Gombe Journal of Geography and Environmental Studies (GOJGES)

Vol. 1 N0.3 Dec. 2020

e-ISSN: 2714-321X

p-ISSN: 2714-3201

http://www.gojgesjournal.com

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 1 N0.3 Dec. 2020, e-ISSN: 2714-321X; p-ISSN: 2714-3201

EVALUATING TRENDS AND CHARACTERISTICS OF CLIMATIC VARIABLES (Rainfall and Temperature) AT BAUCHI WEATHER STATION, NIGERIA

[1]Udeh Ejeh Lawrence*, [2]Nnachi Solomon Uduma, and [2]Ikpe Elisha
[1]Department of Geography, Federal University, Gashua, Yobe State, Nigeria.
[2]Department of Geography and Environmental Management, Ahmadu Bello University, Zaria-Nigeria.
***Corresponding Author's E-mail: findlawejeh2000@yahoo.com.**

Abstract

This study aims to evaluate the trends and characteristics of rainfall and temperature data records at Bauchi climatic station for 45 years (1970-2014). The results were analyzed using descriptive statistics presented in tables and charts. The rainfall data series was separated into three sub-periods of 15 years each (1970-1984; 1985-1999 and 2000-2014). The results showed that the rainfall series increased sequentially from the first to the third sub-period. Positive trend line equations occurred in all the rainy trends except for the first rainy sub-period and onset rainy dates, which showed downward trends below the mean implying that the study area experienced early onset, and late cessation dates and longer days in LRS. Temperature data series were also analysed with maximum temperatures occurring in April while minimum temperatures occurred in December. The relationship between monthly rainfall and temperature for the station showed that average temperatures of 30-35°C led to increases in the mean monthly rainfall from 280-300 mm in July and August and at 15-20°C, there was little or no rainfall. The findings of this study, therefore, revealed that high temperature induces high rainfall. The study thus recommended the following: improving climatic data and continuous data monitoring, public enlightenment on the impacts of climate change, the use of air conditioners and energy-saving appliances in buildings during high temperatures, adoption of viable adaptive strategies by farmers and the establishment of meteorological research institutes in the study area for state and national development planning.

Keywords: *Characteristics, Climatic, Rainfall, Temperature, Trends, Variables*

1. Introduction

In recent decades, an increase in temperature and rainfall extremes with negative effects on crop production is registered. Climate scenarios predict the continued trend of extreme temperatures occurrence and changes in rainfall distribution during the year. Crop production depends on current weather conditions as well as on long-term climate variability (Sreda, Stredova, and Roznovsky, 2012). Globally, increased rainfall and temperature variability, climate change, and increased human activities have been and will continue to adversely modify the natural resource and the environment as a whole. Climate exerts a strong influence on the relevant socio-economic sector and people's livelihood in sub-humid and semi-arid zones of northern Nigeria where the drying condition has been on the increase. These changes are occurring at an unprecedented rate thereby drastically reducing bio-productivity of the physical environment. This uncoordinated and undocumented process of change is a threat to food security and the apparent poverty level typical of northern Nigeria (FAO, 1996).

Rainfall stands out as perhaps the single, unique element of all the climatic elements such that it's 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 (Oladipo, 1987; Nnachi, 2014). 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 (Kipkorir, 2002). Understanding rainfall and temperature 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 economic development (Herath, 2004).

In Nigeria, the dominant feature of rainfall is its seasonal character. The large energy content of the 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 (Ayoade, 1973). 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 to yield, the rate of evapotranspiration and soil moisture content may help promote or hinder crop production.

According to Trenberth, Jones, Ambenja, Bojariu, Easterling and Zhai (2007), there is a general concern that global temperatures and sea level are rising and will continue to rise throughout 21st century and that temperatures at the surface have risen globally, with regional variations. Ogunrayi, Akinseye, Goldberg and Bernhofer (2016) reported that temperature rises during the dry periods (November – March) and gradually cools at the approach of the wet season. The result is further supported by the findings of Odjugo (2010) which reported an increase by 1°C in the temperature of Nigeria from 1940 to 2010. High temperature affects plant through its effects on the availability of water which is very important in the process of photosynthesis. Thus, with high temperature and strong solar radiation, evapotranspiration increases, thereby increasing water stress on the plant which reduces maximal photosynthesis. Increased temperature may also result in reduced water availability, leaf turgor, leaf water potential and stomata opening thereby reducing plant growth rate (Colom and Vazzana, 2000).

The geographical location of Bauchi State, Nigeria is generally prone to drought, wind, and water erosion, thereby promoting geo-environmental degradation. This region is marginal land, where crops experience moisture stress and often fail mainly as a result of the effect of the repeated prolonged drought. Although agriculture is the major occupation in this region, desertification, repeated drought, crop failure and southward migration of the inhabitant signal is the fact that food security is threatened. Thus, this study aimed at assessing the trends and characteristics of rainfall and temperature series at Bauchi weather station, Nigeria.

2. Study area

Bauchi State is in the north-east geo-political zone of Nigeria and was created in 1976. The state is located between latitudes 9°30' and 12°30' North of the equator and between longitudes 8°45' and 11°0' East of the Greenwich meridian. It is bounded in a clockwise direction by Yobe, Gombe, Taraba, Plateau, Kaduna, Kano and Jigawa States. There are 20 Local Government Areas in the state (National Bureau of Statistics, 2009).

Bauchi State covers about 49,259 Km^2 with a population of 4,653,066 according to the 2006 census. The state is heterogeneous, with predominant tribes like Hausa, Fulani, Jarawa, Tangale, Waja, Balewa, Sayawa, and Tarewa. The major language is Hausa. The entire western and northern parts of the state are generally mountainous and rocky. This is as a result of the closeness of the state to the Jos

(Plateau State) and Cameroon mountains (National Bureau of Statistics, 2009).

The mean daily maximum temperature ranges from 27.0°C to 29.0°C between July and August and 37.6°C in March and April. The mean daily minimum ranges from 22.0°C in December and January. The sunshine hours range from about 5.1 hours in July to about 8.9 hours in November. October to February usually record the longest sunshine hours in Bauchi. Humidity ranges from about 12% in February to about 68% in August. The rainy season months are May to September when humidity ranges from 37% to 68%. Monthly rainfall ranges from 0.0mm in December and January, to about 343mm in July. The onset of rain is often in April while they end virtually by October (Wikipedia, 2008). The area is drained by River Gongola, which originates in the Jos Plateau area. The vegetation of Bauchi is Sudan Savanna type. The vegetation gets richer towards the southern part. The soil of Bauchi is a sandy loam type. Bauchi is an agricultural area by its vegetation type. Besides its vast fertile soil is an added advantage for growing crops such as maize, rice, millet, groundnut, guinea corn, etc (Odiana and Ibrahim, 2015).

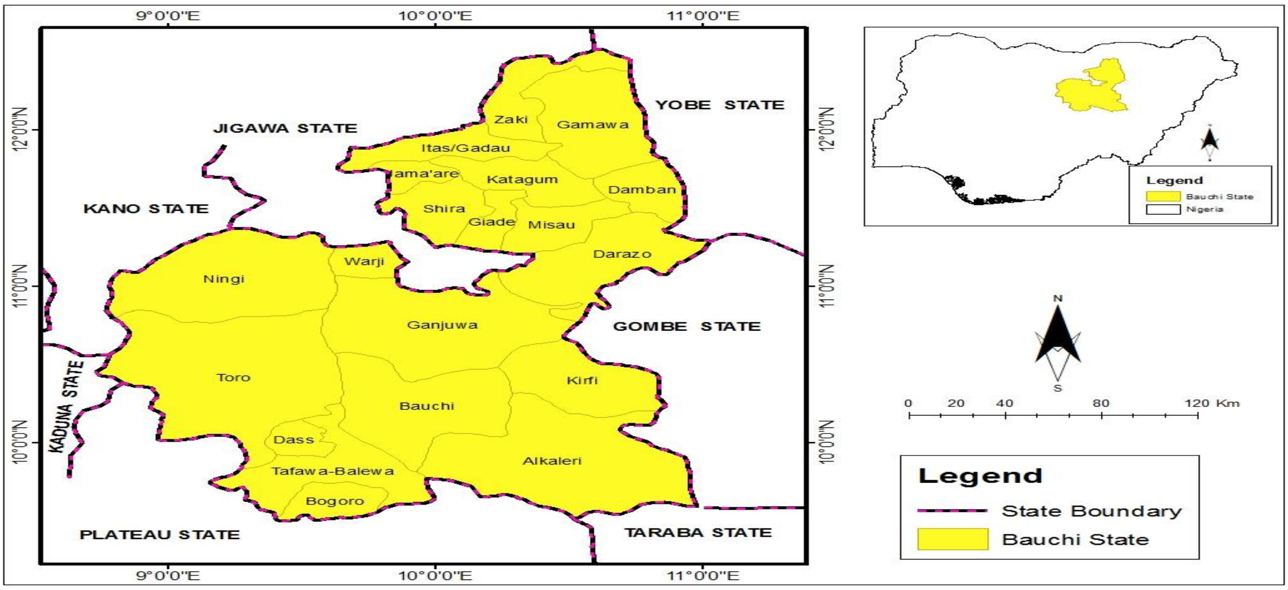

Figure 1: Bauchi State, Nigeria
Source: Adopted from Administrative map of Nigeria (2020)

3. Materials and Method

3.1 Source and Type of Data

The study design involved the collection and analyses of rainfall and temperature data (1970 -2014) for Bauchi meteorological station obtained from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos. The rainfall and temperature data were used to characterize and analyze the climate of the study area. The data were analyzed using tables, trend line graphs, and bar charts. The results of the analyses are presented in tables, on line-graphs and bar charts.

3.2 Test for Normality

The standardized coefficient of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were calculated for testing the normality of the annual rainfall series (1970-2014) and the 15-years sub-periods (1970-1984; 1985-1999 and 2000-2014). These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. If the absolute value, Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at 95% confidence level or 0.05 significance level. Any value outside the normal curve is judged to be abnormal.

3.3 Rainfall Characteristics

The rainfall data obtained from NIMET for forty-five years (1970–2014) was added for each of the years beginning from January to December to give the TAR received in the Bauchi station. The long-term mean was determined by summing all annual rainfall records and dividing by the number of years. The Standard deviation explains the measure of the dispersion of rainfall values from the mean. The mean was subtracted from each of these rainfall values and the sum of their squared differences divided by the number of rainfall years. The square root of the result gives the Standard deviation. The Coefficient of Variation equals the standard deviation divided by long-tern mean multiplied by 100. The general and 15-years sub-periodic rainfall series (1970-1984; 1985-1999 and 2000-2014) for all these rainfall variables were determined.

3.4 Temperature Characteristics

The annual mean temperature was obtained by summing up all the monthly temperatures for each of the minimum and maximum temperatures and dividing by the number of months in a year. The monthly mean temperature was derived from the addition of each month from 1970–2014 and dividing it by the number of years (45 years).

3.5 Determination of Onset, Cessation, and Length of Rainy Season

Various methods abound for characterizing the climate of an area (determination of onset dates, cessation dates and length of the rainy season), for example, Walter (1967), Ilesanmi (1972), Kowal and Knabe (1972), Stern, Dennett, and Dale (1982b); Stern and Coe (1982); Olaniran (1984 and 1988), Sivakumar (1988) and Adefolalu (1993). Walter's (1967) method remains the best method for determining the onset and cessation dates of rains and LRS and adopted for this study because according to Ati (1996) and Sawa and Adebayo (2011), it has better coverage, it is more scientific and reliable in the semi-arid regions in determining the onset dates, cessation dates, and LRS.

Several approaches have been developed over the years for characterizing the climate of an area, but this research adopted Walter's (1967) method. According to Walter (1967), the onset date of rain is the product of the number of days in the month from January whose cumulative rainfall is greater than or equal to 51mm and the difference between 51 and the total amount of rainfall in the preceding month divided by the total amount of rainfall in the month with cumulative rainfall greater than or equal to 51mm, mathematically expressed as:

Onset date = $Ndx\left(\frac{51\text{mm}-\text{TRA}}{\text{TRx}}\right)$

Where;

Ndx = number of days in the month from January whose cumulative rainfall is ≥ 51 mm.

TRA= total rainfall in the month preceding the month with cumulative rainfall ≥ 51mm.

TRx = total rainfall in the month with cumulative rainfall ≥ 51mm.

Fifty – one millimetres of rainfall are used as the threshold because it is the required amount of the available moisture necessary for effective germination, growth and development of crops.

According to Walter (1967), the cessation date of rain is determined, similarly with the onset but in reverse order. It is the product of the number of days in the month from December whose cumulative rainfall is greater than or equal to 51mm and the difference between 51 and total rainfall of the month before the month whose number is greater or equal to 51 mm divided by the total amount of rainfall in the month whose cumulative rainfall ≥ 51 mm.

This value is subtracted from the total number of days in the month whose cumulative rainfall ≥ 51 mm.

Cessation date = $Ndx\left(\frac{51\text{mm}-\text{TRA}}{\text{TRx}}\right)$

Where;

Ndx= number of days in the month from December whose cumulative rainfall is greater than
or equal to 51 mm

TRA= total rainfall in the month before the month with greater than or equal to 51 mm from
December

TRx = total rainfall of the first month with cumulative rainfall greater than or equal to 51 mm

In the end, the answer obtained is subtracted from the number of days in the month with the cessation date. According to Walter (1967) LRS is the number of days between the onset date of the rains and the cessation date of the rains.

4. Results and Discussion

4.1 General Statistics of Annual Rainfall Characteristics in the Study Area

The annual rainfall series for Bauchi from 1970 to 2014 were subjected to descriptive statistical analysis as shown in Table 1.

Table 1: General Statistics for Annual Rainfall in Bauchi Climatic Station (1970-2014)

TAR (mm)	Long-term Mean (mm)	SD (mm)	CV (%)	Max (Year)	Min (Year)	Range (Years)	Z_1	Z_2	Mean Onset Date	Mean Cessation Date	Mean LRS (Months)
48647.3	1081.05	265.56	24.57	1912.1 mm (2013)	725.6 mm (1985)	1186.5 Mm (28 years)	1.157	1.096	9th May	12th Sept.	125 days (4months)

***Source**: Fieldwork for Bauchi climatic station (2020)*

4.2 General normality rainfall test

The annual rainfall series for Bauchi station was subjected to the normality test using the coefficients of Skewness (**Z_1**) and Kurtosis (**Z_2**) as illustrated in Table 1. The results of both coefficients showed that the series had no significant deviation from the normal curve (1.96) at a 95% confidence level showing normal distribution of data since the results were below 1.96.

4.3 Long-term statistics of annual rainfall

Table 1 showed that Bauchi experiences a very high Total Annual Rainfall (TAR) with a long-term mean of 1081.05 mm for the entire period. However, the Standard Deviation (SD) from the mean was not significant enough judging from the Coefficient of Variation (CV), which was below 30%. The range of annual rainfall was high at 1186.5 mm for close to three decades, which showed an irregular, fluctuating pattern of rainfall. The maximum rainfall was recorded in the year 2013 close to the latter period of the data (1912.1 mm) while the minimum rainfall (725.6 mm) occurred in the 1980s. This observation coincides with the research of Sawa (2010) and Nnachi (2014) who observed that northern Nigeria experienced drought conditions from the 1970s to the 1980s and significant rainfall rise occurred during the millennium with a long term mean of between 900 and 1200mm. A significant difference of 28 years running close to three decades was calculated between the maximum and minimum values. The mean onset date is in early May while the mean cessation date is mid-September. This shows early-onset and mid-to-late cessation giving a LRS that averagely lasts for 4 months. Wuyep and Daelong (2020) stressed that although rainfall in Jos is fluctuating annually, deviations of annual rainfall figures from the long-time mean are on the decrease.

4.4 Trends in Annual Rainfall (TAR)

Trends in the TAR are presented in Figure 3. The TAR data for the study area was used to describe the pattern of rainfall during the period reviewed and to show the trend in TAR within the period reviewed (1970 – 2014).

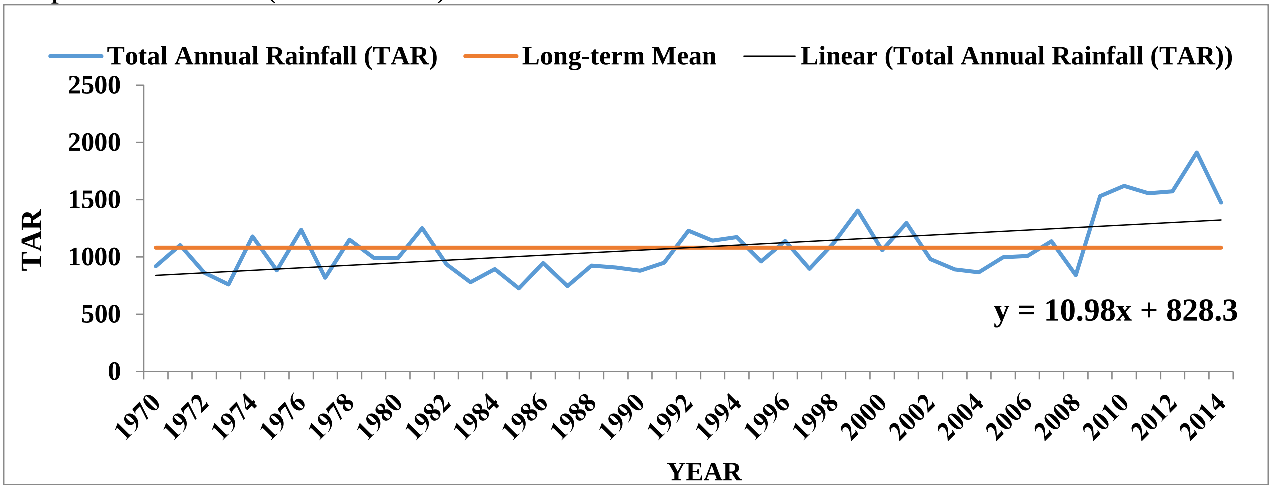

Figure 3 – Trends in Annual Rainfall for Bauchi station (1970-2014)
***Source**: Fieldwork for Bauchi climatic station (2020)*

The trend in annual rainfall series from 1970 to 2014 presented in Figure 3 shows that between 1970 and 1981, TAR was fluctuating above and below the mean but slipped below the mean from 1982 to 1992. It then slightly rose above the mean between 1993 and 2001. It went below normal between 2002 and 2008. After that, a significant rise took place above the mean from 2008 until the end of the data. Generally, this trend explains that the Bauchi climatic station had experienced a close to normal trend with the mean except in 2008 where there appeared to be a significant rise. The linear equation for the TAR is Y= 10.98x + 828.3 showing a positive trend line which signifies an above normal scenario that is favourable for crop production. According to Ojo and Ilunga (2018), the availability of adequate information on rainfall characteristics of an area is very important to farmers in making vital decisions relevant to agricultural practices.

That there is a positive increase in the trend of TAR agrees with the findings of Odiana and Ibrahim (2015) which reported an increasing TAR in Bauchi by 0.2mm per annum. The result further coincided with the findings of Sawa (2010) and Nnachi (2014) which reported that most parts of northern Nigeria experienced an increase in rainfall between 1990 and 2000. This result further corroborated with the findings of Ogunrayi, Akinseye, Goldberg, and Bernhofer (2016) which reported that rainfall in Akure, Nigeria is characterized by alternating wet and dry periods with a tendency towards a wetter condition, which implies an increase in the TAR and LRS. According to Olaniran (2001), Nigeria is characterized by alternating wet and dry conditions with rainfall anomaly showing wetter than normal rainfall conditions.

More so, that the TAR of the study area is increasing agrees with the observation made by Building Nigeria's Response to Climate Change (BNRCC, 2011) which reported that Nigeria is now experiencing wetter conditions in recent years. These results agree with the work of (Ojo and Ilunga 2018) that the rainy period in a tropical location can fluctuate in length, time of occurrence, and severity. This result is supported by Ati, Stiger, Iguisi, and Afolayan (2009) who stated that evidence from nine stations in northern Nigeria, shows that there is a significant increase in annual rainfall amount in the last decade of their study.

Table 2: General Statistics for 15-Years Periodic Rainfall for Bauchi (1970-2014)

Periods	TAR (mm)	Periodic Mean (mm)	SD (mm)	CV (%)	Max (mm)	Min (mm)	Range (mm)	Z_1	Z_2
1st Period (1970-1984)	14753.9	983.6	163.82	16.66	1251.2 (1981)	759.4 (1973)	491.8 (8 years)	0.402	-1.140
2nd Period (1985-1999)	15149.5	1010.0	186.53	18.47	1404.8 (1999)	725.6 (1985)	679.2 (14 years)	0.443	-0.115
3rd Period (2000-2014)	18743.9	1249.6	337.62	27.02	1912.1 (2013)	839.7 (2008)	1072.4 (5 years)	0.448	-1.053

***Source**: Fieldwork for Bauchi climatic station (2020)*

4.5 Periodic rainfall normality test

The normality test for the 15-year sub-periods using the coefficients of Skewness (**Z_1**) and Kurtosis (**Z_2**) in Table 2 showed that the rainfall data series for the first, second and third sub-periods were normally distributed at 95% confidence level for Skewness and did not deviate significantly from the normal curve of 1.96 unlike the coefficient of Kurtosis which appeared to be abnormal to the negative for all periods.

4.6 Periodic statistics of annual rainfall

Table 2 also showed the 15-year periodic rainfall characteristics for Bauchi station from 1970-1984, 1985-1999 and 2000-2014. In comparing each of the three sub-periods, there appeared to be an increasing trend in all the variables used from the first period to the third period except for Minimum rainfall where it was higher in the first period than the second. Owing to that fact, there were significant increases in other variables like TAR, Periodic Mean, Standard Deviation (SD), Coefficient of Variation (CV), Maximum, and Range of rainfall showing that rainfall was accelerating within the study area. Table 2 also showed that the years when maximum and minimum rainfall occurred for each period followed a particular trend with Minimum rainfall occurring at the earlier years of the periods while maximum rainfall occurred at the latter years of the periods. The years in the range of rainfall showed a greater disparity in the second period than the first and this explains that the rainfall pattern was fluctuating significantly in these two periods. However, the third period (2000-2014) showed lesser years in annual rainfall range and higher rainfall values than other periods. This corresponds with Nnachi (2014) who stated that most parts of northern Nigeria including Zamfara State began experiencing increasing appreciable rainfall amounts from the earlier part of the millennium, which is a sign of more wet years in the millennium.

4.7 Trends in the first periodic rainfall series (1970-1984)

The Trends in the first 15 years-periodic rainfall series (1970-1984) are presented in Figure 4. The TAR data for the study area was used to describe the pattern of rainfall during the period reviewed and to show the trend in rainfall within the period reviewed.

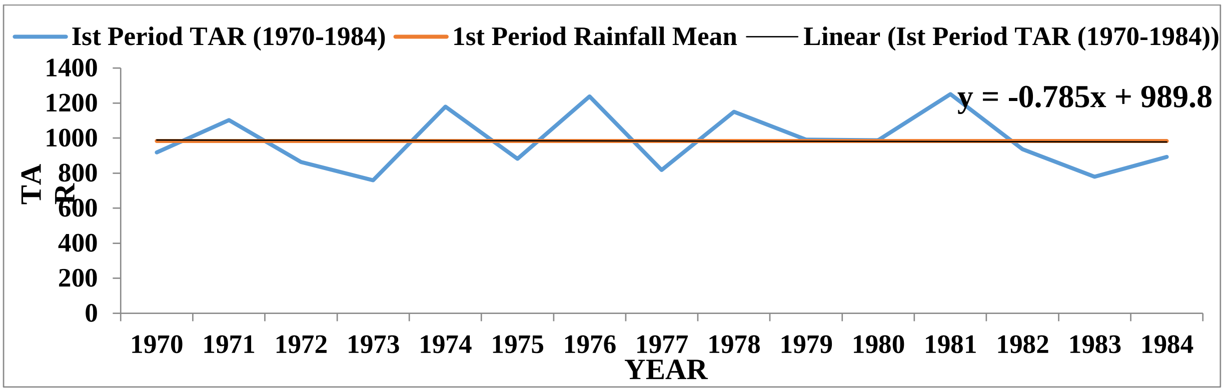

Figure 4 – Trends in 1st Periodic Annual Rainfall for Bauchi station (1970-1984)
***Source**: Fieldwork for Bauchi climatic station (2020)*

Figure 4 showed a fluctuating rainy trend above and below the periodic mean from the beginning to the end of the period. However, there were significant TAR rises above the mean in 1971, 1974, 1976, 1978, and 1981. Other years when TAR was below normal include 1970, 1972, 1973, 1975, 1977, 1983, and 1984. It was observed that the years where TAR increase above the mean was less than years of decrease, the trend line equation for Bauchi station was to the negative. The linear equation is y= -0.785x + 989.8 which implies that TAR was declining in the first period. This result coincided with the findings of Sawa (2010) and Nnachi (2014) observations of drought occurrences in northern Nigeria owing to the decline in rainfall values from the early 1970s to the late 1980s.

4.8 Trends in second periodic rainfall series (1985-1999)

Trends in the second 15 years-periodic rainfall series (1985-1999) are presented in Figure 5. The TAR data for the study area was used to describe the trend and pattern of rainfall during the period reviewed.

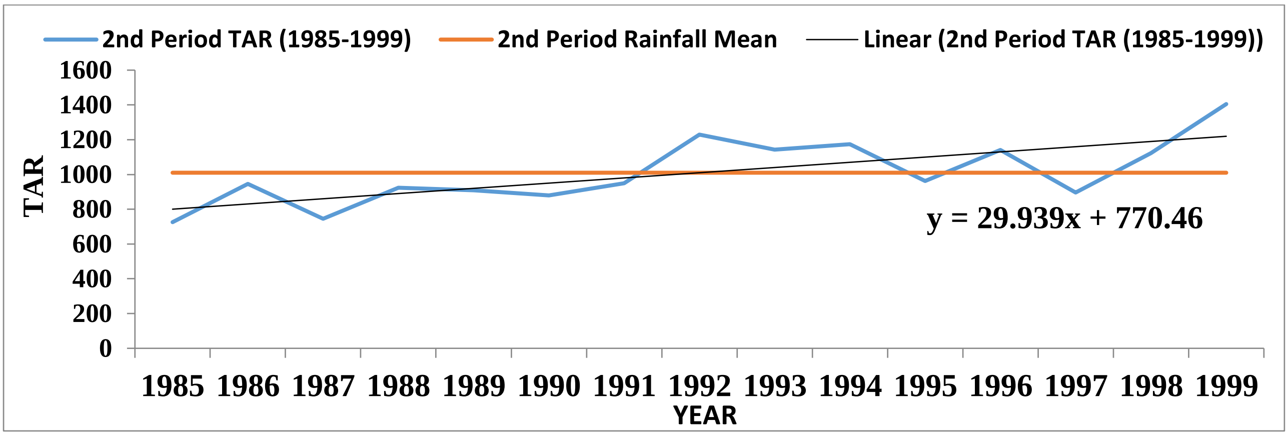

Figure 5 – Trends in 2nd Periodic Annual Rainfall for Bauchi station (1985-1999)
Source: Fieldwork for Bauchi climatic station (2020)

Figure 5 shows that from 1985 to 1991, TAR was below the periodic mean but rose above the mean from 1992 to the end of the period except for 1995 and 1997 where decreases in TAR were experienced. The trend line equation (Y= 29.939x + 770.46) was to the positive which showed that the TAR was increasing in the second period of the data. The TAR increase in the late 1990s for Bauchi station coincided with Nnachi (2014) observation for Zamfara state in which appreciable rainfall amounts were recorded in the late 90s in some parts of northern Nigeria. Besides, Ati (2006) investigated the rainfall characteristics in drought-prone areas in Nigeria and the result indicates that the annual rainfall totals over Nigeria started decreasing in the 1960s but the last decade especially the late 1990s had been witnessing increasing annual rainfall totals.

4.9 Trends in third periodic rainfall series (2000-2014)

Trends in the second 15 years-periodic rainfall series (2000-2014) are presented in Figure 6. The TAR data for the study area was used to describe the pattern and trend of rainfall during the period reviewed.

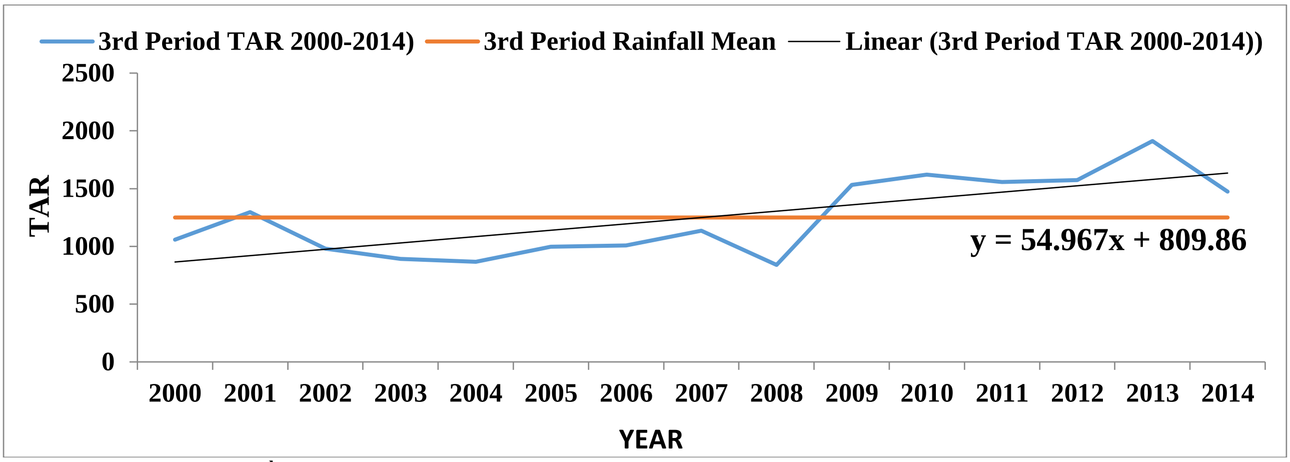

Figure 6 – Trends in 3rd Periodic Annual Rainfall for Bauchi station (2000-2014)
***Source**: Fieldwork for Bauchi climatic station (2020)*

Figure 6 showed that from the year 2000 to 2008, TAR values were below the periodic mean. But from 2009 to 2014 which marked the end of the data, TAR values rose higher than the mean. The trend line equation (Y = 54.967x + 809.86) was to the positive which showed that the TAR was increasing in the third period of the data which is a good omen for agriculturalists who depend on rainfall for their daily activities. According to the Food and Agricultural Organisation (FAO, 1986), rainfall is the single most important meteorological parameter that conditions agriculture as it provides the water necessary for the functioning of the soil-plant-atmosphere-system.

More so, that the TAR of Bauchi is increasing corroborated with the observation made by Building Nigeria's Response to Climate Change (BNRCC, 2011) which reported that Nigeria is now experiencing wetter conditions in recent years. These results agree with the findings of (Ojo and Ilunga 2018) that the rainy period in a tropical location can fluctuate in length, time of occurrence, and severity. Ati, Stiger, Iguisi further support this result, and Afolayan (2009) who stated that evidence from nine stations in northern Nigeria, shows that there is a significant increase in annual rainfall amount in the last decade of their study.

4.10 Relationship between long-term mean and periodic means of rainfall amount

Tables 3 and 4 showed the 15-year non-overlapping sub-periods (1970-1984, 1985-1999 and 2000-2014) and the 25-year overlapping sub-periods (1970-1994, 1980-2004 and 1990-2014) with their means related to the long-term mean and used to determine sub-periods that were wet above normal and those that were dry below normal.

Table 3: Periodic Statistics of Annual Rainfall for Bauchi station (1970-2014)

15-years (Non-Overlapping sub-periods)	Long-term Mean (mm)	Periodic Means (mm)
1970-1984	1081.05	983.6
1985-1999	1081.05	1010.0
2000-2014	1081.05	1249.6

Source: *Fieldwork for Bauchi station (2020)*

Table 4: 20-years Overlapping Statistics of Annual Rainfall for Bauchi station (1970-2014)

25-years (Overlapping sub-periods)	Long-term Mean (mm)	Periodic Means (mm)
1970-1994	1081.05	975.1
1980-2004	1081.05	1003.7
1990-2014	1081.05	1185.8

Source: *Fieldwork for Bauchi station (2020)*

Tables 3 and 4 show that the 15-years non-overlapping and the 25-years overlapping rainfall means were above the long-term mean only in the third sub-periods (2000-2014 and 1990-2014) respectively. However, other sub-periodic means fell below normal. This result for Bauchi station is the case for most parts of northern Nigeria as explained by Sawa and Adebayo (2011) and Nnachi (2014) who postulated that rainfall declined from the late 1960s to the late 1980s often referred to as long drought periods in northern Nigeria but the rains began to increase above normal in the millennium.

4.11 Determination of Onset Date, Cessation Date, and Length of Growing Season (LRS)

The precise onset and cessation dates as well as the amount and the distribution of rainfall each year are usually some of the needs of farmers to ensure that they realize a bumper harvest of crops. The information is strongly dependent on the unique characteristics of high seasonal, monthly, and daily variability in its moisture content and the vertical depth. Therefore, the onset, cessation dates and growing Season as well as the amount and the distribution of rainfall each year could show high variability in subsequent years (Ojo and Ilunga (2018). The Onset date, Cessation date and LRS for Bauchi station are presented in Table 4.

Table 4 shows that the onset of the rainy season for the 45 years fell between April 6th (2004) and June 8th (2007). Cessation rainy dates, on the other hand, occurred between August 2nd (1991) and October 29th (1975). The LRS lasted between two to six months with the highest LRS recorded in 2009 (183 days) followed by 1976 (179 days) while the shortest duration was recorded in 1987 (66 days). Onset dates were early in April until early June. Cessation dates occurred in early August to late October. The early-onset date is a good omen for farmers in the study area who depend heavily on rainfall for their crop planting. Late cessation and a maximum LRS of 6 months will also facilitate crop maturity, growth, and development.

Table 4: Derived Precipitation Characteristics for Bauchi Climatic Station (1970 - 2014)

Year	Onset Date	Julian Days	Cessation Date	Julian Days	Length of Rainy Season
1970	26-May	146	04-Sep	246	100 days
1971	13-May	133	06-Sep	248	115 days
1972	27-Apr	118	19-Sep	262	144 days
1973	04-Jun	155	04-Sep	246	91 days
1974	06-May	126	02-Sep	233	107 days
1975	15-May	135	29-Oct	302	167 days
1976	21-Apr	112	17-Oct	291	179 days
1977	04-Jun	155	09-Sep	251	96 days
1978	13-May	133	02-Sep	244	111 days
1979	06-May	126	02-Sep	244	118 days
1980	14-May	135	04-Sep	247	112 days
1981	06-May	126	06-Sep	248	122 days
1982	04-May	124	04-Sep	246	122 days
1983	17-May	137	11-Sep	253	116 days
1984	07-May	128	08-Sep	251	123 days
1985	13-May	133	10-Sep	252	119 days
1986	03-Jun	154	04-Sep	246	92 days
1987	28-May	148	03-Aug	214	66 days
1988	21-Apr	112	08-Sep	251	139 days
1989	08-May	128	28-Oct	301	173 days
1990	13-May	133	07-Sep	249	116 days
1991	08-Apr	98	02-Aug	213	115 days
1992	01-May	122	03-Sep	246	124 days
1993	14-May	134	26-Oct	299	165 days
1994	14-Apr	104	01-Sep	243	139 days
1995	07-May	127	05-Sep	247	120 days
1996	11-May	132	02-Sep	245	113 days
1997	02-Jun	153	06-Sep	248	95 days
1998	31-May	151	07-Sep	249	98 days
1999	02-Jun	153	09-Oct	282	129 days
2000	16-May	137	05-Sep	248	111 days
2001	05-May	125	08-Sep	250	125 days
2002	20-Apr	110	05-Sep	247	137 days
2003	27-Apr	117	04-Sep	246	129 days
2004	06-Apr	97	27-Aug	239	142 days
2005	09-May	129	05-Sep	247	118 days
2006	10-May	130	03-Sep	245	115 days
2007	08-Jun	159	08-Sep	250	91 days
2008	17-May	138	04-Sep	247	109 days
2009	09-Apr	99	09-Oct	282	183 days
2010	04-May	124	11-Oct	284	160 days
2011	25-Apr	115	14-Oct	287	172 days
2012	07-May	128	03-Sep	246	118 days
2013	05-May	125	14-Oct	287	162 days
2104	17-Apr	107	05-Sep	247	140 days
Mean	**09-May**		**12-Sep**		**125 days**

***Source**: Fieldwork for Bauchi station (2020)*

4.12 Trends in Onset Dates at Bauchi Station

The linear trend and trend line equation for the onset dates of rainfall is shown in Figure 7 for Bauchi station. The onset dates were plotted against years.

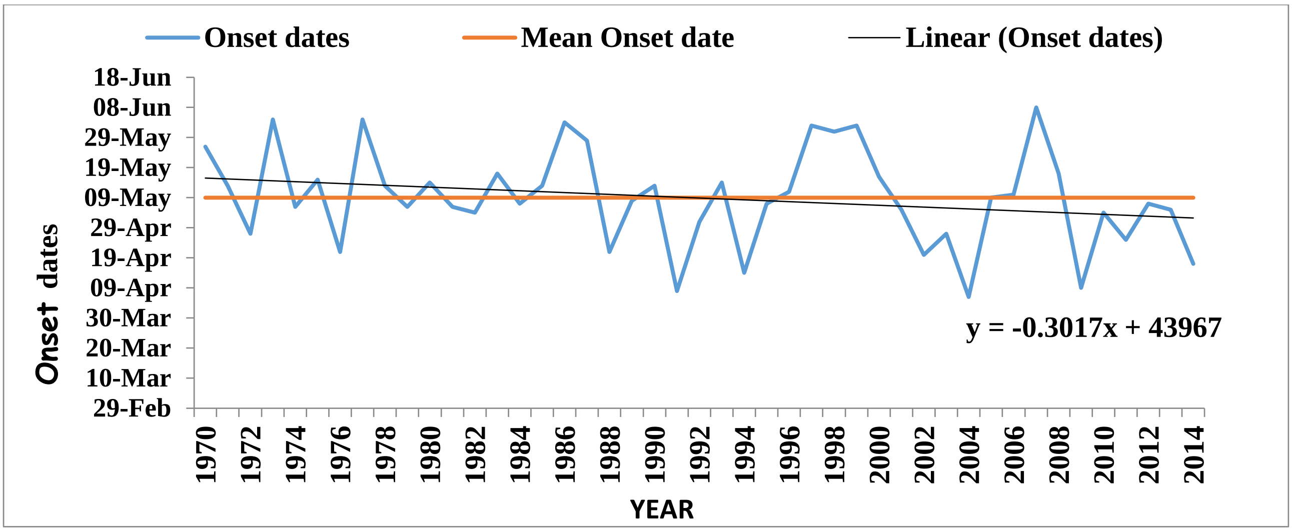

Figure 7 – Trends in Onset Dates of Rainfall for Bauchi Station (2000-2014)
***Source**: Fieldwork for Bauchi climatic station (2020)*

Figure 7 showed many 'noisy' fluctuations in the onset dates from 1970 to 2014. It also showed early onset of the rainy season in the study area which means that the rains are coming early as indicated by the trend line equation Y = -0.3017x + 43967. The mean onset date is May 9^{th,} which is early enough for farmers to start planting especially farmers who depend on the early rains for plant germination, growth and optimal yield. Figure 7 further indicates that the rains started with late onset dates above the mean, which continued in a fluctuating pattern above and below normal until it decreased below the mean towards the end of the data indicating early onsets. The Bauchi experience of early-onset rainy dates agrees with the findings of Ekoh (2020) which stated that rainfall is now coming early (early-onset dates) in Sokoto State, Nigeria. However, this result disagrees with the study of Ikpe, Sawa, and Ejeh (2017) which reported late-onset dates and frequent agricultural drought in Sokoto State, Nigeria.

4.13 Trends in Rainy Cessation dates at Bauchi station

The linear trend and trend line equation for the cessation dates of rainfall is shown in Figure 8 for Bauchi station. The onset dates were plotted against years.

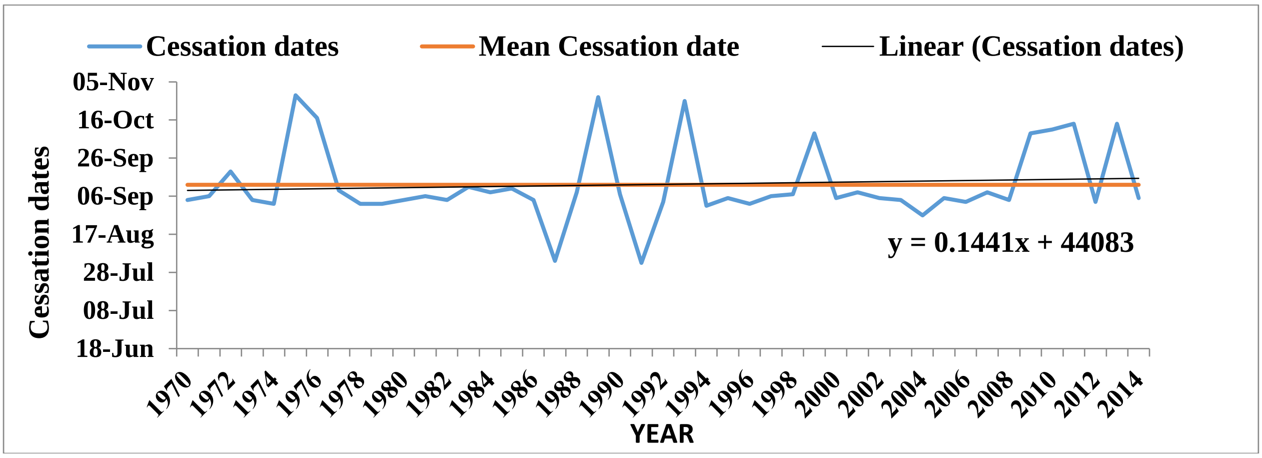

Figure 8 – Trends in Cessation Dates of Rainfall for Bauchi Station (2000-2014)
Source*: Fieldwork for Bauchi climatic station (2020)*

Figure 8 shows that the cessation dates of rainfall for the study area were characterized by marked 'noise' (variability) from year to year. The mean cessation date is 12th September. The graph (Fig. 8) indicates an increasing trend in cessation dates as the trend line equation (y = 0.1441x + 44083) is positive. This means that the rainfall cessation date comes relatively later than normal to the mean, that is, there is a slight delay in the ending of the rainy season. This is also good news for farmers in the study area as some crops may have adequate moisture for later-stage development. That there is a mid to late cessation of rainfall in Bauchi station disagrees with the findings of Ikpe, Sawa, and Ejeh (2017) which reported early cessation of rainfall in Sokoto State, Nigeria.

4.14 Trends in Length of Rainy Season (LRS)

Figure 9 depicts the linear trend and trend line equation for the LRS.

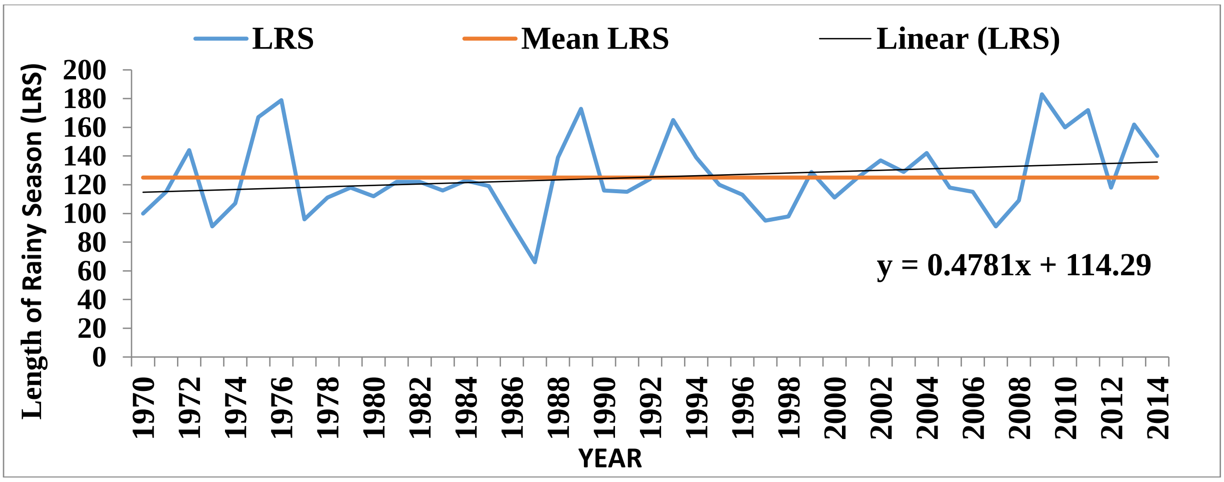

Figure 9 – Trends in Length of Rainy Season for Bauchi station (2000-2014)
Source*: Data Analysis for Bauchi climatic station (2020)*

Figure 9 shows a positive trend line equation of y= 0.4781x + 114.29, which indicates a positive, upward trend in LRS. The mean LRS was 125 days, which averagely covers 4 months. However, this confirms the marked yearly 'noises' on the trend line which was low at the beginning of the data but gradually began to increase till the end of the data. For instance, in the year 1970, the LRS was as low as 100 rainy days, which began to fluctuate above and below normal hitting high rainy-days' peak of 179 days (1976), 173 days (1989), 165 days (1993), 183 days (2009) and 162 days (2013). The increasing LRS is owing to the fact that the mean onset date is early (May 9th) while the mean cessation date is late (September 12th). Hence, the early onset dates and late cessation dates imply longer days in LRS. That the LRS in Bauchi is on a gradual increase disagrees with the result of Sawa, Adebayo, and Bwala (2014) which indicated that the hydrological growing season of Kano State is progressively shortening.

4.15 Trends in Temperature

Trends in annual mean temperature and monthly mean temperature are presented in Figure 10 and Figure 11 respectively. To describe the pattern of temperature during the period reviewed, the minimum and maximum temperature data for the study area was used to show the trend within the period reviewed (1970 – 2014).

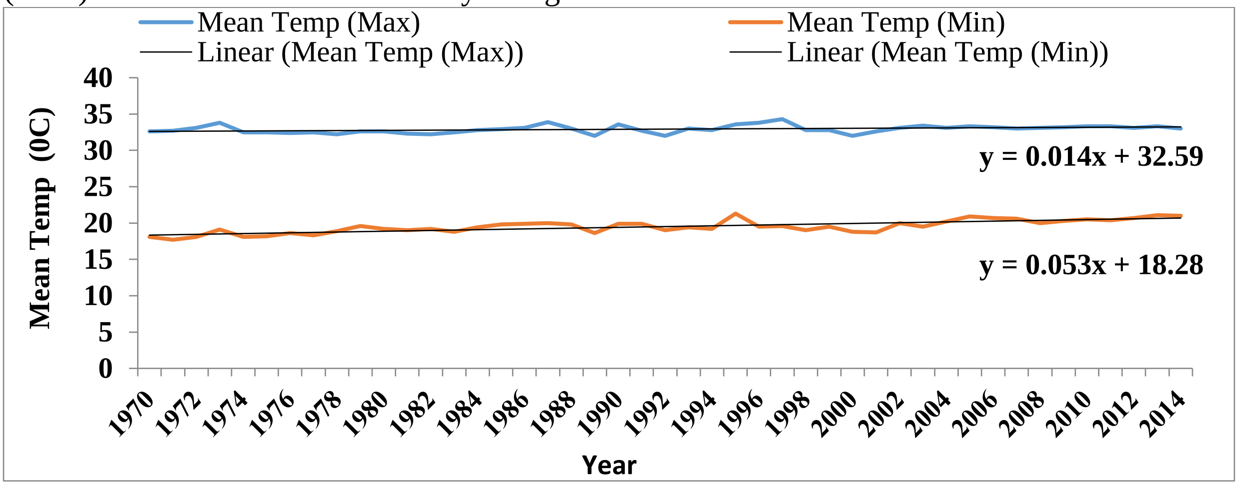

Figure 10 – Trends in Mean Annual Temperature for Bauchi station (1970-2014)
***Source**: Fieldwork for Bauchi climatic station (2020)*

Trends in mean annual minimum and maximum temperatures for the Bauchi station from 1970-2014 are presented in Figure 10. The graph showed a near normal data for both temperatures with the trend line equations indicating positive trends for both (Max; y = 0.014x + 32.59 and Min; y = 0.053x + 18.28). This implies that there is an increase in temperature of the study area within the period reviewed. The average mean temperature of Bauchi increases by 0.0299^{o}C per annum. National Academy of Science and The Royal Society (2008) stated that Earth's average surface air temperature has increased by about 0.8cc since 1900, with much of the increase-taking place since the mid-1970. The warming as from 2005 to the next twenty (20) years is projected to be about 0.20 ^{o}C per decade (IPCC, 2007). The mean annual temperature of Bauchi is 28.50c (Wikipedia, 2015). Trenberth, Jones, Ambenja, Bojariu, Easterling, and Zhai (2007) reported that there is a general concern that global temperatures and sea levels are rising and will continue to rise throughout the 21st century and that temperatures at the surface have risen globally, with regional variations. Ogunrayi, Akinseye, Goldberg, and Bernhofer (2016) in their study "Descriptive Analysis of Rainfall and Temperature Trends over Akure, Nigeria reported that temperature rises during the dry periods (November – March) and gradually cools at the approach of the wet season. The result is further supported by the findings of Odjugo (2010) which reported an increase of 1°C in the temperature of Nigeria between 1940 and 2010.

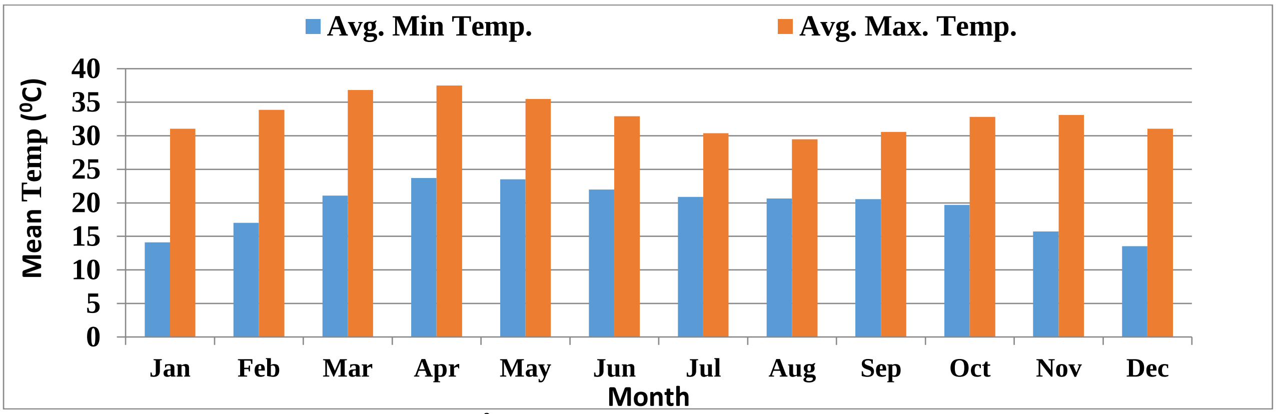

Figure 11 – Monthly Mean Temperature (^{0}C) for Bauchi Station (1970-2014)

***Source**: Fieldwork for Bauchi Climatic Station (2020)*

Figure 11 shows the monthly mean temperature for Bauchi station from 1970 to 2014. The highest Mean maximum temperature was in April while the coldest Mean minimum temperature was in December. This corresponds with Ayoade (1973; 1982) report that the climate of the tropics is characterized by two distinct seasons, hot and rainy season between April and October and the cold, dry harmattan season between November and March. On a general note, the average monthly temperature is high in the study area.

4.16 Relationship between Rainfall and Temperature

Figure 12 shows the relationship between two climatic variables, rainfall, and temperature of Bauchi station from 1970-2014. As the rainfall bar graph increases in July and August, the mean maximum and minimum temperature reduced in the same months and vice versa. From Figure 11, an average temperature of about 30-35^{0}C induced high rainfall of 280-300 mm in July and August. This coincides with the rainy season in most northern parts of Nigeria according to Ayoade (1973; 1982). However, in January and December, average temperatures of 15-20^{0}C with little or no rainfall coincides with the cold, harmattan season of most northern Nigeria states. The implication of the above result shows that high temperature instigates rainfall within the study area.

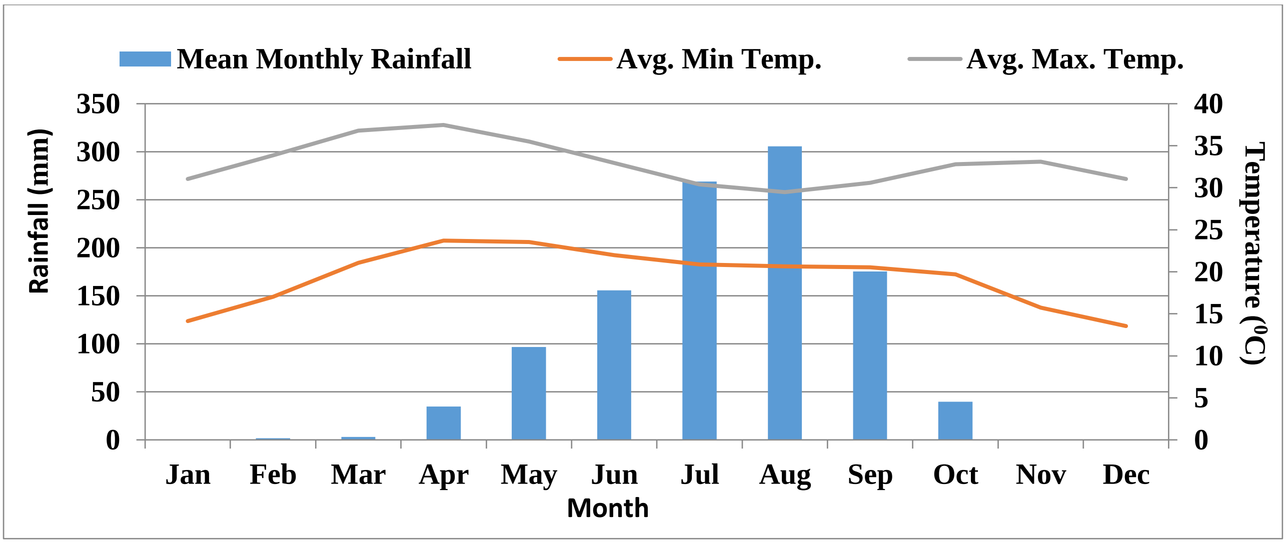

Figure 12 – Relation between Rainfall and Temperature for Bauchi Station (1970-2014)

***Source**: Fieldwork for Bauchi climatic station (2020)*

5. Conclusion

This study has evaluated the trends and characteristics of climatic variables in Bauchi State. The rainfall data series for Bauchi station was separated into three non-overlapping sub-periods of 15-years each (1970-1984; 1985-1999 and 2000-2014) and 25-years overlapping sub-periods (1970-1994; 1980-2004 and 1990-2014). The study has established that the rainfall variables increased from 1st to 3rd period with the latter having higher values than other periods when compared with the long-term mean of 1081.05 mm. The mean onset date of rainfall was May 9th, while the mean cessation date was September 12th. The average LRS was about 4 months (125 days). The results of trend line equations were all positive for all climatic trends except for 1st rainy period and onset dates which were declining to the negative implying that the study area experienced early onset and late cessation dates and longer days in LRS. Temperature data series were also analyzed with maximum temperatures occurring in April and minimum temperatures in December. Relating monthly rainfall and temperature showed that when the average monthly temperature was about 30-35°C, the mean monthly rainfall rose from 280-300 mm in July and August, and at 15-20°C, there was little or no rainfall. From the analysis, it can be deduced that rainfall and temperature are both increasing appreciably and significantly in the study area from the millennium as propounded by Sawa (2010) and Nnachi (2014) and this is a good omen for farmers and planners in the area.

6. Recommendations

Based on the findings of the study, the following recommendations were made;

1. Continuous updating of climatic and monitoring of climatic trends in the study area will encourage the analyses of climate change and variability in the study area.
2. Adoption of viable adaptation strategies for farmers based on early rainfall onset and late cessation dates with high average monthly temperature such as planting the best quality drought-resistant seeds, crop rotation, shifting cultivation, application of organic and inorganic fertilizer, terracing, afforestation, etc.
3. Extreme temperature increases reduced by the use of air conditioners and other home-made appliances that helps to conserve energy should be used in buildings to reduce the effects of high temperatures within the study areas
4. Public enlightenment programmes through talk shows, symposiums, peaceful rally protests through several media platforms on the impacts and effects of rainfall and temperature changes on population.
5. Establishment of agro-climatological research institutes in the study area for academic research and development planning purposes.

References

Adefolalu, D. O. (1993). World Meteorological Organization. Lecture Series 1: 1-4.

Ati, O. F. (1996). A comparison of Methods to Detect the onset of Growing Season and its Trends for some Stations in the Sudan Savanna in Northern Nigeria. M.Sc, Thesis, Department of

Geography, Ahmadu Bello University, Zaria. http//doi/abs/10.1002/joc.712

Ati, O. F. (2006). Rainfall Characteristic in Drought -Prone Sudano-Sahelian Zone of Nigeria. Unpublished Ph.D Dissertation. Department of Geography, Ahmadu Bello University, Zaria, Nigeria.

Ati, O. F., Stiger, C. J., Iguisi, E. O. and Afolayan, J. O. (2009). Profile of Rainfall Changes and variability in the Northern Nigeria, 1953 - 2002. *Journal of Environmental and Earth Sciences*, 1(2), 58 -63.

Ayoade, J. O. (1982). Climate 4: Evaporation, Evapotranspiration and Humidity In: Barbour, K. M., Oguntoyinbo, J. S., Onyemelukwe, J.O.C., and Nwafor, J.C. (eds). *Nigeria in Maps*. Nigerian Publishers Service Ltd, Ibadan, pp. 20-21.

Brazel, S. W. and Balling, R. C. (1986). Tropical Analysis of Long-term atmospheric moisture levels in Phoenix and Arizona. Journal of Climate and Applied Meteorology. Vol. 25. pp. 112-117.

Colom, M. R. and Vazzana, C. (2000). Drought Stress Effects on three Cultivars of *Eragrostis Curvula*: Photosynthesis and Water Relations. Department of Agronomy and Land Management, University of Florence, Italy, Pledelle Cascine 18, 50-144.

Ikpe, E., Sawa, B. A. and Udeh, E. L (2017). Evidence of Climate Change and Adaptation Strategies in Sokoto State, Nigeria. IORS *Journal of Environment*, 2(1) 17-23.

Ilesanmi, O.O. (1972). An empirical formulation of the onset, advance and retreat of rainfall in *Nigerian Journal Tropical Geography*, 34: 17-24.

IPCC (2007). Fourth Assessment Report. Working Group 1: The Physical Science. Accessed Available: http://www.ipcc.gov

Kowal, J.M. and Knabe, D. T. (1972). An Agro-climatic Atlas of Northern States of Nigeria. Ahmadu Bello University Press, Zaria, pp: 111.

Odiana, S. and Ibrahim, A. (2015). An Assessment of the Evidence of Climate Change in Bauchi, Nigeria. Journal of Applied Sciences and Environmental Management, 19(3) 375-381.

Odjugo (2010). Regional Evidence of Climate Change in Nigeria. *J. Geogr. Regional Plann*. 3(6):142-150.

Ogunrayi, O. A., Akinseye, F. M. Goldberg, V. and Bernhofer, C. (2016). Descriptive Analysis of Rainfall and Temperature Trends over Akure, Nigeria. *Journal of Geography and Regional Planning*, 9(11): 195-202.

Olaniran, O. J. (1984). The onset of rains and the start of the growing season in Nigeria. *Nigerian `Geographical Journal*, 34: 17-24.

Olaniran, O. J. (1988). The distribution in space of rain days of rainfall of different amounts in the tropics; Nigeria as a case study. *Geoforum*, 19(4): 507-520.

National Academy of Science and The Royal Society (2008) Climate Change Evidences and Causes. Accessed 30 January 2015 Available: http:// dels.nas.edu

Nnachi, S. U. (2014). Vulnerability Assessment and Adaptive Strategies of grain Farmers to Climate change in Shinkafi Local Government Area, Zamfara State, Nigeria. A Published M.Sc. Thesis, Geography Department, ABU, Zaria.

Sawa, B. A. (2010). Climate change and Spatio-temporal Variability in Occurrence of Dry Spells in Northern Nigeria. IN: - *The Zaria Geographer*. Geography Dept. ABU-Zaria. Vol.18, No. 1, 2010. pp 23.

Sawa, B. A. and Adebayo, A. A. (2011). The Impact of Climate Change on Precipitation Effectiveness Indices in Northern Nigeria. *Research Journal of Environmental and Earth Sciences* 3(5): 481-486, 2011.

Sivakumar, M. V. K. (1988). Predicting rainy season potential from the onset of the rains in southern sahelian and sudanian climate zones of West Africa. Agric. *Forest Meteorology* 42: 295-305.

Stern, R. D. and Dale, I. C. (1982). Statistical methods for tropical drought analysis based on rainfall data. Project AZ1: A Report on data requirements for estimating the likelihood of droughts. WMO Programme Res. *Tropical Meteorology*, (PRTM), 35.

Stern, R. D., Dennett, M. D. and Dale, I. C. (1982b). Analyzing daily rainfall measurements to give agronomically useful results II: A modeling Approach: *Experimental Agriculture*, 18: 237-253.

Trenberth, K. E, Jones, P. D, Ambenje, P, Bojariu, R, Easterling, D, Klein Tank, A, Parker, D, Rahimzaden, F., Renwick, J.A. Rusticucci, M., Soden, B., and Zhai, P. (2007) Observation: Surface and Atmospheric Climate Change. In: Solomon, S., Quin, Manning, M, Chen, Z., Marquis, M,.Averyt, K.B, Tignor M., and Miller, H.L (Eds) . *Climate Change 2007: The Physical Science Basis*, pp 235-336.Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. United Kindom and Newyork, N Y: Cambridge University Press. Retrieved February, 5 2009 from http://www.ipcc.ch/pdf/assessment-report/ar4/wg l/ar4-wg l-chapter2.pdf

Streda, T., Stredova, H. and Roznovsky (2012). Climatic Region Characteristics in Context of Climate Development, Journal of Bioclimatology of Ecosystems. See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/264046883

Wikipedia (2015). Climate of Bauchi. Accessed 15 February 2015 Available: http:// www.wikipedia.org