ANALYSIS OF HEAVY RAINFALL IN GUINEA SAVANNA ZONE, NIGERIA

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Abstract
One of the components of rainfall in Nigeria is heavy rainfall. This study is titled analysis of heavy rainfall in Guinea Savanna Zone, Nigeria (GSZN). Daily rainfall data were obtained from the Nigerian Meteorological Agency (NiMet)for the period of 1981-2015 (35 years). The daily heavy rainfall (≥50*) parameter was extracted from the data. Methods of analysis included the total annual and monthly heavy rainfall computations for each data collection point and the study area. Results were presented in figures and discussed. Findings revealed that 1998 and 1992 recorded the highest and lowest frequencies of heavy rainfall over the study area. High inter-annual variability was also observed and it is on the rise. The highest frequency in the occurrence of monthly heavy rainfall over the study area was in August. The study concluded that heavy rainfall is experienced in the study area annually with single maxima in August. The recommendations focused on the need for the constructions of more dams, lakes and water reservoirs, proper town planning, public enlightenement campaign on safety during heavy rainfall as well as the incorporation of heavy rainfall forecast into the Seasonal Rainfall Prediction (SRP) and daily weather forecast by NiMetto mitigate the effects of heavy rainfall.*

Keywords: Rainfall, heavy rainfall, rainfall forecast, global warming and flooding.

Introduction
Rainfall remains the most important weather parametre which affects both man and his environment especially in Nigeria. Man's primary economic activities in Nigeria are to a large extent depend on rainfall. In the Tropical Africa with particular reference to Nigeria, rainfall plays significant roles in agriculture, water resources, vegetal growth/cover and water transportation. According to Audu *et al* (2018a), agriculture in Nigeria is still largely rain-fed. Due to the importance of rainfall, it has become a topical issue of discourse in some disciplines such as meteorology, climatology, agricultural science, hydrology, environmental science/management and other physical and earth sciences.

The derived rainfall parameters such as the onset, cessation, duration, variability, intensity, wet spell, dry spell and drought are of concern because they affect man directly and his activities as they are not always favourable. For instance, high rainfall intensity and heavy/prolong rainfall result in soil erosion, landslide, water pollution and flooding. According to Nwagbara *et al* (2010), even when the basins and rivers exist to carry the flood, heavy rainfall often causes their carriage capacities to be exceeded, thus resulting in flooding. Nigerian Meteorological Agency (NiMet) (2013) opined that, weather and climate variations often explain changes in agricultural performance, floods, drought/desertification, water supply and diseases.

In recent years, Nigeria is experiencing global warming, rainfall variability and climate change (Adakayi, 2008; NiMet, 2016; Obateru, 2017). These conditions are linked to the occurrence of heavy rainfall. According to Chup (2005), rain is one type of precipitation and it implies water droplets with a radius of 0.5–7 mm which are associated mainly with convective clouds. According to Karl *et al* (1996); Groisman and Coauthors (1999), heavy rainfall climatologically is a 24 hours accumulation of rain which exceeds 50.8 mm. Odekunle *et al* (2008), Dami (2008); Ifabiyi and Ojoye (2013); referred to heavy rainfall as an accumulation of rain >50 mm per day (24 hours). According to Audu *et al* (2018b), heavy rainfall refers to an accumulated rainfall of 50 mm and above per day (within 24 hours). In this study, heavy rainfall is taken to be an accumulated rainfall ≥50 mm in a day (24 hours). NiMet embarks on the Seasonal Rainfall Prediction (SRP) and daily weather forecast. Rainfall forecast is the probability that >0.01 inch (0.25 mm) of rainfall will be experienced in a single spot averaged in the forecast zone (National Weather Service, 2009). Prolong, heavy and frequent rainfall over an area is the major cause of flooding (Audu *et al*, 2018a). According to Amaechi (2018),NiMet's SRP had predicted events of floods in Nigeria in 2012, 2016 and 2017 and it has been proven that these forecasts occurred.

Most of the studies undertaken on rainfall over Nigeria and specifically in the study area laid emphasis on rainfall in general (Ibrahim *et al*, 2018; Audu *et al*, 2018a). Hence, this research aimed at analyzing both inter-annual and monthly heavy rainfall event in the Guinea Savanna Zone, Nigeria (GSZN) with the hope of suggesting ways of harnessing its potentials and averting the hazards usually associated with it.

Research Questions

(i) What is the characteristic of inter-annual heavy rainfall in the study area?
(ii) What are the characteristics of monthly heavy rainfall over the study area?

The Study Area

The study area is the Guinea Savanna Zone, Nigeria (GSZN) which lies between longitudes 4^o–10^oE and latitudes 6^o–11^o30^1N (Figure 1).It is bordered to the north by the Sudano–Sahelian Zone, Nigeria (SSZN) and to the south by the Rain Forest, Nigeria (RFN). It enjoys both wet (which starts in April) and dry (which starts in October) seasons while the harmattan is experienced between November and February. The annual rainfall ranges between 1300mm–2200mm (Binbol, 1995; Abdulkadir, 2007; Odekunle *et al*, 2007; Yusuf and Yusuf, 2008; Audu, 2012a; Yusuf, 2012). Mean annual temperature is about 28.03^{o}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 study area consists of gently undulating plain with some hills, ridges and plateaux whose heights are between 300m-900m.(Ola, 2001).In the aspect of vegetation, the zone is the largest vegetation belt in Nigeria. According to Audu *et al* (2018b), the region comprises of tall and thick grasses as well as tall trees with broad leaves. The trees are scattered and deciduous. There is also the presence of gallery forests along water courses of Rivers Niger and Benue.

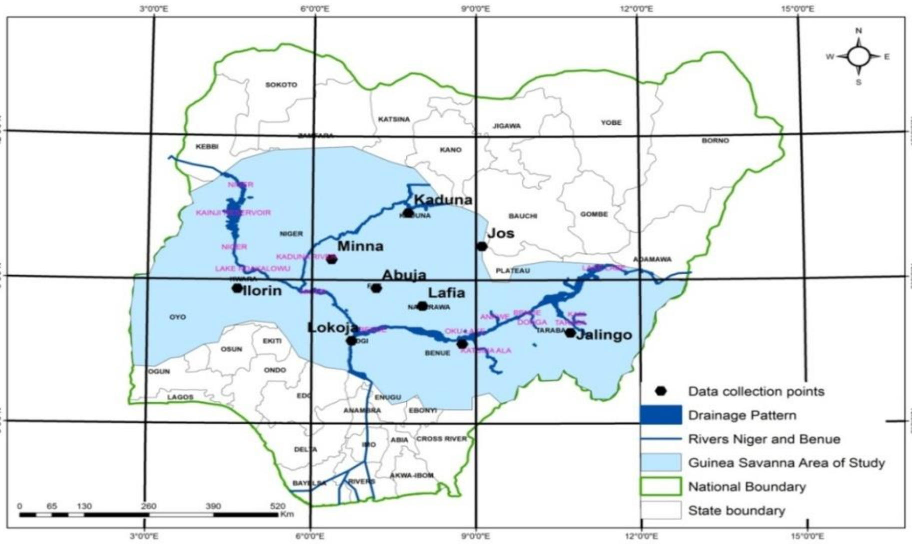


Figure 1: Map of Nigeria showing the study area
Source: National Space Research and Development Agency (NASRDA), Abuja (2018)

Materials and Methods

Daily rainfall data for Makurdi, Lokoja, Ilorin, Lafia, Minna Jos and Kaduna, 1981-2015 (35 years); Abuja, 1983–2015 (33 years) and Ibi, 1981–2013 (33 years) were used for this study. The data points are spread across the GSZN. These data were sourced from the Nigerian Meteorological Agency. The rainfall data were in numerical form and 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 was highlighted and the greater than was clicked. The available text box with the desired threshold value ≥ 50mm was then clicked and all the rainfall value ≥ 50mm appeared. The total annual heavy rainfall per station was calculated thus:

$$T_{yr/s} = f(R \geq 50) \quad 1$$

Where:
$T_{yr/s}$= Total yearly (annual) heavy rainfall per station (data collection point)

The total annual heavy rainfall for the study area (Guinea Savanna Zone, Nigeria) was calculated to give the regional view using the following equation:

$$T_{yr/Reg} = f(R \geq 50) \quad 2$$

Where: $T_{yr/Reg}$ = Totalyearly(annual) heavy rainfall for the study area
The total monthly (January-December) heavy rainfall per station was calculated thus:

$$T_{m/s} = f(R \geq 50) \quad 3$$

Where:$T_{m/s}$ = Total monthly heavy rainfall per station (data collection point)

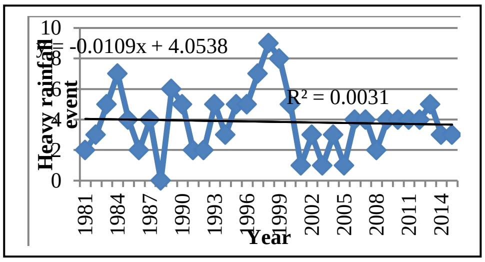
The total monthly heavy rainfall for the study area was calculated thus:

$$T_{m/Reg} = f(R \geq 50) \quad 4$$

Where: $T_{m/Reg}$= Total monthly heavy rainfall for the study area.
From equations 3 to 6, F= frequency of occurrence of heavy rainfall and R= rainfall

Results and Discussion

Figure 1 shows the result on heavy rainfall over the study area. There is inter-annual variation in heavy rainfall over the zone. According to Gbode (2014), rainfall is a highly variable weather parameter with different spatial and temporal distribution patterns globally making the classification of rainfall regions across an area to be considered essential for understanding the rainfall distribution patterns across an area. The highest total number of heavy rainfall was observed in 1998 while the lowest was recorded in 1992. It could be recalled that most data collection points in the study area had the highest annual rainfall in recent time in 1998 and 1999 (Eze *et al*, 2014; Audu *et al*, 2018a). Ayansina and Ogunbo (2009) cited in Ochei and Oluleye (2017) observed seasonal rainfall variability in Guinea Savanna and concluded that rainfall variability will continue to be on the increase as an element of climate change. Heavy rainfall is on the rise over the study area and could be attributed to global warming. Figure 2 shows the analysis on annual heavy rainfall over Makurdi which shows high degree of fluctuation. All the years under study experienced heavy rainfall except 1988. 1998 recorded nine (9) events of heavy rainfall which is the highest for the station followed by 1999 with eight (8) events. There is a decline in heavy rainfall over the station in recent years hence the negative trend. Figure 3 shows the analysis on heavy rainfall in Lokoja. It shows high degree of variability. The lowest occurrence of only one (1) event was recorded in year 2000 while the highest of eight (8) events were recorded in 1995 and 2009. All the years experienced heavy rainfall event. Heavy rainfall seems to be on the increase with a positive trend line. There is a regular variability in heavy rainfall over Ibi (figure 4). However, in recent years; the event seems to be on a decline hence a negative trend line. 1997 had zero (0) event while 1993 and 1995 had the highest record of six (6) events each.



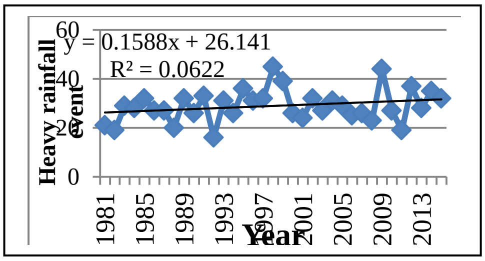
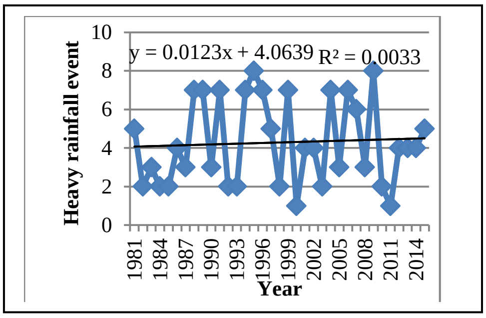


Figure 1:Frequency of heavy rainfall over GSZN, 1981-2015
Figure 2:Frequency of heavy rainfall over Makurdi, 1981-2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019



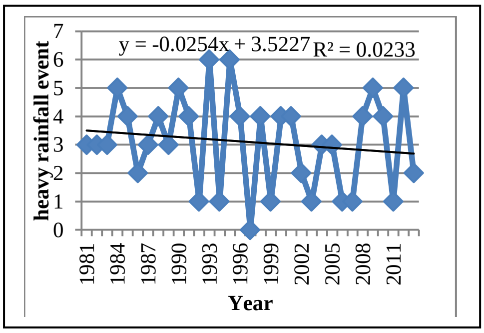
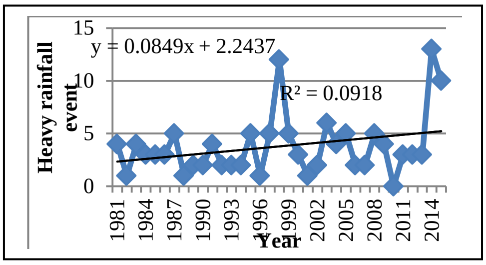


Figure 4:Frequency of heavy rainfall over Ibi, 1981-2013
Figure 3:Frequency of heavy rainfall over Lokoja, 1981-2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Figure 5 shows that all the years under study experienced heavy rainfall in Ilorin except 2010. 1998 has twelve (12) heavy rainfall events which are the highest, followed by 2014 with thirteen (13) and 2015 having ten (10). Heavy rainfall over the station exhibits double maxima attribute. The result further shows that heavy rainfall is on the increase hence the positive trend line. 1984–1986, 1992–1994 and 2011–2013 maintained the same number of events consecutively. Moderate variability is observed. Figure6 shows the result on heavy rainfall over Lafia. 1998 and 1999 recorded the highest of nine (9) each. 1988 recorded zero (0) event with high variability. There is an increase in the event and such a positive trend line is observed as well as high variability. Figure 7 is the result on Abuja. 1985 and 2002 experienced the highest number of heavy rainfall of eight (8) events each with high variability in heavy rainfall over the station. 1992, 1996, 2000 and 2013 had zero (0) heavy rainfall. There is a decline in the event hence a negative trend line. Figure 8 displays the result on Minna. Heavy rainfall is on a steady increase hence having a positive trend line. All the years under study experienced heavy rainfall with 2009 having the highest event of seven (7), while the lowest is one (1) which was recorded in 1981, 1984, 1999, 2002 (4 years). Variability is also experienced at the station.



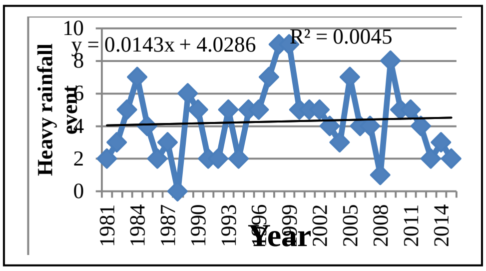
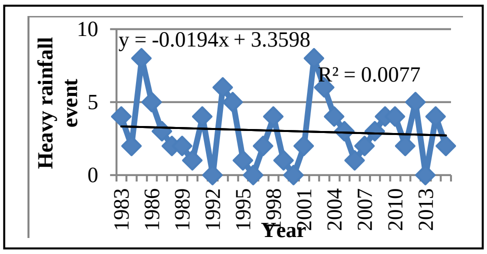


Figure 5: Frequency of heavy rainfall over Ilorin, 1981-2015
Figure6: Frequency of heavy rainfall over Lafia, 1981-2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019



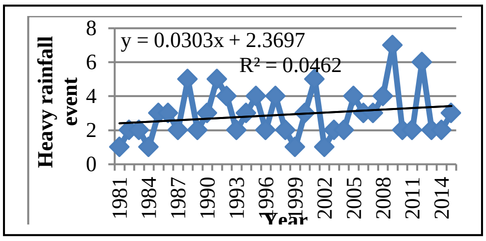
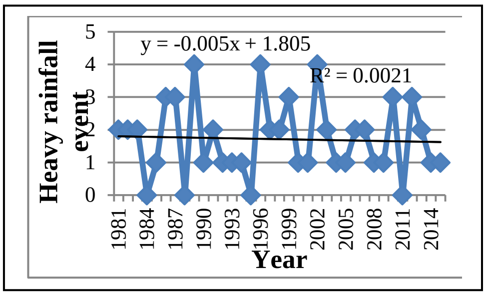


Figure 7: Frequency of heavy rainfall over Abuja, 1983-2015
Figure8: Frequency of heavy rainfall over Minna, 1981-2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Figure 9 is the result on heavy rainfall in Jos. Four (4) years recorded zero (0) event of heavy rainfall (1984, 1988, 1995 and 2011). 1989, 1996 and 2002 had the highest heavy rainfall events of four (4) each. High variability is also observed in heavy rainfall at the station. However, heavy rainfall seems to be on the decrease hence a negative trend line. Figure 10 shows the analysis on heavy rainfall over Kaduna. Three (3) years (1989, 1997 and 2008) recorded zero (0) event while 2013 recorded the highest event of eight (8). Variability seems to be moderate except in 2013 that it rose astronomically. Results also indicated that in recent time, heavy rainfall is on the increase giving rise to a positive trend line.



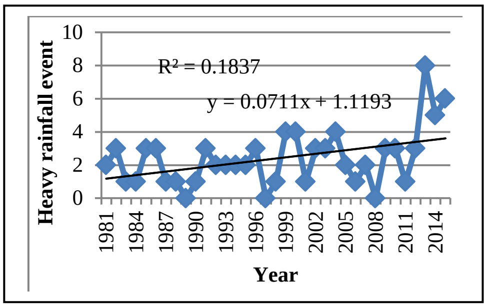
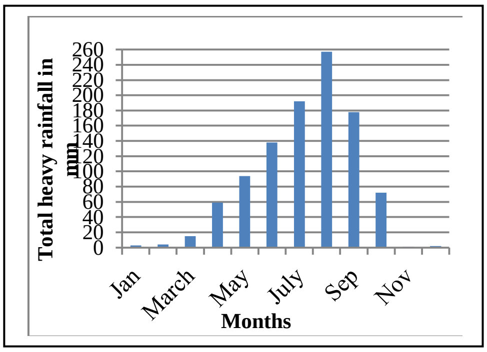


Figure 9: Frequency of heavy rainfall over Jos, 1981-2015
Figure10: Frequency of heavy rainfall over Kaduna, 1981-2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

This study also looked at the monthly heavy rainfall in the study area. Figure 11 shows the frequency of monthly heavy rainfall over GSZN. It shows that the region has heavy rainfall throughout the year. However, heavy rainfall becomes more pronounced between April-October which coincides with the onset, cessation and duration of rain over the region (wet season). August has the highest total heavy rainfall over the area. This also coincides with the period that the zone experiences the highest mean rainfall. According to Agumagu (2016), the Sahel region of West Africa experiences the peak rainfall in August. Akinbobola *et al* (2018) opined that in northern Nigeria; the peak monthly rainfall of 91 mm was observed in August. Single maximum heavy rainfall is observed in August over the region. This is to say that the occurrence of heavy rainfall follows the general pattern of rainfall distribution over the area.



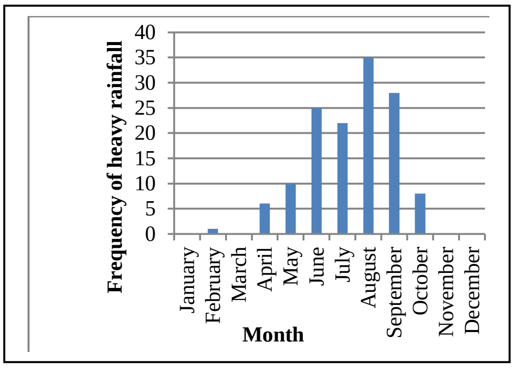
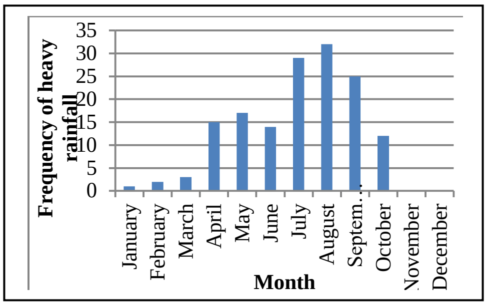


Figure 11: Frequency of monthly heavy rainfall over GSZN1981– 2015
Figure 12: Frequency of monthly heavy rainfall over Makurdi, 1981–2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Figure 12 shows the monthly heavy rainfall over Makurdi. January, March, November and December recorded zero (0) heavy rainfall between 1981–2015. The distribution shows double maximum in June and August with August recording the highest heavy rainfall. Heavy rainfall is concentrated mostly between April and October which coincides with the rainy season in the area. A total of one hundred and thirty five (135) heavy rainfall events were recorded within the period of study. Figure 13 shows the result on monthly heavy rainfall over Lokoja. The station records heavy rainfall between January and October within the period under study. The station also observes double maxima heavy rainfall in May and August. However, the bulk of the heavy rainfall is concentrated between April–October. The months of November and December record zero (0) heavy rainfall. A total of one hundred and forty nine (149) events were recorded within the period under study.



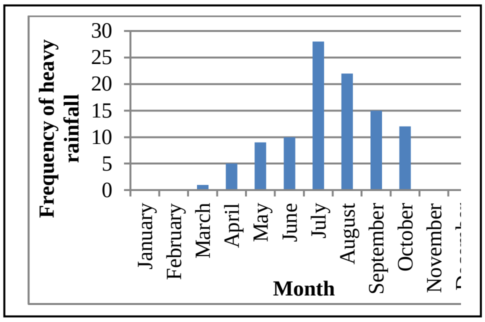
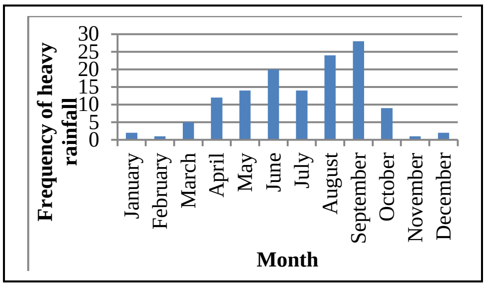


Figure 13: Frequency of monthly heavy rainfall over Lokoja, 1981-2013
Figure 14: Frequency of monthly heavy rainfall over Ibi1981–2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Figure 14 is the result on monthly heavy rainfall over Ibi. The station observes heavy rainfall between March–October, while January, February, November and December record zero (0) frequency of heavy rain. The station also experiences the single maximum in July. A total of one hundred and two (102) vents were observed. Figure 15 reveals the result of the monthly heavy rainfall over Ilorin. All the months experienced heavy rainfall with double maxima in June and September with September having the highest frequency. The bulk of the heavy rainfall is concentrated between April–October. A total of one hundred and thirty two (123) events were recorded.



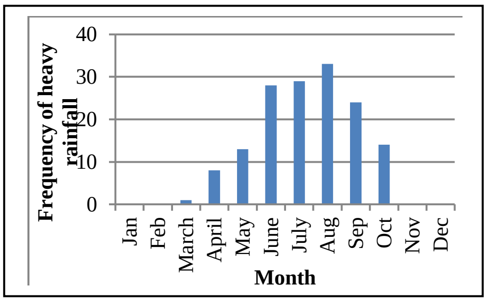
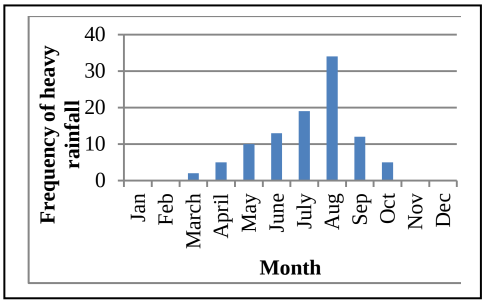


Figure 15: Frequency of monthly heavy rainfall over Ilorin, 1981–2015
Figure 16: Frequency of monthly heavy rainfall over Lafia, 1981–2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Figure 16 reveals the monthly distribution of heavy rainfall over Lafia which is experienced between March–October with its bulk concentrated between April–October with single maximum in August, while January, February, November and December recording zero (0) heavy rainfall. A total of one hundred and fifty (150) events were recorded within the period under study. Figure 17 shows that Abuja experiences heavy rainfall between March–October. The station experiences single maximum, while the highest occurs in August. Akinbobola *et al* (2018), observed that peak monthly mean rainfall of about 490 mm was experienced in August in 2010 over Abuja. However, January, February, November and December record zero (0) heavy rainfall. A total of one hundred (100) heavy rainfall events were recorded within the period of study.



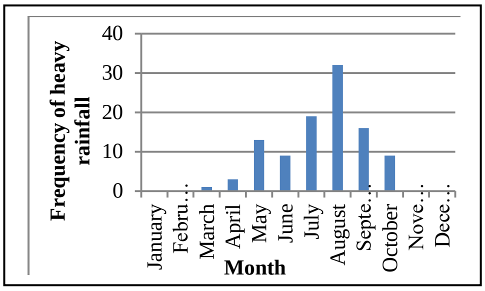
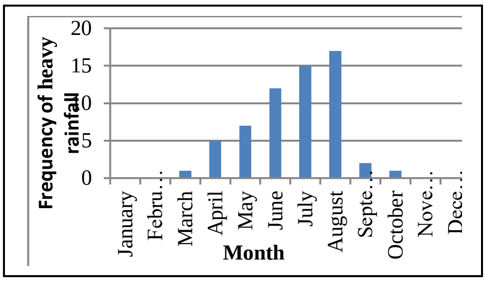


Figure17: Frequency of monthly heavy rainfall over Abuja1981-2015
Figure 18: Frequency of monthly heavy rainfall over Minna, 1983–2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Figure 18 shows the result on heavy rainfall over Minna which occurs between March–October with its bulk occurring between May–October. Double maximum is observed in May and August, while the highest is observed in August. January, February, November and December record zero (0) occurrence. A total of one hundred and two (102) events were recorded during the period of study. Figure19 shows the result on heavy rainfall over Jos. Heavy rainfall is experienced between March–October. The bulk of the heavy rainfall is concentrated between April–August with single maximum in August which also represents the month with the highest frequency of heavy rainfall. However, January, February, November and December record zero (0) occurrence of heavy rainfall. A total of sixty (60) heavy rainfall events were recorded. Figure 20 is the result on heavy rainfall over Kaduna. January, February, April, November and December record zero (0) occurrence of heavy rainfall. The remaining months experience heavy rainfall. However, the bulk of it is concentrated between June–September. The station observes single maximum heavy rainfall with the highest recorded in August and September. A total of eighty four (84) events were recorded within the period under study.



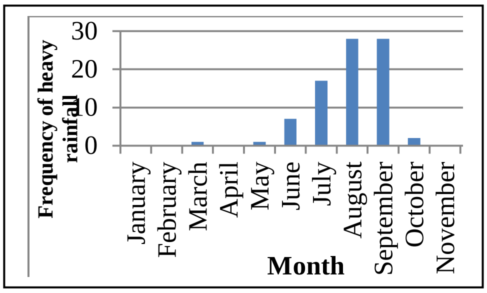


Figure 19:Frequency of monthly heavy rainfall over Jos 1981–2015
Figure 20:Frequency of monthly heavy rainfall over Kaduna, 1981–2015
Source: Authors' computation, 2019
Source: Authors' computation, 2019

Conclusion and Recommendations

This study has revealed the occurrence of heavy rainfall over the study area. All the years experienced heavy rainfall with high inter-annual variability and a rising scenario. 1998 recorded the highest number while 1992 recorded the lowest heavy rainfall over the study area. The results on frequency of monthly heavy rainfall revealed that the study area has single maxima monthly with the highest occurrence in the month of August which is highly prone to flooding

The monthly heavy rainfall occurs throughout the year, but mostly between April and October. According to NiMet (2017), the rising trend of rainfall in Nigeria is in agreement with temperature increase, as it is expected that the increase in temperature (global warming) would result to increase in evapo-transpiration and condensation and thereby producing more rains which could result to flooding and other rainfall impacts. The variability observed in the rising and declining of heavy rainfall across the data collection points could be attributed to the differences in latitudinal locations of the stations, local peculiarities, effect of climate variability and climate change.

Based on the findings of this research, it is recommended that more dams, lakes and water reservoirs (surface and underground) should be constructed to store excess water during heavy rains for dry season’s use as well as to mitigate flooding. Proper town planning is advocated with adequate drainage system. The National Emergency Management Agency (NEMA), National Orientation Agency (NOA), mass and social media (especially radio, television and Facebook) and Non-Governmental Organisations (NGOs) should enlighten the public on safety during and immediately after heavy rainfall. This has become necessary because some people attempt walking or driving through floods and get drowned in the process. Also, forecast of heavy rainfall should be incorporated into the Seasonal Rainfall Prediction (SRP)and daily weather forecast by NiMet for the study area.

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