

## Analysis of rainfall variation over northern parts of Nigeria

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### ABSTRACT

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*rainfall, Northern Nigeria, skewness, kurtosis, coefficient of variation*

This study investigates rainfall variation in some parts of northern Nigeria. This was done by assessing the variations in rainfall characteristics in the study area; to identify areas/stations with highest/lowest mean annual rainfall amount and finally predict the values for the periods 2012 to 2030. Monthly rainfall amount data of fourteen synoptic stations in some parts of Northern Nigeria used in this study for the period of forty-two years (1971-2012) was obtained from the Nigerian Meteorological Agency. Statistical measures (mean, median, maximum, minimum, standard deviation, variance, skewness, kurtosis and coefficient of variation), time series and forecast the year 2030. The analysis of rainfall variations from the study area shows that Jos recorded the highest mean annual rainfall amount of 1263.2mm and Nguru recorded the lowest amount of 470.2mm over the years, which also has the minimum rainfall variability with 12% coefficient of variation. The year 2001 recorded the highest mean annual rainfall total of 14991.3mm, while 1983 recorded the lowest amount (645.7mm). Kano has the highest coefficient of variation value of 38% during the study period. Thus, rainfall has been on the increase within the study periods.

## 1. INTRODUCTION

Rainfall stands out as perhaps the single, most unique element of all the climatic elements such that its total amount, intensity, duration, variability, reliability and its spatial and temporal distribution influence phenomenon especially in the tropical region where prevailing economic activity is simply agro-based [1-2].

Recently, in Africa and Nigeria in particular, the emphasis of many scholars in the study of tropical climatology has been the consideration of rainfall characteristics, such as rainfall amount, duration and intensity. Rainfall is the meteorological phenomenon that has the greatest impact on human activities and the most important environmental factor limiting the development of the semiarid regions [3]. Understanding rainfall variability is essential to optimally manage the scarce water resources that are under continuous stress due to the increasing water demands, increase in population, and the economic development [4].

In Nigeria, the dominant feature of rainfall is its seasonal character. The large energy content of rainfall system is its variability from year to year which is mainly attributed to the fluctuation in the movement of the two different dominant air masses, the Inter Tropical Discontinuity [5-6]. Despite the recent advances made in science and technology, farmers and their crops are still left at the mercy of rainfall especially in Sub-Saharan Africa, where the Northern region of Nigeria lies. Hence water supply for agricultural practices is highly dependent on precipitation. Moreover in areas where the climate is greatly influenced by drought and desertification, the condition of precipitation in relation to yield, the rate of evapo-transpiration and soil moisture content may help promote or hinder crop production. This is subject to

availability of moisture at the evaporating surface and the ability of the atmosphere to vaporize the water.

The variability of rainfall and the pattern of extreme high or low precipitation are very important for agriculture as well as the economy of the state. It is well established that the rainfall is changing on both the global and the regional scales due to global warming [7-8].

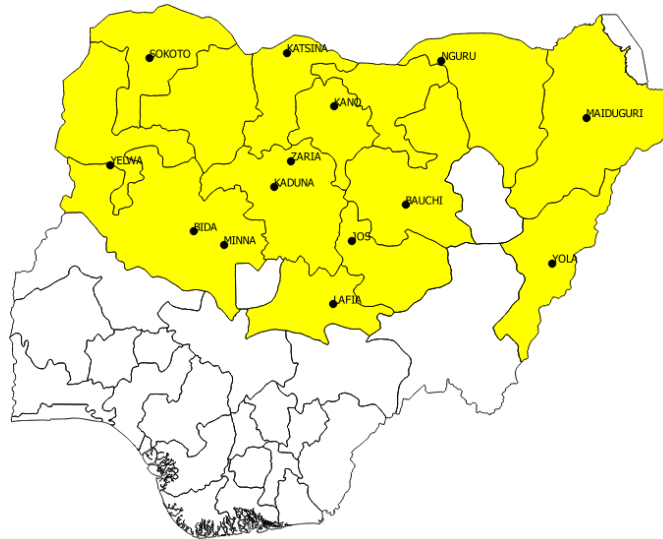
The knowledge of climate variability over the period of instrumental records and beyond on different temporal and spatial scale is important to understand the nature of different climate systems and their impact on the environment and society [9].

Earlier studies in this region indicate declining annual rainfall totals creating scarcity of water for agricultural production and needs for more effective water resources development [10-11]. Most of these studies were based on records terminating in the late 1980s and the early 1990s.

Adefolalu [12] 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. Eludoyin et al. [13] studied monthly rainfall distribution in Nigeria between 1985-1994 and 1995-2004 and noticed some fluctuations in most months within the decades.

## 2. STUDY AREA

The study areas lies between latitudes 9°N to 14°N and longitudes 3°E to 14°E. The synoptic stations used in the study are shown in Figure 1.



**Figure 1.** Map of Nigeria showing study area

### 3. MATERIALS AND METHODS

#### 3.1 Data

The data used in this study include monthly rainfall (mm) for fourteen synoptic stations in northern parts of Nigeria from the Nigerian Meteorological Agency for the period of 1971 to 2012. Interpolation and averaging for missing data were done for Bauchi, Bida, Minna, Yola, Zaria and Jos.

#### 3.2 Method

Microsoft excel statistical software package and Statistical Package for Social Sciences (SPSS) were used for the analysis. The data were subjected to statistical analysis using measures of central tendency such as mean, mean deviation and median; measures of dispersion such as range, variance and standard deviation as well as a measure of relationship (coefficient of variance).

$$\text{Mean} = \frac{\sum_{i=1}^n X_i}{n} \quad (1)$$

$$\text{Variance} = \frac{\sum(x-x)^2}{n-1} \quad (2)$$

$$\text{Coefficient of Variation (CV)} = \frac{SD}{\bar{x}} \times 100 \quad (3)$$

$$\text{where: SD is standard deviation} = \sqrt{\frac{\sum(x-x)^2}{n-1}} \quad (4)$$

### 4. RESULTS AND DISCUSSION

#### 4.1. Statistics of rainfall summaries in the study area by stations

Table 1 shows the result of the statistical analysis for rainfall summaries by stations. The highest amount of mean annual rainfall in the study area from 1971-2012 was observed in Jos with total sum of 1263.2mm, followed by Minna (1206.5mm) and Kaduna with 1198.1mm respectively. While, the least amount was recorded at Nguru with the sum of 419.0mm, followed by Katsina with 548.1mm and Maiduguri with the sum of 569.6mm respectively.

**Table 1.** Statistics summaries of mean annual rainfall by station from 1971-2012

SYNOPTIC STATION	NUMBER OF YEARS (1971-2012)	SUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	VARIANCE	SD	KURTOSIS	SKEWNESS	C.V%
BAUCHI	42	41441.4	1036.0	989.8	725.6	1619.6	894.0	41571.5	203.9	0.9	0.9	20
BIDA	42	46767.0	1113.5	1144.1	213.1	1407.7	1194.6	40493.5	201.2	8.8	-2.2	18
JOS	42	53052.9	1263.2	1246.6	814.7	1646.2	831.5	23948.4	154.8	1.8	-0.3	12
KADUNA	42	50319.9	1198.1	1224.4	827.9	1484.9	657.0	28948.4	170.1	-0.4	-0.3	14
KANO	42	39907.5	950.2	919.7	416.1	1872.0	1455.9	131691.5	362.9	0	0.7	38
KATSINA	42	23020.5	548.1	542.8	262.0	955.7	693.7	25139.6	158.6	-0.4	0.3	30
MAIDUGURI	42	22785.2	569.6	587.8	263.5	897.1	633.6	21839.1	147.8	-0.6	0	26
MINNA	42	50672.2	1206.5	1215.3	823.4	1582.9	759.5	28180.4	167.9	0.4	-0.3	14
NGURU	42	17597.3	419.0	415.2	226.7	696.9	470.2	15437.7	124.3	-0.4	0.4	30
POTISKUM	42	24435.0	643.0	648.5	372.0	966.1	594.1	22397.0	149.7	-0.4	-0.1	23
SOKOTO	42	25976.1	633.6	626.7	373.2	1146.7	773.5	21511.2	146.7	2.4	0.9	23
YELWA	42	41751.3	994.1	978.4	584.0	1566.2	982.2	32220.4	179.5	3.3	1.1	18
YOLA	42	35694.8	870.6	908.8	468.5	1121.7	653.2	23884.2	154.6	0.6	-0.9	18
ZARIA	42	43046.9	1024.9	992.2	685.6	1409.3	723.7	26896.8	164.0	-0.3	0.2	16

Kano recorded the highest maximum annual rainfall total with the sum of 1872.0mm, while Bida recorded the lowest minimum annual rainfall total with the sum of 213.1mm. Nevertheless, Kano also had the highest rainfall range of 1455.9mm and the least was observed at Nguru (470.2mm).

The skewness showed negative values in Kaduna, Bida, Yola and Jos (i.e. the stations had the tendency of below average rainfall distribution), while other stations had positive skewness (i.e. the tendency of having above average rainfall distribution).

The coefficient of variation shows that 38% variation occurred in Kano within the study period. This makes Kano station with highest rainfall variability, followed by Katsina

and Nguru with values of 29% and 30% each. While Jos, Katsina and Minna recorded the least stations with values of 12% and 14% each respectively.

#### 4.2 Annual rainfall summaries

Table 2 shows the statistical summaries of mean annual rainfall from 1971-2012. The year 2001 recorded the highest mean annual rainfall total of 14991.3mm, followed by 2003 (14437.7mm), 1978 (14235.8mm) and 1999 with the total sum of 14330.0mm. While, the least mean annual rainfall total was recorded in 1983 (9040.3mm) and 1987 (9893.6mm).

**Table 2.** Statistics of mean annual rainfall summaries in the study area (1971-2012)

YEAR	STATISTICS											
	NO. OF STATION	SUM	AVERAGE	MEDIAN	MINIMUM	MAXIMUM	RANGE	SD	VARIANCE	KURTOSIS	SKEWNESS	C.V %
1971	14	11895.0	849.6	852.7	328.3	1431.8	1103.5	345.4	119285.1	-1.2	0.1	41
1972	14	11488.9	820.6	846.8	247.6	1368.3	1120.7	339.3	115157.9	-0.7	0.1	41
1973	14	10270.1	733.6	786.4	258.9	1360.7	1101.8	343.6	118091.7	-1.0	0.3	47
1974	14	13231.8	945.1	975.5	472.2	1441.2	969.0	315.0	99203.9	-1.5	0.0	33
1975	14	12650.8	903.6	819.6	544.1	1393.6	849.5	331.7	110046.9	-1.4	0.5	37
1976	14	13108.4	936.3	939.4	430.9	1446.3	1015.4	327.7	107386.4	-1.3	0.0	35
1977	14	11829.3	845.0	841.5	372.0	1354.4	982.4	262.1	68708.6	0.1	0.1	31
1978	14	14235.2	1016.8	962.4	496.7	1582.9	1086.2	382.5	146327.7	-1.5	0.1	38
1979	14	13083.8	934.6	894.9	587.8	1476.0	888.2	274.9	75542.7	-0.6	0.6	29
1980	14	12502.1	893.0	896.9	339.6	1287.2	947.6	280.1	78449.0	-0.5	-0.3	31
1981	14	12045.4	860.4	930.3	428.9	1272.4	843.5	303.7	92252.1	-1.6	-0.1	35
1982	14	11442.9	817.4	876.9	354.0	1330.4	976.4	345.2	119165.7	-1.4	0.1	42
1983	14	9040.3	645.7	652.1	226.7	1086.2	859.5	247.9	61444.7	-0.5	-0.1	38
1984	14	10594.1	756.7	823.0	331.3	1345.0	1013.7	346.9	120349.3	-1.4	0.2	46
1985	14	11112.9	793.8	759.2	399.2	1223.1	823.9	325.8	106151.0	-1.8	0.1	41
1986	14	11534.1	823.9	832.4	240.5	1229.9	989.4	297.9	88756.7	-0.6	-0.4	36
1987	14	9893.6	706.7	722.8	251.3	1289.1	1037.8	339.1	114979.6	-1.1	0.4	48
1988	14	12991.5	928.0	1014.2	320.6	1237.7	917.1	291.3	84842.2	-0.1	-1.0	31
1989	14	11356.1	811.2	785.4	338.6	1232.0	893.4	266.8	71206.7	-0.8	0.1	33
1990	14	10713.8	765.3	810.3	242.1	1230.9	988.8	302.7	91603.6	-1.0	-0.1	40
1991	14	12768.7	912.1	914.0	235.5	1411.4	1175.9	382.7	146454.5	-1.1	-0.4	42
1992	14	12075.2	862.5	961.8	333.1	1241.9	908.8	315.0	99240.8	-1.1	-0.6	37
1993	14	12029.9	859.3	966.2	262.0	1250.7	988.7	329.6	108668.4	-0.9	-0.6	38
1994	14	13214.0	943.9	906.3	453.1	1537.3	1084.2	326.1	106323.6	-0.6	0.2	35
1995	14	11658.4	832.7	888.1	317.7	1279.3	961.6	308.9	95448.8	-1.2	-0.2	37
1996	14	12772.1	912.3	989.4	268.8	1382.0	1113.2	334.6	111969.0	-0.7	-0.5	37
1997	14	13363.0	954.5	1021.2	493.3	1329.3	836.0	312.1	97395.8	-1.6	-0.3	33
1998	14	14153.1	1010.9	1067.1	431.6	1872.0	1440.4	368.0	135409.8	1.3	0.5	36
1999	14	14330.0	1023.6	1069.5	310.9	1566.2	1255.3	374.5	140213.5	-0.6	-0.5	37
2000	14	13033.2	930.9	1028.5	353.8	1274.5	920.7	297.9	88726.0	-0.9	-0.6	32
2001	14	14991.3	1070.8	1193.0	466.0	1789.4	1323.4	350.0	122482.0	-0.1	0.1	33
2002	14	12663.7	904.6	921.6	441.6	1582.7	1141.1	316.8	100391.4	0.3	0.4	35
2003	14	14437.7	1031.3	930.1	653.3	1468.3	815.0	286.1	81848.4	-1.4	0.3	28
2004	14	13546.9	967.6	1055.1	543.0	1379.4	836.4	284.1	80735.6	-1.5	-0.3	29
2005	14	13135.7	938.3	947.2	519.1	1376.3	857.2	248.4	61708.0	-0.7	0.0	26
2006	14	13091.1	935.1	964.7	409.5	1524.0	1114.5	308.9	95445.1	-0.3	0.1	33
2007	14	11915.8	851.1	814.6	213.1	1409.9	1196.8	324.8	105486.0	-0.3	-0.1	38
2008	14	11467.8	819.1	840.5	338.9	1271.3	932.4	315.8	99718.9	-1.4	0.0	39
2009	12	12421.9	955.5	992.2	366.5	1531.3	1164.8	398.6	158891.5	-1.5	-0.2	42
2010	12	13558.3	1042.9	1098.1	466.5	1619.6	1153.1	285.1	81268.5	1.1	-0.1	27
2011	11	10166.6	924.2	1020.5	398.9	1646.2	1247.3	378.5	143264.7	-0.4	0.2	41
2012	9	10653.5	1183.7	1231.0	696.9	1680.0	983.1	354.0	125351.2	-1.5	-0.2	30

The minimum amount of rainfall was recorded in 2007 with a value of 213.1mm followed by 1991 (235.5mm), 1990 (242.1mm) and 1993 (262.0mm) respectively. Thus, the highest amounts of maximum rainfall were recorded in 1998 with a value of 1872.0mm followed by 2001 (1789.4mm),

2012 (1680.0mm) and 2010 (1619.6mm).

The distribution of the data is positively skewed in 1971, 1972, 1973, 1974, 1975, 1977, 1978, 1979, 1982, 1984, 1985, 1987, 1989, 1994, 1998, 2001, 2002, 2003, 2005, 2006, 2008 and 2011 (i.e. the tendency of having above average rainfall

distribution). Other years not mentioned were negatively skewed. The kurtosis showed a negative value in 1977, 1988, 2002 and 2010 (i.e. flatter than normal peak distributions). While the other years had negative kurtosis (i.e. peak flattest than the average) values during the year of consideration. The year 1987 has the highest coefficient of variation value of 48% followed by 1973 (47%) and 1984 (46%), while the least was recorded in 2005 with a value of 26% followed by the year 2010 (27%) and 2003 (28%) as shown in table 2.

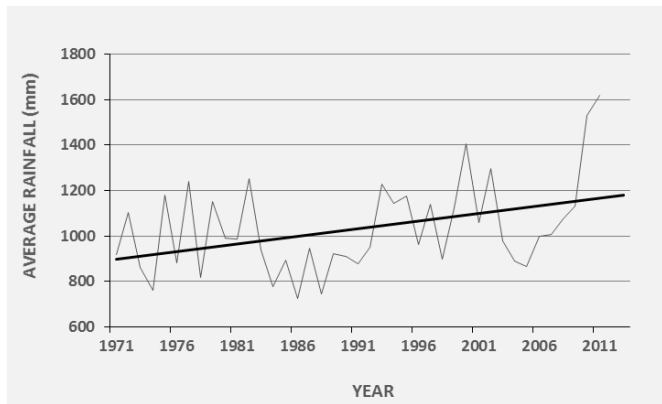
### 4.3 Rainfall distribution trend

#### 4.3.1 Mean annual rainfall distribution

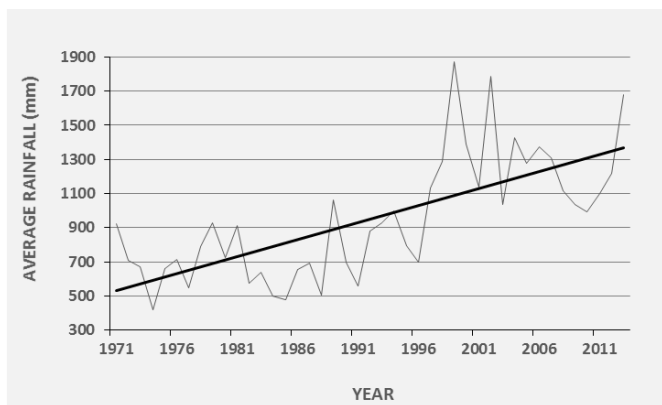
The mean annual rainfall distribution from the study area ranges from 420mm to 1263mm over the entire 42 years of study. Generally, there were upward and downward shifts during the study period.

An upward trends of mean annual rainfall are significant in Bauchi as shown in figure 2, Katsina (figure 3) Maiduguri (figure 4), Nguru (figure 5) and Yelwa (figure 6) respectively. However, downward rainfall trends were also noticeable at Kaduna and Yola stations (figure 7 & 8). A downward trend was noticed in the mean annual rainfall in all stations from 1983-1984, it was later rise up steady till 2008 as shown in figure 9.

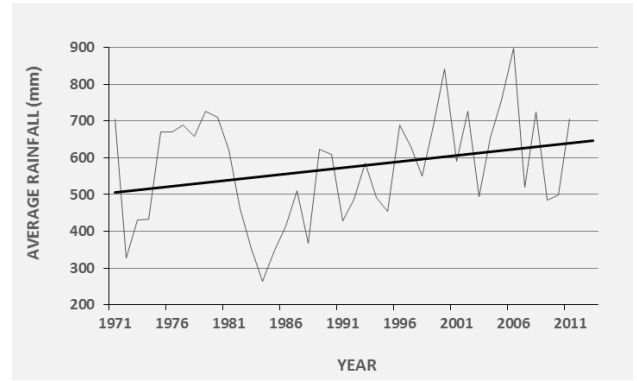
The time series straight line equation obtained ( $y=3.8229x+811.83$ ). This indicates that a continuous rise from 1971 to 2012. This was an evidence that rainfall was improving in the study area as shown in figure 9.



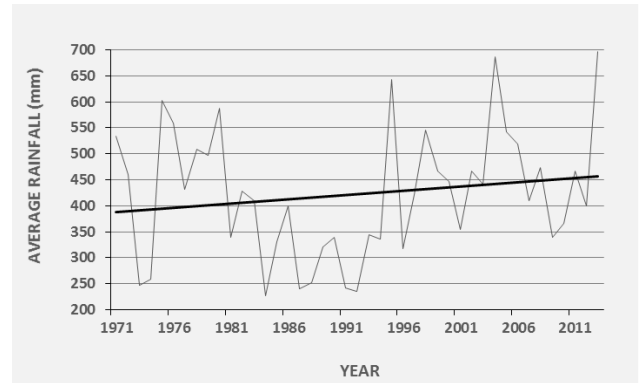
**Figure 2.** Mean annual rainfall total in Bauchi from 1971-2012



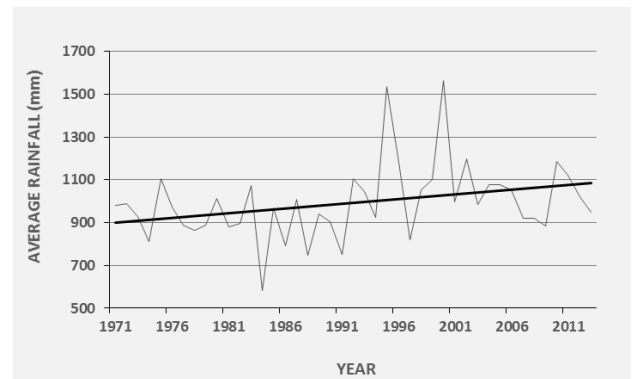
**Figure 3.** Mean annual rainfall total in Katsina from 1971-2012



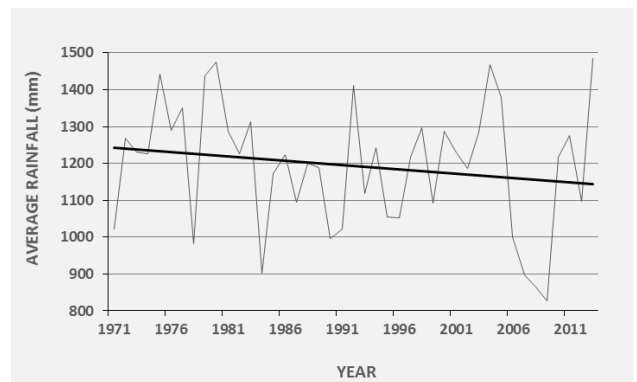
**Figure 4.** Mean annual rainfall total in Maiduguri from 1971-2012



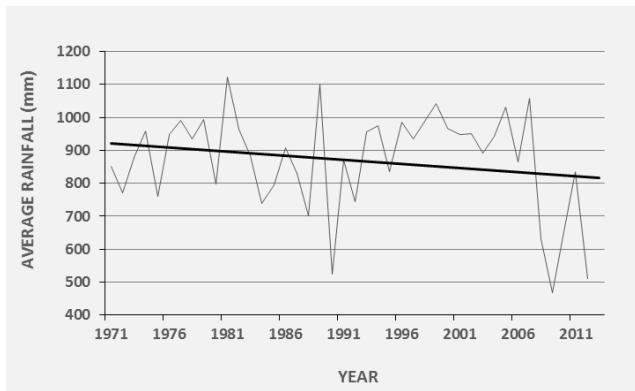
**Figure 5.** Mean annual rainfall total in Nguru from 1971-2012



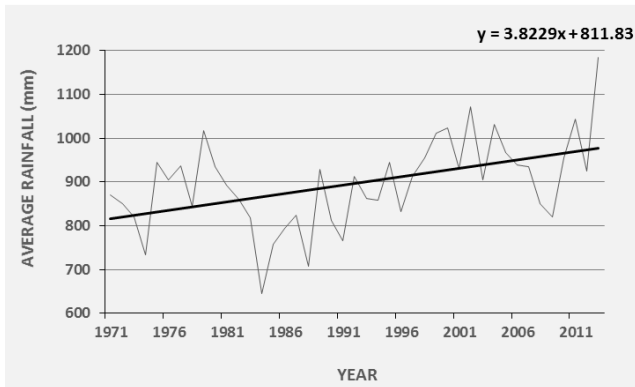
**Figure 6.** Mean annual rainfall total in Yelwa from 1971-2012



**Figure 7.** Mean annual Rainfall in Kaduna from 1971-2012



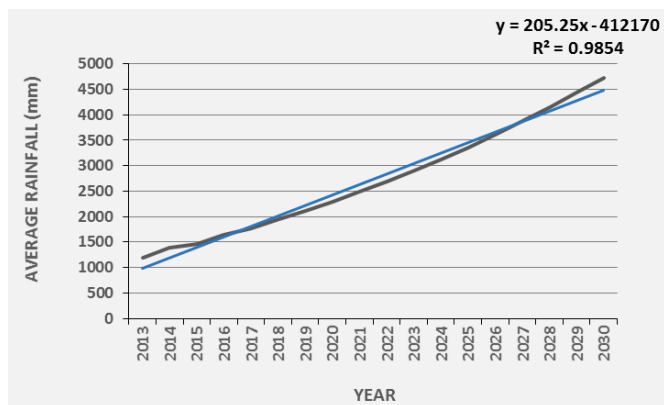
**Figure 8.** Mean annual rainfall total in Yola from 1971-2012



**Figure 9.** Mean annual rainfall total in the study area from 1971-2012

#### 4.3.2 Mean annual rainfall forecast from 2013 to 2030

The forecasted linear equation of the time series was obtained as  $y=205.25x-412170$ . The trend line shows a continuous rise from 2013 to 2030 (figure 10). This was an evidence that there will be an improved rainfall amount across the study area for the forecasted years.



**Figure 10.** Mean annual rainfall in the study areas from 2013-2030 (forecast)

## 5. CONCLUSIONS

This study provides valuable insight into various degrees of rainfall as well as variability over the study area. The results revealed that Nguru recorded the least mean annual rainfall

over the years, while the highest mean annual rainfall was recorded in Jos, it also has the minimum value of 12% of coefficient of variation. Kano has the highest rainfall variation of 38%, followed by Nguru and Katsina with 30% each respectively. However, rainfall (both the observed and predicted) shows an increase within the study area. Further studies should be carried out using rainfall and temperature base on climatic zones of the northern region.

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