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^o–10^oE of the Greenwich Meridian and latitudes 6^o–11^o30^1N 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^{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 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.

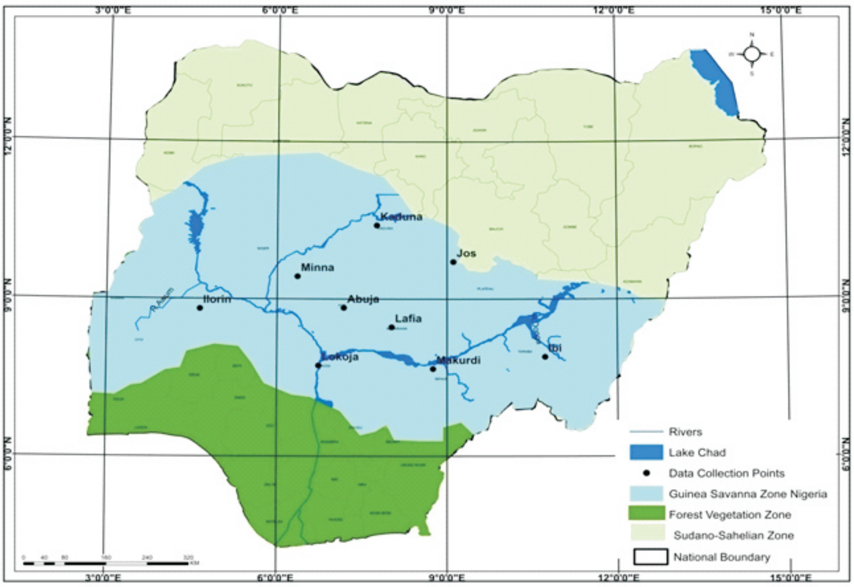


Figure 1: The Study Area

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 $\geq$ 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 $\propto$ (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 $\propto$ is taken as 0.05. Indices M_1 and M_2 were determined from:

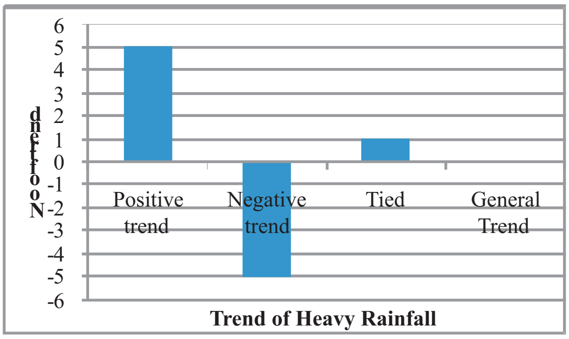
$$M_1 = \frac{N-C_\alpha}{2} \quad 7$$

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

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.



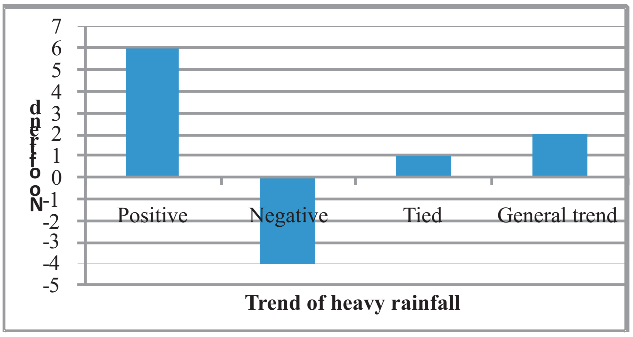


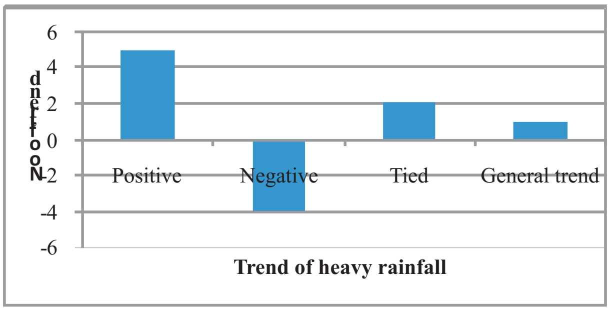
Figure 2: Trend of heavy rainfall over Makurdi, 1981–2015

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.



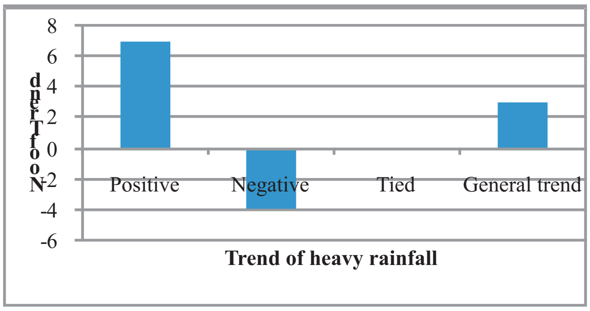


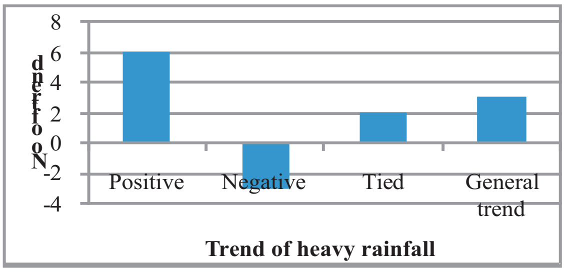
Figure 4: Trend of heavy rainfall over Ibi, 1981–2013

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.



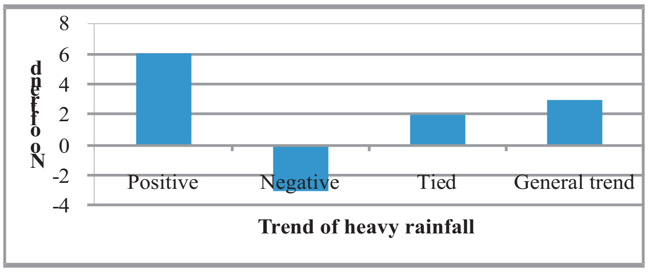


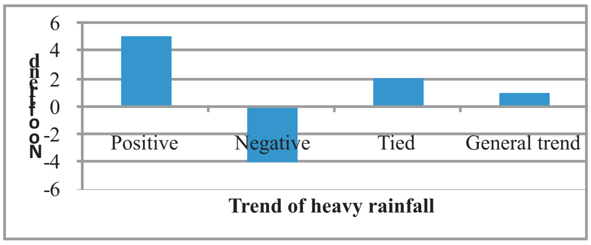
Figure 6: Trend of heavy rainfall over Lafia, 1981–2015

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.



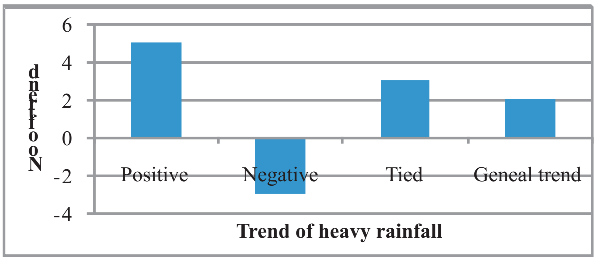
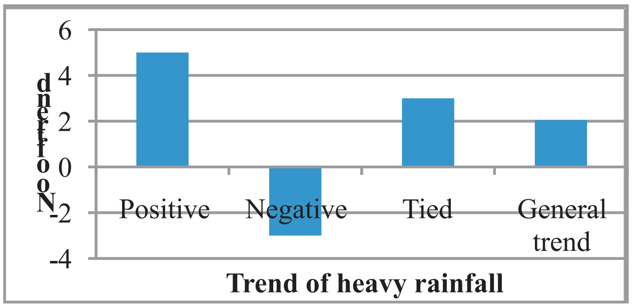


Figure 8: Trend of heavy rainfall over Minna , 1981-2015 **Figure 9:** Trend of heavy rainfall over Jos, 1981-2015

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.



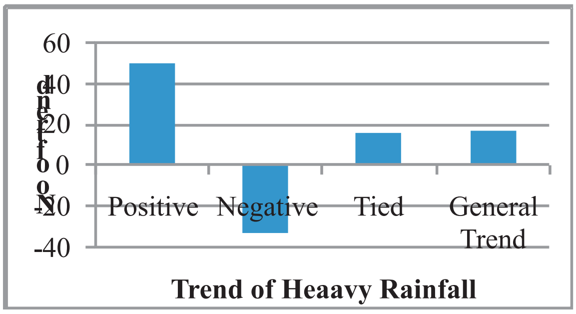


Figure 10: Trend of heavy rainfall over Kaduna, 1981-2015 **Figure 11:** Trend of heavy rainfall over GSZN, 1981-2015

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.

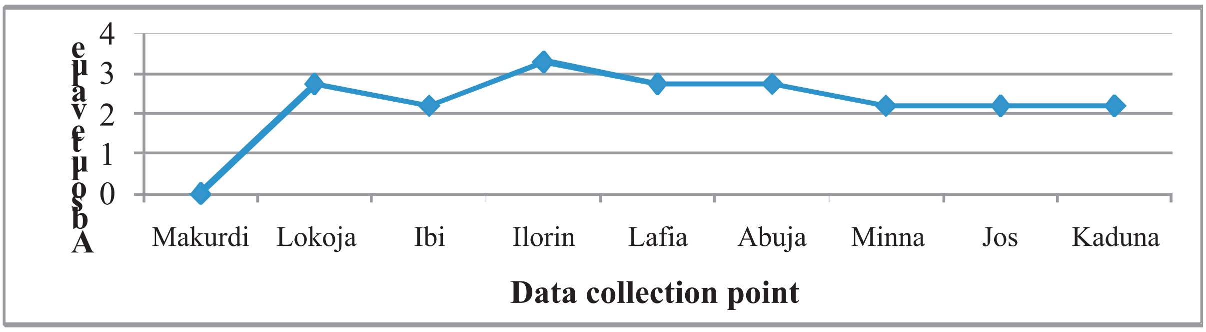


Figure 12: Standard normal deviate of heavy rainfall trend for all data collection points

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*.

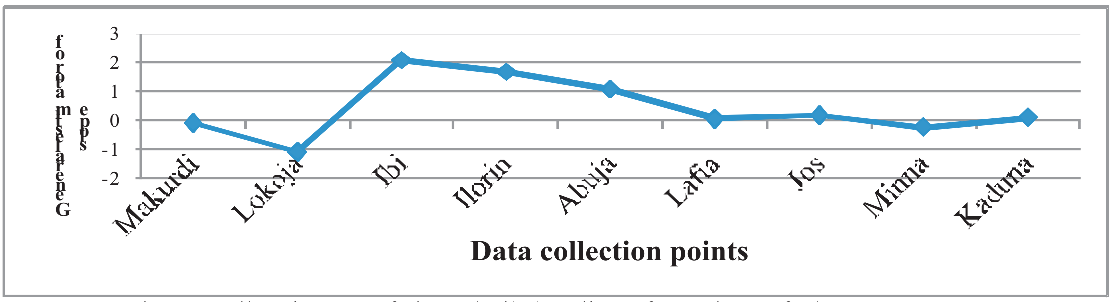


Figure13: The overall estimator of slope (Q*) (median of N values of Q)

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.

References

Abdulkadir, A. (2007). An Appraisal of the peoples' perception of environmental degradation issues in Minna, Niger State, Nigeria. *Abuja Journal of Geography and Development* 2 (1),104–126.

Adamu, A., & Umar, A. (2016). Trend analysis of rainfall and temperature time series of Zaria, Nigeria. In O.D. Jimoh, M.Y. Otache, R.A. Adesiyi and M. Saidu (eds). Nigeria Association of Hydrological Sciences (NAHS). Proceedings of the 7th International Conference on Water Resources and Sustainable Development. Pg. 50.

Asnani, G. C. (2005). Tropicalmeteorology. *Revised Edition*. 1,1-17.

Attah, D. A. (2013). Climate variability and its impact on water resources of lower Kaduna Catchment. Unpublished PhD Thesis, Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria–Nigeria.

Audu, E. B. (2012a). A descriptive analysis of rainfall for agricultural planning in Lokoja Local Government Area of Kogi State, Nigeria. *International Journal of Science and Technology.* 2 (12), 850–855.

Audu, E. B. (2012b). An Analytical View of Temperature in Lokoja, Kogi State, Nigeria. *International Journal of Science and Technology*. 2 (12), 856–859.

Audu, E. B; Muhammed, A.Y; Umar, A. & Audu, H.O. (2014). Climate change impact on rainfall pattern and the implication on food security in Lokoja Local Government Area of Kogi State, Nigeria. *Developmental Journal of Science and Technology Research (DJOSTER).* Faculty of Applied Sciences and Technology, Ibrahim Badamasi Babangida University, Lapai, Niger State and Nigeria. 3(1):48–59.

Audu, E. B., Abubakar, A. S., Ojoye, S., Mohammed, M., & Mohammed, S. Y. (2018). Characteristics of annual rainfall over Guinea Savanna Zone, Nigeria. *Journal of Information, Education, Science and Technology, School of Technology Education, Federal University of Technology, Minna, Niger State, Nigeria.* In press.

Binbol, N. L. (1995). Climate: In Geographic perspective on Nasarawa State. Onaira Printing and Publication Company, Keffi, Nasarawa State. Pg.2.

Dami, A. (2008). A perspective of environmental change in the Nigeria's section of the Chad Basin. Unpublished PhD Thesis, Obafemi Awolowo University, Ile–Ife.

Garba, I. K., Nsofor, G. N., Abubakar, A. S. & Abdulkadir, A. (2018). Evaluation of trend in flood events on riparian communities of Shiroro Dam, Nigeria. *Journal of Science, Technology, Mathematics and Education (JOSTMED).* Department of Science Education, Federal University of Technology, Minna, Niger State, Nigeria. 14(1):44-53.

Ibrahim, I., Emigilati, M. A., Suleiman, Y. M., Ojoye, S., & Yahaya, T. I. (2018). Effectiveness of early waning methodology and standardized precipitation index for drought monitoring over Guinea Savanna Zone, Nigeria. *Journal of Science, Technology, Mathematics and Education (JOSTMED).* Department of Science Education, Federal University of Technology, Minna, Niger State, Nigeria. 14(2):1-8.

Ifabiyi, I. P., & Ojoye, S. (2013). Rainfall trend in the Sudano–Sahelian ecological Zone of Nigeria. *Earth Science Research*. 2(2):194–202.

Jain, S. K., & Kamar, V. (2012). Trend analysis of rainfall and temperature Data for Indian. Review Article, Current Science, 102(1):37–49.

Jimoh, H. I. (2000). Man–Environment Interactions. In H.I. Jimoh and I.P. Ifabiyi (eds). Contemporary issues in Environmental Studies. Haytee Press & Publishing Co. LTD, Ilorin, Kwara State, Nigeria. Pg. 22.

Karabulut, M; Gurbuz, M., & Korkmaz, H. (2008). Precipitation and temperature trend analysis in Samsun. *Journal of International Environmental Application and Science*, 3 (5): 399–408.

Longobardi, A, & Villari, P. (2009). Trend analysis of annual and seasonal rainfall time series in the Mediterranean Area. *International Journal of Climatology*, Royal Meteorological Society. 10(2):30–58.

Meera, N, & Priyanca, F. (2015). Daily weather forecasting using artificial neural network. *International Journal of Computer Applications*. 121(22):9–13.

National Space Research and Development Agency, Abuja (2018). The Study Area.

Ola, B. (2001). The federal capital territory of Nigeria: A geography of its development. University Press, Ibadan.

Odekunle, T. O; Orinmoogunje, I. O. O. & Ayandele, A. (2007). Application of geographic information system (GIS) to assess rainfall variability impacts on Crop Yield in Guinean Savanna Part of Nigeria. *African Journal of Biotechnology*. 6(18):2100–2113.

Odekunle, T. O; Andrew, O, & Aremu, O.S. (2008). Towards a wetter Sudano–Sahelian Ecological Zone in the Twenty–First Century Nigeria. Weather, 63(3): 66-70.

Oriola, E. O. (2000). Flooding and flood management. In H.I. Jimoh and I.P. Ifabiyi (eds). Contemporary issues in Environmental Studies. Haytee Press & Publishing Co. LTD, Ilorin, Kwara State, Nigeria. Pg. 100.

Salahu, U. A. (2017). Analysis of thunderstorm and dry spell variabilities over Sudano– Sahelian Belt of Nigeria. Post Graduate School, Federal University of Technology, Minna, Niger State, Nigeria. Pp. 4, 7 and 11–13.

Somsubha, C., & Dwayne, R.E. (2016). Long–term trend tnalysis of trecipitation and air temperature for Kentucky, United States. *Climate.* 4(10):1–15.

The Nigerian Meteorological Agency (NiMet) (2017). Climate review bulletin. Pg. 39.

Yusuf, A. A., & Yusuf, H. A. (2008). Evaluation of Strategies for Soil Fertility improvement in Northern Nigeria and the way forward. *Journal of Agronomy*. 7, 15–24.

Yusuf, Y. O. (2012). An Assessment of spatial distribution of rainfall amount in Zaria, Kaduna State. In M.A. Iliya, M.A. Abdulrahim, I.M. Dankani and A. Oppokumi (eds). Climate Change and sustainable development. Geography Department, Usumanu Dan Fodio University, Sokoto and Association of Nigerian Geographers (ANG). Proceedings of 52nd Annual Conference of ANG. Pg. 69.