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Rainfall Dynamics and Climate Change in Kano, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MMB initiated the topic and supervised the work. Author MUM designed the study, performed the data source, analysis and interpreted the result and the first draft of the manuscript. While author AA checked the analyses and the interpretation and draw the conclusion and author MA sourced the materials for the study area and other relevant literatures. All authors read and approved the final manuscript.

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ABSTRACT

This study examined the extent of climate change in Kano through rainfall data analysis. Rainfall data for one hundred years (1914-2013) of Aminu Kano International Airport synoptic meteorological station obtained from Nigerian Meteorological Agency (NIMET) was used in explaining the rainfall trend. Descriptions of monthly, annual and decadal rainfall averages were computed using Microsoft excel. The Normality of the data was tested using Shapiro- test for normality. Onsets, cessations and length of the rainy seasons were used to test variability of rainfall from time to time. The seasonality and standardize precipitation indices for ten year periods were performed. Trend lines and ten year moving averages were plotted. The findings revealed variability in both amount and length of raining season. The findings further revealed that drought and near drought conditions were experienced in the seventies and eighties. In the last two decades however there were improvements in moisture conditions. Trends of all the indices revealed an improvement in rainy condition except in the length of rainy season. The study concluded that even though changes were noticed in rainfall characteristics, it is difficult to ascertain climate change in the area on the basis of rainfall fluctuations. The research

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recommended the integration of other climatic variables and approaches as means for establishing changes or otherwise of climate in the study area.

Keywords: Rainfall; dynamics; climate change; trends; Kano.

1. INTRODUCTION

Climate is seen as the state of the atmosphere of an area over a long period of time. It is the synthesis of weather over a long period of time at a given area [1]. It is dynamic in nature, hence climate is continuously changing. [2] stated that, concentration of greenhouse gases in the atmosphere has increased over the past few decades and this has resulted to changes in climatic condition. This alteration according to [3] is expected to change rainfall characteristics such as the rainfall amounts, intensity, duration and frequency and also observed that, such changes are occurring in the amount, intensity, frequency and type of precipitation. Precipitation generally exhibits large natural variability, and El Niño and changes in atmospheric circulation patterns such as the North Atlantic Oscillation have a substantial influence in the tropical Africa.

Inter-governmental Panel on climate Change, [4] report indicated the global temperature increase since 1950 and which resulted in the increasing heat waves and intensification of hurricanes and other tropical storms. The report has further asserts that even though precipitation has been highly variable (both spatially and temporally) in the last 100 years over many parts of the world, significantly increased precipitation has been observed between 1980 and 2005 in eastern parts of North and South America, Northern Europe and Northern and Central Asia. In contrast, reduction in rainfall has been observed in the West African Sahel, the Mediterranean, Southern Africa and parts of Southern Asia. [4] noted that even though climate change is one vast area of study, of precipitation is one topic that deserve urgent attention within climate change.

National Oceanic and Atmospheric Administration, [5] attempted to find the extent to which climate is caused by anthropogenic forces, and its potential impacts. An in-depth study of the climate parameters, i.e., rainfall and temperature, is seen as important means for better understanding of the recent, past and present climate of a region [6]. Rainfall pattern is an important variable in sub-Saharan Africa on which agricultural activities are hinged to [7]. The extent to which an area is experiencing an increasing rate of wetness or dryness invariability affects agriculture. This situation is clearly noticed in the Sudan-Sahel savanna region of Nigeria. In West Africa, a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20–40% in the period 1968–1990 as compared with the 30 years between 1931 and 1960 [8].

All temperature indices are pointing a general warming trend since 1960. As for the rainfall related indices, although there was a general tendency of decreased annual total rainfall, the observed trends are not as uniform as in temperatures and some indices clearly indicate that extreme rainfall events have become more frequent during the last decade [9].

At global level [10] examines the change pattern of precipitation as an indicator of global climatic change. The study concluded that precipitation in high latitudes is increasing Northern Hemisphere but reductions in China, Australia and the Small Island States in the Pacific; and that equatorial regions become more variable, i.e., increased variance. The study however attributed these changes to major ocean currents. A study by the [11] also predicted future tropical cyclones (typhoons and hurricanes) as becoming more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures, SSTs. [11] studied the global SST and precipitation patterns. The study employed some models of temperature and precipitation relation and concluded that the SST patterns is changing and the change strongly affect precipitation, creating, among other features, an equatorial maximum in rainfall change over the Pacific.

[12] analysed drought occurrence and the utilization of Rainfall for agriculture in Northern Nigeria. The study used some selected stations in the Savannah belt of Northern Nigeria covering the period of 1930 to 1990 using various statistical methods enumerated by [13]. The study shows that the lengths of the rainy season vary with latitude and an inverse relationship has been observed with total annual rainfall. Also the study concluded that rainfall in the area is highly variable in time and space due to both natural and anthropogenic causes.

[2] evaluated the extent and degree of severity of droughts in the Sudano- Sahelian Ecological Zone of Nigeria. In the study rainfall data spanning a period of 60 years (1949- 2008) were used. They employed the use of normalized rainfall Index in depicting periods of different drought intensities in the region. The results revealed that the zone was characterized by larger extent of severe drought and that 1970s and 1980s were characterized by severest drought than any other decade in the study period. In addition the study determined the mean probability of recurrences of mild, moderate and severe drought in the region. In the study no attempt were made to explore the extent of changes in rainfall forms, patterns or amounts in the region. In view of all that this study, set out to answer the following questions:

(a) Why Kano is out standing in the increasing rainfall trends in the recent years?
(b) What would the long term rainfall pattern looks like in the tropical Africa?
(c) Is the closely dense human settlement zone really translated into climate change scenario?

2. MATERIALS AND METHODS

A century rainfall records was obtained from Malam Aminu Kano International Airport (MAKIA) meteorological station. The data contained monthly rainfall records, which were used in calculating the mean monthly and annual rainfall for the station. Shapiro- test for normality was used to test the normality of the data to see whether the rainfall distribution in the area is normal or otherwise. The choice is guided by the simplicity of the test. Standardized precipitation index (SPI) developed by [14] for monitoring drought conditions based on rainfall was used. The SPI can detect the high variation of drought in the period of the area which is computed by dividing the difference between the normalized seasonal precipitation and its long- term seasonal mean by the standard deviation. The formula for drought calculation is:

$$SPI = \frac{Xij - \bar{X}}{SD}$$

Where, x is the seasonal precipitation at the *i*th rain gauge and *j*th observation, the long-term seasonal mean and s.dis its standard deviation. The SPI is defined theoretically as the sub-areas under a normal (Gaussian) probability distribution function. It has many advantages over other drought indices which require more than two variables. It needs consideration of only two parameters, the arithmetic mean and the standard deviation [14] see Table 1.

Table 1. Drought categorization values

Drought classes	SPI value
Extremely wet	>2
Very wet	1.5 to 1.99
Moderately wet	1 to 1.50
Near normal	-0.99 to 0.99
Moderately drought	-1 to -1.49
Severally drought	-1.5 to -1.99
Extremely drought	-2<

Source: [14]

Onset of the rainy season (the day in which there is substantive amount of moisture in the soil to sustain plants growth and development) was obtained by using the formula [15,16].

Onset =

$$\text{The number of days in the month X} \frac{(51 - \text{Accumulated rainfall of the previous months})}{\text{Total rainfall for the month}}$$

Where month X is the first month with a rainfall greater 51 mm in a year. The get the actual day of the onset Julian calendar was used.

Cessation is the day in which moisture is reduced to a level lower than it can sustain plant growth and development. This does not necessarily means that the last day of the rainfall. This is computed in the same way as the onset except that the computation is done back ward from December [16]. The length of the rainy season (LRS) is the difference between the onset and the cessation date of rainfall.

The Seasonality Index (SI) proposed by Walsh and [17] is applied to quantify the annual rainfall regimes. These indices can show differences in relative seasonality even in areas with 2 or 3 rainfall peaks throughout the year. The SI is defined as the sum of the absolute deviation of mean monthly rainfall from the overall monthly mean divided by the mean annual rainfall.

$$SI = \frac{1}{R} \sum_{n=1}^{n=12} \left| \bar{x}_n - \frac{\bar{R}}{12} \right|$$

Where $\bar{x}_n$ is the mean rainfall for month *n* and $\bar{R}$ is the mean annual rainfall. This index can vary from zero (if all the months have equal rainfall) to 1.83 (if all the rainfall occurs in a single month)

Table 2 below gives the interpretation of the results and classification of the study area into different rainfall regimes by [17].

Table 2. Seasonality index and rainfall regime

SI class	Rainfall regime
≤0.19	Very equitable
0.20 – 0.39	Equitable with definite wet season
0.40 – 0.59	Rather seasonal with a shorter drier season
0.60 – 0.79	Seasonal
0.80 – 0.99	Markedly seasonal with a long drier season
1.00 – 1.99	Most rain in three months or less
>1.99	Extreme, almost all rain in 1 – 2 months

Adapted from [17]

2.1 Study Area

2.1.1 Location

Kano State covers an area extending between Latitudes 10º 3'N and 12º 4'N of Equator and Longitude 7º 4'E and 9º 3'E of the Prime maridian. It is bounded to the North West by Katsina State, to the South West by Kaduna and to the North East by Jigawa State, while to the South East by Bauchi State (Fig. 1).

Kano experiences four distinct seasons, *Rani* (warm and dry)*, Damina* (wet and warm), *Kaka* (cool and dry) and *Bazara* (hot and dry) closely associated with the movement of the Inter Tropical Discontinuity (ITD) zone. The mean annual Rainfall is about 884mm varying greatly from as low as 600mm in the north to 1200 mm in the Southern tips. On the average, the wettest month is August has the highest number of rainstorms and sediment generation while the mean annual temperature in area ranges from 26ºC to 32ºC, with the high diurnal temperature ranges of 13.1ºC and relative humidity of 17% - 90% [18,19].

2.1.2 (MAKIA)

The Highlands of Kano occupy a relatively small area to the south and constitute part of the foot slopes of the Jos Plateau which lies further south. The elevation is generally above 650 m and reaches well over 1000 m around the Rishi Hills. Most of the rocky outcrops in this zone are of Younger Granites, and the local relief is up to 300 m. The plains are developed on rocks of the Basement Complex and outcrops of these rocks constitute most of the hills, both grouped and ungrouped. The Low Chad Plains occupy the section of the Region east of the Hydro-Geological Divide. The elevation of this zone is about 420 m, with a local relief of about 20 m. The beds of the alluvial channels which are prominent in this zone lie at elevations of about 10 to 20 metres lower than the average given above [20,21].

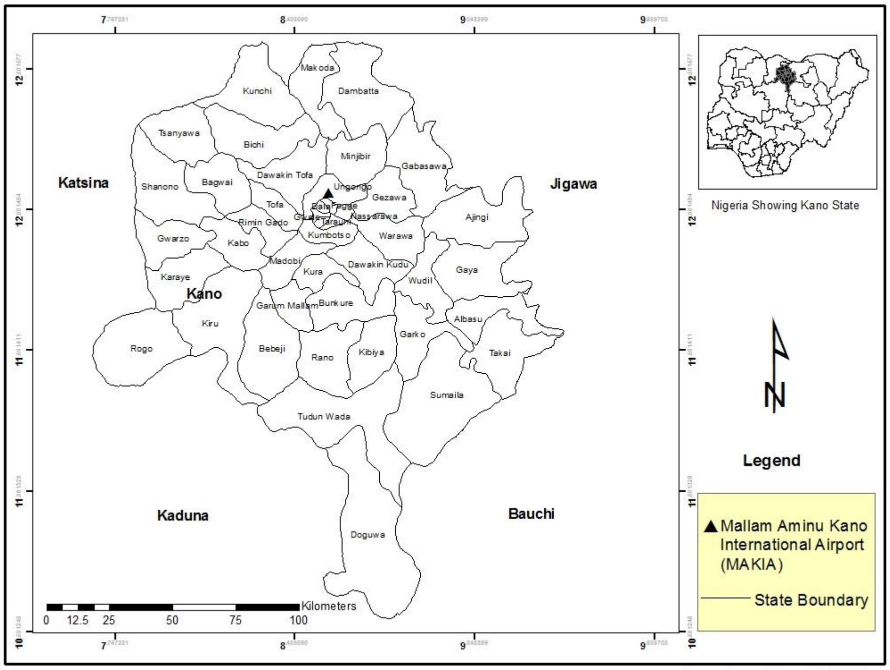
3. RESULTS AND DISCUSSION

3.1 Monthly Rainfall Variation

The results in Table 3 revealed that rainfall in the area is concentrated within the five month (May-September) with August having the highest amount. November, December, January, February and March form the dry periods (Fig. 2). Throughout the period of study it never rains in November and December. Even though rainy days are in April (59 times), March forms the normal onset month, having mean rainfall greater than 51 mm. There is high rainfall variability between months of the years as shown by the coefficient of variance. However the wettest month of the year (August and July) have the least variability. Most of the monthly values are positively skewed indicating that most rainfall values are above the mean. This corroborates some findings by [12] that indicated the fact that climate of the region is becoming wetter.

The Shapiro-Wilk test also shows that only August has a normal distribution of rainfall among the wet months. This corresponded with [22] that rainfall in the Nigeria dryland areas is highly variable.

The rainfall amount is equally variable between years (Table 4). The mean annual rainfall of the area is 897.7 mm, and maximum and minimum values are 1872 mm and 419.6 mm respectively. 1973 was the driest year of the period while 1998 was wettest. 1973 corresponds with severe 1973/74 drought that affects most part of sub-Saharan Africa. Annual amount is less variable than monthly value (CV is 30%), hence difficult to establish changes in climate by looking at seasonal variation.



Source: Dept. of Geog. BUK (2014)

Fig. 1. Kano State showing Aminu Kano International Airport

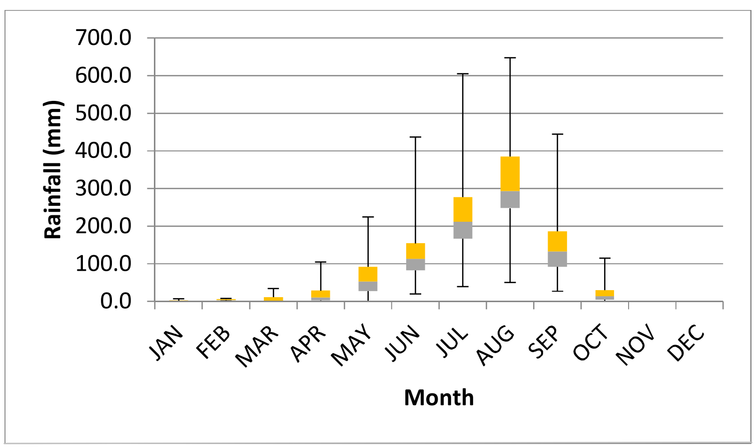


Fig. 2. Monthly rainfall distribution

Decadal mean annual values however show the immediate two decades (1994-2003 and 2004-2013) as the wettest decade of the century indicating that Kano is becoming wetter, other studies have shown that city is also becoming greener which might invariably be linked to this [23,24].

The annual SPI values were determined for trend analysis. The result of the SPI revealed more positive in the last two decade, confirming that the climate is getting wetter in recent years. The ten period moving averages, the rainfall regime in the area is highly variable in the area (Fig. 3). However a sharp increase was witness in the last twenty years with peak around 2006 and 2007. The trend line show improvement in rainfall on average in the study area.

Table 5 revealed that rainfall in the area was near normal in most of the year. However moderate droughts were experience eight times and moderately wet years were witnessed four times in the century. Moderately droughts were experienced in 1942, 1949, 1968, 1972, 1976, 1981 and 1987. The moderately wet years were 1999, 2003, 2005 and 2006, all the slight wet years are in the last two decade. The four severe drought experienced in the area were 1944, 1973, 1983 and 1984. Mean decadal SPI of the area indicated near normal precipitation in the area in almost all the century except the last two decades 1994 – 2003 and 2004 – 2013 which suggest sharp change in the climate (Table 6).

Rainfall seasonality change is another good indicator of climate change. The result revealed some fluctuation in rainfall seasonality in the area (Fig. 4). The seasonality trend show that on average rainfall season is increasing in the area. This refutes some of the assertions made in the past that the rainy season is becoming shorter in the area. The decadal moving averages revealed that length of the rainy season is becoming longer in the last two decade.

There is only one year of equi table with definite wetter and ten years with seasonal rain and short dries season, most of the year correspond with the slightly wet years explained in the anomaly.

However mean decadal seasonality index results revealed that rainfall are mostly markedly seasonal or seasonal in nature (see Table 8). Only two mean decade values were found to be extreme this indicated that seasonality period has become shorter which means some elements of climatic changes in rain seasonality as the rainfall in the area is becoming more seasonal-concentrating two to three months-in recent years (Table 7).

The finding revealed that mean length of rainy season in the area is 105 days, 31 is the lowest length recorded in 1973 and 157 days is highest recorded in 1991. The coefficient of variance of rainy season is 0.2 indicating low variability. The onset of rainy season predominantly May/June, but on few occasion the rainy season may begin early in April or late in October (Fig. 5a). The season normally ends in September as can be seen in Fig. 5b.

Table 3. Descriptive summaries of the monthly rainfall in Kano (1914-2013)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Mean	2.1	4.2	7.5	17.8	62.5	128.7	231.7	308.9	142.2	20.2
Standard error	1.5	1.3	2.7	2.7	4.6	6.8	10.4	10.8	7.4	2.6
Standard deviation	3.0	2.8	10.5	20.9	46.1	68.1	103.8	107.8	74.1	20.6
Coeff. Of Var.	143.5	67.0	140.3	117.0	73.8	52.9	44.8	34.9	52.1	102.0
Kurtosis	3.8	-2.0	1.8	4.4	0.9	3.8	2.1	0.4	1.7	5.9
Skewness	1.9	0.3	1.6	1.9	1.0	1.5	1.1	0.3	0.9	2.0
Maximum	6.6	7.8	34.5	104.6	224.3	436.4	604.7	646.9	444.1	114.5
Minimum	0.2	1.0	0.2	0.2	0.5	19.3	39.1	50.5	26.9	0.5
Count of rain (%)	4.0	5.0	15.0	59.0	100.0	100.0	100.0	100.0	99.0	65.0
Number of outliers	0.0	0.0	1.0	1.0	3.0	2.0	3.0	1.0	2.0	1.0
Shapiro-Wilk test										
W	0.71	0.95	0.7	0.79	0.93	0.9	0.93	0.98	0.95	0.82
p-value	0.02	0.72	0	0	0	0	0	0.23	0	0
Normal	No	yes	No	No	no	no	No	yes	No	No

Sources: Data analysis (2015)

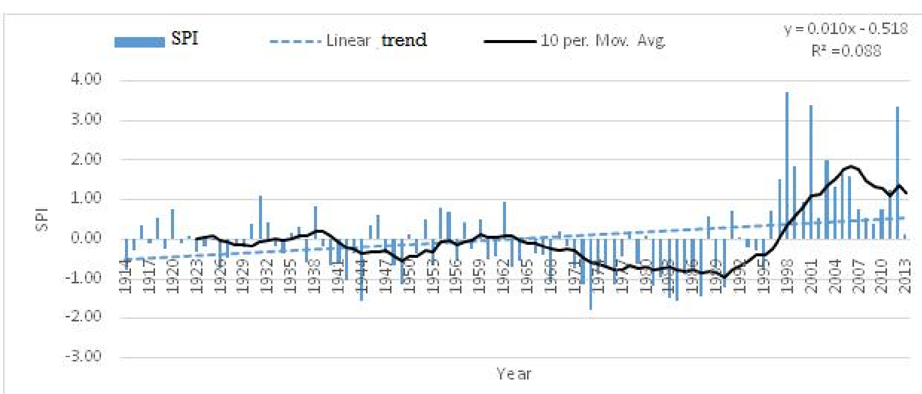


Fig. 3. SPI trend and moving averages in Kano (1914-2013)

Table 4. Decadal mean annual rainfall

Period	Mean annual
1914-1923	889.8
1924-1933	892.3
1934-1943	828.1
1944-1954	809.3
1954-1965	916.7
1964-1973	734.3
1974-1983	702.3
1984-1993	747.2
1994-2003	1253.2
2004-2013	1203.3
Overall Mean = 897.7, CV.=30%, Min= 419.6 and Max 1872	

Sources: Data analysis (2015)

Table 5. SPIS ummaries in Kano Area

Intensity	Percent
Extremely wet	3
Moderately drought	8
Moderately wet	4
Near normal	81
Severe drought	4
Total	**100**

Source: Data analysis (2015)

The trend analysis revealed that the length of rainy season decrease on average between 1914 and 2013. The 10 period moving average however shows lowest duration of the rainy season were experienced between seventies and eighties (Fig. 6). These periods corresponded with the severe drought experience in the area is. It is however difficult to establish climate changes from the average decadal length of rainy season alone but combining all other factors discussed one can vividly see it as a reality. What can only be inferred is that droughts and near droughts condition were experienced between 1970s and 1980s. The causes of that might be influenced by the interplays of the natural variability in the atmosphere circulation. However, the recent increase in rainfall of the area is off cause the result of anthropogenic factors. Urban Kano is increasing five fold in the recent years than what it used to be in the 1970s and the emission of green house gases is also on the increase.

Table 6. Decadal SPI in Kano

Period	SPI	Remark
1914-1923	-0.03	Near Normal
1924-1933	-0.02	Near Normal
1934-1943	-0.26	Near Normal
1944-1954	-0.33	Near Normal
1954-1965	0.07	Near Normal
1964-1973	-0.62	Near Normal
1974-1983	-0.74	Near Normal
1984-1993	-0.57	Near Normal
1994-2003	1.34	Moderately Wet
2004-2013	1.15	Moderately Wet

Source: Data analysis (2015)

Table 7. Rainfall seasonality indices in Kano (1914-2013)

Seasonality	Percent
Equable with definite wetter Season	1
Seasonal with short drier season	10
Seasonal	25
Markedly seasonal	29
Most rain in 3 month or less	24
Extreme (almost all rain in 1-2 Month)	11
Total	**100**

Source: Data analysis (2015)

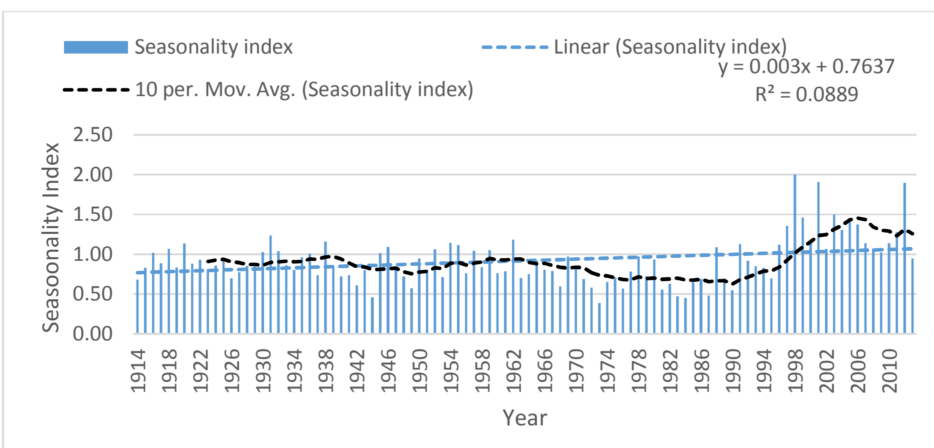


Fig. 4. Rainfall seasonality index trend and moving averages in Kano (1914-2013)

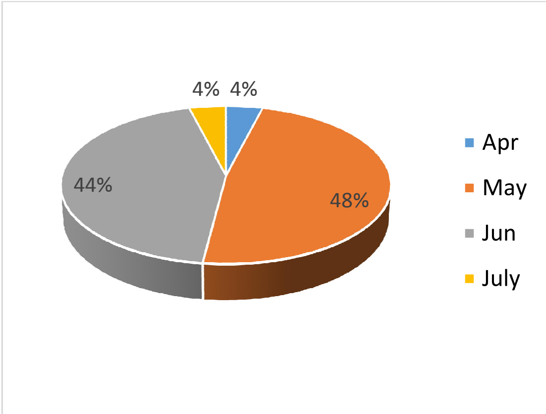


Fig. 5a. Rainfall onset (1914-2013)

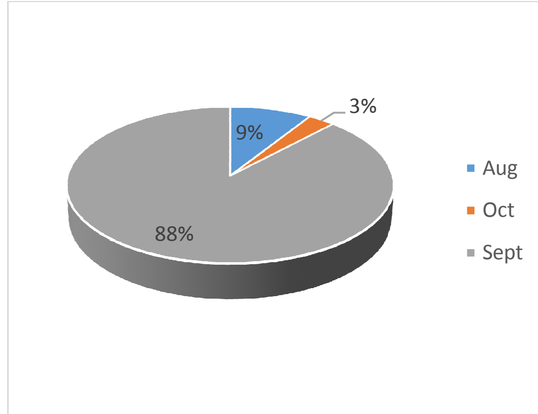


Fig. 5b. Rainfall cessation (1914-2013)

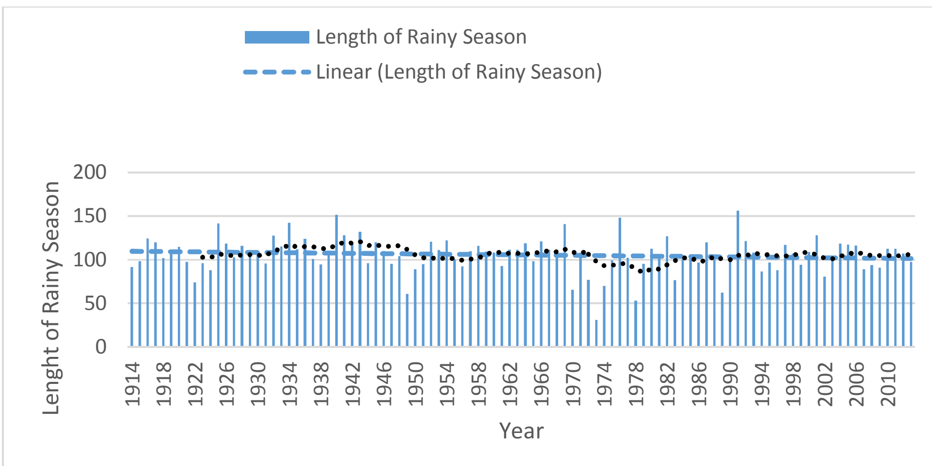


Fig. 6. Duration of rainy season trends in Kano (1914-2013)

Table 8. Decadal rainfall seasonality indices in Kano (1914-2013)

Period	Seasonality index	Remarks
1914-1923	0.91	Markedly Seasonal
1924-1933	0.91	Markedly Seasonal
1934-1943	0.84	Markedly Seasonal
1944-1954	0.82	Markedly Seasonal
1954-1965	0.94	Markedly Seasonal
1964-1973	0.73	Seasonal
1974-1983	0.70	Seasonal
1984-1993	0.75	Seasonal
1994-2003	1.31	Extreme
2004-2013	1.26	Extreme

Source: Data analysis (2015)

4. CONCLUSION AND RECOMMENDATIONS

The study shows that the rainfall in the area is more of cyclical, because rainfall amount was high in the 1930s and low around 1970s and then increase in 1990s to date .Therefore the study concluded that even though elements of climatic changes were noticed in rainfall characteristics, it is difficult to ascertain climate change in the area on the basis of rainfall fluctuations alone. The research recommended the integration of other climatic variables and approaches as means for establishing changes or otherwise of climate in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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