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Full Length Research Paper

Trend analysis of precipitation in Birnin Kebbi, Nigeria

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Abstract

Birnin Kebbi is in the North West geoploitical zone of Nigeria. The major occupation of the people in this region is farming, which depends on rainfall and other factors. This article presents statistical and trend analyses of the rainfall in Birnin Kebbi. Rainfall data in the region for a period of 1915- 2007 were collected from archives. The existence of trend and statistical analyses were conducted on yearly total rainfalls using non-parametric techniques. The study revealed that overall averages of yearly and monthly total rainfall were 787.53±24.03 mm and 112.21 ±25.31 mm respectively. Yearly total rainfall has Mann-Whitney of 112, 40 and 50 between 1915 and 1946; 1947 and 1977 and between 1978 and 2007. These parameters show that there are significant trends in the rainfall in term of yearly total for the period. Sen's estimator revealed that there are significant upward trends for yearly total (1.03mm/year), (10.33 mm/year) and (-9.04 mm/year) within a period of 1915- 1946; 1947 – 1977 and 1978 – 2007. There is a significant downward trend for yearly total of 9.04mm/year within a period of 1978 – 2007. It was concluded that there is a significant downward trend in the yearly total and mean rainfalls at Birnin Kebbi in the last three decades (30years), which can be attributed to climate change.

Keywords*:* Hydrological data, trend analysis, drought, flood, non-parametric, geopolitical zones.

INTRODUCTION

The effects of climatic change and variability have been analyzed by many researchers in a variety of geophysical fields. Most previous studies concerning long-term climatologic trends have focused on surface air temperature and precipitation. Previous studies have reported effects of climate change on water quality variables; on stream flow; on precipitation; and on lake levels (Partal and Kahya, 2005). From these and other studies, a range of potential climatic impacts on the hydrologic regime for various geographic areas can be hypothesized. Correlations between hydrologic variables and meteorological variables were evaluated by Burn and Hag Elnur (2002). The article documented similarities in trends and hydrologic patterns in two different variables at selected locations. They utilized only the Mann–Kendall test to detect trends for 18 hydrologic variables that reflect different parts of the hydrologic cycle from a network of 248 Canadian stream-flow catchments. Most previous studies have used Kendall's test to identify hydroclimatologic trends and possible climatic variations. Partal and Kahya (2005 described two classes of procedures in detail: (i) intrablock methods (procedures that compute a statistic, such as Kendall's, for each block or season and then sum these to produce a single overall statistic) and (ii) aligned ranks method (procedures that first remove the block effect from each datum, second sum the data over blocks, and finally produce a statistic from these sums).

Abaje et al. (2010) stated that one of the most significant climatic variations in the African Sahel since the late 1960s has been the persistent decline in rainfall. The Sahel is characterized by strong climatic variations and an irregular rainfall that ranges between 200mm and 600 mm with coefficients of variation ranging from 15 to 30%. It was reported that a rainfall decrease of 29-49%

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has been observed in the 1968-1997 period compared to the 1931-1960 baseline period within the Sahel region. The West Africa region has experienced a marked decline in rainfall from 15 to 30% depending on the area. The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994. This was considered to be the wettest year of the past 30 and was thought to perhaps indicate the end of the drought. The pattern of rainfall in northern Nigeria (Birnin Kebbi inclusive) is highly variable in spatial and temporal dimensions with inter-annual variability of between 15 and 20% (Abaje et al., 2010). As a result of the large inter-annual variability of rainfall, it often results in climate hazards, especially floods and severe and widespread droughts with their devastating effects on food production and associated calamities and sufferings.

Rainfall is one of the key climatic resources of Kebbi (Kebbi State, Nigeria). Crops and animals derived their water resources largely from rainfall. It is considered as the main determinant of the types of crops that can be grown in the area and also the period of cultivation of such crops and the farming systems that can be practiced. Nigeria is a country with diverse ethnic groups practicing different cultures, and having variations in farming and religion beliefs. The country can primarily be divided into two major geographical zones namely the North and South, though that has historical underlying (Obot et al., 2010). Furthermore, both the North and South are segmented into three regions each, making a total of six geopolitical zones. These six geopolitical zones in the country are; North East, North West, North Central, South West, South East and South South (Figure 1). Policies, resource allocations, sites of infrastructures and even political and other appointments are mostly considered by zoning in Nigeria. Kebbi is in Kebbi state which is in North West geoplotical zone of Nigeria. Kebbi State came into being on August 27, 1991. It was created out of the old Sokoto State. The capital is Birnin-Kebbi. Its major towns include Birnin-Kebbi, Argungu and Yelwa. The state has a population of 3,630, 931 and has a total land area of 36,800 km^2. Kebbi State shares boundaries with Sokoto State on the North-Eastern axis, Zamfara State on the Eastern part, Niger state on the Southern part and Republic of Niger on the Western part. Kebbi State is divided into 21 local government areas, four emirate councils (Gwandu, Argungu, Yauri and Zuru), and 35 districts. The climate is semiarid with a zone of savannah-type vegetation as part of the sub-Saharan Sudan belt of West Africa.

Rainfall is concentrated in a short wet season, which extends from mid-May to mid-September whilst the dry season (with no single rain) lasts more than 7 months. Farming is the major occupation in the place. It is well known that crop production in semi-arid regions is largely determined by climatic and soil factors. The pattern and amount of rainfall are among the most important factors that affect agricultural systems. Rainfall is the limiting factor in the area. Rainfall governs the crop yields and determines the choice of the crops that can be grown. These show that a detailed knowledge of rainfall regime is an important prerequisite for agricultural planning. The analysis of rainfall for agricultural purposes must include information concerning the trends or changes of precipitation, the start end and length of the rainy season, the distribution of rainfall amounts through the year, and the risk of dry and wet spells. The purpose of this study is to characterize trend of total amount of rainfall in Birnin Kebbi, Kebbi state, Nigeria.

MATERIALS AND METHOD

Information on rainfall in Birnin Kebbi were collected from institutions, local government headquarters, state and Federal government archives (Ministry of Water Resources; Nigerian Meteorological Agency (NIMET) Abuja; and also from Literature such as Akintola (1986). The rainfall data obtained ranged data from 1915 to 2007. The data were analysed using non-parametric analyses with a particular attention to trend of the rainfall over the years.

Statistical tools commonly used to detect significant trends in climatic and hydrological time series is either or the non-parametric test such as Mann-Whitney U, Wilcoxon W, Mann-Kendall or Spearman's rank correlation and the parametric test such as student's t-test (Loveday, 1980; Guttman et al., 1971). The non-parametric test is considered better because it is a function of the ranks of observation and it displays much insensitivity to outliers unlike the parametric counterpart. Slopes(S) of the existence trend were determined using Sen's estimator and overall slopes (Tan (β +α +φ) were computed as follows:

$$S = \frac{R_A - R_B}{N_A - N_B} \qquad (1)$$

$$Tan(\alpha+\beta+\phi) = \frac{Tan\alpha + \dfrac{Tan\beta + Tan\phi}{1 - Tan\beta * Tan\phi}}{1 - Tan\alpha + \dfrac{Tan\beta + Tan\phi}{1 - Tan\beta * Tan\phi}} \qquad (2)$$

Models that relate yearly total rainfall to the year were developed from the trend analysis using statistical and fuzzy logic techniques.

RESULT AND DISCUSSION

Result of this study is discussed in the following

Table 1. Statistical summary of yearly total rainfall in Birnin Kebbi

Year	**1915**	**1916**	**1917**	**1918**	**1919**	**1920**	**1921**	**1922**	**1923**	**1924**	**1925**	**1926**	**1927**	**1928**	**1929**	**1930**	
Total Rainfall (mm)	824.7	551.6	796.3	1010.8	756.1	701.7	1342.2	640.2	949.0	410.2	274.5	965.5	693.8	694.7	952.7	808.8	
Mean (mm)	68.7	46.0	66.4	84.2	63.0	58.5	111.8	53.4	79.1	34.2	22.9	80.5	57.8	57.9	79.4	67.4	
SD	96.5	61.0	101.9	119.1	115.5	87.8	131.8	81.9	116.9	81.2	50.1	80.9	79.1	76.0	105.1	94.3	
Maximum	274.5	151.3	305.8	355.6	370.7	271.4	343.9	214.5	311.5	268.8	167.6	213.4	258.0	227.3	266.0	268.6	
Minimum	1.7	0.0	11.1	13.9	0.0	2.3	27.3	0.6	11.0	7.4	4.8	62.0	17.9	31.0	3.0	4.1	
Year	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Rainfall (mm)	751.0	821.3	717.5	749.9	1090.7	989.7	702.2	733.0	830.4	606.5	623.8	779.3	784.8	819.7	826.4	1420.9	916.7
Mean	62.6	68.4	59.8	62.5	90.9	82.5	58.5	61.1	69.2	50.5	52.0	64.9	65.4	68.3	68.9	118.4	76.4
SD	94.2	106.4	79.6	113.3	162.9	125.8	104.6	105.5	103.3	67.7	70.9	93.4	101.5	108.8	111.7	166.9	110.9
Maximum	291.9	312.1	213.9	361.6	532.0	404.5	329.1	349.9	332.3	177.2	202.3	275.1	271.1	279.1	276.9	397.7	310.1
Minimum	20.5	0.0	27.9	0.0	0.0	0.0	0.0	2.0	16.2	0.0	15.9	23.3	8.3	11.1	0.0	26.3	26.2
Year	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Rainfall (mm)	1206.9	1054.7	1108.8	828.8	1103.9	918.5	1196.5	854.2	1113.4	1091.2	1025.4	704.8	1131.4	711.1	578.6	979.0	993.6
Mean	100.6	87.9	92.4	69.1	92.0	76.5	99.7	71.2	92.8	90.9	85.4	58.7	94.3	59.3	48.2	81.6	82.8
SD	133.2	129.8	150.0	89.2	134.7	84.6	171.3	103.0	141.0	123.3	122.7	106.3	133.0	86.6	69.0	102.8	123.8
Maximum	398.3	250.7	495.0	222.7	397.8	187.8	570.6	284.1	342.8	276.2	333.1	356.7	303.0	222.9	211.1	277.4	364.9
Minimum	0.0	20.0	30.7	35.3	24.2	22.7	0.6	17.6	4.0	26.4	9.1	0.0	2.8	0.0	9.4	47.5	0.0
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Rainfall (mm)	938.6	791.2	772.0	555.9	863.6	1008.9	757.8	624.6	502.7	631.0	664.2	926.9	846.5	746.8	667.1	624.4	623.7
Mean	78. 2	65.9	64.3	46.3	72.0	84.1	63.1	52.1	41.9	52.6	55.3	77.2	70.5	62.2	55.6	52.0	52.0
SD	116.0	80.8	92.0	58.3	101.1	135.0	100.6	59.0	63.6	71.7	69.8	88.4	114.3	93.9	92.6	73.3	76.5
Maximum	358.4	195.4	283.6	150.5	240.1	342.7	328.0	147.1	142.8	196.6	165.0	208.3	375.1	273.3	297.2	216.0	233.4
Minimum	5.4	29.6	1.1	22.7	15.3	4.0	0.0	41.2	0.0	19.4	0.0	76.5	0.6	0.0	0.0	14.4	0.0
Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Rainfall (mm)	637.4	692.7	523.0	477.8	532.9	418.0	781.0	656.1	732.7	864.1	614.9	719.3	853.6	571.0	746.9	723.0	947.4
Mean	53.1	57.7	43.6	39.8	44.4	34.8	65.1	54.7	61.1	72.0	51.2	59.9	71.1	47.6	62.2	60.2	79.0
SD	103.3	87.3	59.8	55.9	68.2	44.6	99.4	79.8	112.1	87.1	73.8	94.8	127.2	80.6	99.7	78.6	133.0
Maximum	336.3	256.9	140.4	151.3	169.5	146.2	255.2	215.6	389.1	236.7	184.6	266.8	398.3	224.6	269.8	196.8	419.9
Minimum	6.7	0.0	0.0	0.0	0.0	5.0	0.0	18.6	0.0	13.6	0.0	0.0	0.0	2.7	7.8	18.3	1.9
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007								
Rainfall (mm)	797.0	806.4	819.4	860.9	885.0	701.9	708.5	828.2	712.5								
Mean	66.4	67.2	68.3	71.7	73.8	58.5	59.0	69.0	59.4								
SD	105.5	118.8	118.4	94.6	122.4	101.0	76.0	113.5	90.4								
Maximum	340.8	405.0	404.1	259.4	323.3	332.1	191.6	352.5	263.9								
Minimum	34.0	29.7	0.0	0.0	0.0	0.0	3.9	21.7	0.0								

Table 2. Statistical summary of monthly total rainfall in Birnin Kebbi

Monthly	January	February	March	April	May	June	July	August	September	October	November	December
Mean	0.04	0.07	1.86	9.06	49.97	138.18	194.33	242.24	135.01	16.68	0.11	0.00
Maximum	3.36	3.36	37.30	117.71	172.96	397.71	404.99	570.64	419.89	128.02	9.97	0.00
Minimum	0.00	0.00	0.00	0.00	0.00	11.10	63.62	75.26	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	5.15	43.57	135.18	182.45	222.88	128.30	9.07	0.00	0.00
Standard Deviation	0.35	0.47	6.56	19.23	41.98	79.97	80.49	102.12	80.83	24.80	1.03	0.00
Coefficient of Variation	964.37	678.60	351.82	212.33	84.01	57.87	41.42	42.16	59.87	148.74	0.00	0.00

Table 3. Non parameter test of summarised statistical data

Year	Statistical Analysis											Number of samples
	Mean (Median) Rank Total	Mann-Whitney U	Wilcoxon	Z = $\frac{x - \bar{x}}{\sigma}$	Asymptotic Significant (2 tailed)	Median	Slope ($S = \frac{R_A - R_B}{N_A - N_B}$) mm/year	Kruskal – Wallis (Chi-Squared)	Kolmogrov – Smirnov Test			
1915-1930	16.53	112	248	-0.316	0.752	779.3	1.03	0.034	absolute	Positive	Negative	15
1931-1946	15.50								0.304	0.304	-0.179	16
1947-1961	10.67	40	160	-3.162	0.002	918.5	10.33	2.64	0.625	0.000	0.625	15
1962-1977	21.00											16
1978- 1992	20.67	50	186	-2.767	0.006	719.3	-9.04 (1.06)	3.89	0.621	0.621	0.000	15
1993-2008	11.63											16

categories: statistical summary of rainfall (annual mean precipitation); monthly rainfall trend and sequential analyses.

Statistical Summary

Table 1 presents yearly total, yearly mean, maximum, minimum and standard deviation (SD) of the rainfall for all years (1915 – 2007). The table shows spatial distribution of the rainfall. From the table yearly total rainfall has a decreasing trend with the strongest downward magnitude in the group 1978 – 2007. The lowest magnitude in downward trend was in the period between 1947 – 1977. The same trends were observed for the yearly mean, median and yearly minimum rainfalls. These trends show that there is a decline in the magnitude of rainfall in the city. Also these results agree with literature such as Adelana et al. (2006). These downward trends in rainfall can be attributed to climate change as

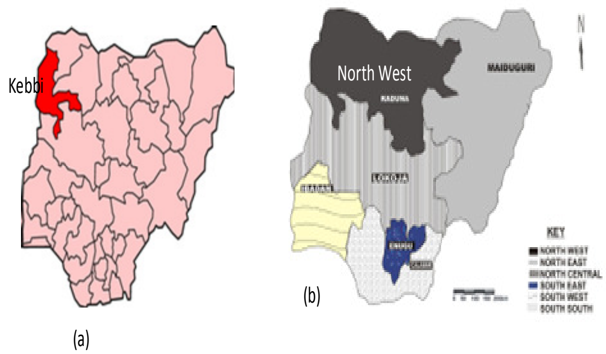

Figure 1: Map of Nigeria

(a) showing kebbi state
(b) showing the six geopolitical zones

highlighted in Odjugo (2009; 2010). Literature presents change in temperature across Nigeria within this period. From the figure, between 1901 and 1935 the temperature change was 0.5^{0}C (28 – 28.5 ^{o}C) for the region; between 1936 and 1970 the temperature change was 0.5^{0}C (28.5 – 29 ^{o}C) and between 1971 and 2006 the temperature change was 0.5^{0}C (29 – 29.5 ^{o}C). All these show that there is an increase in temperature (1.5^{o}C), while the total yearly rainfall dropped from 824.7mm to 712.5 mm, a drop from 68.7 mm to 59.4 mm in the monthly mean with a drop from 274.5 mm to 263.9 mm in the monthly maximum. It shows that there are drops of 74.7mm / ^{o}C; 6.2 mm / ^{o}C and 7.1 mm / ^{o}C for total yearly rainfall, monthly mean and monthly maximum rainfalls respectively.

Monthly Rainfalls

Table 2 presents monthly mean, median, maximum and minimum rainfalls in the city. The table revealed that the rainy period in Birnin Kebbi is between April and October, with June, July, August and September as significant rainy months. The month August has the highest magnitude of monthly rainfall with July, September and June in decreasing order. This shows that for farming activities in rainy seasons crops with maximum water demand month of six months are the best for the area. Similar results were presented in Adelana et al (2006) for monthly mean and monthly evaporations.

Trend Analysis

The result of trend analyses are discussed in the following ways: Trend of yearly rainfalls with the sequences of the monthly and yearly rainfalls.

Trends of yearly rainfalls

Table 3 presents results of non- parametric analyses (mean rank, sum of rank; Mann- Whitney, Wilcoxon, standard anomaly index (SAI; Z), median rank, Sen's test Kruskal Wallis and Chi- Squared). From these analyses presented in the table it was observed that there are upward trends in the total, mean, maximum and minimum rainfall in the city between 1915 and 1946, but these trends were not statistically significant at 95 % confidence level. Between 1947 and 1977 there are upward trends in the rainfall parameters with SAIs of -3.162; -0.316 for between 1915 and 1946 with -2.767 for between 1978 and 2007 respectively. Asymptotic significant (probability) of these rainfall parameters were found to be 0.752; 0.002 and 0.006 forthese periods respectively. SAI provides an area average index of relation rainfall yields based on the standardization of total, mean, maximum and minimum rainfalls. These magnitude of SAI ($Z > 1.96$) and probabilities show that the downward trends are statistically significant at 95 % confidence level. Also the sign ($Z< 0$) revealed that the values were less than expected overall mean rainfall and that there was more dryness in the period between 1947 and 1977 than the period between 1915 and 1946.

Sen's estimators revealed that yearly total rainfalls have trends of 1.03 mm/year; 10.33 mm/year and -9.04 mm/year for a period of 1915 – 1946; 1947 – 1977 and 1978 – 2007 respectively. Overall slopes for yearly total; rainfalls was found to be 1.06 mm/year. Magnitudes of Chi-squared, Kolmogrov- Smirnov and Kruskal –Wallis tests revealed that these trends are statistically significant, which indicates that there are significant trends in the yearly total; mean; maximum and minimum in the area.

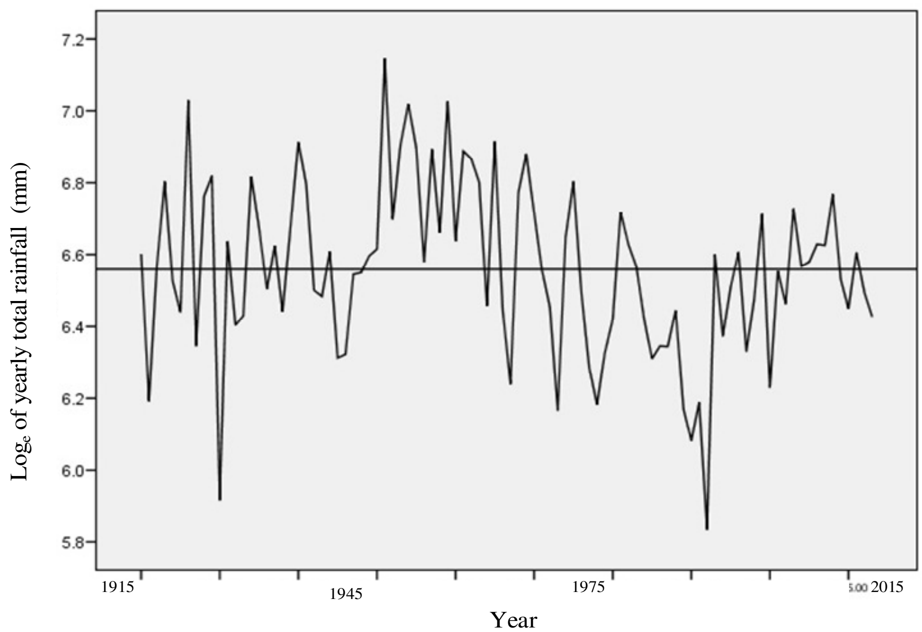

Figure 2: Sequence of yearly total rainfall

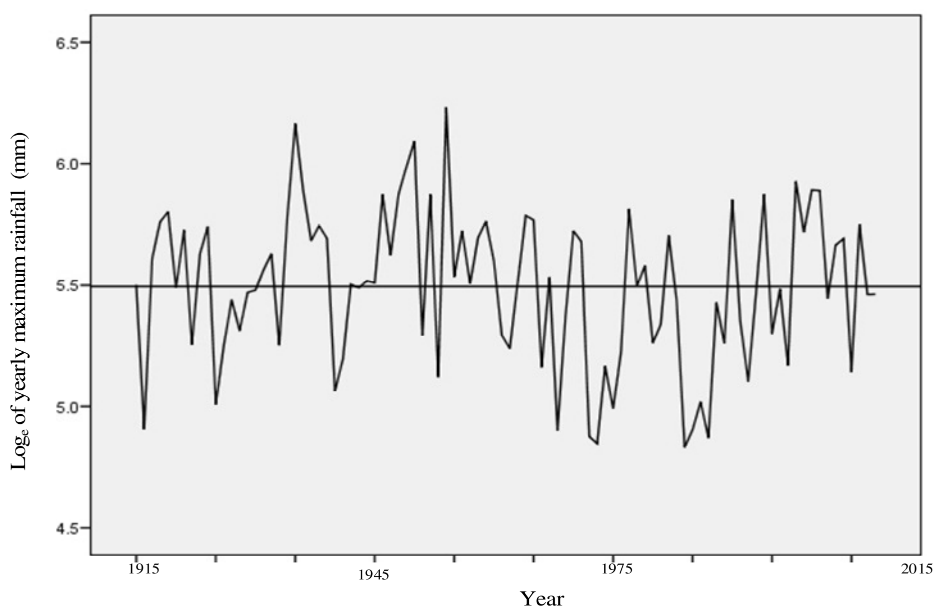

Figure 3: Sequence of yearly maximum rainfall

Sequence analysis of the rainfalls

Figures 2–12 present sequential values of the rainfalls in Birnin Kebbi. The figures apparently show decreasing trends in the rainfalls. Figures 2–5 illustrate the downward trends appearance of the yearly total, maximum, minimum and mean rainfalls. In all these cases the appearance of strongest decreasing trend

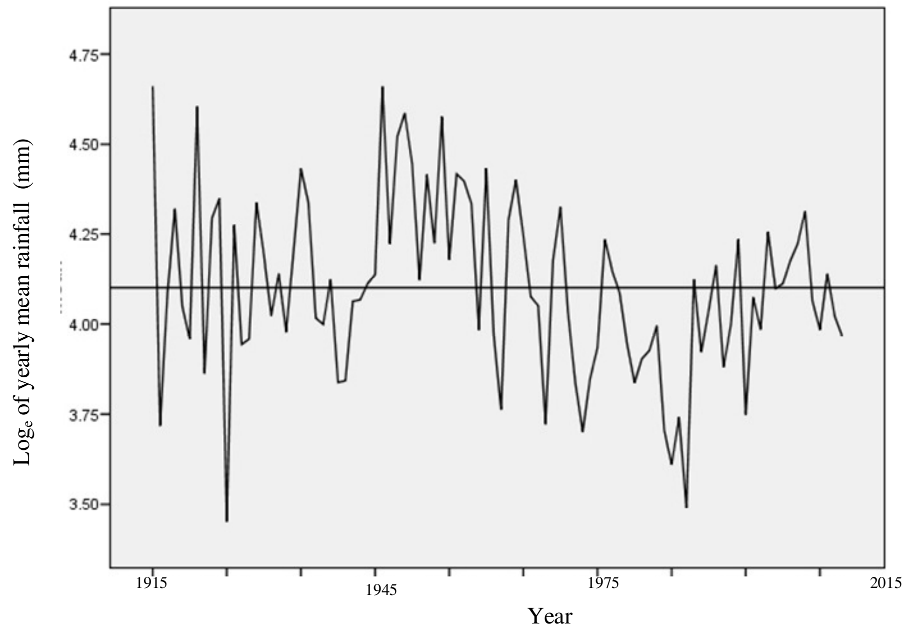

Figure 4: Sequence of yearly mean rainfall

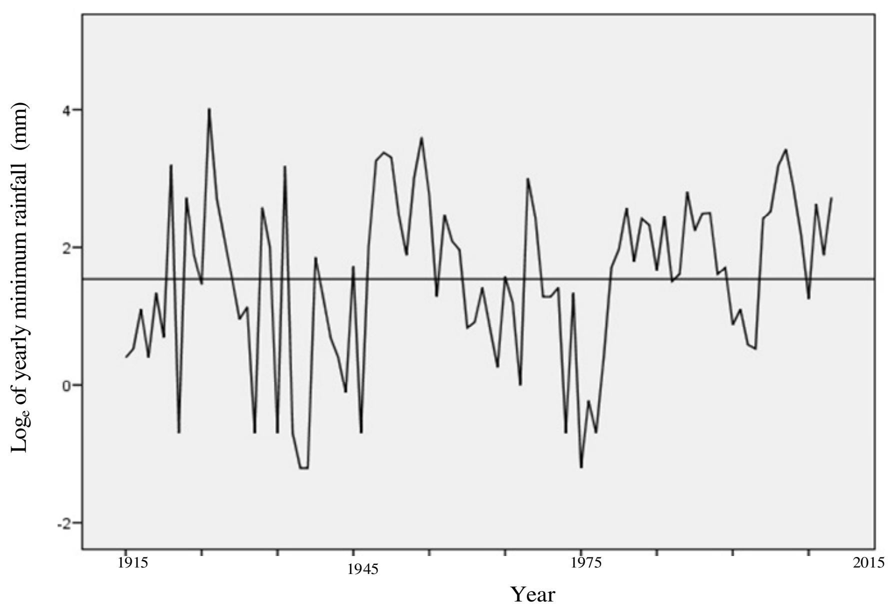

Figure 5: Sequence of yearly minimum rainfall

occurred between 1978 and 2007 (the last three decades). Figures 7, 8, 9 and 11 present appearance of slightly increasing trends in rainfall within the period (in the months May, June and September), while figures 5, 6, 10, 11 and 12 present appearance of decreasing trends in monthly rainfall. Figure 7 presents neither increasing nor decreasing trends in rainfalls. These trends can be attributed to climate change, which

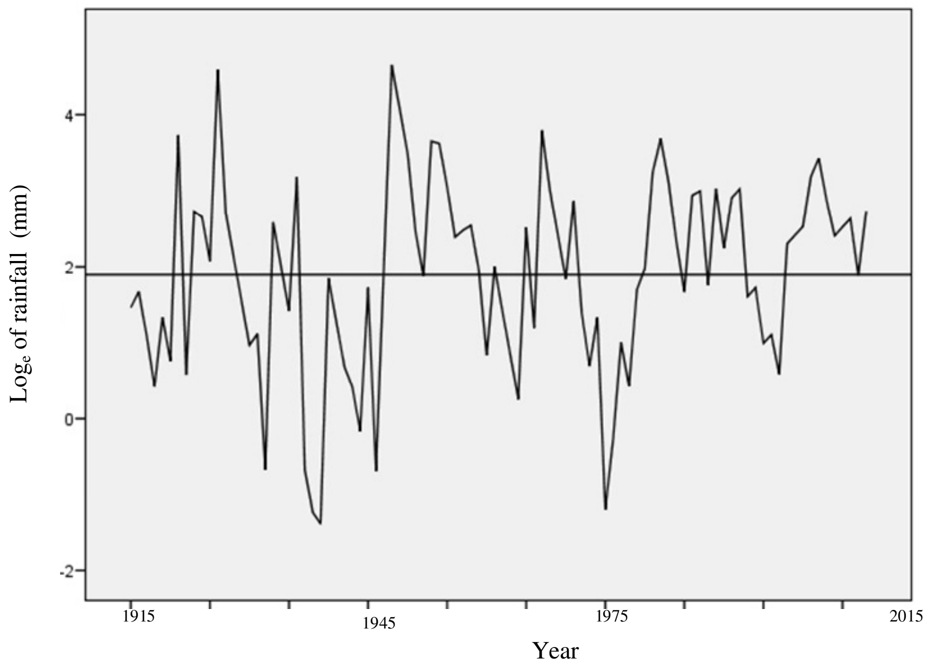

Figure 6: Sequence of rainfall in the month of April

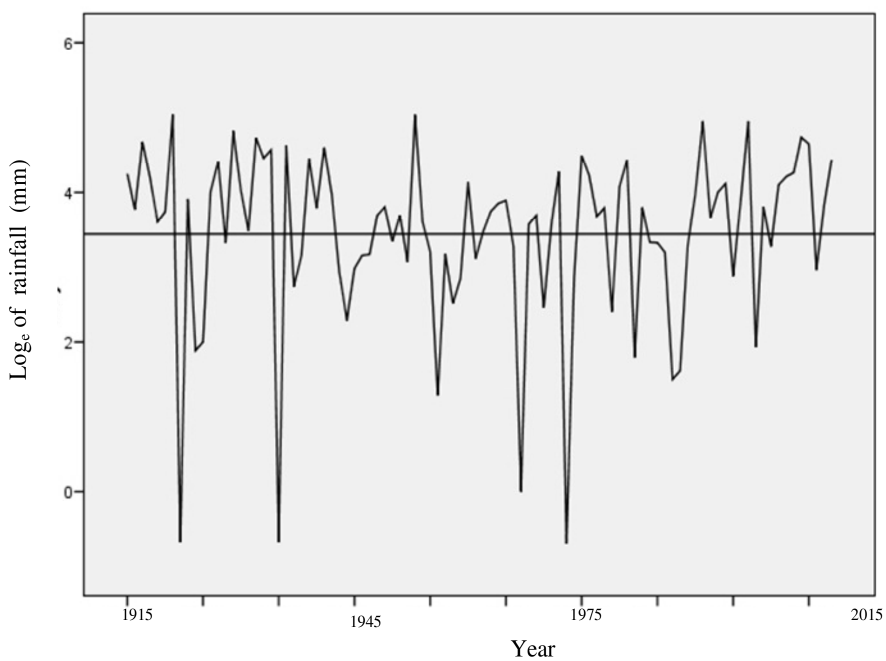

Figure 7: Sequence of rainfall in the month of May

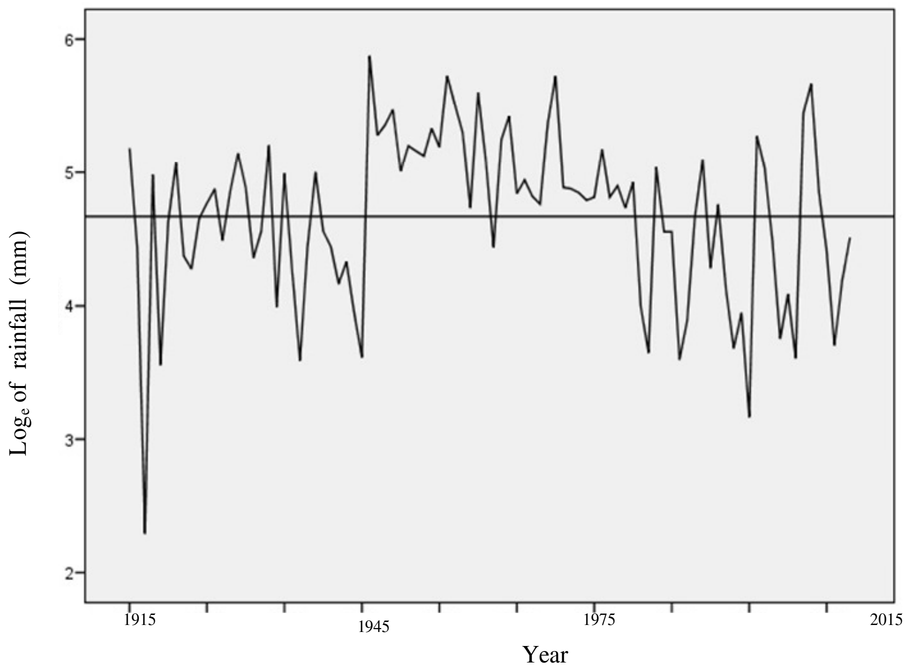

Figure 8: Sequence of rainfall in the month of June

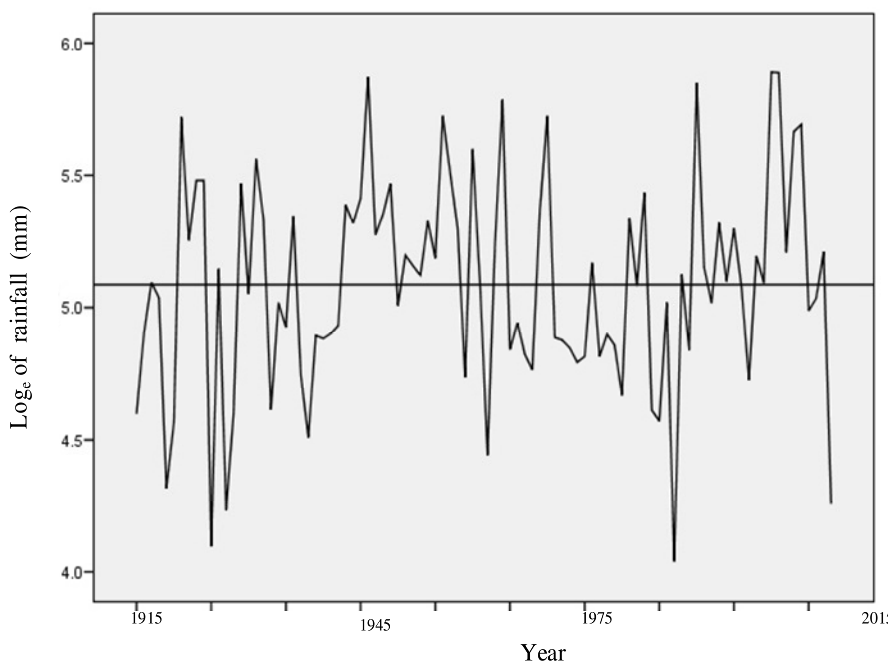

Figure 9: Sequence of rainfall in the month of July

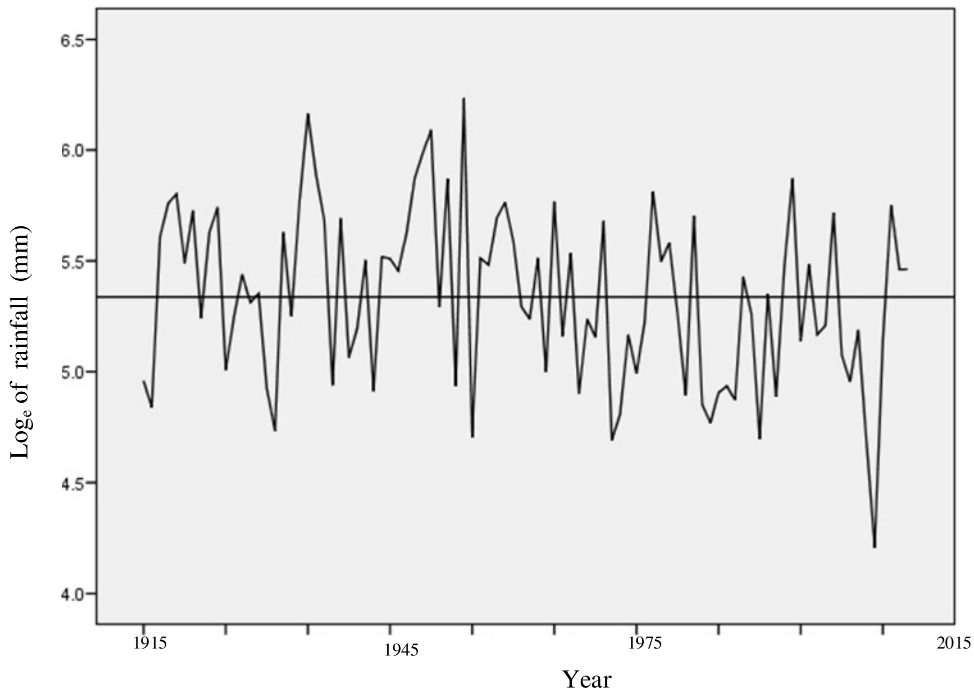

Figure 10: Sequence of rainfall in the month of August

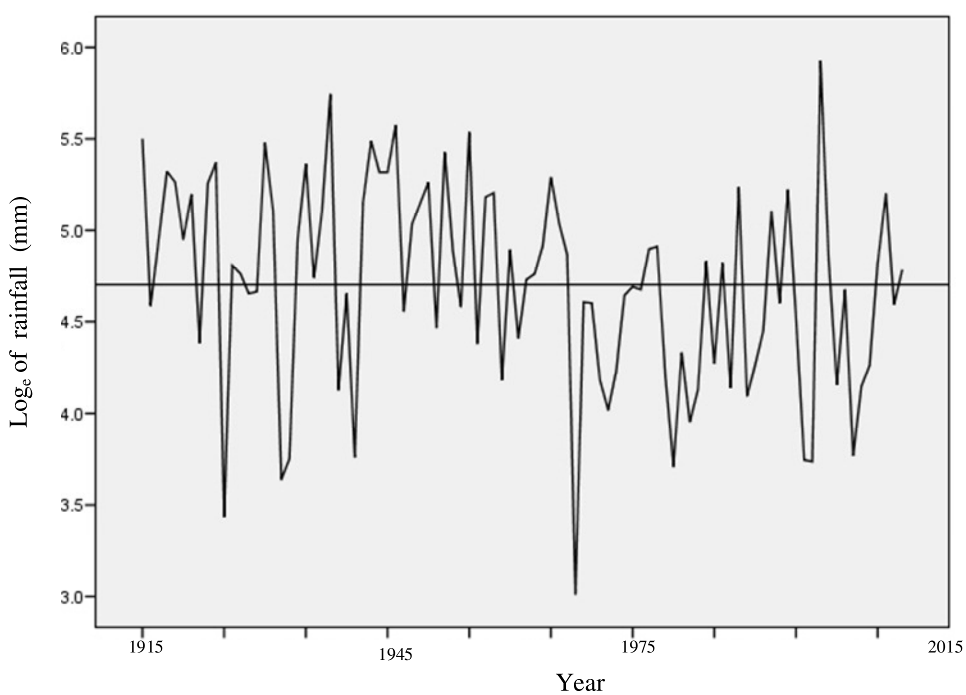

Figure 11: Sequence of rainfall in the month of September

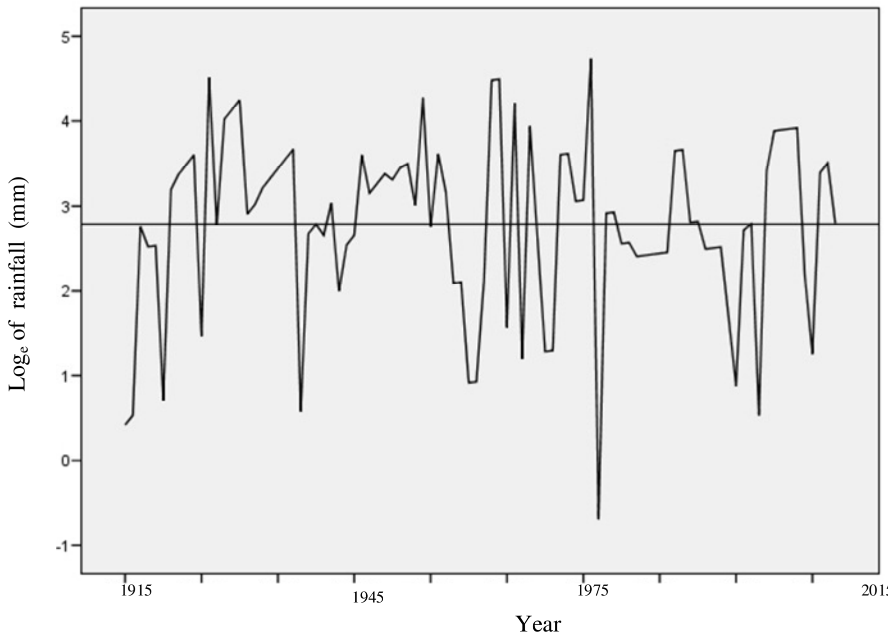

Figure 12: Sequence of rainfall in the month of October

manifest itself in the city as temperature increment and reduction in rainfall in the month of April, May, August, September and October.

CONCLUSION

It can be concluded based on the study that:

- the rainfall pattern has changed in Birnin Kebbi,
- there are trends in the rainfalls pattern (yearly total, mean, maximum and minimum),
- Downward trends of the rainfall are statistically significant; and
- The trend revealed that the months August and September have downward trends

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Symbols and abbreviations

$\overline{Y_{obsi}}$	average of actual rainfall values(mm)
$\overline{Y_{cali}}$	average of expected rainfall (mm)
Y_{cali}	expected rainfall values of each model (mm)
CD	coefficient of determination
Err^2	total error
MSC	model selection criterion
n	number of data points
N_A	number of samples in group A
N_B	number of samples in group B
p	number of parameters
R_A	rank of group A
R_B	rank of group B
Tan (β)	Slope of group B
Tan (φ)	Slope of group C
Tan(α)	Slope of group A
Y_{obsi}	obtained rainfall values from the model(mm)
α	angle of group A
β	angle of group B
φ	angle of group C