CHARACTERISTICS OF ANNUAL RAINFALL OVER GUINEA SAVANNA ZONE, NIGERIA

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Abstract
Thisresearch was aimed at studying the characteristicsof annual rainfall over Guinea Savanna Zone, Nigeria. The data used were monthlyrainfall (mm) obtained from the Nigerian Meteorological Agency, Oshodi, Lagos, 1981-2015 (35 years) for Makurdi, Lokoja, Ilorin, Jos, Lafia, Minna and Kaduna; Abuja, 1983–2015 (33 years) and Ibi, 1981–2013 (33 years). Long term rainfall mean, multiple mean comparism, simple linear regression, regression coefficient, maximum, minimum, standard deviation (SD), skewness, kurtosis and cumulative of variation (CV) were used for analysis. Results were presented in table and figures.The conclusion revealed moderate inter-annual rainfall variation, alternate upward and downward trends as well as a general upward trend in recent years. It was also discovered that inter-rainfall characteristics vary across the data collection points even though they are within the same climatic zone. Recommendations focused on the need for similar studies to be carried out to cover other characteristics of rainfall over the study area and in other ecological regions of Nigeria. Short–term weather forecast was also advocated.

Key words: Rainfall, variability, global warming, water resources, weather forecast

1. Introduction

Weather affects man in almost all his daily activities. In every part of the world, the weather patterns have determined the traditional patterns of food, clothing, housing, agriculture, transportation and social festivals (Asnani, 2005). In Nigeria, rainfall seems to be the most important climate variable because of its role in human activities. The most important human activity in Nigeria remains agriculture which is still largely rain-fed due to inadequate technology for mechanised farming. Rain is also a major source of water for domestic uses and recharging of underground water. According to Eke (2017), rainfall is without doubt the single and most critical physical climatic variable influencing human activities in West Africa.

Rainfall is unevenly distributed across Nigeria as it varies over climaticzones and meteorological stations in onset, cessation, duration, number of rain days, daily, weekly, monthly, annual, pentad and decadal distribution; frequency, magnitude as well as type. Over the Guinea Savanna Zone, Nigeria (GSZN), rainy season generally starts in April and ends in October with changing patterns inform of early/late onset, early/late cessation, normal/abnormal duration (shorter or longer than normal) as well as normal/abnormal accumulated daily, weekly, monthly, and annual. According to Dada (2016), rainfall patterns have changed over the years as a result of global warming and climate change.

Upward and downward trends in both annual and inter-annual rainfall are witnessed in Nigeria and it is an important feature of rainfall. The study of Iornongo (2016) observed an increasing trend of rainfall in most years over Gboko, Benue State. Also, Okoro (2017) observed an increasing trend in rainfall over Bida, Niger State between 2007-2016. The alternate upward and downward trends in rainfall over Nigeria are becoming a major concern to both government and public. Increasing rainfall trend results mostly into flooding as witnessed in September, 2018 in states like Kogi, Niger, Benue and Kwara. According to Iornongo (2016), the inter-annual variation of rainfall mostly in northern Nigeria is much and result into climate and weather hazards especially floods. Previous studies on GSZN regarding rainfall focused on individual data collection points without focusing on the entire GSZN (Mohammed, 2010; Dada, 2016; Iornongo, 2016; Eke, 2017; Okoro, 2017). Hence, this research is aimed at studying the characteristics of annual rainfall over the entire Guinea Savanna Zone, Nigeria (GSZN).

2. The Study Area

TheGuinea Savanna Zone, Nigeria (GSZN)is centrally located in Nigeria. It is located between longitudes 4°–10°E andlatitudes 6°–11°30'N (Figure 1). The study area is characterized by two (2) major prevailing winds namely; Tropical Maritime Airmass (mT) and Tropical Continental Airmass (cT) (Adakayi, 2000 cited in Ama, 2017). The alternate occurrence of these prevailing winds leads to the occurrence of two (2) distinct seasons which also occur alternately. These seasons are wet (rainy) and dry seasons. Rainfall is moderate with 60% falling in July, August and September. Rainfall occurs in association of squall lines, lightening, thunderstorms and strong winds (Ama, 2017; Omasoro, 2017). The highest mean temperature is recorded in March. Dry season is experienced between October-April (Mohammed, 2010).

The relief of the study area is made up of both high and lowlands (Maxlock, 1980 cited in Omasoro, 2017; Olayinka, 2017). It is predominantly underlain by Precambrian **gneisses**, granite and schists of crystalline basement complex. Its soils comprise mostly sand, silt, clay and laterite (Iornongo, 2016; Omozuapo, 2016; Oshin, 2008 cited in Ama, 2017; Omasoro, 2017).

The vegetation of the study area is savanna (Physical Setting, Niger State cited in Okesola, 2016). This vegetation has been severely altered by man through numerous activities such as bush burning, farming, firewood harvesting, mining/excavations, constructions and settlement.

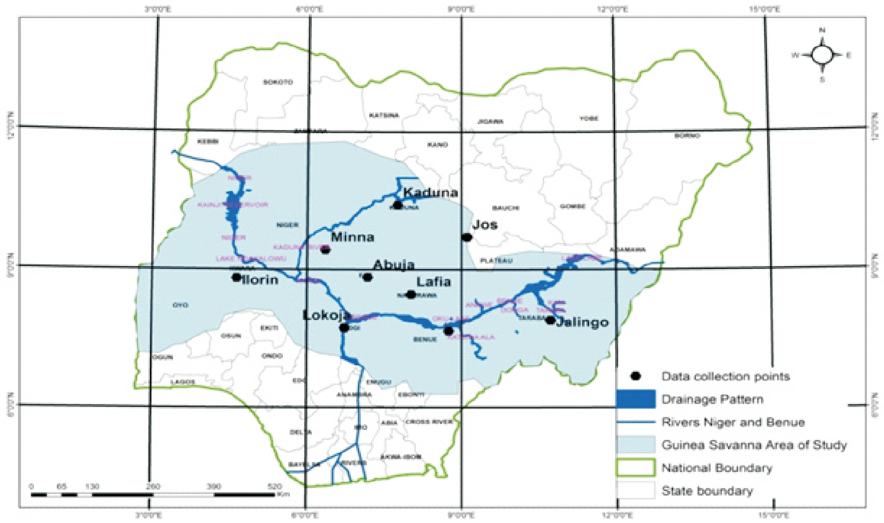


Figure 1: The Study Area
Source: National Space Research and Development Agency (NASRDA) (2018)

Materials and methods
Secondary data on monthlyrainfall (mm) which were in numerical form for Makurdi, Lokoja, Ilorin, Lafia, Minna Jos and Kaduna, 1981-2015; Abuja, 1983–2015 and Ibi, 1981–2013 were used for this study.These data were sourced from the Nigerian Meteorological Agency, Oshodi, Lagos. The data points are evenly distributed across the GSZN.

The annual rainfall (mm) was calculated thus:
Let y = years, x = monthly rainfall (mm)

$y_1 = y_{1.1} + y_{1.2}............y_{1.3}..................y_{1.12}$

$y_2 = y_{2.1} + y_{2.2} + y_{2.3} + ... y_{2.12}$

$y_3 = y_{3.1} + y_{3.2} + y_{3.3} + ... y_{3.12}$

$y_{35} = y_{35.1} + y_{35.2} + y_{35.3} + ... y_{3.12}$

$$yi = \sum_{i=1}^{n} xji$$

where j= 1,2,………35; i =1,2,………number of months in a year
Simple linear regression analysis was used to ascertain the relationship between the independent and dependent variables per year. It was calculated thus:

$y = mx + c$ 2

Where: y = dependent variable, x = independent variable, c = intercept of the trend on y axis, m = slope.
To specify how much of the variation in the dependent variable is characterized by a variation in the independent variable x, R-square (R^2) was used and calculated as thus:

$$R^2 = 1 - \frac{SSE_{reg\_line}}{SSE_{mean\_y}} \quad 3$$

$$SSE_{reg-line} = \sum_{i-1}^{n} (y_i - (mx_i + b))^2$$

$$SSE_{mean_y} = \sum_{i-1}^{n} (y_i - \bar{y})^2$$

Where: SSE = sum of square error, regline = regression line
The annual rainfall mean was calculated after Ekeruo *et al* (1989) as thus:

$$\bar{x} = \frac{\sum x}{N} \quad 4$$

Where: $x = mean, \sum x = sumofrainfall, N = numberofyears$
Multiple mean comparism was used to determine the difference in terms of mean annual rainfall across the data collection points.
The skewness coefficient was used to determine the measure of deviation of the data from symmetry of the distribution. It was calculated after Brown (2016) as thus:

$$g_1 = m_3/m_2{}^{3/2}$$

Where: $m_3 = (x - \bar{x})^{\frac{3}{n}}\ and\ m_2 = \sum(x - \bar{x})^{2/n}$ 5
To determine the tailedness of the probability distribution of a real-valued random rainfall, kurtosis was used and calculated after Brown (2016) as thus:

$$a4 = \frac{m_4}{m_2}\ and\ excess\ kurtosis = g_2 = a_4 \quad 3$$

Where: $m_4 = \sum(x - \bar{x})^{\frac{4}{n}} and\ m_2 = \sum(x - \bar{x})^{\frac{2}{n}}$ 6
In equations 7 and 8, n=sample size, $m_3 and\ m_4 = 3rd\ and\ 4th\ moments\ of\ data\ set, m_2 = variance$
To show how spread out the data values are, standard deviation (σ) was used and calculated as thus:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i-1}^{N}(x_i - \mu)^2} \quad 7$$

Where: μ=mean, x=total annual rainfall, $\sum$=sum, n=number of data set (years)
Cumulative of variation was calculated after Umar (2010) to determine the degree of variation in rainfall over the years as thus:

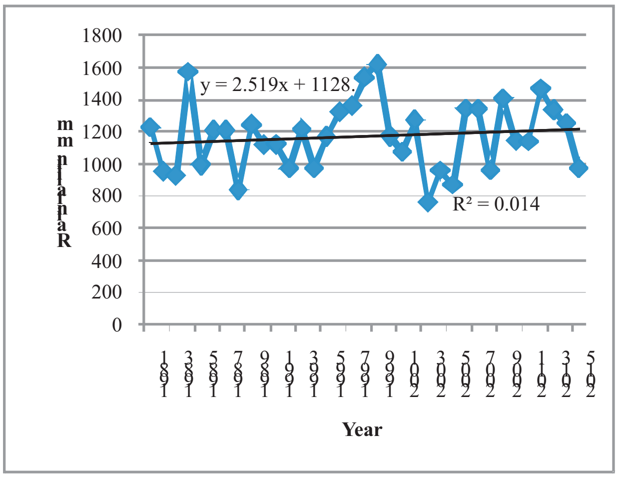
$$CV = \frac{SD}{x}\ X\ 100\% \quad 8$$

Where: CV = cumulative of variation, SD= standard deviation, $\bar{x}$ = mean

Results and Discussion
Figs. 2-11. Show the annual rainfall (mm) over data collection points in the study area. The study area enjoys moderate annual rainfall as well asrainfall variability.Rainfall variability over the study area shows diverse spacio and temporal (space and time) patterns of occurrence due to differences in latitudinal locations and other localized factorsamong which are relief and vegetation. The highest rainfall of about 2456.90 mm in the study area was recorded at Ilorin in 2014, while the lowest rainfall of about 697.1 mm was also recorded at Ilorin in 2002.The data collection points are experiencing alternate upward and downward trends. Results also showed that in recent time, Makurdi, Lokoja, Ilorin, Jos, Lafia, Minna and Kaduna are experiencing upward trend in annual rainfall hence, positive linear trend while Abuja and Ibi are experiencingdownward trend.Nigerian Meteorological Agency(NiMet) (2017) confirmed increase in annual rainfall over Nigeria from 2006 to 2017.The alternate upward and downward trends are due to the effects of global warming, climate variability and climate change (Audu *et al*, 2012).

The annual rainfall of below normal (less than mean) recorded by somemeteorological stations over the study area in 1980s are attributable to drought (Ishiaku *et al*, 2018) which occurred in Nigeria mostly in the Sudano-Sahelian and Guinea Ecological Zones in the late 1970s and extended to 1980s (Adejuwon and Jegede, 2011; Ojoye, 2013; Adeogun *et al*, 2016). Rainfall of below normal is also evidence of dry spells and droughts over the study area.

In addition, rainfall of above normal (above the mean) (table 1) in all the data collection points is the direct effect of global warming occasioned mostly by the socio-economic activities of man among which are gas flaring (Audu, 2013), fossil fuel consumption, farming, over grazing, lumbering, urbanization, construction and industrialization. Adakayi (2015) observed an increase in maximum temperature over Northern Nigeria. NiMet (2017) confirmed increase in temperature across Nigeria in recent years.



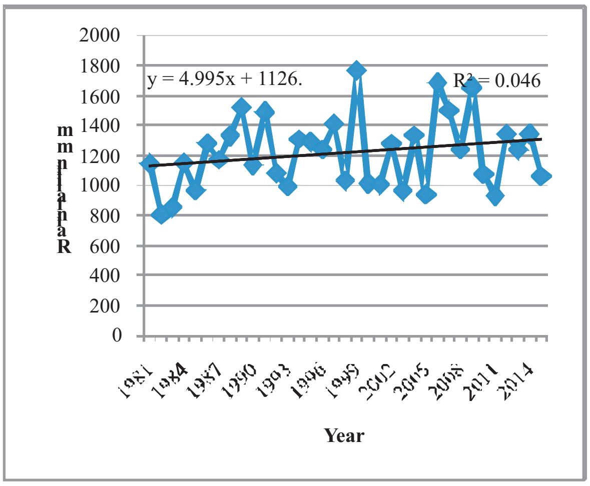
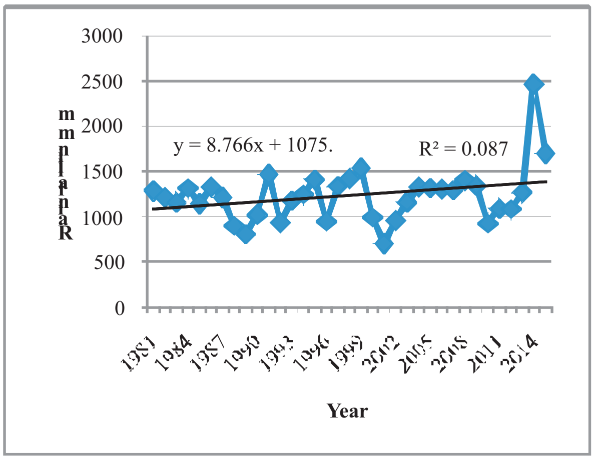


Figure 2: Annual rainfall over Makurdi, 1981–2015 **Figure 3:** Annual rainfall over Lokoja, 1981–2015
Source: Authors' computation, 2018 **Source:** Authors' computation, 2018



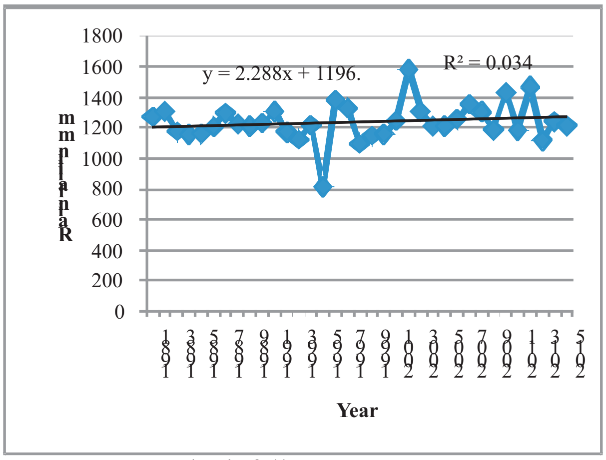
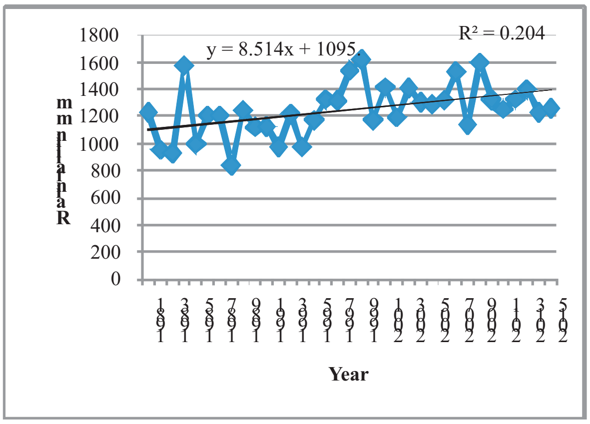


Figure4: Annual rainfall over Ilorin, 1981–2015 **Figure 5:** Annual rainfall over Jos, 1981–2015
Source: Authors' computation, 2018 **Source:** Authors' computation, 2018



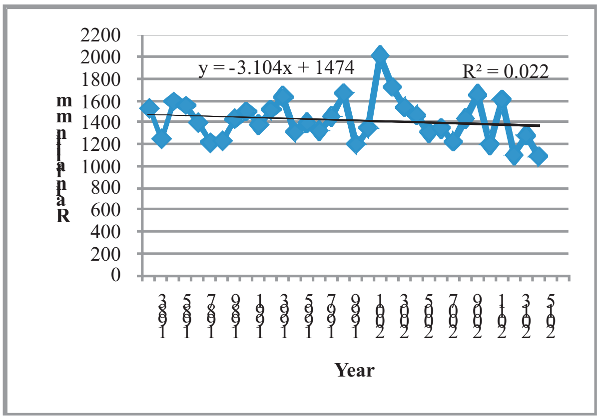
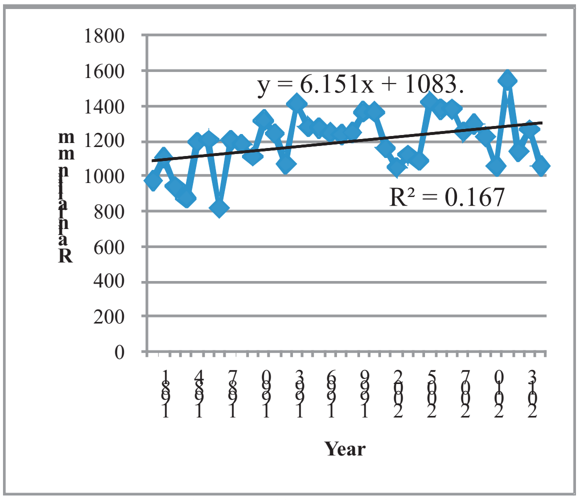


Figure 6: Annual rainfall over Lafia, 1981–2015 **Figure 7:** Annual rainfall over Abuja, 1983-2015
Source: Authors' computation, 2018 **Source:** Authors' computation, 2018



Figue 8: Annual rainfall over Minna, 1981-2015
Source: Authors' computation, 2018

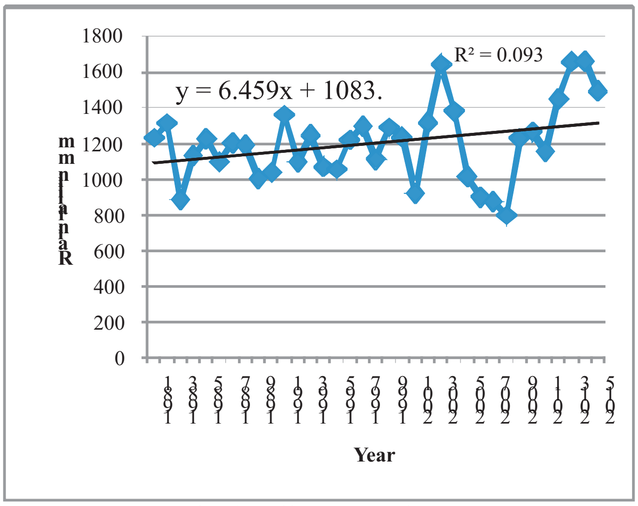


Figure 9: Annual rainfall over Kaduna, 1981-2015
Source: Authors' computation, 2018

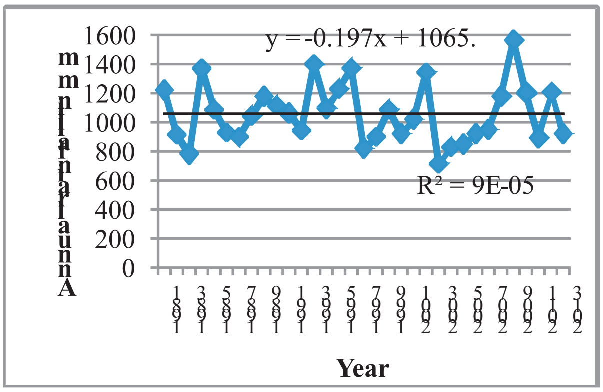


Figure10: Annual rainfall over Ibi, 1981-2013
Source: Authors' computation, 2018

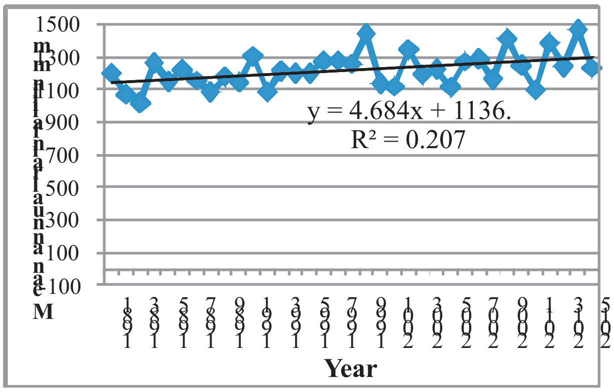


Figure 11: Mean annual rainfall over GSZN, 1981–2015
Source: Authors' computation, 2018

The coefficient of multiple determinations (R^2) for the study area is positive (Figure 11). However, the values vary among data collection points (Figures 2-9). The implication of the R^2 is that positive changes are occurring in the inter-annual rainfall across the study area. On the contrary, Ibi is experiencing no change (Figure 10).

According to Figure 11, lowest mean rainfall in the GSZN (study area) was recorded in 1983 while the highest mean was recorded in 2014. The zone is experiencing moderate rainfall variability, while the range is about 446.96 mm. The linear equation is positive supporting the upward trend in rainfall over the region. Ibrahim *et al* (2018), observed an insignificant upward trend in rainfall over some meteorological stations in Savanna region, Nigeria.

Table 1 shows the simple statistical analysis of annual rainfall over the study area. The mean in the study area is above 1000 mm and it is within the range of 1000 mm–1200 mm except for Abuja which is above 1400 mm.Rainfall around the mean is regarded as normal, while rainfall below or above the mean is regarded as abnormal. Mean rainfall for the entire study area (GSZN) based on this study is moderate about 1220.43 mm.

All the data collection points have high ranges signifying great inter-annual variations of rainfall. The high SD also confirms the great size in deviations in inter-annual rainfall over the area. The coefficient of variation (CV) for the data points is high. This by implication means that variation in inter-annual rainfall is great. It is greater over Ilorin with the highest value of 24% and lowest over Jos with a value of 10%. The CV for Ilorin is the highest partly due to the astronomical increase in annual rainfall in recent years especially 2014. The kurtosis and skewness are not close to zero (0) hence depicting that inter-annual rainfall variation is great over the study area.

Table 1:Simple statistical analysis of annual rainfall (mm) over the data collection points

Data point / statistics	Makurdi	Lokoja	Ibi	Ilorin	Lafia	Abuja	Minna	Jos	Kaduna
Mean(mm)	1173.50	1213.22	1061.92	1233.0	1249.92	1421.20	1191.69	1237.09	1202.35
Range(mm)	855.60	962.60	850.60	1759.8	777.20	923.50	724.80	768	865.50
Min (mm) year	761.50 (2003)	804.50 (1982)	718.50 (2003)	697.10 (2001)	839.90 (1988)	1088.20 (2015)	818.40 (1987)	814.70 (1995)	793.4 (2008)
Max (mm) year	1617.10 (1999)	1767.10 (1999)	1569.1 (2009)	2466.6 (2014)	1617.10 (1999)	2011.70 (2002)	1543.20 (2012)	1582.70 (2002)	1658.90 (2014)
Skewness	.157	.557	.530	1.874	-.039	.638	-.236	-.261	.438
Kurtosis	-.526	-.134	-.292	7.358	-.248	.925	.022	3.809	.384
SD	212.92	234.68	206.03	302.98	193.59	200.78	163.35	126.77	195.37
CV	18%	19%	19%	24%	15%	14%	13%	10%	16%

Source: Authors' computation, 2018

The implications of the results on water resources and agriculture are enormous. When rainfall is above normal, there will be abundant surface and underground water. Excessive surface water leads to soil erosion and flooding as well as high water level in water bodies which also leads to riverine flooding and landslides (as experienced in Kogi State in 1999) as well as high rate of recharging of underground water especially where rainfall is concentrated within few months, weeks and/or days. Above normal rainfall is due to global warming which is causing high rates of evaporation and relative humidity. Below normal rainfall, leads to acute shortage of surface as well as underground water (due to low infiltration) which also affects domestic water supply especially in rural areas with high dependence on rain water harvesting and collection of water from streams, ponds, rivulets, lakes, dams and rivers.

In the area of agriculture, rainfall below the mean has negative effects in form of crop failure. Crop growth and yields are usually affected inform of delayed planting, poor germination, stunted growth, low flowering and low yield. According to Anuforom (2016), soil moisture conditions respond to precipitation anomalies on a relatively short scale; while the ground water, steam flow and reservoir storage reflects the longer-term precipitation anomalies.

Conclusion and Recommendations

This study is to ascertain the characteristics of annual rainfall over Guinea Savanna Zone, Nigeria (GSZN). The findings revealed moderate inter-annual rainfall, diverse spacio and temporal rainfall variation, alternate upward and downward trends as well as a general upward trend in recent years. The lowest accumulated mean rainfall amount was recorded in 1983 while the highest was in 2014. The range is 446.96 mm. It was also discovered that rainfall characteristics vary across the data collection points even though they are within the same climatic zone. It is therefore recommended that similar studies should be carried out to cover other characteristics of rainfall over the study area and in other ecological regions of Nigeria. Rainfall forecast (very short, short, medium and long-term) should be given more attention with its results disseminated to the grass root so as to serve as early warning against both annual and inter-annual rainfall variations.

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