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Climate Change in Extreme Northern Nigeria: Evidence from Rainfall Trend in Sokoto State

Adamu Ahmed, Ma'aruf Murtala*

Department of Geography,
Jigawa State College of Education
P.M.B. 1002,
Gumel Jigawa State
Email: maarufmurtala@gmail.com

Abstract
Studies over the years have shown there are many indicators that can be used to assess the evidence of climate change in a region. Some of these indicators include decreasing rainfall amount in the continental interiors and increasing rainfall in the coastal areas. Thus, this study focuses on climate change in Northern Nigeria: evidence from Rainfall trend in Sokoto State. In order to achieve this, rainfall data for Sokoto from 1956 to 2015 was used. Standardized coefficient of Skewness and Kurtosis for the meteorological station was employed to test the normality of the data. In order to examine the trend, 10-year running mean and linear trend lines were calculated and plotted using Microsoft Excel Statistical tool (2016). The rainfall series was also sub-divided into 10 years non-overlapping sub-periods and Cramer's test was then used to compare the means of the sub-periods with the mean of the whole record period. The result revealed that rainfall amount is generally increasing (Y=0.5775X+633.81) in the study area in recent years at the rate of 0.0047% per annum and that the amount is fluctuating. The study recommends that more opportunities should be provided by the government for professionals to study and develop realistic methods for utilization of ground water without socio-economic concerns, as well as managing flood events. In such a case, it would be possible to counter drought and flood crises occurrence in the study area and other areas having the same climatic conditions.

Keyword: Cramer's test, rainfall, climate change, sub-periods and trend

INTRODUCTION
Climate change refers to some observable variations in the climate system that are attributable to human (anthropogenic) activities, especially those that alter the atmospheric composition of the earth and ultimately lead to global warming (Ozor *et al.*, 2010). Intergovernmental Panel on Climate Change [IPCC] (2007) defines climate change 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, which persists for an extended period typically decades or longer. The most crucial thing about the concept of climate change is not only the time involved but also the degree of variability that the change is subjected to (Ayoade, 2003).

Evidence shows that climate change is increasing rainfall variability and the frequency of extreme events such as drought, floods, and hurricanes (IPCC, 2007). It was predicted that Africa is likely to warm across all seasons during this century with annual mean surface air temperatures expected to increase between 3^0C and 4^0C by 2099, roughly 1.5 times the average global temperatures (Boko et al, 2007). Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5-20 percent from December to

**Author for Correspondence*

February, and decrease rainfall by 5-10 percent from June to August by 2050 (Hulme *et. al.* 2001; IPCC, 2007). Fluctuations of climatic elements, particularly rainfall in northern Nigeria is not new especially in the northwestern ecological zone which comprises the northern Guinea, and Sudan-Sahel ecological zones of West Africa (Asiedu, 1992; Abdulkarim, Oladipo & Balarabe, 2015).

Rainfall variability is a major characteristics of the Sahelian climate, the last 40 years (since 1969) have witnessed dramatic reductions in mean annual throughout the region (Diop, 1996; Le-Barbe & Lebel 1997; Ekpo, 2007; Camberlin & Diop, 2003; Giannini, Saravanan & Change, 2003 and Dai *et al.,* 2004). According to IPCC (2001) a rainfall decrease of 29-49 percent has been observed in the 1968-1997 period compared to the 1931 – 1960 baseline period within the Sahel region. In Northwest zone of Nigeria, particularly, rainfall shows a vivid effect on agriculture. Rain is essential to agriculture because without water no plant can survive. Thus, a regular rainfall is essential for healthy plants, too much or very little rainfall can harm plants and agriculture. Extreme weather events have attracted considerable attention in recent years because of the large losses of life as well as tremendous increase in economic losses caused by such extreme events (Easterling *et al.,* 2000).

Available literature on Nigeria shows the existence of spatial differences in the nature of disasters (Daura, 2014). While oil and gas pollution is largely a Niger Delta problem, drought and quelea birds infestation occur in the Northern States [National Emergency Management Agency], NEMA (2012). Several studies in the Northern region have indicated that the onset of the raining season is highly variable and unpredictable (Ati, 1996; Iguisi 1996). One of the several hypotheses put forth to explain the decline of rainfall in West Africa and Nigeria in particular is the reduced northward excursion of the Inter-Tropical Discontinuity (ITD) during the raining season (Odekunle, Andrew and Aremu, 2008). In addition, Odekunle (2006) noted that the displacement of ITD south of its normal position would result in drier years. The ITD is situated well to the north of West Africa in July and August thereby allowing Nigeria to be totally under the influence of Tropical Maritime Air mass (Hassan and Abdulhameed, 2012). In agreement with these views, (Traore et al, 2000) concluded that a reduced summer incursion of ITD would correspondingly result in a decrease in the Sahelian rainfall.

Sokoto State is located in the semi-arid region, where desertification is intensifying and rainfall unreliable for crop production (Odjugo and Ikhuoria, 2003). With further significant variations in the climate of the Sahel being predicated by the General Circulation Models (GCMs), it is important that scientific studies be undertaken at regional level so as to provide society with accurate information on the real and potential impacts of extreme climate variability, as well as, the mitigation and adaptation options available. At a time when the world is grappling with diverse environmental problems including global warning, ozone depletion, acid rain, killer hurricanes, destructive thunderstorms, recurrent drought and major flood episodes, any effort at finding explanations to these and other problems should be quite significant, since the environmental, social and economic cost of extreme climatic variability is bound to be enormous from the standpoint of society and human activity. This study therefore examined climate change in Sokoto State, Northern Nigeria: evidence from Rainfall trend.

STUDY AREA

Sokoto State of Nigeria is located in the extreme Northern western parts of Nigeria between Latitudes 11^{o} 03'N and 13^{o} 50'N and Longitudes 4^{o} 14'E and 6^{o} 40'E (Abubakar, 2006). The area so defined covers a land area approximately 27,825km^2. It shares borders with Niger Republic in the northern part, Kebbi State in the Western and Southern parts, and Zamfara State to the East (Figure 1).

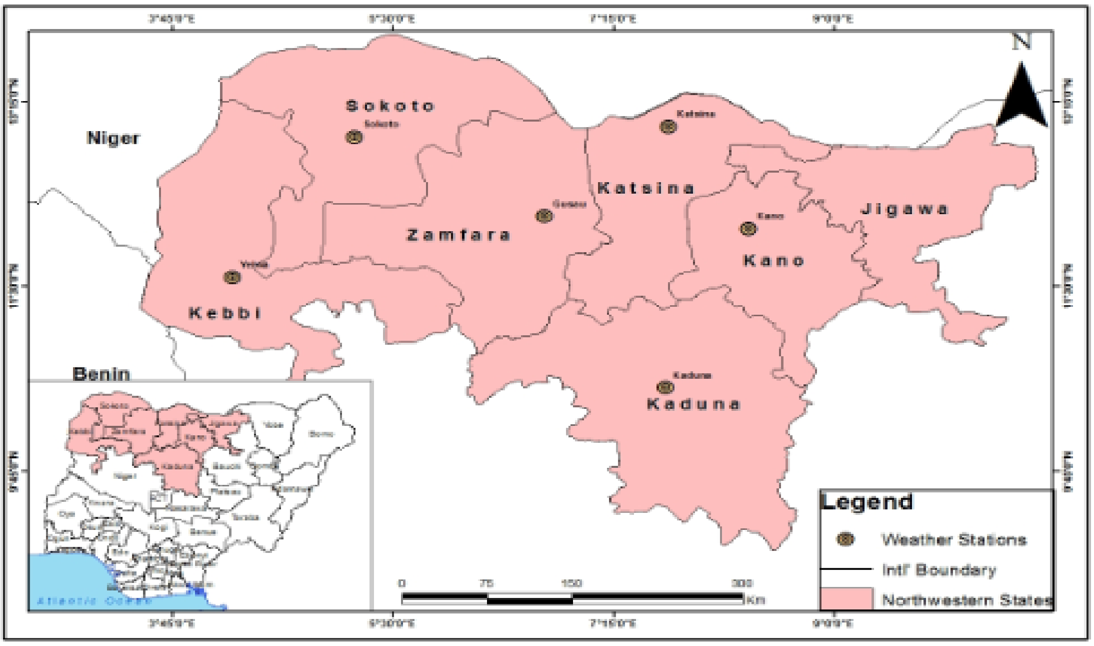

Figure 1: Study Area

The climate of the study area is the tropical wet-and-dry type (Koppen's Aw climate type). The wet season starts 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, 2016). In the study area, the annual average rainfall varies. The rainfall intensity is very high between the months of July and August (ranging from 60mm hour^{-1} to 70mm hour^{-1}) (Abaje, Sawa, Iguisi and Ibrahim, 2015). The highest temperatures are experienced about April while minimum temperatures are usually in December. Maximum temperature could be as much as 40.6^{0}C while the minimum could be as little as 12.8^{0}C. Sokoto state has humidity values of 20% in April and the diurnal values could fall from 30% a down to 10% in the afternoon. This is characteristics of the harmattan season when the dry and dust-laden North-East trade winds are blowing from the Sahara under cloudless but dusty conditions. The variations in humidity also reflect variations in temperature (Murtala, Iguisi, Ibrahim, Yusuf and Inobeme, 2018).

MATERIALS AND METHODS

Data Collection

Monthly rainfall data for period of 60 years (1956-2015) was obtained from the archive of Nigerian Meteorological Agency. The data was collected for synoptic station (1205.51) namely Sokoto in the Northern Nigeria (Table 1). This station was selected because it was a synoptic station in the drought prone region of the country (Murtala, Iguisi, Ibrahim, Yusuf and Inobeme, 2018) and it equally satisfied the general criteria used by the European Climate Support Network [ECSN] (2014) that: data must be available for at least 40 years, missing data must not be more than 10% of the total, missing data from each year must not exceed 20%, more than three months consecutive missing values are not allowed, and lastly, the data were tested and found to be normally distributed.

Table 1: Meteorological station in Sokoto

Station	Station No.	Latitude	Longitude	Altitude	Period	No. of years
Sokoto	1205.51	12°55′N	05°12′E	309.00m	1956-2015	60

Source: Nigeria Meteorological Agency (NIMET).

Data analysis

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by (Brazel & Bailing, 1986) was used to test for the normality in the seasonal (May to October) rainfall series for the station. These are the months during which most of the region receives over 85% of their annual rainfall totals (Murtala, Iguisi, Ibrahim, Yusuf and Jonathan, 2018). The standardized coefficient of Skewness (Z_1) was calculated using:

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

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

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

where $\bar{x}$ is the long term mean of x_i values, and N is the number of years in the sample. 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.

To examine the nature of the trends in the rainfall series, 10-year running mean was calculated and plotted using Microsoft Excel Statistical tool (2016). This was used to smoothing the time series. Linear regression was also used to determine the linear trends of the rainfall for the station. It was computed as:

$$y = a + bx \quad \text{................................…… 3}$$

Where a the intercept of the regression line on the y-axis; b is the slope of the regression line. The rainfall series was sub-divided into non-overlapping sub-periods (1956-1965, 1966-1975 through to the last sub-periods 2006-2015). Cramer's test adopted by Lawson, Balling, Peters and Rundquist, (1981) was then used to compare the means of the sub-periods with the mean of the whole record period. In applying Cramer's test, the mean **(** $\bar{x}$ **),** and the standard deviation (δ), were calculated for each station in the study area for the total number of years (*N*), under investigation. The purpose of this statistic was to measure the difference in terms of a moving *t*-statistic, between the mean **(** $\bar{x}k$ **),** for each successive n-year period and the mean ($\bar{x}$) for the entire period. The t-statistic is computed as:

$$t_k = \left(\frac{n(N-2)}{N - n(1 + \tau_k^2)} \right)^{1/2} \tau_k \quad \text{..................................... 5}$$

where τ_k is a standardized measure of the difference between means given as:

$$\tau_k = \frac{\bar{x}k - \bar{x}}{\delta} \quad \text{...................................….. 6}$$

where $\bar{x}$k is the mean of the sub-period of n–years, $\bar{x}$ and δ are the mean and standard deviation of the entire series respectively, and t_k is the value of the student *t*–distribution with *N*–2 degrees of freedom. This is then tested against the "students" $t-$distribution table at 95%

confidence level appropriate to a two-tailed form of test. When t_k is outside the bounds of the two-tailed probability of the Gaussian distribution (equal to 1.96 at 95% confidence level), a significant shift from the mean is assumed.

RESULTS AND DISCUSSION

Rainfall Normality

The results of the Standardized Coefficient of Skewness (Z_I) and Kurtosis (Z_2) for the station are presented in Table 2. The results of Z_1 and Z_2 of data for the stations revealed that the rainfall data of the station was normally distributed at 95% confidence level. Therefore, no transformation was made to the rainfall series.

Table 2: Standardized Coefficients of Skewness and Kurtosis for the Meteorological Stations

Statistics	Sokoto
Mean($\bar{x}$)	651.43
Standard Dev. (δ)	146.74
Skewness (Z_1)	0.74
Kurtosis (Z_2)	1.19
Minimum Value	373.2
Maximum Value	1150.6

*Significant at 95% confidence level

Annual rainfall trend and fluctuation

Figure 2 shows the graphical presentation of the annual rainfall trend and for the station smoothened out with the 10-year running mean. Generally, the 10-year running mean for the station was above the long-term mean from the early 2000s to the end of the study period. The results in Figure 2 reveal year 2010 was the wettest year in the study area within the study period. Similarly, the linear trend line for the station generally shows an increasing trend (Y=0.5775X+633.81). It is therefore clear from the results of the 10-year running mean and the linear trend line that the rainfall has been increasing in recent years at the rate of 0.0047% per annum.

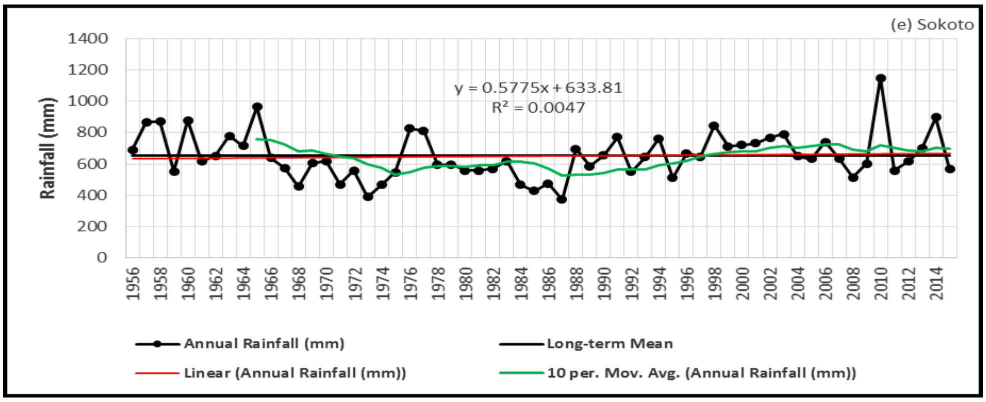

Figure 2: Rainfall Trends in Sokoto

The result of Cramer's test for variability in the 10-year non-overlapping sub-period of annual rainfall in the station was presented in Table 3.

Table 3: Variability in 10 year non-overlapping sub-period analysis of rainfall (Cramer's Test)

Sub-period	Sokoto
1956-1965	2.01*
1966-1975	-2.15*
1976-1985	-1.08
1986-1995	-1.09
1996-2005	1.38
2006-2015	1.02

*Significant at 95% confidence level

The results revealed two significant cases at 95% confidence level in all. There were two significant cases in the sub-periods 1956-1965 and 1966-1975 while, the sub-period (1956-1965) was significantly wetter and above the long-term mean. It could also be observed from the results (Figure 2 and Table 3) dominance of positive Cramer's test (t*k)* in the last two decades of this study. Besides, the sub-period 1966-1975 had statistically significant negative case for Sokoto while, the sub-periods 1976-1985 and 1986-1995 all had negative cases as well. These negative cases were significantly drier at 95% confidence level than the long-term condition as indicated by their negative t*k* values. Thus, it could be observed from these sub-periods, that the periods 1956 -1965, 1996-2005 and 2006 -2015 are wet years. On the other hands, the periods 1966-1975, 1976-1985 and 1986-1995 are dry years in the study area. Interestingly, this period coincided with the droughts of the 1970s and 1980s that ravaged the northern part of the country. This finding agrees with previous studies conducted by Oladipo (1993) and Easterling *et. al*. (2000) that a long run of dry years since the early 1970s has also been confirmed for the zone. Nicholson, Some and Kone (2000) observed that a critical examination of the last two sub-periods (1996-2005 and 2006-2015) revealed that all the *tk* values were positive. This implies that rainfall in the Sokoto is increasing in recent years. This is in agreement with studies conducted by Odekunle and Adejuwon (2006), Adefolalu (2007) and Ati, Stigter, Iguisi & Afolayan (2009) that the late 1990s have been witnessing increasing annual rainfall totals. This supports the facts that climate change in the study area is changing.

CONCLUSION AND POLICY RECOMMENDATION

Different statistical methods were used to portray temporal trend of rainfall in the Sokoto. The 10-year running means and the linear trends generally showed that rainfall amount is increasing in recent years. The non-overlapping sub-period analysis also revealed that the last two sub-periods (1996-2005 and 2006-2015) have witnessed increase in rainfall. Thus, this study recommends that more opportunities should be provided by the government for professionals to study and develop realistic as well as managing flood events. In such a case, it would be possible to counter drought and flood crises occurrence in the northwestern zone and other areas having the same climatic conditions.

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