the rainfall data did not vary considerably from the mean for the entire period.

When the coefficients of variation were calculated for the 5-year periods, irrespective of the months of the year, it was seen that only the coefficients of variation for rainfall equalled or exceeded 25 perccent. Therefore, for each of the studied period, there was significant variability in rainfall, but not the other studied variables.

To dissect the variations observed and account for when they occurred, the coefficients of variation were re-calculated for all the months in the studied period. The values for wind speed were lower than 25 percent in all the months. Similarly, the coefficients of variation for relative humidity for all the months during the said period were lower than 5 percent.The data for temperature were the lowest, as they ranged from 1.1–2.2 percent. The coefficients of variation for rainfall were however higher than those of the other studied variables. They however reached or exceeded 25 percent only in January, February, November and December – the driest months of the year. Therefore, only rainfall had significant variability and it occurred only in the dry seasons of the years studied.

The periodicity index data showed that there was slight periodicity for all the 5-year periods (for the 30 studied years) except for the 1995-1999 period when there was uniform periodicity. The rainfall seasonality data showed that rainfall seasonality was equable for all the 5-year periods studied, but had a definite wetter season in only the 1990-1994, 1995-1999, and 2005-2009 periods (Table 1).

Trend and Slope Analysis

Using the Mann-Kendall test, the statistical significances of the trends for all studied variables were tested while the Sen's method was used to estimate the magnitude of the trends. Since the(α value (equivalent to the regular statistical *P* value) less than 0.05 is considered significant and the values greater than 0.05 therefore warrant a rejection of the null hypothesis and an acceptance of the alternate hypothesis (that there is a trend).

The results for the Mann-Kendall test for wind speed showed that there was no trend for wind speed for the studied period; while even the confidence intervals for the magnitude of the slope were all less, , than –0.1. It is seen that for relative humidity and rainfall.There was a significant trend (relative humidity: $Z = +0.38$; $a > 0.1$; $Q = 0.000$; rainfall: $Z = -0.68$; $\alpha > 0.1$; Q –0.433).

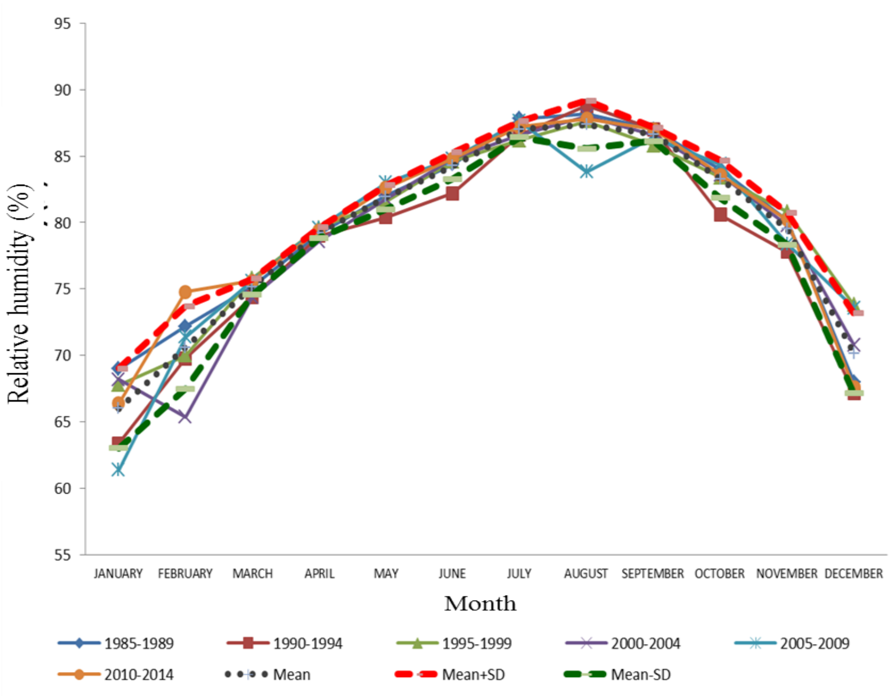

Figure 1: Mean monthly relative humidity data for 30 years, 1985-2014 (Source: Researcher's Field work)

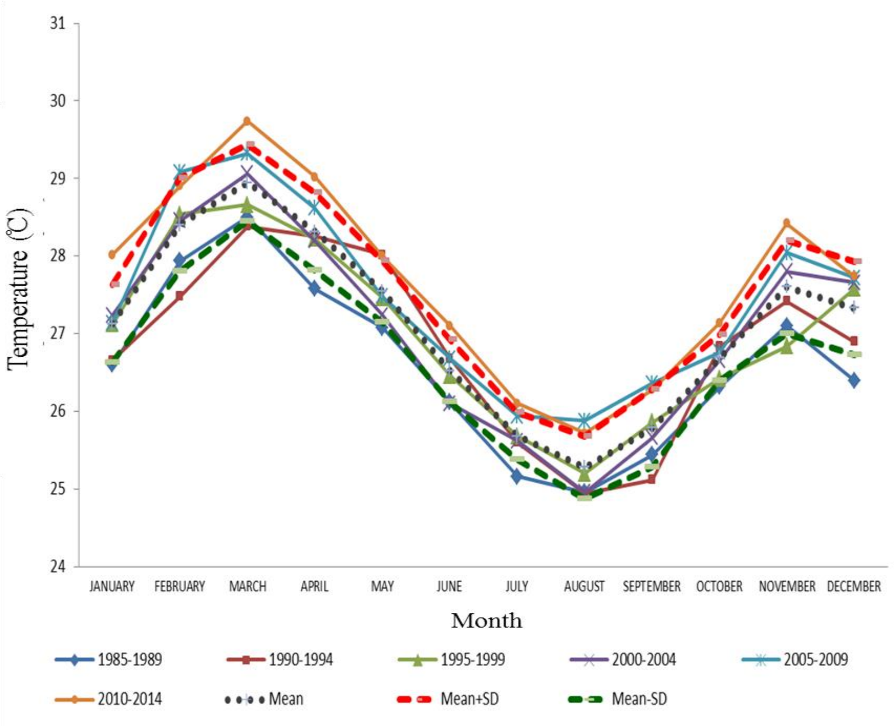

Figure 2: Mean monthly Temperature data for 30 years, 1985-2014 (Source: Field work)

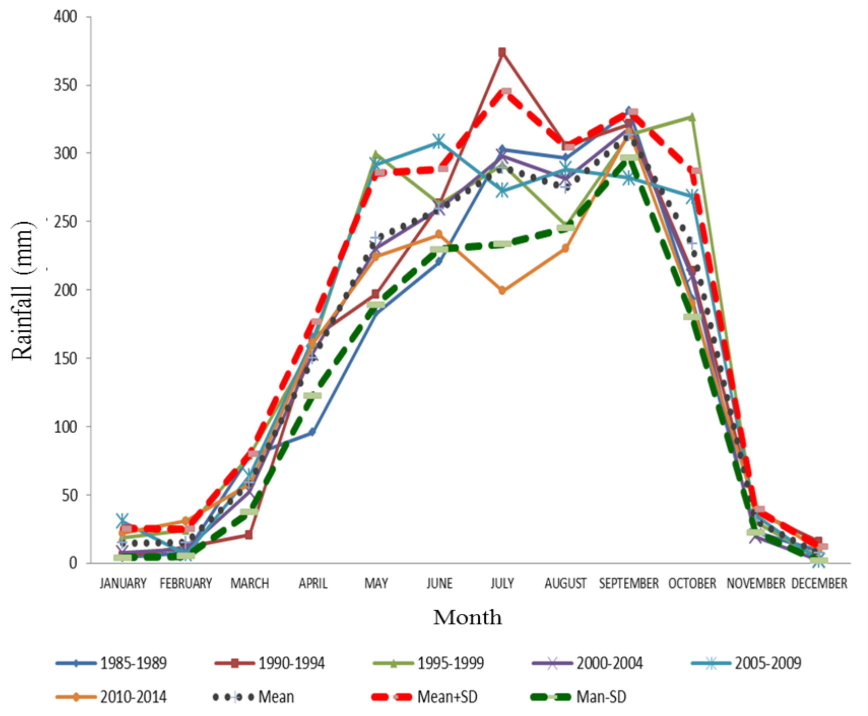

Figure 3: Mean monthly rainfall data for 30 years, 1985-2014 (Source: Field work)

	Precipitation Periodicity Index	Rainfall Seasonality Index
1985-1989	22.74	0.02
1990-1994	21.50	0.21
1995-1999	17.98	0.21
2000-2004	21.34	0.05
2005-2009	20.50	0.22
2010-2014	21.06	0.13

Source: Authors' calculation

The data below was generated for while testing for trends in the climate variables.

Table : Trend and slope estimates statistics

	Mann-Kendall trend					Sen's slope estimate		
Time series	First year	Last Year	N	Test Z	Sig.	Q	Qmin95	Qmax95
Rainfall	1985	2014	30	-0.68		-0.433	-2.026	1.193
	1985	2014	30	-4.68	***	-0.054	-0.070	-0.036
Wind speed								
Rel. humidity	1985	2014	30	0.38		0.000	-0.028	0.031
Temperature	1985	2014	30	4.05	***	0.032	0.020	0.041

Source: Researcher's data analyses

DISCUSSION

It is seen that there was no trend for temperature and the Sen's estimate for the magnitude of the slope was very small. Akin to the earlier data from the trend analysis, the patterns of the residual agree with data from. Rainfall for the studied period had a negative trend with a modest (negative) magnitude. it is seen that other than during the rainy season, considerable variation in mean rainfall values occurred only in March of the 1990-1994 period when apparently the first rains were lighter than usual or there was a false onset. Mean rainfall values were lower than the mean minus one standard deviation limit in April and June (1985-1989), and July and August (2010-2014) only. For relative humidity, there was a positive trend of very small magnitude. From Figure3, The pattern of the residuals is also in tandem with data presented earlier in precipitation periodicity index and rainfall seasonality index for period under study.

CONCLUSION

Rice production and Climate Change study examined the impact of climate variables (rainfall, temperature, relative humidity and wind speed) on rice in Ayamelum LGA of Anambra State from 1985-2014. It also examined whether variability existed in the climate variables; if there was a trend in the variables in the study area. Appropriate statistical tools were used for data analysis. The findings of the study showed that rice was cultivated mainly by young and literate, small-holder farmers with 10 or more years of experience (on the average). While rainfall had considerable variability during the study period, relative humidity, temperature and wind speed did not have any significant variability. Rainfall had a significant negative trend ($Z = -0.68$; $\alpha > 0.1$), relative humidity had a significant positive trend ($Z = +0.38$; $\alpha > 0.1$), but temperature and wind speed had no significant trend. Though rice yield has increased above the mean in the last few years, the differences were not found to be significant.

REFERENCES

Dyson, T. (1996). Population and food: global trends and future prospects. London, Routledge, pp. 227

Seck, P.A., Diagne, A., Mohanty, S., and Wopereis, M.C.S. (2012). Crops that feed the world, 7: Rice. *Food Security* 4, 7-24.Osiname, O.A. (2002). Review of current status, policy and prospects of rice production in Nigeria. Paper presented at the Rice Stakeholders Workshop. NISER 19th – 20th November, 2002.

Mbam, B.N. and Edeh, H.O. (2011). Determinants of farm productivity among smallholder rice farmers in Anambra State, Nigeria. *Journal of Animal and Plant Sciences* 9,1187- 1191.

Ekpoh, I.J. (2014). Slow response to *climate change* in Nigeria: need for urgent and comprehensive action. *Studies in Social Sciences and Humanities*, 1,19-29.

Evans, A. (2009). The feeding of the nine billion: global food security for the 21st century. Chatham House, London. pp. 59

Alliance for a Green Revolution in Africa (AGRA) (2014). Africa agriculture status report: Climate change and smallholder agriculture in sub-Saharan Africa. AGRA, Nairobi, Kenya. Pp1-182.

Nwalieji, H.U. and Uzuegbunam, C. O. (2012). Effect of climate change on rice production in Anambra State, Nigeria. *Journal of Agricultural Extension* 16, 81-91.

Aye, G.C. and Ater, P.I. (2012). Impact of climate change on grain yield and variability in Nigeria: A stochastic production model approach. *Mediterranean Journal of Social Sciences* 3,142-150

Sarkar, R.K., Reddy, J.N., Sharma, S.G., Ismail, A.M. (2006). Physiological basis of submergence tolerance in rice and implications for crop improvement. *Current Science* 91, 899-906

You, L., Ringler, C., Nelson, G., Wood-Sichra, U., Robertson, R., Wood, S., Guo, Z., Zhu, T. and Sun, Y. (2010). What is the irrigation potential for Africa? Discussion Paper. Washington, DC: International Food Policy Research Institute.

Le Houerou, H.N., Popov, G.F. and See, L. (1993). *Agro-Bioclimatic Classification of Africa*. Agro meteorology Series Working Paper, 6, FAO, Research and Technology Development Division Agro meteorology Group, Rome, pp 227

Seck, P.A., Diagne, A., Mohanty, S., and Wopereis, M.C.S. (2012). Crops that feed the world, 7: Rice. *Food Security* 4, 7-24.

Kukla, G., and T.R. Karl. (1993). Night-time warming and the greenhouse effect. *Environmental Scienceand Technology* 27,1468-1474.

Anambra State Government (2011*). Anambra State Statistical Year Book, 2011.* Awka, pp 138-140

Kuiper, P.J.C. (1993). Diverse influences of small temperature increases on crop performance. In: *International Crop Science*, vol. I. Crop Science Society of America, Madison, WI, pp 309-313.

Gilbert (1987) Gilbert, R.O. (1987). Statistical methods for environmental pollution monitoring. New York: Van Nostrand Reinhold , pp 23-45.

Ekpoh, I.J. and Nsa, E. (2011). Extreme climatic variability in North-western Nigeria: An analysis of rainfall trends and patterns. *Journal of Geography and Geology* 3,51-62.

Walsh, P.R.D., and Lawler, D.M. (1981). Rainfall, seasonality, description, spatial, pattern and change through time. *Weather* 36, 201–208

Hassan, S.M., and Adefolalu, D.O. (2003). Precipitation periodicity and agricultural land use demarcation Zuma, Kaduna State.:*Journal of Pure Applied Sciences* 5, 29–35.

Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T. and Amnell, T. (2002). Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates – the Excel template application MAKESENS. Finland Finnish Meteorological Institute, Helsinki,pp 8-11.

Springmann, Mason-D'Croz, Robinson, Garnett, Godfray, Gollin, Rayner, Ballon, and Scarborough(2016) Global and regional health effects of future food production under climate change: a modelling study. *Lancet* 387, 1937–1946