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Rainfall and Temperature trends in Samaru and Minjibir, Northern Guinea and Sudan Savannas of Nigeria

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Abstract

The changing trend of rainfall and temperature has been shown to vary in magnitudes in different regions of the globe and this has raised a lot of concerns with regards to the changing climate. This study investigated the rainfall and temperature trends from data collected from two research centers located in Samaru, Zaria (11º 11'N; 7º38'E and Minjibir, Kano (11º59'N; 8º 34'E), both in the northern Guinea and Sudan Savannas of Nigeria respectively. Mean annual rainfall from 1968 to 2017 was 1015.9 mm in Samaru and shows a trend of later onset and early cessation. In Minjibir, mean annual 744.5mm of rainfall (1975 -2017) whose onset was almost the same for the years studied, show a trend of early cessation. Standardized rainfall anomaly was experienced in 43% of years between late 1960's to early 1990's with varying degrees of drought from moderate to severe, while conditions of no drought to extreme wetness was observed from 2000's till date with exception of few years. Similar trend was observed in Kano, with 39% of the years in the 1970's to 1990's with moderate to severe droughts, with no drought in the years from 2000's till date. An increasing trend at the rate of 0.61ºC and 0.34ºC at Samaru and 0.67ºC and 0.76ºC at Kano for the maximum and minimum temperatures respectively was experienced, with mean minimum temperatures of 17.2 ºC in 1995 (the lowest recorded from 1968) and 20.9 ºC in 2013 in Samaru. Mean maximum temperatures were 29.5 ºC in 1970 and increased to 34.5 ºC in 2017 in Samaru, while the highest mean maximum temperature was 35.4 ºC recorded in 2011 for Minjibir. These results show the climatic cycles for rainfall and drought events and the increasing global temperatures, confirming a changing climate. Mitigation and adaptation strategies in these agroecological zones and the globe in general remain a crucial option to the consequences of climate change.

Key words: Climate change, northern guinea savanna, Sudan savanna, drought

Introduction

The global climate has changed rapidly with the global mean temperature increasing by 0.7^{0}C within the last century with the rates of change being significantly different among regions (IPCC 2007). This is primarily due to the varied types of land surfaces with different surface albedo, evapotranspiration and carbon cycle affecting the climate in different ways (Nicholson and Nicholson, 1993). Increasing flood risk is now being recognized as the most important sectoral threat from climate change in most parts of the Savanna region. Druyan (2011) notes that since the 1990s seasonal rainfall over the Sahel have somewhat recovered but not to the levels of the 1950s. Several studies have adduced extreme rainfall to be the major cause of flood worldwide. Such studies include Bunting et al. (1976), Folland et al. (1986) and Odekunle (2001). Other studies have identified the characteristics of extreme rainfall that are associated with flood frequency to include duration, intensity, frequency, seasonality, variability, trend and fluctuation (Olaniran,1983). Adefolalu (1986) studied the rainfall trends for periods of 1911–1980 over 28 meteorological stations in Nigeria with 40 years moving average showing appearance of declining rainfall. New (2006), showed evidence of increase in dry spell durations and rainfall intensity with observed trends for temperature extremes more apparent than precipitation.

In this study, records of rainfall and temperature are considered because among all the climatic elements, rainfall is the most variable element in northern Nigeria, both temporally and spatially and such variations can have significant impacts on economic activity (Adefolalu, 1986; Ekpoh, 1991; Mortimore and Adams, 2001, Ekpoh and Ekpenyong, 2011), while temperature though not variable in this ecological zone, measurements showed that averaged over the globe, the Earth's surface has warmed by about 0.8ºC (with an uncertainty of about ±0.2ºC) since 1850.The mean air temperature in Nigeria between 1901 and 2005 was 26.6ºC while the temperature increase for the 105 years was 1.1ºC (Odjugo, 2007). This is obviously higher than the global mean temperature increase of 0.8 °C recorded since 1850 when actual scientific temperature measurement started (Spore 2008; IPCC 2007). Thus, in this study, both rainfall and temperature are analyzed in terms of changes in their statistical descriptors.

Although Samaru and Kano areas are vulnerable to extreme weather events, there is still a lack of reliable information about how future changes in temperature and precipitation regimes will affect them. This brings about the need for more scientific work that can reduce the current knowledge gap for the future climate in order to make investments in agriculture and other weather-dependent livelihoods inherently less risky.

It is against this background that this study focuses on the trends of rainfall and temperature in the study areas. The aim of this study was to analyze the variability in rainfall and temperature at annual and seasonal timescales and examine vulnerability of the areas to these two key meteorological variables. The specific objectives were to: i) examine local scale rainfall and temperature variability and trends by using a relatively long historical data from Samaru and Kano stations, and ii) assess the recent behaviour and relationships of rainfall and temperature in a changing climate.

Materials and Methods

Study area

The study_comprises two research centers of the Institute for Agricultural Research, Samaru, Zaria and Minjibir in Kano located in northern Guinea and Sudan Savanna of Nigeria, respectively (Fig. 1). Samaru station is found between latitude 11º 11'N; and longitude 7º 38'E and Minjibir is located between latitude 11º 59'N and longitude 8º 34'E. The climate of these locations are essentially influenced by the two dominant air masses affecting the entire ecological zone vis-à-vis the tropical continental air mass (cT) which is dry and dusty, originating from the Sahara Desert and the warm tropical maritime (mT) air mass originating from the Atlantic Ocean. The zone demarcating these two air masses, known as the Inter Tropical Convergence Zone (ITCZ) is what principally determines the influence of both air masses, the interplay of which gives rise to the two distinct seasons as dry and wet seasons on this region.

The rainfall pattern in the two locations is uni-modal, with the wet or rainy season starting around mid-May in Samaru and around mid-June in Kano. The season ends about middle of October in Samaru area and early October in Kano. On average, the dry season lasts for about seven month from October to May and October to June in Samaru and Minjibir, respectively (Kowal and Knabe, 1972).

Samaru is one of the most conducive places in the northern Savanna with an annual mean temperature of about 27.5^{0}C over fifty years. The area has an average relative humidity of 36.0% during the dry season and 78.5% for the wet season (NCAT, 2008). Minjibir on the other hand, has an average annual temperature of about 32^{o}C while the average relative humidity for the dry and wet season periods are 35% and 76% respectively. The warmest months of the two locations are April and May when the daytime temperatures can exceed 38^{o}C and 40^{o}C respectively (Anosike, 1999).

Data sources and methods of analysis

The data used for the study were historical rainfall and temperature records of Samaru and Minjibir spanning 1968 – 2017 (50 years) and 1973 – 2017 (45 years) respectively. The data were collected from the Meteorological unit of the Institute for Agricultural Research of Ahmadu Bello University, Zaria, Nigeria.

Various methods of data analysis were employed in the study. Analysis of the data involved characterizing long-term mean values, and calculation of indices of variability and trends at monthly, seasonal and annual time steps. The coefficient of variation (CV) and the Precipitation Concentration Index (PCI) were used as statistical descriptors of rainfall variability. The PCI values were calculated as given by Oliver (1980); PCI = $100*[\Sigma Pi^2/ (\Sigma Pi)^2]$Where *Pi* is the rainfall amount of the ith month; and *Σ*= summation over the 12months. According to Oliver (1980), PCI values of less than 10 indicate uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration, and values of 21 and above indicate very high concentration.

Standardized anomalies of rainfall were calculated and used to assess frequency and severity of droughts, as in Agnew and Chappel (1999); $S = [Pt - Pm]/ \sigma$.Where, *S* = standardized rainfall anomaly.
Pt = annual rainfall in year *t*.
Pm = long-term mean annual rainfall, over a given period of observation.
σ= standard deviation of rainfall over the period of observation.
The drought severity classes are extreme drought ($S < -1.65$), severe drought ($-1.28 > S > -1.65$), moderate drought ($-0.84 > S > -1.28$), and no drought ($S > -0.84$).

Results and discussions

The rainfall data collected from the study areas were processed and subjected to trend analysis. The summary of the trends of the rainfall and temperature characteristics studied and the analysis of climatic data are presented in Tables 1 and 2.

Table 1: Summary of the trend of rainfall characteristics studied

S/No.	Climatic Elements	Samaru	Kano
1.	Annual rainfall	Increasing	Increasing
2.	Onset date of rains	Increasing	Increasing
3.	Cessation date of rains	Decreasing	Decreasing
4.	Length of rainy season	Decreasing	Decreasing
5.	Annualmaximum temperature	Increasing	Increasing
6.	Annual minimum temperature	Increasing	Increasing
7.	Standardized rainfall anomaly	Increasing	Increasing
8.	Precipitation concentration index	Highly concentrated	V. highly concentrated

Table 2: Summary of analysis of climatic data

S/No.	Variable	Samaru	Kano
1.	Mean annual rainfall (mm)	1015.9	744.5
2.	Coefficient of variation (%)	15.2	22.6
3.	Mean onset date of rain	21-May	4-Jun
4.	Mean cessation date of rain	7-Oct	20-Sep
5.	Precipitation concentration index	18.9	22.6
6.	Mean maximum temperature (°C)	29.7	33.9
7.	Mean minimum temperature (°C)	13.3	19.9

Annual Rainfall

Annual rainfall data show increasing trend in the two study areas. The trends of annual rainfall in both stations showed an upward trend at the rate of 3.7mm per year for Samaru and 5.5mm per year for Kano stations. (Figs. 1a and b). Previous studies on climate change in this ecology Oluwasemire and Alabi (2004) and Oruonye (2014 a, b) shows that the rainfall decreases from south to north as annual rainfall decreases with increase in latitude. Rainfall averages in the study area for the period 1968 to 2017 is 1015.9mm (Table 1a) and 1973 - 2017 is 744.5mm (Table 1b) for Samaru and Kano respectively.

In the two stations, lower rainfall amount of below 1000mm were recorded in about 90% of the years from 1980 to 1996 for Samaru while below 800mm were recorded for the period 1979 to 1999 for Kano. This agrees with findings of Ati *et al*., 2007.

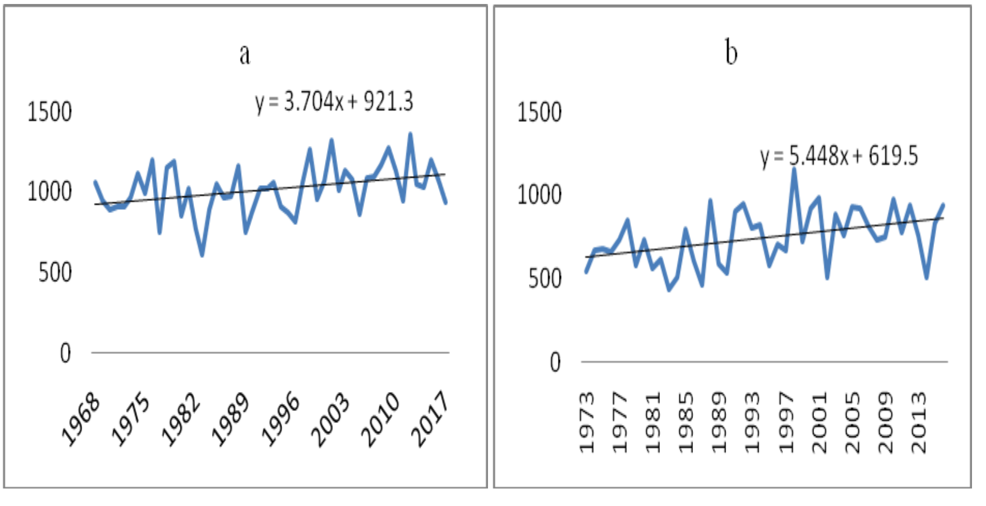
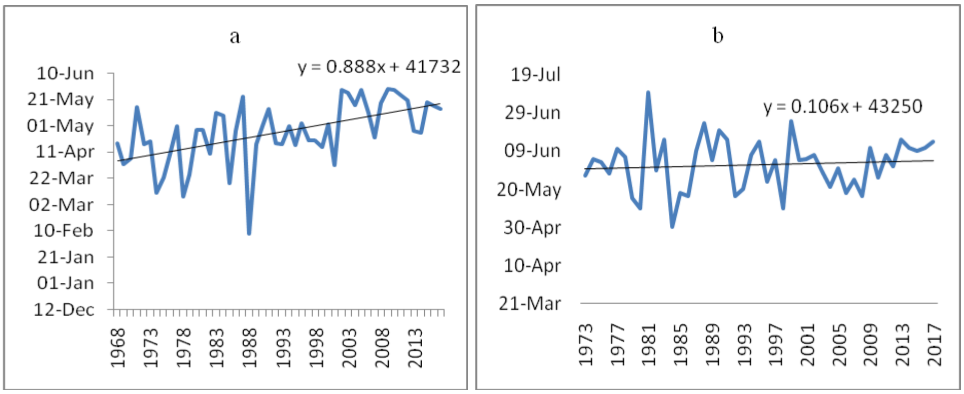


Fig.1: a. Samaru Total Annual Rainfall and b. Kano Total Annual Rainfall

Rainfall Onset and Cessation

Rainfall Onset is not the first day the rain falls (Adebayo and Oruonye, 2013), for agricultural purpose, it refers to the time a place receives an accumulated amount of rainfall sufficient for the growing of crops. Omotosho *et al* (2000) define onset of rains in Nigeria as the beginning of the first two rains totaling 20 mm or more, within 7 days, followed by 2 to 3 weeks each with at least 50% of the weekly crop water requirement. Rainfall cessation on the other hand, refers to the termination of the effective rainy season. It does not imply the last day rain fell, but when rainfall can no more be assured (Adebayo and Oruonye, 2013). Omotosho *et al* (2000) defined the rainfall cessation as any day from 1 September after which there are 21 or more consecutive days of rainfall less than 50% of crop–water requirement. The 50% crop–water requirement being 5 mm for Samaru as given by Kowal and Knabe (1972).

The result from this study shows that the two study areas are experiencing upward trends of onset dates which can conveniently be interpreted as increasing late onset of rain (Table 1 and Figs. 2a and b). This indicates that the rain is starting late and hence the beginning of growing season is being delayed in the study area. This was reported in previous studies by Oluwasemire and Alabi (2004), Adebayo (2012), Yamusa *et al*., (2013) and Oruonye (2014 a,b). The result also exhibits a downward trend of the cessation date of rain in the study areas (Table1 and Fig. 3a and b). This clearly shows that the rains now end earlier in the study areas. The specific date of occurrence of either the onset or cessation of the rains is an important consideration in determining the beginning and end of the growing season in an area (Umar, 2010). Efficient crop production in the tropics is equated with the onset of rain and cessation of rainy season and its variability. This is because, onset, cessation and length of the rainy season form important components of moisture resources status for determining the potential of various crops (Olanrewaju, 2006).



Figs. 2: a. Rainfall onset dates of Samaru and b. Rainfall onset dates of Kano

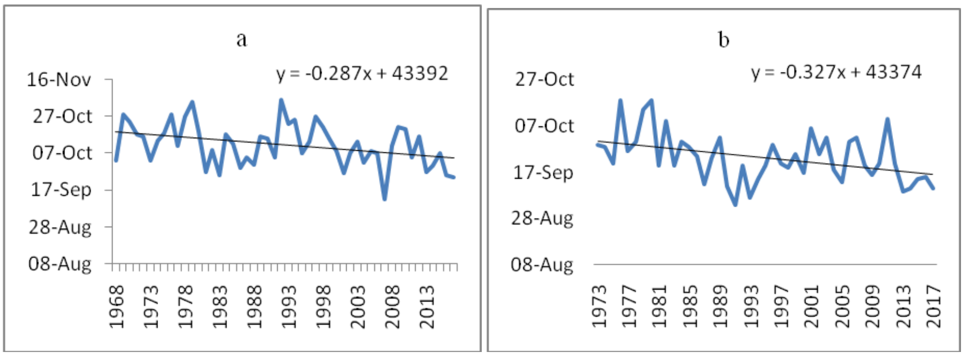


Fig. 3: a. Rainfall cessation dates of Samaru and b. Rainfall cessation dates of Kano

Standardized Rainfall Anomaly

From the result presented in figures 4a and b and table 1, the standardized anomalies of rainfall for the two stations showed increasing trends during the periods thus experiencing very dry, near normal to very wet conditions with the exception of some isolated mild, moderate and severe droughts. In Samaru, about 43% of the years between the late 60s to early 90s experienced varying degrees of drought ranging from moderate to extreme conditions while from the year 2000 to date, with the exception of some couple years, the condition has been of no-drought to extreme wetness. The situation in Kano station is very much similar with about 39% of the years in the early study period recording varying degrees of drought episodes ranging from moderate to severe drought conditions while from the year 2000 to date also, the condition has been of no-drought to extreme wetness.

The recent decrease in the intensity and frequency of drought occurrence in the two areas may be due to apparent increase of wet condition in the area. Findings of this research is in agreement with the observations made by Ati *et al*., 2007 and Abaje *et al*., 2012, that the Sudano-Sahelian Ecological Zone of Nigeria has been experiencing decreasing number of drought occurrences and consequently increasing wetness in recent years.

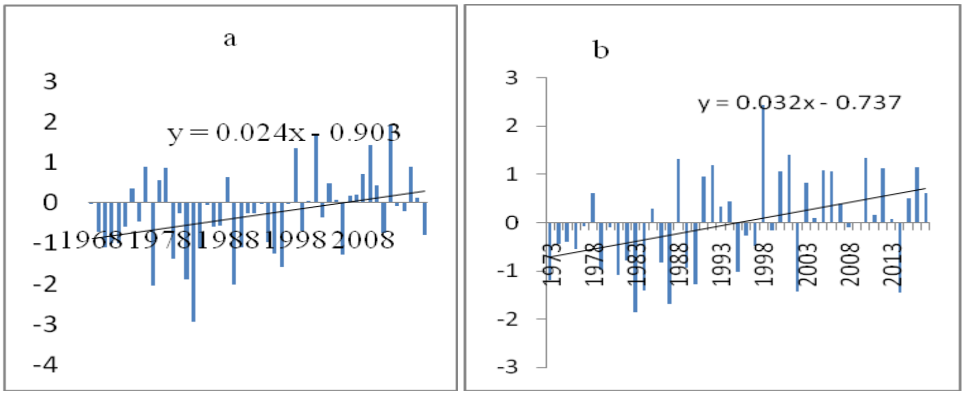


Fig. 4: a. Samaru Rainfall anomaly and b. Kano Rainfall anomaly

Temperature trends

Figures 5a and b showed the trend line for the mean monthly maximum and minimum temperature of the two stations. In both stations, the highest maximum temperatures recorded were in the months of April as (35°C) for Samaru and (40°C) for Kano while the highest minimum temperatures were recorded in the same months as (20°C) and (25°C) for Samaru and Kano respectively.

Figure 6a reveals an ascending trend line for temperature at Samaru station from 1968 – 2017 at the rate of 0.61°C and 0.34°C for the maximum and minimum temperatures respectively. The lowest maximum temperature occurred in 1970 (29.5°C) and the highest was recorded in 2017 (34.5°C) while the lowest and highest minimum temperatures recorded were in 1995 (17.2°C) and 2013 (20.9°C) respectively, with the mean minimum temperature of 26.3°C. Figure 6b also reveals an ascending trend line for temperature at Kano station (1973 - 2017) at the rate of 0.67°C and 0.76°C for the maximum and minimum temperatures respectively. The lowest and highest maximum temperatures were recorded in 1984 (31.5°C) and 2011 (35.4°C) respectively. The lowest and highest minimum temperatures recorded were in 1984 (17.8°C) and 2013 (22.3°C) respectively.

The observed continuous increase in temperature in the two stations from 2011 to 2017 may be due to global warming. Findings of this research are in agreement with the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC 2007) which stated that since the year 2000, global warming trend has continued – the decade2000-2009 was, globally, around 0.15ºC warmer than the decade1990-1999.

a. b.

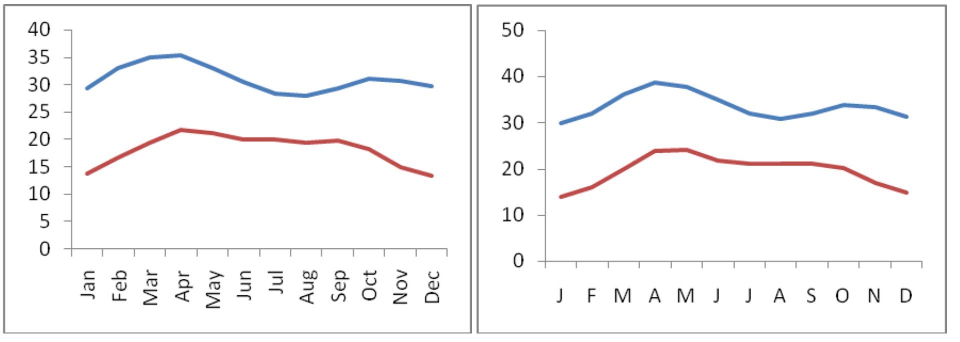


Fig. 5: a. Samaru maximum and minimum temperature trend and b. Kano maximum and minimum temperature trend

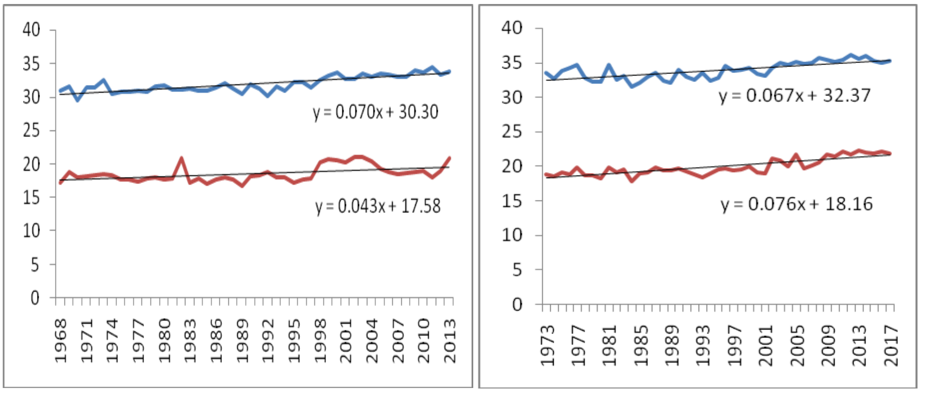


Fig. 6: a. Samaru mean maximum and minimum temperature and b. Kano mean maximum and minimum temperature.

Conclusion

The observed continuous increase in temperature in the two stations is a clear indication of the observed global warming by scientific researches as reported by IPCC 2007 4AR which stated that since the year 2000, global warming trend has continued. This has impacted negatively on man's sources of livelihood in the areas of agriculture in general which is the mainstay of the people in the study area as well as ecosystem and biodiversity.

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