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Technology Education for Capacity Building

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The Journal of Information, Education, Science and Technology (JIEST) publish by School of Science and Technology Education, Federal University of Technology, Minna, Nigeria released volume 4, No. 1 (June, 2017 Edition).

JIEST is a multi-disciplinary Journal that contains research findings on diverse topics in Information, Education, Science and Technology. The Editorial Board receives articles throughout the year.

My unreserved appreciation goes to the Dean, School of Science and Technology Education of the above University for her tireless efforts in making sure that the demand of the Editorial Board are always met, I thank the University management for assisting in disseminating information regarding this Journal using the University website and Bulletin.

I thank the Editorial Board for their good work and for ensuring that articles are published twice in a year (June and December). The efforts of the contributors to this volume are commendable. It is not easy to conduct a research and have it published. The Editorial consultants and Reviewers made their inputs towards improving the work of contributors and I really appreciate their efforts.

Our readers comments, advice, suggestions are welcome for further improvement on the quality of the Journal.

Prof. Gambari A. Isiaka
Managing Editor.

INSTRUCTION TO CONTRIBUTORS

JIEST is the journal of researches in information, Education, Science and Technology of the School of Technology Education, Federal University of Technology, Minna. The editorial board of the journal welcomes scholarly and original articles (Theoretical and Empirical) on current issues in the fields of information, education, science and technology that possess national and universal application. In addition, the Journal also publishes scholarly and original articles from allied disciplines that have education significance and values.

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TABLE OF CONTENTS

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.

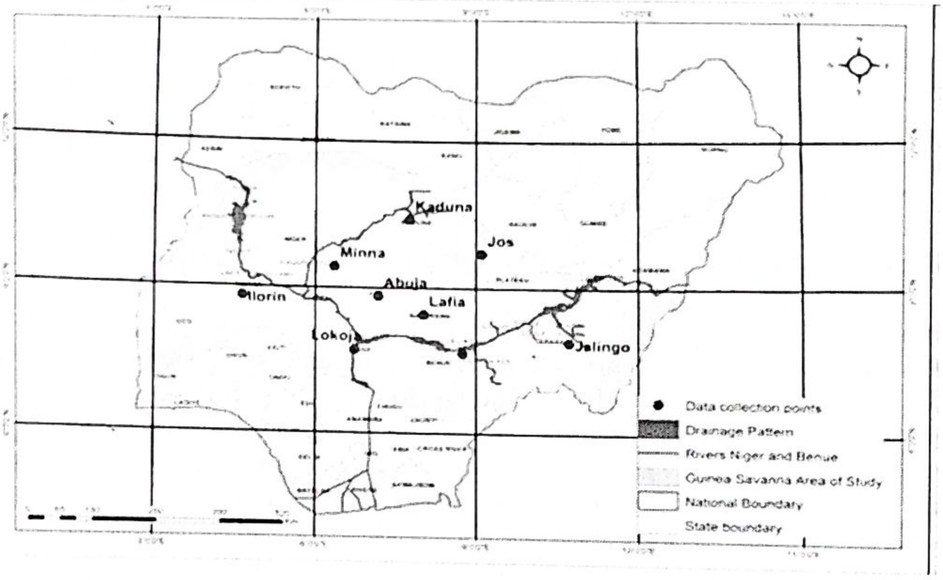


Figure 1: The Study Area

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)

$y_1 = y_{1.1} + y_{1.2} \ldots\ldots\ldots y_{1.3} \ldots\ldots\ldots y_{1.12}$

$y_2 = y_{2.1} + y_{2.2} + y_{2.3} + \ldots y_{2.12}$

$y_3 = y_{3.1} + y_{3.2} + y_{3.3} + \ldots y_{3.12}$

$y_{35} = y_{35.1} + y_{35.2} + y_{35.3} + \ldots y_{3.12}$

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

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:

$$R^2 = 1 - \frac{SSE_{reg\ line}}{SSE_{mean\ y}}$$

$$SSE_{reg-line} = \sum_{i-1}^{n} (y_i - (mx_i + b))^2 \quad 3$$

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

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: $x = mean,\ \sum x = sum of rainfall,\ N = number of years$
Multiple mean comparism was used to detemine the difference in terms of mean annual rainfall across the data collection points.
The skewness coefficient was used to detemine 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:

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

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 detemine the degree of variation in rainfallover 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.

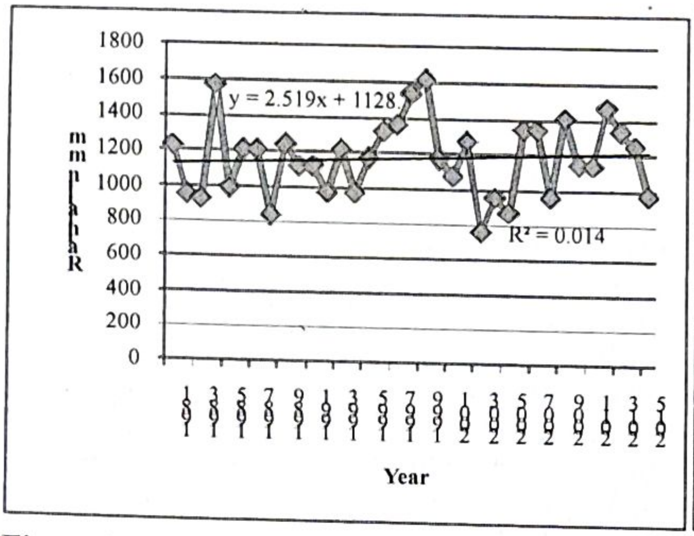


Figure 2: Annual rainfall over Makurdi, 1981–2015
Source: Authors' computation, 2018

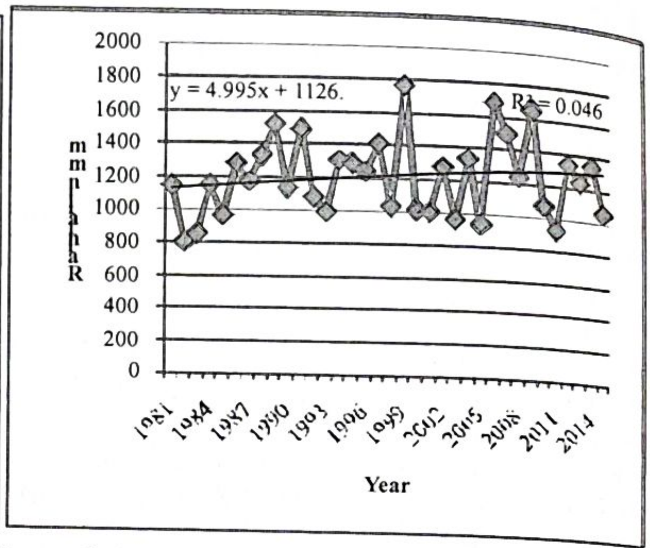


Figure 3: Annual rainfall over Lokoja, 1981–2015
Source: Authors' computation, 2018

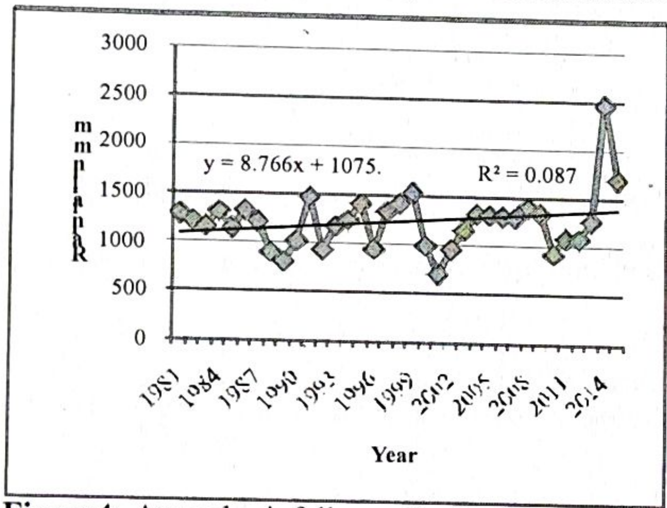


Figure4: Annual rainfall over Ilorin, 1981–2015
Source: Authors' computation, 2018

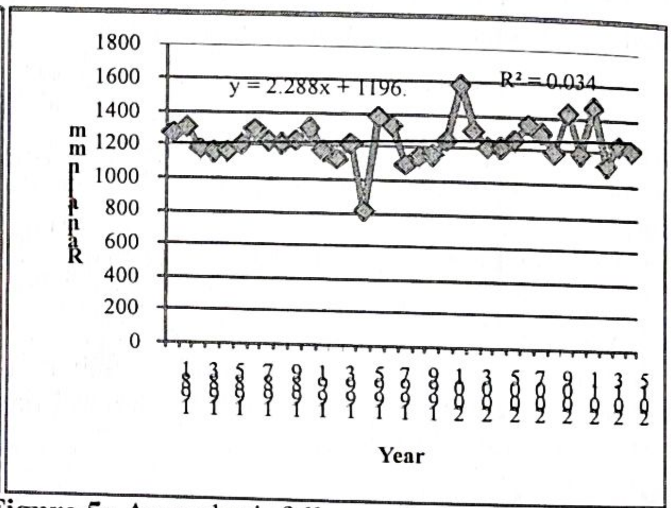


Figure 5: Annual rainfall over Jos, 1981–2015
Source: Authors' computation, 2018

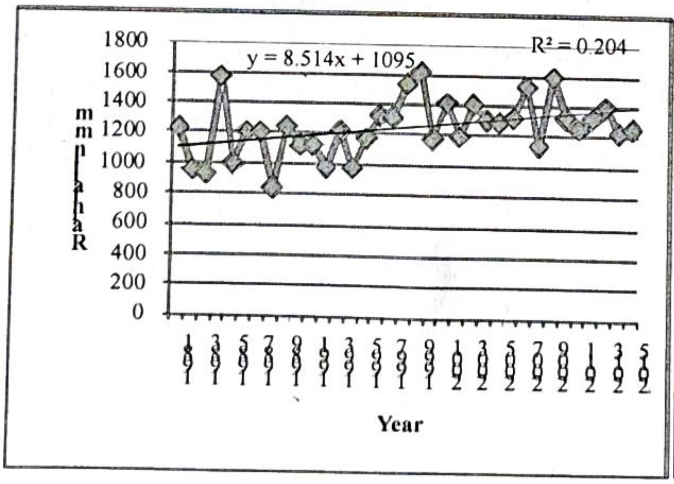


Figure 6: Annual rainfall over Lafia, 1981–2015
Source: Authors' computation, 2018

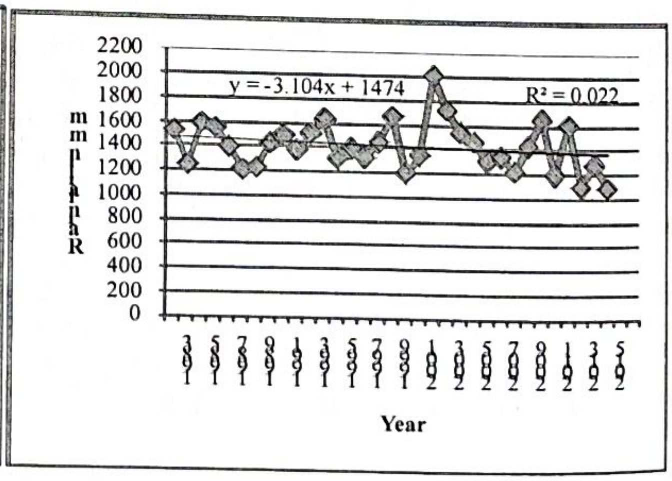
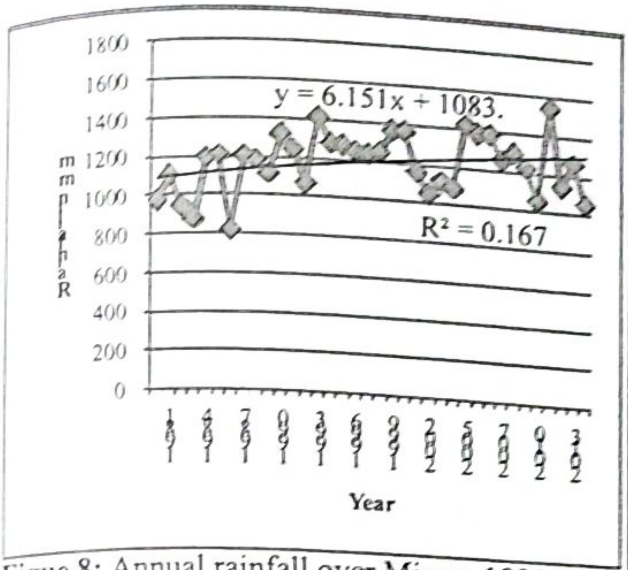


Figure 7: Annual rainfall over Abuja, 1983-2015
Source: Authors' computation, 2018



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

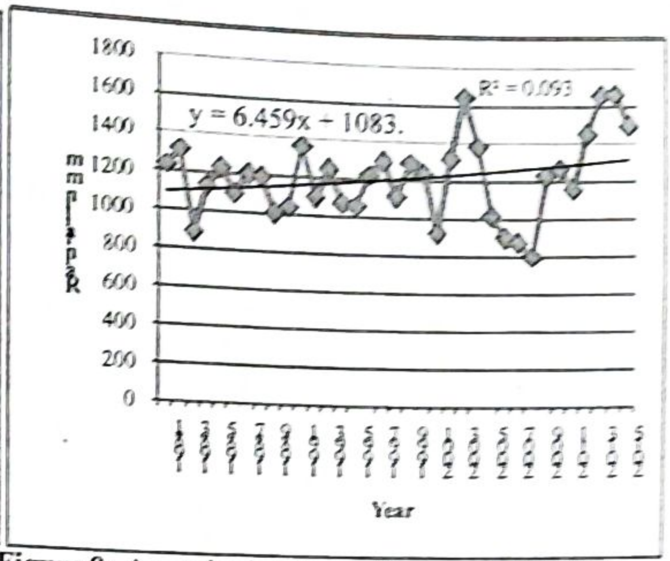


Figure 9: Annual rainfall over Kaduna, 1981-2015
Source: Authors' computation, 2018

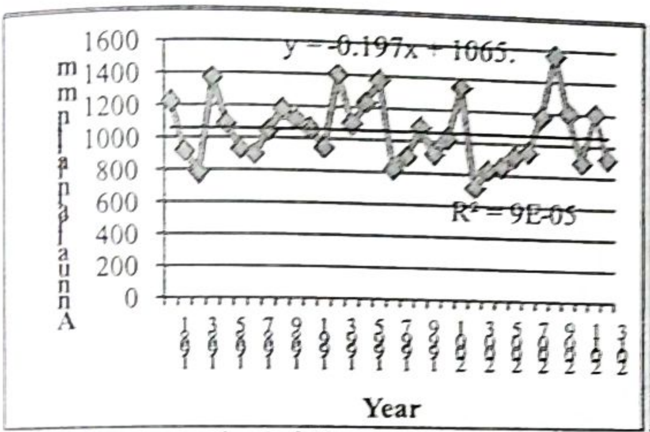


Figure10: Annual rainfall over Ibi, 1981-2013
Source: Authors' computation, 2018

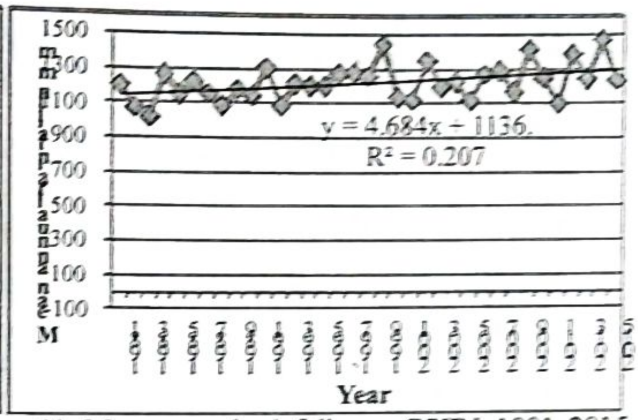


Figure 11: Mean annual rainfall over GSZN, 1981–2015
Source: Authors' computation, 2018

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)	761.50	804.50	718.50	697.10	839.90	1088.20	818.40	814.70	793.4
year	(2003)	(1982)	(2003)	(2001)	(1988)	(2015)	(1987)	(1995)	(2008)
Max(mm)	1617.10	1767.10	1569.1	2466.6	1617.10	2011.70	1543.20	1582.70	1658.90
year	(1999)	(1999)	(2009)	(2014)	(1999)	(2002)	(2012)	(2002)	(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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TREND IN HEAVY RAINFALL OVER THE GUINEA SAVANNA ZONE, NIGERIA

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Abstract
Heavy rainfall which implies an accumulated rainfall of 50 mm and above/day (24 hours) is witnessed in Nigeria during the wet season hence this research. The research was aimed at examining the trend of heavy rainfall in the Guinea Savanna Zone, Nigeria (GSZN). Daily rainfall (mm) data spanning from 1981–2015 obtained from Nigerian Meteorological Agency (NiMet), Oshodi, Lagos; were used. Results were presented in both table and figures, while the non-parametric tests-man Kendall slope method was used for analysis. The research concluded that a significant positive trend in heavy rainfall over the study area with great variability across the data collection points was observed.This is likely to give rise to more flooding. The recommendations focused on similar research to be conducted in other ecological zones in Nigeria as well as heavy rainfall forecasting and the construction of more drainage network.

Key words: Rainfall, heavy rainfall, rainfall intensities, weather and flooding.

Introduction

Rainfall is an important element of weather and it varies over time and space in onset, duration, intensities, cessation, frequency and type. In the tropics, rainfall is seasonal occurring mostly in wet season. Rainfall is very important in Nigeria mostly because of its use in agriculture, domestic water supply and ensuring stream flow (hydrology). According to Salahu (2017), rainfall is a seasonal phenomenon in tropical monsoonal climate and it occurs in spells.

Rainfall intensities vary as well over time and space. According to Meera and Priyanca (2015), rainfall intensities can be categorized into: no rain (0.0 mm/day), very light (0.1-2.4 mm/day), light rain (2.5-7.5 mm/day), moderate rain (7.6-35.3 mm/day), rather heavy (35.6-64.4 mm/day), exceptionally heavy (120 mm/day when the amount is near the heaviest in a month or season), heavy rain (64.5-124.4 mm/day), very heavy (124.5-244.4) and extremely heavy (>244.5).

The concept of heavy rainfall has been variously defined by several authors in Nigeria. Odekunle*et al* (2008); Dami (2008) as well as Ifabiyi and Ojoye (2013) referred to heavy rainfall as an accumulation of rain >50 mm/day (24 hours). Over the Guinea Savanna Zone, Nigeria (GSZN) (the study area) and based on this study, heavy rainfall refers to an accumulated rainfall of 50 mm and above/day (24 hours). Heavy rainfall is expected in Nigeria as a result of global warming, climate variability and climate change (Audu *et al*, 2014). Several studies have been carried out in Nigeria and the study area on rainfall (Ibrahim *et al*, 2018; Audu *et al*, 2018). However, none of these studies seem to study the trend of heavy rainfall over the GSZN. This forms the basis for this research.

The Study Area

The study area is the Guinea Savanna Zone, Nigeria (GSZN). Itlies between longitudes 4°–10°E of the Greenwich Meridian and latitudes 6°–11°30'N of the equator(Figure 1). To the north, it is bordered by the Sudano–Sahelian Zone while to the south; it is bordered by the Rain Forest. There are two (2) marked seasons in the study area. These are the rainy or wet season (April-October) and the dry season (October-April), while a local wind known as harmattan is experienced between November and February. The annual rainfall ranges between 761.50 mm–2456.90mm (Binbol, 1995; Abdulkadir, 2007; Odekunle *et al*, 2007; Yusuf and Yusuf, 2008; Audu, 2012a; Yusuf, 2012; Audu *et al*; 2018). Mean annual temperature is about 28.03°C. Dry season relative humidity is about 30%, while the wet season relative humidity is about 70% (Audu, 2012b). The average daily wind speed is about 89.9km/hr.

The relief of the study area consists of gently undulating plain,hills, ridges and plateaux with heights of 300m-900m (Ola, 2001). The major drainage features in the study area include rivers such as Niger, Benue, Kaduna, Dinya, Sarkin Pawa, Gurara, Usuma, Awum and KatsinaAla; dams such as Lower Usuma, Kainji and Shiroro; wide flood plains along the rivers and the confluence at Lokoja (Audu, 2012a; Audu, 2012b; Garba *et al*, 2018). The vegetation consists of thick grasses (mostly in the wet season)and scattered deciduous trees.

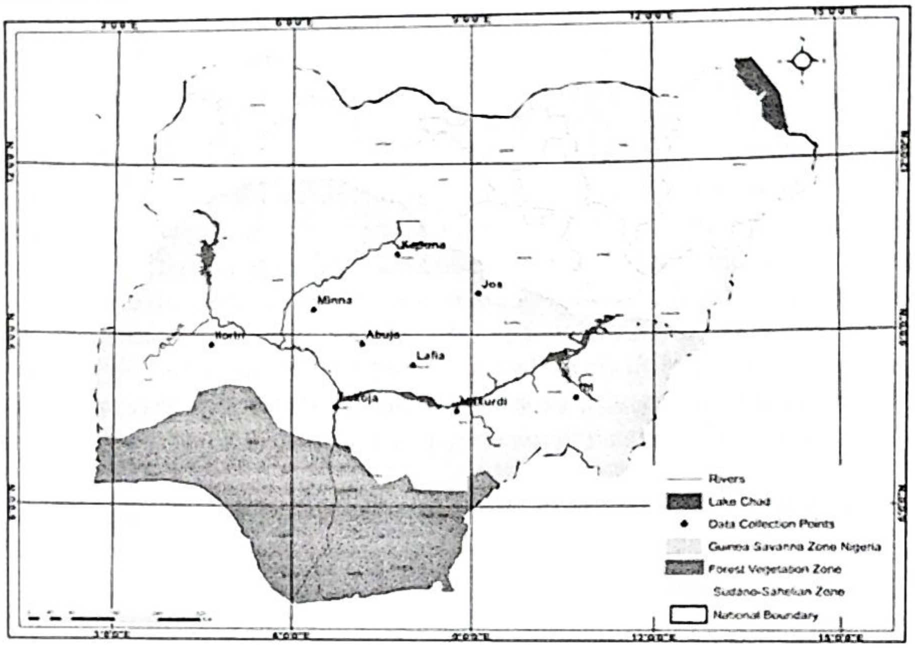


Figure 1: The Study Area

Source: National Space Research and Development Agency (NASRDA) (2018).

Materials and Methods

Daily rainfall data sourced from the Nigerian Meteorological Agency, Oshodi, Lagos; were used for this research.The data collection points were Makurdi, Lokoja, Ilorin, Lafia, Minna Jos Kaduna, 1981-2015; Abuja, 1983–2015 and Ibi, 1981–2013.

The daily rainfall data were in numerical form and measured in millimeter (mm). The heavy rainfall data were extracted from the daily rainfall through the use of micro soft excel. All the cells containing the considered data were selected. The conditional formatting was then chosen, cells rules were highlighted and the greater than was clicked. The available text box with the desired threshold value of ≥ 50 mm was then clicked and all the dates with rainfall greater than this value were extracted. The criterion used to determine this value was the threshold value of heavy rainfall earlier defined for this study as rainfall of about 50 mm and above/day (24 hours).

Trend (*S*) analysis was used to determine the increase or decrease in heavy rainfall. The presence of trend is designated by either positive sign or negative sign, while zero implies no trend (Adamu and Umar, 2016). The method used to detect the trend of rainfall over the study area was the non–parametric tests (Longobardi and Villari, 2009; Jain and Kumar, 2012; Attah, 2013). The non–parametric tests used were the Mann Kendall slope methods (Theil, 1950; Sen, 1968 both cited in Karbulut *et al*, 2008; Longobardi and Villari, 2009). The Mann–Kendall statistic *S* of the series *X* is given by Mann (1945); Kendall *et al* (1975) cited in Somsubhra and Dwayne (2016) as:

$$S = \sum_{i-1}^{n-1} \sum_{j=i+1}^{n} sgn(xj - xi) \quad 1$$

Where *sgn* is the signum function. The variance associated with *S*is calculated from Mann (1945 cited in Somsubhra and Dwayne, 2016), Mdarres and Sarhadi (2009 cited in Somsubhra and Dwayne, 2016) as:

$$\frac{V(s)=n(n-1)(2n+5)-\sum_{k}^{m}=1t_k(t_k-1)(2t_{k+5})}{18} \quad 2$$

Where m is the number of tied groups and t_k is the number of data points in group k. In case where the sample size n >10, the test statistics $Z(S)$ is calculated from Mann (1945 cited in Somsubhra and Dwayne, 2016), Mdarres and Sarhadi (2009 cited in Somsubhra and Dwayne, 2016) as:

$$Z(S) = \begin{cases} \frac{S-1}{\sqrt{V(S)}}, if\ S>0 \\ 0,\ if\ S = 0 \\ \frac{S+1}{\sqrt{V(S)}}, if\ S<0 \end{cases} \quad 3$$

Positive value of $Z(s)$ indicates increasing trends, while negative $Z(s)$ value reflects decreasing trends. Trends are considered significant if the absolute values -$|Z(s)|$ are greater than the standard normal deviate -$Z_{1-\alpha/2}$ for the desired value of ∝ (taken as 0.05 in this study).

The Theil–Sen approach (TSA), a commonly used method to quantify the magnitude of trend the in time series was used in this study. The TSA is consid ered more robust than the least-squares method due to its relative insensitivity to extreme values and better performance even for normally distributed data (Hirsch, Slack and Smith, 1982 cited in Somsubhra and Dwayne, 2016). In general, the slope Q between any two values of a time series x was estimated from Somsubhra and Dwayne (2016) as thus:

$$Q = \frac{x_k - x_j}{k-j}, k \neq j \quad 4$$

For a time series x having n observations, there are a possible $N = n(n-1)/2$ values of Q that can be calculated according to Sen's method. The overall estimator of slope is the median of these N values of Q. The overall slope estimator Q* is thus calculated after Somsubhra and Dwayne, (2016):

$$Q* \begin{cases} Q_{(N-1)/2},\ N\ odd \\ \frac{Q_{N/2} - Q_{(N+2)/2}}{2}\ N\ even \end{cases} \quad 5$$

Where significant trends in the data were detected, 95% confidence interval s were calculated u sing the non–parametric techniques as described by Salmi *et al* (2002 cited in Somsubhra and Dwayne, 2016). The quantity C_α was first calculated as:

$$C_\alpha = Z_{1-\alpha/2}\sqrt{V(s)} \quad 6$$

Where Z is again the standard normal deviate, $V(s)$ is as defined earlier and ∝ is taken as 0.05. Indices M_1 and M_2 were determined from:

$$M_1 = \frac{N - C_\alpha}{2} \quad 7$$

$$M_2 = \frac{N - C_\alpha}{2} \quad 8$$

Where N is as previously defined.

Results and Discussion

Figure 2 shows heavy rainfall trend (S) over Makurdi. There are equal positive and negative values of five (5) each while its tied is one (1) hence given riseto zero (0)general trend meaning there is no significant trend in heavy rainfall at the station. Figure 3 shows the result of heavy rainfall trend (S) over Lokoja. There are six (6) positive, four (4) negative and one (1) tied and as such the general trend is positive meaning there is a significant trend in heavy rainfall over the station.

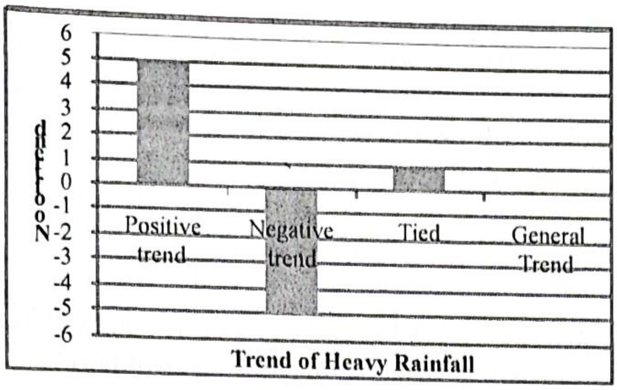


Figure 2: Trend of heavy rainfall over Makurdi, 1981–2015

Source: Authors' computation, 2018

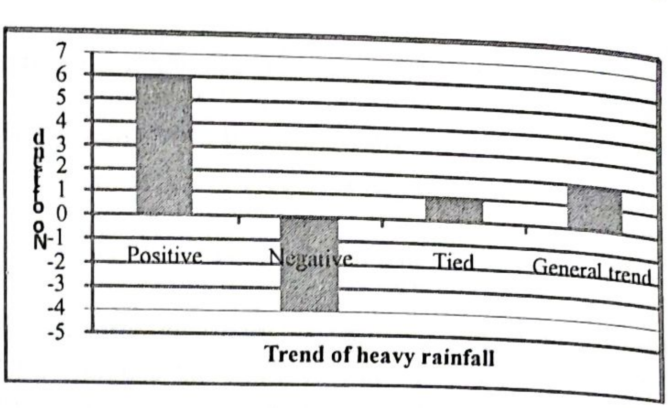


Figure 3: Trend of heavy rainfall over Lokoja, 1981–2015

Source: Authors' computation, 2018

Figure 4 is the result of heavy rainfall trend (*S*) over Ibi. There are five (5) positive and four (4) heavy rainfall trends as well as two (2) tied hence, there is a significant positive generaltrend in heavy rainfall in the area.Figure 5 is the result of the heavy rainfall trend (*S*) on Ilorin. There are seven (7) positive and four (4) negative trends with zero (0) tied hence general positive trend. Therefore, there is a significant trend in heavy rainfall over Ilorin.

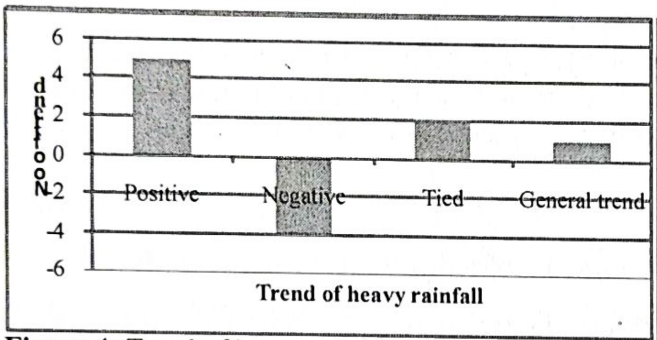


Figure 4: Trend of heavy rainfall over Ibi, 1981–2013

Source: Authors' computation, 2018

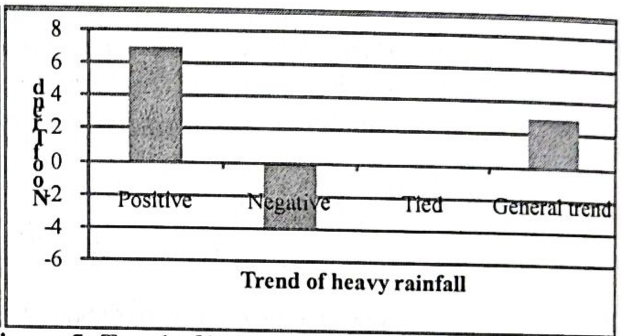


Figure 5: Trend of heavy rainfall over Ilorin, 1981-2015

Source: Authors' computation, 2018

The result of heavy rainfall trend (*S*) over Lafia as shown in Figure 6 shows six (6) positive and three (3) negative trends with two (2) tied. The general trend therefore is positive and it means that, there is a significant trend in heavy rainfall.Figure 7 shows the result on heavy rainfall trend (*S*) over Abuja. According to the result, there are six (6) positive values, three (3) negative values and two (2) tied given rise to general positive trend which indicates that there is a significant trend in heavy rainfall.

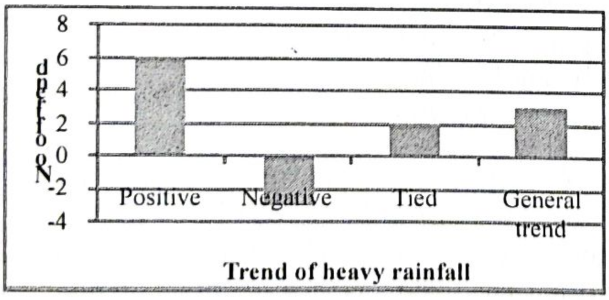


Figure 6: Trend of heavy rainfall over Lafia, 1981–2015

Source: Authors' computation, 2018

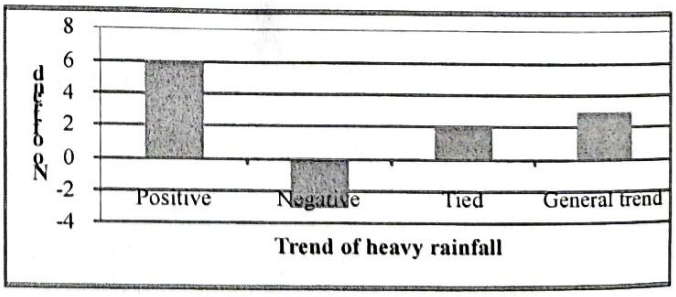
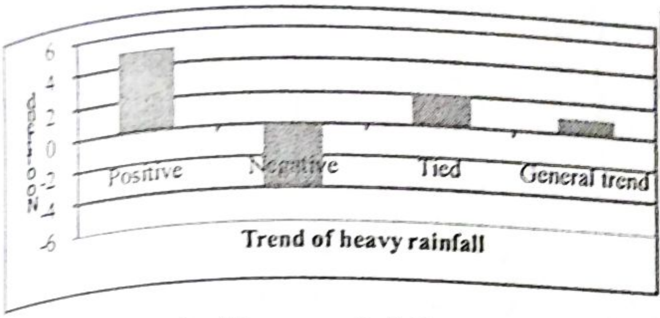


Figure 7: Trend of heavy rainfall over Abuja, 1983-2015

Source: Authors' computation, 2018

Figure 8 displays the result of heavy rainfall trend (*S*) at Minna. The result reveals that Minna has five (5) positive values, four (4) negative values and two (2) tied hence having general positive trend. By this result, there is a significant trend in heavy rainfall.



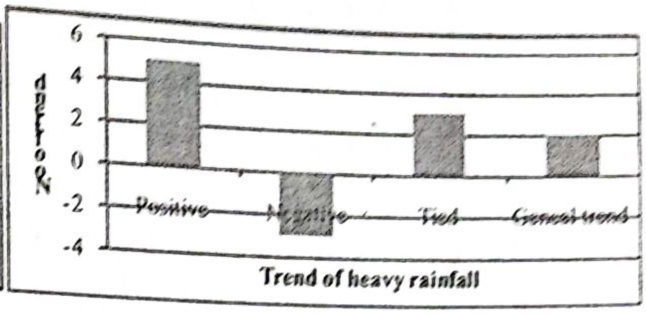
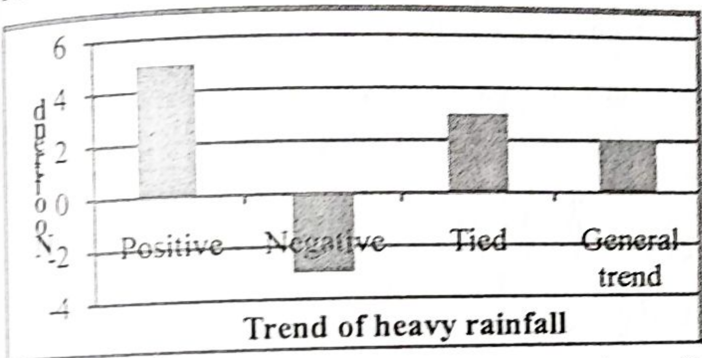


Figure 8: Trend of heavy rainfall over Minna , 1981-2015Figure 9: Trend of heavy rainfall over Jos, 1981-2015
Source: Authors' computation, 2018 **Source:** Authors' computation, 2018

Figure 9 shows the result of trend of heavy rainfall (*S*) over Jos. There are five (5) positive and three (3) negative trends with three (3) tied, while the general trend is positive. There is a significant trend in heavy rainfall over the station. Figure 10 is the result of heavy rainfall trend (S) over Kaduna. There are five (5) positive and three (3) negative trends as well as three (3) tied resulting, while the general trend is positive hence a significant positive trend in heavy rainfall.



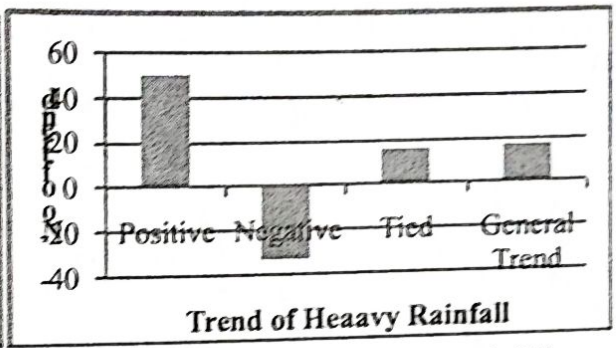


Figure 10: Trend of heavy rainfall over Kaduna, 1981-2015**Figure 11:** Trend of heavy rainfall over GSZN, 1981-2015
Source: Authors' computation, 2018**Source:** Authors' computation, 2018

According to Figure 11, the general trend of heavy rainfall over the GSZN is positive indicating a significant positive trend in heavy rainfall with fifty (50) positive, thirty-three (33) negative and sixteen (16) tied.

The variance (*v*) associated with *S* for all the data points is 1820.78 which shows great variability in heavy rainfall between the data collection points in the study area.
The standard normal deviate of heavy rainfall trend for all data points for this study is 1.96 while the absolute values for the data collection points are shown in Figure12.

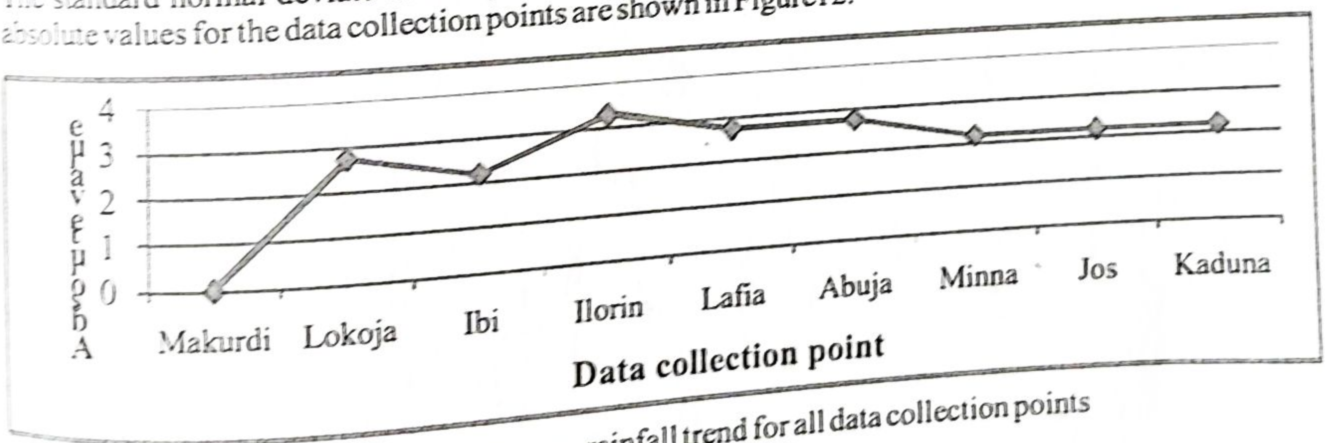


Figure 12: Standard normal deviate of heavy rainfall trend for all data collection points
Source: Authors' computation, 2018

Results shown in Figure 12 indicate that there is no significant trend in standard normal deviate (*Z(S)*) of heavy rainfall over Makurdi, while other stations record positive significant trend. The regional standard normal trend is significant over the study area.

Table 1: General trends (Q) in heavy rainfall over the study area.

S / N	Data point	General trend (Q)	Remark
1	Makurdi	0.03	Positive trend
2	Lokoja	0	No significant trend
3	Ibi	-0.03	Negative trend
4	Ilorin	0.18	Positive trend
5	Lafia	0	No significant trend
6	Abuja	-0.06	Negative trend
7	Minna	0.06	Positive trend
8	Jos	0.03	Positive trend
9	Kaduna	0.12	Positive trend

Source: Authors' computation, 2018

The Q results shown in table 1 indicate that there is no significant trend in heavy rainfall over Lokoja and Lafia, Abuja and Ibi have negative trends while the remaining stations have positive trends. On regional basis, there is a positive trend in heavy rainfall over the study area.

Results of the overall estimator of slope (Q*) are shown in Figure13. Makurdi, Lokoja and Minna have negative Q* while Ibi, Ilorin, Abuja, Lafia, Jos and Kaduna have positive Q*. On a regional basis, the study area has a positive Q*.

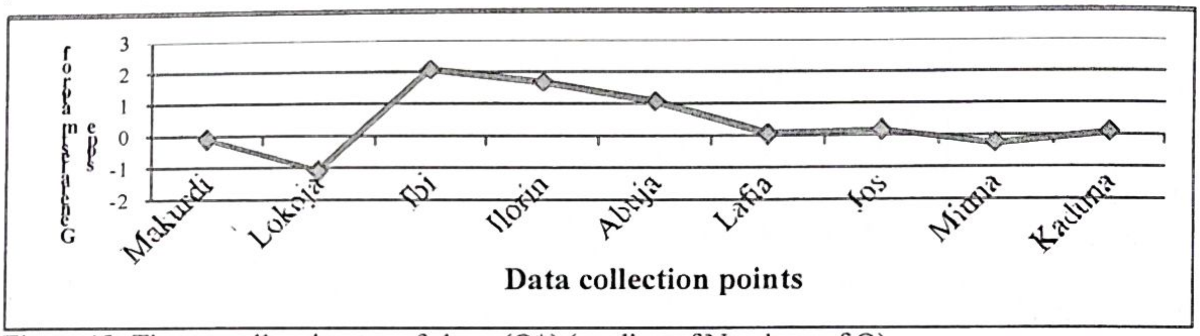


Figure13: The overall estimator of slope (Q*) (median of N values of Q)

Source: Authors' computation, 2018

The 95% (0.05) lower and upper confidence intervals are: M_1 for all the data points = 60, 445 501. 27, while M_2 is =60, 452, 638.73 which means that the data are significant.

Conclusion and Recommendations

This research has confirmed a significant positive trend in heavy rainfall over the study area with great variability across the data collection points. A positive significant trend in standard normal deviate in heavy rainfall was also observed. The implications of these results are that more flooding is eminent over the study with surplus surface and underground water during the wet season. Heavy rainfall with high intensity results in hydro-meteorological hazards such as landslide, soil erosion, water pollution as well as flooding over the study area. According to Oriola (2000), excessively heavy and prolonged rainfall is the commonest universal cause of floods. Jimoh (2000) opined that Ilorin recorded serious flood disasters in 1973, 1974, 1976 and 1979. The Nigerian Meteorological Agency (NiMet) (2017) stated that heavy rainfall in the months of August/September caused the Rivers Niger and Benue to over flow their banks causing some of the worst flooding seen in Benue and Kogi States since 2012. In each of these states, over 100, 000 people were displaced with Lokoja worst affected. According to Asnani (2005), each season in the tropical region has its well marked diurnal cycle of weather. The seasonality of weather with its own daily cycle makes "persistence" principle very useful in 24-hour forecasting in the tropics. Similar research in other ecological zones is recommended to make this study holistic covering the entire country. Efforts should be geared towards heavy rainfall forecasting using modern methods/equipments such as the Numerical Weather Prediction (NWP) and other models to serve as early warning tool. More drainage network should to be constructed especially in cities, while settlements that are too close to large water bodies should be made temporal. These measures would aid in the mitigation and adaptation to the adverse effects of heavy rainfall especially flooding in the study area.

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