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Effects of Climate Change on Cowpea Yield in Kaduna State, Nigeria: Evidence from Rainfall and Temperature Parameters

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Abstract
Climatic fluctuation is one of the major problems of Nigeria's agriculture system. This paper attempts to examine the effects of climate change and variability on cowpea yields in Kaduna State Nigeria. Thus, cowpea yield, temperature and rainfall data spanning periods of thirty years (1987-2016) were employed. The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) were used to test for the normality in the seasonal rainfall series (April to October) for the station. Also, the relationship between climate data (rainfall and temperature values) were tested using bivariate correlation analysis. The result revealed that Z_1 and Z_2 for the station were accepted as normal at 95% confidence level. The results of the correlation analysis indicated a positive (weak) relationship between rainfall values and cowpea yields. It also revealed positive relationship between temperature and cowpea yields. In view of this, it was recommended that, there is need for the development of a comprehensive agricultural and climate change policy that takes into account the risks associated with cowpea production among farmers.

Keywords: Climate change, rainfall, correlation, temperature, cowpea

1. INTRODUCTION
Climate change could be seen as a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period typically decades or longer (Inter-governmental Panel of Climate Change, IPCC, 2007). Climatic change is the combined effects of elevated temperatures and drought, with consequential increase in potential evapotranspiration, constitutes the greatest risk to agriculture in many regions (IPCC, 2001; Building Nigeria's Response to Climate Change, BNRCC, 2011). Increased human activities such as fossil fuel, land-use change and agriculture have increased the amount of carbon dioxide, nitrous oxide and methane by 30, 45 and 15% respectively. This has exacerbated the magnitude and pattern of climate change (Odekunle, 2010). The current trend of highly variable weather events and its effect on life in general and agriculture in particular has made the study and understanding of weather events vital.

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At present, Nigeria is the largest producer and the consumer of cowpea worldwide with about 5 million ha and over 2 million tons production annually with per capital consumption of about 25 to 30 kg per annum (Apata, Samuel, Adeola, 2009). Adejuwon and Ogunkoya (2006) observed that the survival of agriculture is dependent on climate, and the two are inter-related because they both take place globally. A recent research has shown that grains can be used to offset the major impacts of climate change because of their unique position as stable for the growing populations (Ortiz, 1998). Cowpea is considered more tolerant to climate change because of its tendency to form a deep taproot (Food and Agricultural Organization, FAO, 2004). This leads to the interest of this work on cowpea. In Nigeria, particularly Kaduna State, cowpea is of major importance to the livelihoods of millions of people providing nourishment and an opportunity to generate income. Trading fresh produce and processed food and snacks provides rural and urban women with the opportunity for earning cash income; and as a major source of protein, minerals and vitamins in daily diets, its positive impacts on the health of women and children (Ole, Anette and Awa, 2009).

Despite the importance of cowpea, its production is beset with constraints such as drought, flooding, salt –stress and extreme temperatures, all of which are expected to worsen with climate change (Apata, Samuel, Adeola, 2009). Yield is mainly determined by ecological factors including climate, soil and pests and diseases. Thus, any changes in these factors could lead to changes in yield and therefore contribute to inter-annual changes in crop yield (Adejumon, 2006). Adefolalu (1983) rightly pointed out that plants do not only depend on the amount of rainfall receive for growth, development and yield but on how much water is available to them as soil moisture. When these amount becomes available within the length of the days and months to which the soil is able to retain enough moisture required, it would enhance good yield. In addition, in the tropical environment, temperature and rainfall are the most important determinants of vegetation, as temperatures are high all the year round, they are non-limiting to plant growth but determine the types of plants to be grown (Nwafor, 1982; Asiedu, 1992). Similarly, Adefolalu (1991) observed that climate, particularly, precipitation has not been accorded the deserved priority in agricultural planning in Nigeria. Thus, the general neglect of this natural resource may be based on the impression that the tropical climate is equitable. In view of this, Ati, Iguisi and Afolayan (2007) observed that, the longer duration means more rain fed crops can be cultivated and more rainwater can be harvested for water resources development.

Thus, not all rainfall is effective but only the portion that contributes to evapo-transpiration could be considered as effective (Abubakar and Yamusa, 2013). An important prerequisite for efficient intensification of agricultural production is an understanding of climate – crop relationships. Although, the effects of short – term weather fluctuations on cowpea yields have been well recognized for a long time, but they have not been well studied and understood in Nigeria, especially in Kaduna State where it is generally believed that the weather is favourable for crop production. Some studies have been conducted to assess the impact of climate change on agriculture in developing countries (notably studies conducted by: IPCC 2007; Timko and Singh 2008; Brown 2009; Ayinde 2010; Oyerinde, Chuwang and Oyerinde, 2013). These studies point to the concern for the present and future climate observations, weather trends and their implications for agriculture that continue to inspire researchers as well as public and policy level interests regarding the analysis of climate change in relation to agricultural productivity. This study therefore seeks to contribute to knowledge by investigating the effects of climate change on cowpea production in Kaduna State. This is the thrust of this present study.

2. STUDY AREA

Kaduna State is located between Latitudes 09° 02'N to 11° 32'N and Longitude 06° 15'E to 08° 38'E. It shares common borders with Katsina State to the North, Nassarawa State and the Federal Capital Territory, Abuja to the South, Kano and Bauchi States to the Northeast, Zamfara State to the Northwest, Niger State to the West, and Plateau State to the Southeast.

The climate of Kaduna State is the tropical wet-and-dry type (Koppen's Aw climate). The wet season lasts from April through October with a peak in August, while the dry season extends from November of one calendar-year to April of the next (Abaje *et al,* 2012). The annual average rainfall varies from about 1733 mm at the extreme southern part of the zone to about 600 mm at the extreme northern part (Abaje *et al,* 2016). The rainfall intensity is very high between the months of July and August (ranging from 60 mm hour^{-1} to 99 mm hour^{-1}) (Oladipo, 1993). The pattern of rainfall in this region is highly variable in spatial and temporal dimensions with an inter-annual variability of between 15 and 20% (Oladipo, 1993; Abaje, 2016).

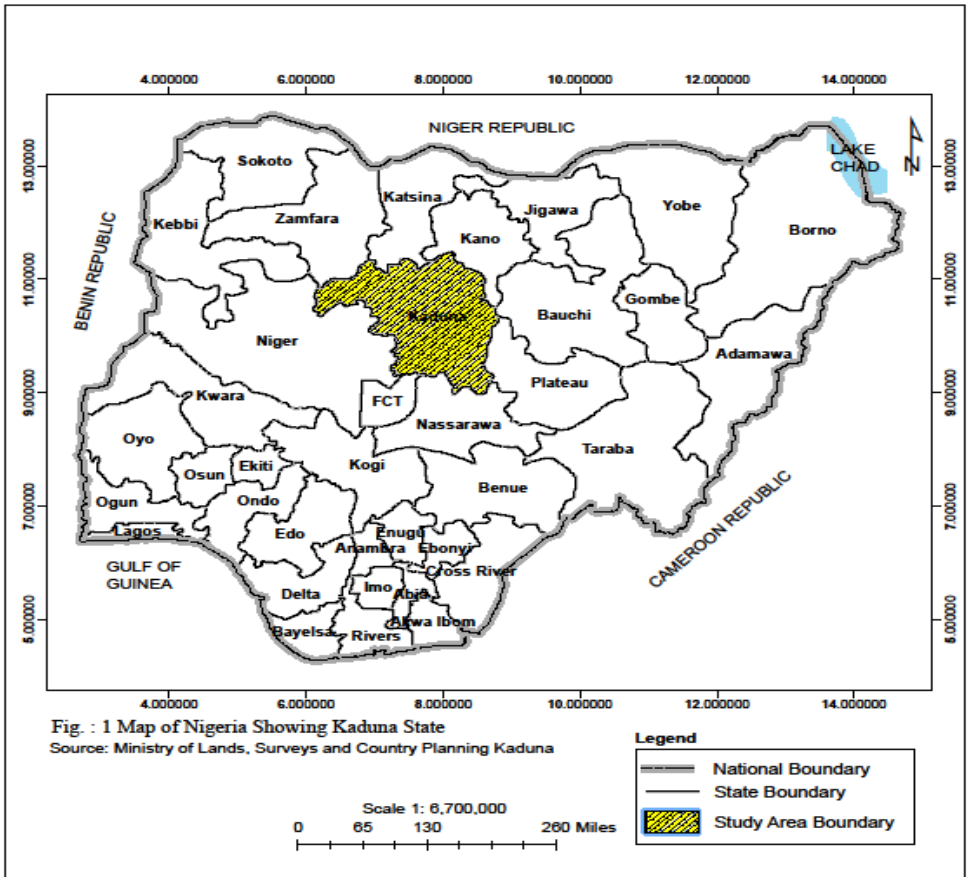

Fig. : 1 Map of Nigeria Showing Kaduna State
Source: Ministry of Lands, Surveys and Country Planning Kaduna

Figure 1: Study Area

The climate is dominated by the influence of the relative warm and moist tropical maritime (mT) air mass, which originates from the Atlantic Ocean associated with Southwest winds in Nigeria; and the relatively cool, dry and stable tropical continental (cT) air mass that originates from the Sahara Desert and is associated with the dry, cool and dusty Northeast Trades known as the Harmattan (Odekunle, 2010). These two air masses (mT and cT) meet along a slanting surface called the Intertropical Discontinuity (ITD). The movement of the ITD northwards across northern part of this zone in August (around latitude 21 to 22°N) marks the height of the rainy season in the whole zone while its movement to the southernmost part around January/February (approximately at 6°N) marks the peak of the

dry season in the zone (Abaje *et al*, 2017). The movement of the ITD is very irregular, varying according to the season from 2° to 5.6° of latitude per month, and the southward retreat of the ITD is faster than its northward advance. While the northward advance is at the rate of about 160 km per month, that of the southward retreat is at about 320 km per month (Ayoade, 2005). This accounts for the rather gentle onset of the rainy season in the zone and its rather abrupt end (Abaje, 2016). The highest average air temperature normally occurs during the hot season (March to May) while the lowest average air temperature occurs during the cold season (December to February) (Abaje *et al*, 2017).

The geology of the study area is underlain by gneisses, migmatites and metasediments of the Precambrian age which have been intruded by a series of granitic rocks of late Precambrian to lower Palaeozoic age (Kowal and Knabe, 1972). More than half of the region is covered by ferruginous tropical soils which are mostly formed on granites and gneiss parent material, and on aeolian and many sedimentary deposits (Kowal and Knabe, 1972; Abaje, 2016). The whole State is covered by savanna vegetation consisting of Guinea savanna, Sudan savanna, and Sahel savanna with the density of trees and other plants decreasing as one moves northwards (Abaje *et al,* 2017).

3. MATERIALS AND METHODS

The research was based on secondary data. Cowpea production data (yield/hectare) covering a period of thirty years (1987-2016) was obtained from the National Bureau of Statistics (NBS), Abuja, and National Agricultural Extension and Research Liaisons Service (NAERLS), Zaria, Kaduna State, while monthly rainfall data for the same period was obtained from the archive of the Nigerian Meteorological Agency (NiMet) (Table 1).

Table 1: Meteorological Station, Kaduna

Stations	Station No.	Latitude	Longitude	Altitude	Period	No. of years
Kaduna	1007.34	10°36′N	07°27′E	644.96m	1987-2016	30

Source: Nigeria Meteorological Agency (NiMet).

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) was used to test for the annual rainfall series for the station. The standardized coefficient of Skewness (Z_1) was calculated using:

$$Z_1 = \left[\left(\sum_{i=1}^{N} (x_i - \bar{x})^{3/N} \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^{2/N} \right)^{3/2} \right] \Big/ \left(6/N \right)^{1/2} \text{ ----------equation (1)}$$

and the standardized coefficient of Kurtosis (Z_2) was determined by:

$$Z_2 = \left[\left(\sum_{i=1}^{N} (x_i - \bar{x})^{4/N} \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^{2/N} \right)^{2} \right] - 3 \Big/ \left(24/N \right)^{1/2} \text{ ----------equation (2)}$$

Where $\bar{x}$ is the long term mean of x_i values, and N is the number of years in the sample. These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. If the absolute value of Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at 95% confidence level.

Trend analysis of temperature, rainfall and cowpea were carried out using Microsoft Excel Tool (2013). Similarly, the relationships between rainfall and the yield of cowpea, and also temperature and yield of cowpea in the study area were tested using bivariate correlation analysis. This is represented as:

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2}\sqrt{\sum (y-\bar{y})^2}}$$ ----------equation (3)

r = Correlation coefficient

Where: x and y = individual observations of dependent and independent variables respectively

$\bar{x}$ and $\bar{y}$ = Mean of dependent *(x)* and independent *(y)* variables respectively.

The cowpea yields value was used as dependent variables and rainfall and temperature values respectively as the independent variable.

4. RESULTS AND DISCUSSION

4.1 General Statistics of Rainfall and Temperature Data

The general statistics of rainfall and average temperature of Kaduna (1987-2016) is presented in Table 2. The results of the standardized coefficient of Skewness (Z_1) and Kurtosis (Z_2) for the station was accepted as normal at 95% confidence level. Therefore, no transformation was made to the rainfall and temperature series.

Table 2 General Statistics of the Rainfall and Average Temperature of Kaduna (1987-2016)

Statistics	**Rainfall (mm)**	**Temperature ^oC**
Skewness (Z_1)	0.23	0.21
Kurtosis (Z_2)	-0.38	0.88
Standard Deviation	207.2	0.43
Range	787.4	2.05
Minimum	848.9	24.9
Maximum	1636.3	27.0

Source: Fieldwork (2017).

The minimum amount of rainfall (848.9 mm) was recorded in 2008 while the maximum amount (1636.3 mm) was recorded in 2013. The standard deviation was 207.2 which is an indication of high rainfall variability in the study area. On the other hand, the study area recorded its annual minimum temperature of 24.9^{o}C in 1989 while the maximum temperature (27.0^{o}C) was recorded in 2009.

4.2 Trends of Rainfall, Temperature and Cowpea Yield.

The result of the trend analysis of annual rainfall and annual cowpea yield is presented in Figure 2. The result shows that cowpea yields appear to be influenced by rainfall during the study period. The linear trend lines for both rainfall and cowpea yield showed an increasing trend. The increasing rainfall trend is in agreement with the result of Abaje *et al* (2012) that most of the synoptic stations in northern Nigeria have been witnessing increasing annual rainfall in recent years.

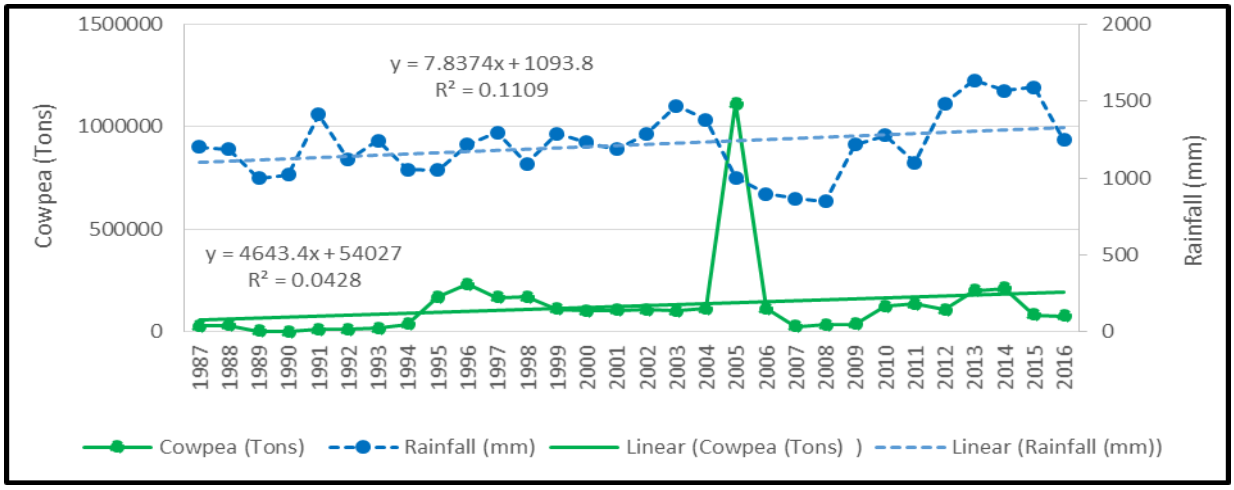

Figure 2: Trends of Rainfall and Cowpea (1987-2016)

The result of the trend analysis of average temperature and annual cowpea yield is presented in Figure 3. The result also shows that cowpea yields appear to be influenced by temperature during the study period. The linear trend lines for both the average temperature and annual cowpea yield showed an increasing trend. The increasing temperature in recent years concurs with the findings of Abaje, Ishaya and Abashiya (2016) using temperature data spanning a period of fourty years (1975-2014).

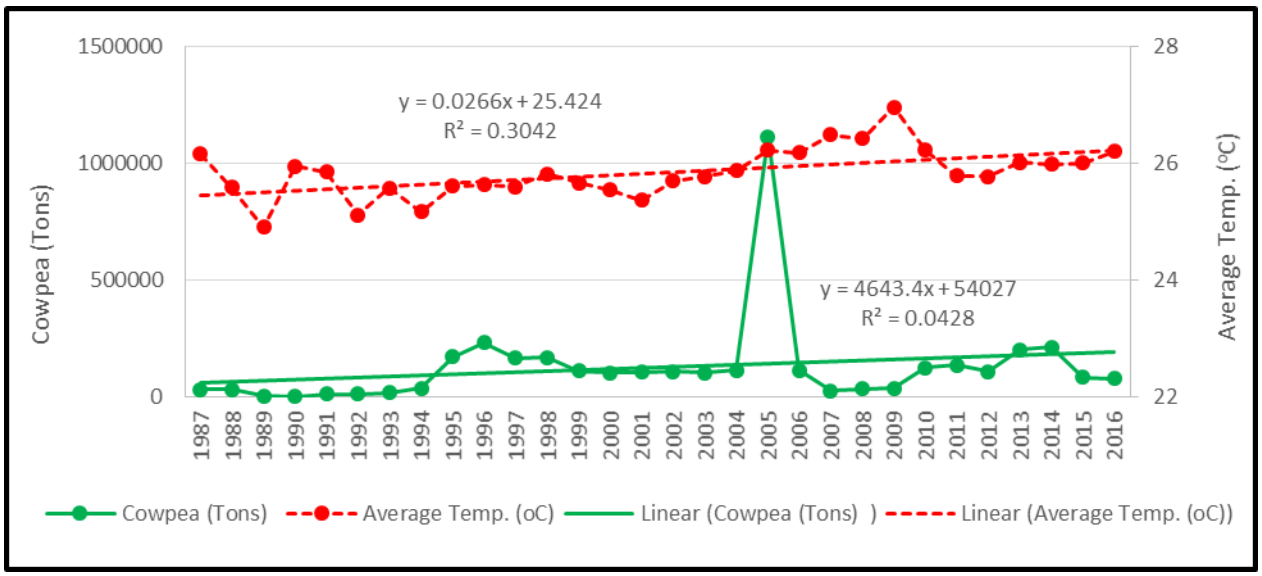

Figure 3: Trends of Average Temperature and Cowpea (1987-2016)

4.3 Relationships between Climate Data (Rainfall and Temperature) and Cowpea Yield. Table 3 and 4 provides the correlation coefficient of annual rainfall and cowpea yields and, average temperature and cowpea in Kaduna State respectively (1987-2016).

Table 3: Statistical Summary Output

Correlation Statistics						
Multiple R	0.055729					
R Square	0.003106					
Adjusted R Square	-0.0325					
Standard Error	200756					
F	0.08723					
Observations	30					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	190591.3	221747.7	0.859496	0.397366	-263638	644821
Rainfall (mm)	-53.1515	179.9628	-0.29535	0.769908	-421.789	315.4856

The correlation analysis indicates the t- ratio for the average rainfall is 0.29535 with an associated P-value of 0.769908. This information reveals there is no significant correlation between average rainfall and yield of cowpea in Kaduna state. Similarly, the coefficient of determination (R^2) is 0.003106 or 0.31% indicating positive (but, weak) relationship between averages annual rainfall and yields of cowpea in the study area. This findings could result in cowpea yield reduction in Kaduna state, which could be severe. This may limit cowpea production and could bring untold hardship to farmers in the study area.

Table 4: Statistical Summary Output

Correlation Statistics						
Multiple R	0.166792491					
R Square	0.027819735					
Adjusted R Square	-0.006900989					
Standard Error	198251.9299					
F	0.801243					
Observations	30					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1876777.93	2237729	-0.8387	0.408742	-6460557	2707001
Average Temp.	77517.70299	86600.18	0.895122	0.378353	-99874.7	254910.1

The results shows that the t- ratio for the average temperature is 0.895122 with an associated P-value of 0.378353. This information reveals that there is no significant correlation between average rainfall and yield of cowpea in Kaduna state. Similarly, the coefficient of determination (R^2) is 0.027819735 or 27.81% indicating positive (but, low) relationship between averages temperature and yields of cowpea in the study area. This implies that, areas suitable for cowpea production could be negatively affected by this low relationship, particularly, the yield potentials of cowpea in the study area could decrease further.

Thus, the relationship between annual rainfall and yields of cowpea is weak. In addition, the relationship between average temperature and yields of cowpea is also low. It is could be said that rainfall and temperature have some impact on the yield of cowpea. Low or weak relationship experienced in the study area could be as a result of the changing climatic conditions in the study area. This finding is in agreement with the result of FAO (2017) that

although higher temperatures can improve crop growth, studies have documented that crop yields decline significantly when daytime temperatures exceed a certain crop-specific level. Ayanwuyi *et al* (2010) also reported that temperature, water vapour, rainfall are all factors that have effects on cowpea outputs at any stage from cultivation through the final harvest. Similarly, Oyiga, Mekbib and Christine (2011) reported that crop production in Sub-Saharan Africa is directly affected by many aspects of climatic change stemming primarily from average temperature increase and change in rainfall amount and patterns.

5. CONCLUSION

In Northern Nigeria, Kaduna State in particular, there are fluctuations in cowpea yield. As a whole, yields of cowpea indicated a low or weak relationship when correlated with annual rainfall and average temperature. Thus, it could be concluded that, this weak or low relationships could be attributed to the effects of climate change conditions in the study area. In view of this, there is need for the development of a comprehensive agricultural and climate change policy that takes into account the risks associated with cowpea yield among farmers. Therefore, Government policies in this area should be based on recent rainfall and temperature trends. This will enhance cowpea production in Kaduna State and Northern Nigeria at large.

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