Analysis of Rainfall Characteristics and Flood Incidences in Ogun River Basin, Nigeria

B.S. Awe*, M.O.Lasisi and F.S. Omotayo

Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic Ado Ekiti, Ekiti State, Nigeria
**Corresponding author*

Abstract: **This study examined rainfall characteristics in the Ogun River Basin concerning flood situations in Ogun and Lagos State through the release of water from Oyan dam. The research objectives are to analyse the rainfall characteristics and determine its effect on flood incidence in Ogun and Lagos State. 20 years rainfall data of the area, sourced from Tropical Rainfall Measuring Mission (TRMM) was used for the analysis. Height Above the Drainage (HAND) model with Terrain Analysis Using Digital Elevation Models (TauDEM) to delineate the flood-prone area. The result of the trend shows the potential of the future intensity of the monthly rainfall due to an increase in urbanization and which may result in extreme flood scenarios. The high amount of rainfall in the area triggers the continuous release of water from the Oyan dam, which has increased the occurrences of downstream flooding in the lower part of the Ogun Basin. The general rainfall trend is not statistically significant since the significance level is greater than 0.1 and the rate of change (Q = 4.94E-01 mm/year) is very low. This potentially indicates that the current trend of rainfall will not change. However, the potential increase in the population, urbanization and climate change in the study area can contribute to an increase in future flood occurrences.**

Keywords: **Climate change, Rainfall, Flood, Urbanization and Disaster**

I. INTRODUCTION

The earth's climate has been dynamic since inception and also, the rapidity, frequency and severity of the consequences of climate change in the last few decades are however increasing at in alarming rate (NRC, 2010). According to Afangideh, *et al*. (2013), the recent and future manifestation of climate change include global warming (increase in temperature), rise in sea level, shifting of global climate zones, changes in the intensity, quality, duration and general pattern of rainfall leading to drought, desertification and flooding; melting of glaciers/polar ice and increased incidences and severity of extreme weather events, among other effects.

The rate at which the extreme events occur in recent years is alarming. Extreme events like cyclones, hurricanes, storm surges, and earthquakes are presently above prediction and projection (Iyanda, 2003). The flood pattern is taking the same direction and dimension as other events mentioned above (IPCC, 2012). Precisely, a flood scenario is briefly and captured by IPCC (2012) as the overwhelming of the normal confines of all bodies of water or the accumulation of water over areas that are not normally infiltrated. This simply means that flood is an abnormal scenario of water flow above the original confines of a defined water body (Middleton, 2003).

In Nigeria, the record showed that flood has the highest incident of natural hazards which has resulted in great losses on life and property (Aderogba, 2012). Causes of the flood are both natural and anthropogenic; the natural causes are heavy rainstorm and ocean storms along the coast while the human causes are as a result of main pipes that convey water, lack of effective drainage systems, dam failure and spills. Nigeria has been recording flood events yearly; it occurs in the form of coastal flood, river flood, flash floods, and urban flood. Many States and cities have witnessed unusual and devastating flood disasters in the last decades, which incapacitated the Government to prevents such disaster. In 1963 Nigeria recorded Devastating flood event in Ibadan city as a result of overflown of Ogun River leading to loss of lives and properties; these hazardous events reoccurred in 1978, 1980 and 2011, with estimated damages and deaths of over 30 billion nairas and 100 people respectively, thus making Ogun River nationally and internationally famous (Adegbola and Jolayemi,2012; Agbola *et al*., 2012). 8 major floods events were recorded in Lagos State between 2011 and 2012 with more than 30 people deaths and many damages to properties (Editor, 2012; Komolafe *et al*., 2014).

The scenario of river flooding in Nigeria is a microcosm of the global view and a mirror of the situation in the study area. Flooding is a big concern for Lagos State, yearly it devises means of curtailing the menace to save lives and properties. The recent occurrence in June 2016, for seven days, the heaven opened up emptying its bellies, filling the surface of the earth with water. Across the State were endless stretches of rainwater, which constituted a heavy flood. The perennial Lagos flooding, experts say, could be attributed to many factors such as torrential rainfall, poor drainage system, poor sewage management and disposal, poor urban planning control, deforestation, and climate change. All of these factors have combined to make flooding a regular occurrence in most areas of the State, particularly the Ogun River downstream areas, such as Akute, Kara market, Ishaji, Isheri, Ojodu-Abiodun, Ajiliti,and Ajegeunle mile 12 axes of Lagos State.

In 2010 Ajegunle Community and its environs experienced flood following the release of water from Ogun/Oshun River. Some measures were being taken by the State Government and part of the measures was routine monitoring of Oyan

Dam, Abeokuta, and Ikere Dam in Iseyin, Oyo State by the joint committee set up by the River Basin Development Authority and Lagos State Government. The essence of the monitoring was to ascertain the level of water in the Dams from time to time. According to Alayande and Agunwanba (2010), urbanization has contributed immensely to the occurrence of floods in Nigeria. They emphasized that the expansion of structural development and population growth into flood-prone areas can increase the incidence of the flood in an area like Kaduna and other northern cities with similar hydrological characteristics as Kaduna. There was the incidence of flood on July 10, 2011, in Lagos which led to the closure of schools, loss of valuable materials beyond computations and destruction of public infrastructures.

Figure. 1: Flood incident in Lagos (Information Nigeria, 2019)

Since the major causal factor of Lagos and Ogun flood is heavy rainfall which results in an overflow of Oyan dam as observed in Fig. 1, this study aimed at analyzing the rainfall characteristics and flood incidences in Lagos and Ogun State with the view to providing a lasting solution to flood menace in the city through various adaptive and mitigation strategies that can be adopted to cope with flood challenges in the study area.

II. THE STUDY AREA

Ogun River Basin, located in Southwestern Nigeria, is bordered geographically by latitude 6^0 26'N and 9^0 10'N and longitudes 2^0 28'E and 4^0 8'E (Fig. 2). The Ogun River takes its source from the Igaran hills at an elevation of about 530m above mean sea level and flows directly southwards over a distance of about 480 km before it discharges into Lagos Lagoon. The major tributaries of the Ogun River are the Ofiki and Opeki River. Two seasons are distinguishable in the Ogun River Basin; a dry season from November to March and a wet season between April and October.

The two major vegetation zones that can be identified within the watershed are the high forest vegetation in the North and Central parts, and the swamp/mangrove forests that cover the southern coastal and flood plains, next to the lagoon.

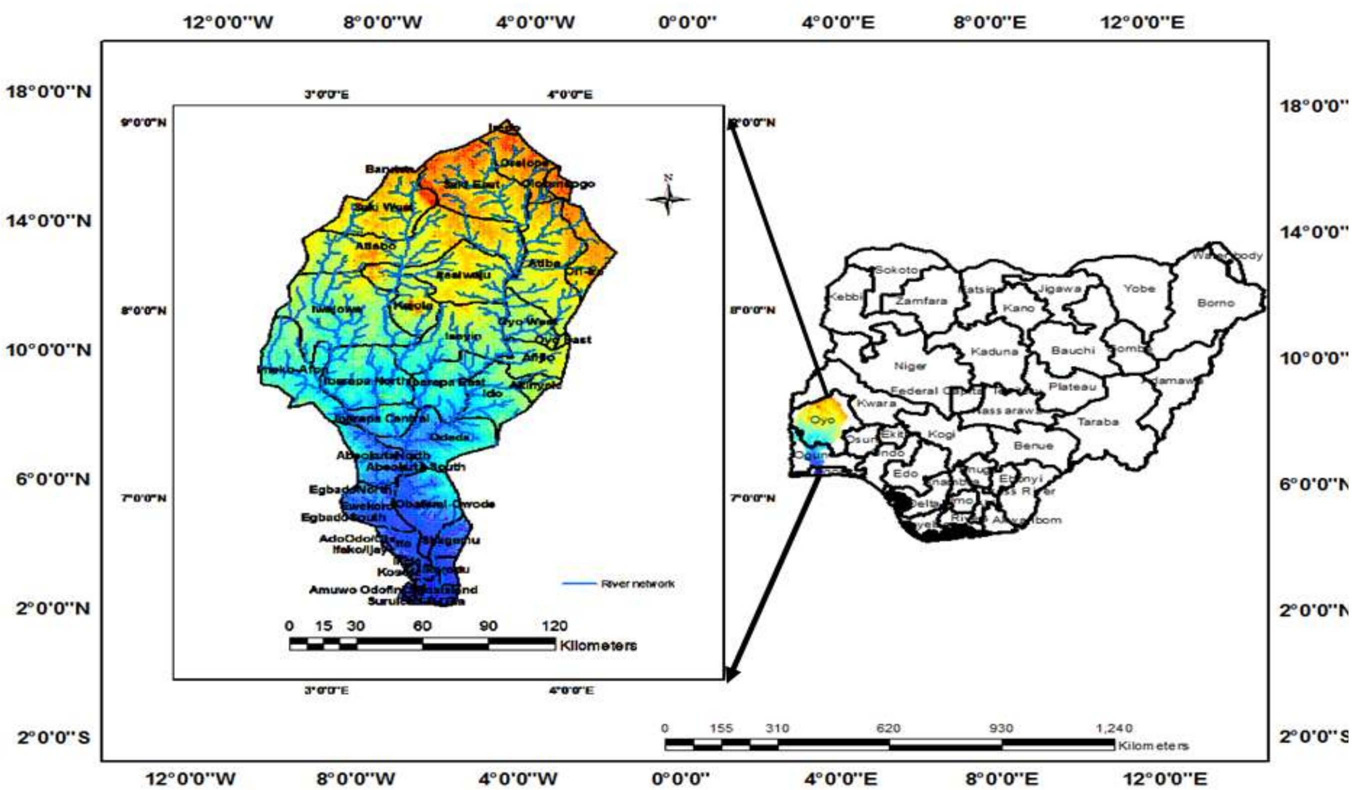

Figure 2: Map of the Study Area

The mean annual precipitation of the study areas falls within the interval 1200 – 1700 mm. The basin falls within the humid subtropical region of Nigeria, with an annual temperature ranging between 22 and 36^{0}C. The Ogun River Basin has an area of about 23688.98 km2 (2.58 % of Nigeria). As a result of high levels of industrialization and urbanization, the population of the basin has increased significantly in recent decades. A significant part of this population occupies the lowland area of Lagos State in the Western part of the basin. The Ogun River Basin has been selected due to the heavy rainfall which results in severe flood events and losses that have occurred in the basin.

III. MATERIALS AND METHODS

3.1 Data Sources

Remotely sensed data is the main data source used for this study. Rainfall data were sourced from Tropical Rainfall Measuring Mission (TRMM) which is the first space mission dedicated to measuring tropical and subtropical rainfall for the year 1998 to 2017.

3.2 Rainfall Characteristic of the Study Area

The bar chart was developed to characterize the monthly rainfall within the years of study (1998 – 2017). The variability of rainfall in the area presents the contribution of high rainfall to the flood disaster

3.2.1 Rainfall frequency

Flood frequency curve analysis was performed using MS-Excel to determine the recurrence interval in years. Equation (1) was used in the determination of the recurrence interval.

$$T = \frac{n+1}{m} \qquad (1)$$

Where:

T = is the recurrence interval in years (T)

n = is the number of annual peak rainfall values in the data series, and

m = is the magnitude rank: 1 is the largest rainfall, 2 is the second-largest rainfall and m is the smallest rainfall in data series.

3.2.2 Rainfall trend analysis

Mann- Kendall Test and Sen's Slope Estimates were performed to determine the trend and magnitude of annual Rainfall (1998 – 2017) in the Basin. Mann- Kendall Test performs two types of statistical analyses. It detects the presence of a monotonic increasing or decreasing trend with the nonparametric Mann-Kendall test and the slope of a linear trend with the nonparametric Sen's method.

The statistical calculation in the Trend Statistics worksheet was updated and the columns in the sheet have the following meaning:

- Time Series: the names of the time series are derived from the annual data worksheet
- First Year: starting year of each time series (1998)
- Last Year: ending year of each time series (2017)
- n: the number of annual values in the calculation excluding missing values (20 years)
- Test S: n is greater than 9, the S value was empty.
- Test Z: since n is greater than 10, the test statistics Z was displayed. The absolute value of Z was compared to the standard normal cumulative distribution to define the trend at the selected level α significance and the value of Z is positive which indicates an upward trend.

*** trend at α = 0.001 level of significance

** trend at α = 0.01 level of significance

* trend at α = 0.05 level of significance

+ trend at α = 0.1 level of significance

The significance level is greater than 0.1and the cell is blank

Rainfall characteristics used include daily, monthly, and yearly amounts of rainfall, bar chart, trends, and return period of rainfall.

3.3 Flood Assessment of the Study Area

3.3.1 Elevation of the study area

ArcGIS 10.0 was used to convert the rainfall data into appropriate layers for use within the specified environmental modeling. The raster data format was used as the principal spatial data model for the entire modeling of the environmental parameters. Fig. 3 shows the DEM of the area.

Elevation analysis is based on the outcome of the development of the Digital Elevation Model (DEM). However, analysis for elevation reclassification is based on the influence of elevation on the flood.

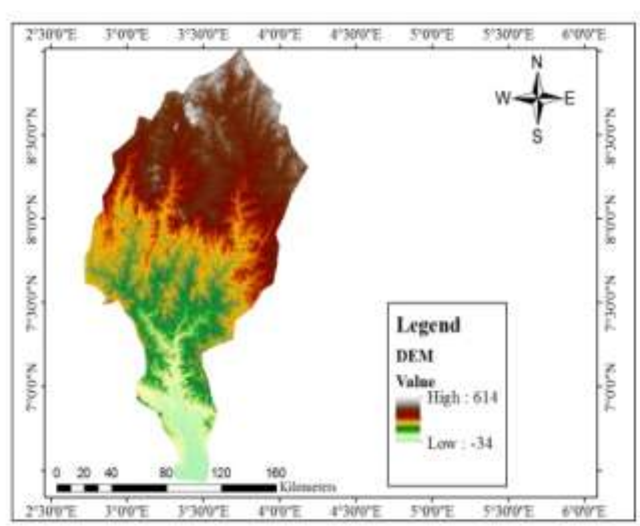

Figure 3: DEM of Ogun River Basin

3.3.2 Spatial distribution of rainfall

The mean values of yearly rainfall of stations within the basins were interpolated in the Geographical Information System (GIS) to show the spatial distribution of rainfalls in the study area. Thus, showing how rainfall contributes to flooding incidence in the study area.

3.3.3 Flood modeling using Height Above Nearest Drainage (HAND) model

The delineated flood hazard zone was simulated using the HAND Model which is a drainage-normalized and flow path-coherent version digital topographical map. It has greater transparency in classifying the hydrological response zones. Using a digital elevation model (DEM) as input, the HAND model is generated using two sets of procedures. The first procedure conditions the DEM by fixing sinks, defining flow paths and calculating an accumulated area map upon which the drainage network is defined. Channel initiation is then established by an accumulated area threshold. The second procedures use local drains direction and the stream network to generate the nearest drainage map, which spatially guides the HAND operator in the production of the normalized topology of the HAND model. The HAND model includes embedded routines for treating the DEM, eliminating sinks and generating drain directions for each cell in the topgrid (D8 approach) and routines for determining flow paths and the drainage network. The drainage network acts as the variable topographical reference on which the hand terrain model is generated (Nobre *et al.*, 2011).

The procedures above were achieved by using TauDEM (Terrain Analysis Using Digital Models) which is a set of Digital Elevation Model (DEM) tools for the extraction and analysis of hydrologic information from the terrain. TauDEM creates a hydrological DEM by raising the elevation of pits to the point where they overflow their confining pour point and drain to the edge of the domain. The next step was D8 flow direction, which takes as input the hydrological correct elevation grid and outputs D8 flow direction and slopes for each grid cell. The number of grid cells draining through each grid cell based on D8 flow directions was run to achieve the D8 contributing area. The contributing area was defined as the threshold value which was used as input in the HAND model flood analysis.

IV. RESULTS AND DISCUSSION

4.1 Rainfall Analysis

Fig. 4 presents the categorical total maximum monthly rainfall of the Ogun River Basin. The extreme monthly rainfall within the selected 20 years shows high variability in the study area without an increase in trend. The high monthly rainfalls in the study area were experienced mostly between September and October, especially in the years 2002 and 2012. The trend shows the potential of the future intensity of the monthly rainfall due to an increase in urbanization and which may result in extreme flood scenarios.

Maximum daily rainfall in Fig. 5 indicates past extreme daily rainfall scenarios with the highest daily peak of 213.2 mm experienced in 2011, which confirmed the reason for the recent occurrence of flooding in Lagos and its environs in 2011. The variability in daily peak rainfall in the study area agrees with the study of Salako (2008), which classified the Ogun River Basin as high erosive due to high rainfall and thus, there was a good match between the rainfall variability and the historical flood event of the area. The rainfall characteristics of this study area make the dam especially Oyan Dam increase the socio-economic impact of the dam on neighboring communities such as domestic purpose, industrial, commercial and cultural. In the history of the dam by Salako (2008). 2012 has the highest water supply of about 10140.2 million m^3 and from Fig. 4 the monthly peak rainfall in the year 2012 is one of the highest values.

The variability in daily peak rainfall in Fig. 5 shows that the highest peak rainfall was experienced in October 2011 and from the historical event of the flood in the area, very high flood experienced in the year was one of the recent flood disasters. The high amount of rainfall in the area triggers the continuous release of water from the Oyan dam, which has increased the occurrences of downstream flooding in the lower part of the Ogun Basin. Thus, there is a persistence flood ravaging the city of Lagos and its environs over the years with significant effects on socio-economic activities. The downstream being the most populous and highly dense and compacted properties are expected to be more exposed to the future catastrophe if the present situation persists.

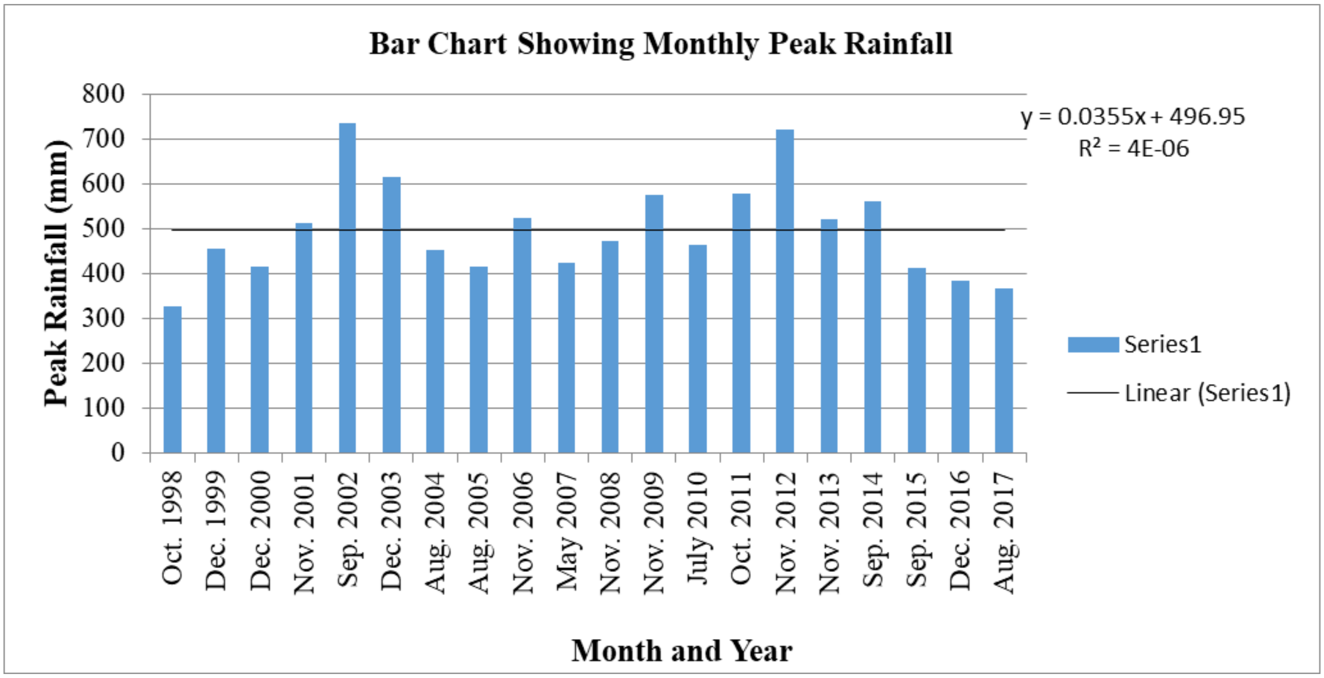

Figure 4: Bar Chart showing Annual Rainfall of the Area

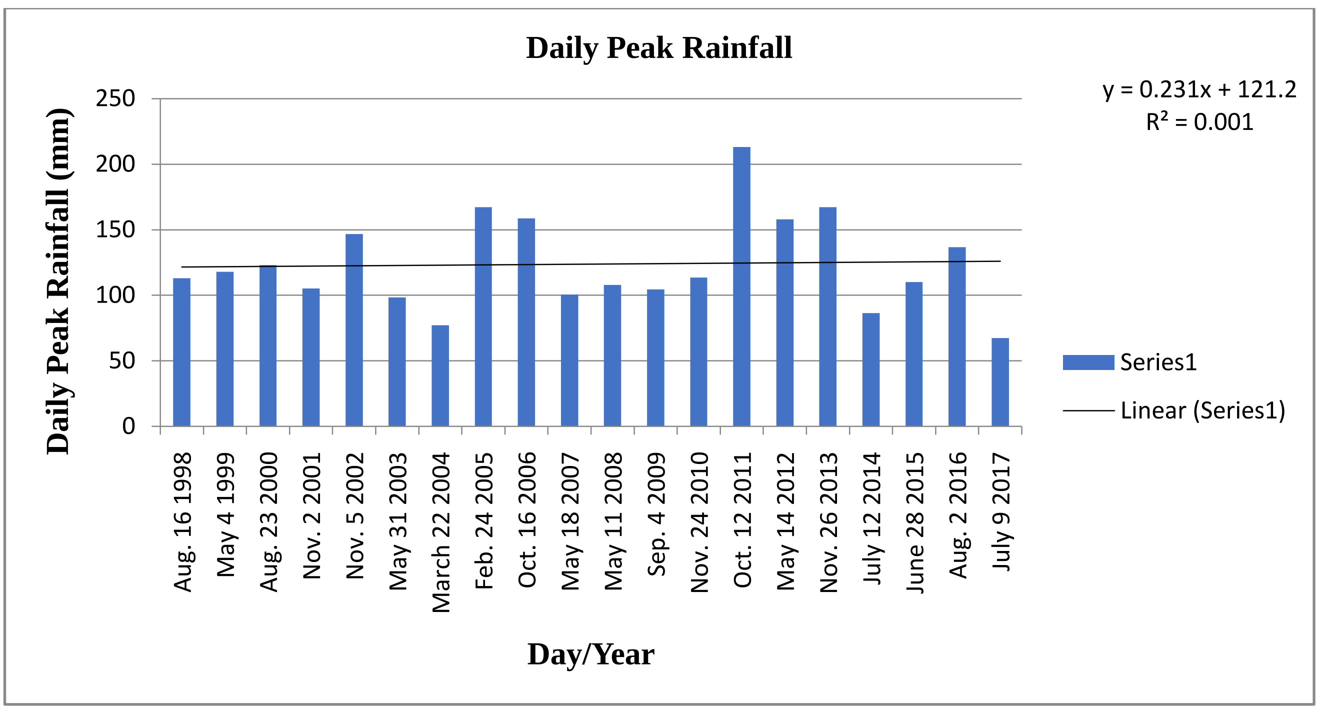

Figure 5: Bar Chart Showing Daily Peak Rainfall

Fig. 6 presents that the rainfall frequency distributions of the area with their potential rainfall intensity have different return periods. The frequency of occurrence determines the depth and intensity of the events expected within a specific period. Extreme events tend to occur in a long year interval than the low events, which occur most frequently. The coefficient of determination R^2 = 0.948 revealed the significant level of the frequency plots for the study area and can, therefore, be utilized for projecting the potential future intensity of rainfall at a given return period. The equation in the graphical representation of the flood frequency curve analysis can be used to deduce the recurrence interval in years. For instance, if x is 200 years, the rainfall would be 307.61 mm. This indicates that in 200 years, there will be an increase in the flood frequency and this could lead to flood incidence as a result of an increase in industrialization and urbanization of the area.

The general rainfall trend in Fig.7 is not statistically significant. Since increase or decrease across the basin showed that the significance level is greater than 0.1 and Z is blank and the rate of change (Q = 4.94E-01mm/year) is very low. This potentially indicates that the current trend of rainfall will not change. However, the potential increase in the population, urbanization and climate change in the study area can contribute to an increase in future flood occurrences.

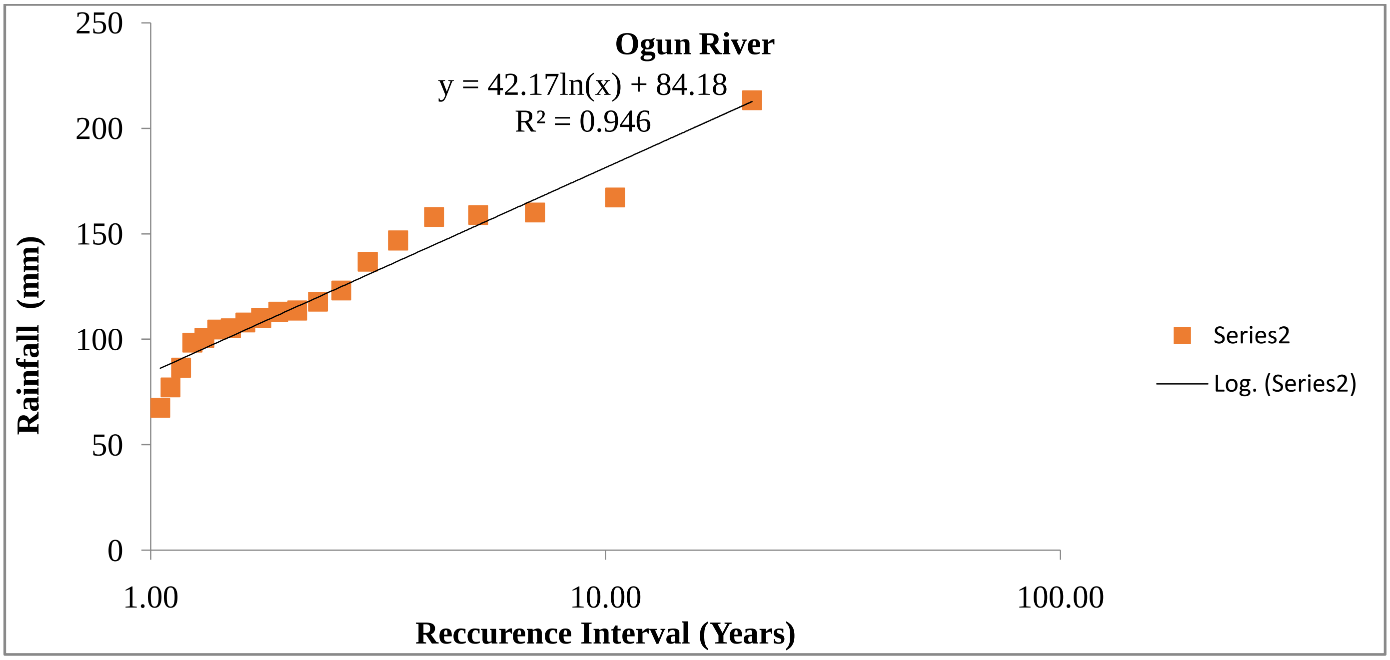

Figure 6: Flood Frequency Curve of Ogun River Basin

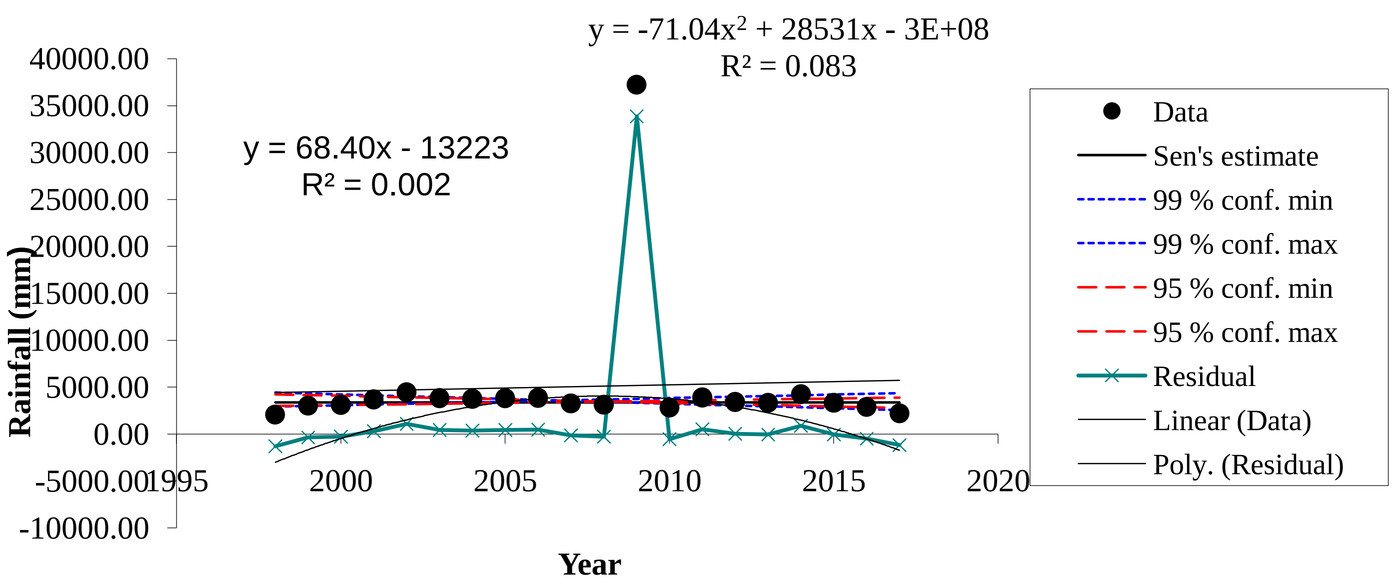

Figure 7: Trend Analysis Curve of Ogun River Basin

4.2 Spatial Distribution of Rainfall

Fig. 8 shows the values of the mean rainfall. This was reclassified into 5 classes, based on their level of intensity and acts as input to the multi-criteria analysis. Generally, there is a distinction in the level of flooding in the study area. It is expected that the area that has extreme flooding has the highest value of mean rainfall (3,128.464057-3,463.736084) and decreasingly to the value of 2,084.794678-2,479.550453 where there is low flooding. Salako, (2008) classified Ogun River Basin into a high erosive class, with high erosive rainfall except for Lagos which have the highest erosive rainfall and classified it as an area of the severe risk of erosion and flooding.

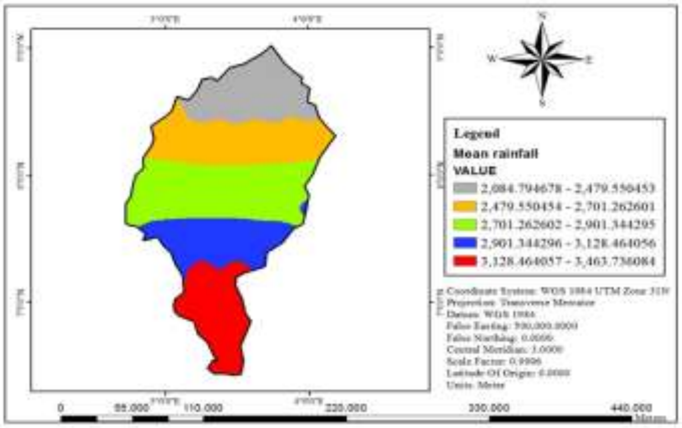

Figure 8: Mean Rainfall Map

4.3 HAND Index

Fig. 9 shows the hazard intensities in the hierarchical order of impact as regards flood occurrence based on the HAND model. The HAND model explained more on the hierarchical order of impact of the flood in the study area because of its greater transparency in classifying hydrological response. It shows the areas that are susceptible to very high flood hazard cut across Lagos, Oyo, and Ogun. The area with very high flood hazard intensity includes Apapa, Lagos Island, Kosofe, Ikorodu, Ikeja, Ifo, Shagamu, Yewa South, Ewekoro, Abeokuta South, Itesiwaju and Abeokuta North. Ibarapa Central, Ibarapa North, Ibarapa East, Kosofe Ota, part of Shagamu and Ikeja are being exposed to high flood hazard zone. The areas exposed to moderately low and very low flood hazard zone are few based on the result of the HAND model.

Significantly, the Hand index reveals more clearly that the river networks and the proximity as potentially very high hazard zones. This is close to the expected results from a typical flood model. In comparison with the multi-criteria analysis, areas designated as very high are in agreement.

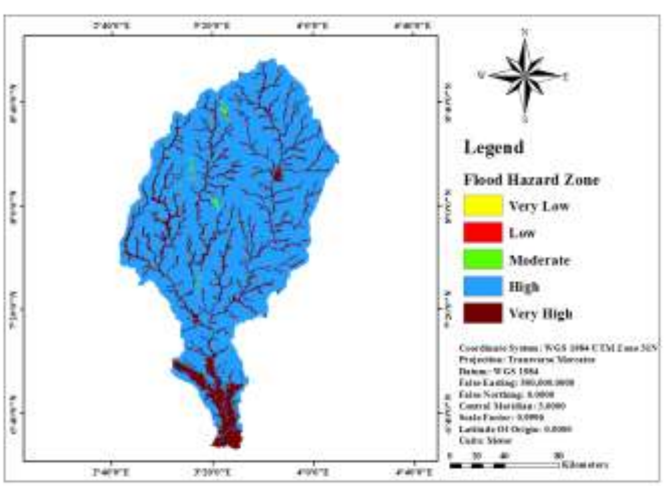

Figure 9: HAND Model Flood Hazard Map of Ogun River Basin

V. CONCLUSION AND RECOMMENDATIONS

Rainfall characteristics and the HAND model were employed to achieve the set goal of the study. The intensity of the rainfall from the analysis leading to the consistent release of the Oyan dam is a major factor of flood incidence in the study area.

Rainfall and Elevation have a high effect on the flood incidence of Ogun, Lagos and their environs. Also, the flood frequency curve is sufficient to detect the frequency of the rainfall and its return period when such flood incidents will likely occur. The area that has the highest value of rainfall (3,128.464057-3,463.736084) in Fig. 8 fall in in the category of very high flood hazard zone as indicated in Fig. 9. The area are Lagos, Ogun and part of Oyo State

The HAND model which shows the flood hazard-prone area as well as the mean rainfall map of the areas reveals that Ogun and Lagos flood incidence has a direct relationship with the rainfall of the area. Thus, the flood hazard zones such as Apapa, Lagos Island, Kosofe, Ikorodu, Ikeja, Ifo, Shagamu, Yewa South, Ewekoro, Abeokuta South, Itesiwaju and Abeokuta North. Ibarapa Central, Ibarapa North, Ibarapa East, Kosofe Ota, part of Shagamu and Ikeja also have the highest mean rainfall.

The rainfall situation of the areas as well as other climatic variables should be continually studied and monitored since they have a major effect on flood occurrence and frequency, and such information should be made readily available to the Urban Planners, Road Engineers and other concerned professional and individual alike in Ogun and Lagos State for effective planning purposes.

A well-designed dyke needed to be constructed to regulate water level at the opening of the Oyan Dam to prevent the Ogun River from covering an area of Ogun Basin.

Proper Urban space planning and management are vital to controlling flood in any place, therefore, Ogun and Lagos State Ministry of Lands, Survey and Urban Development and any other relevant Governmental body must rise to the challenge of ensuring strict compliance with the original, master plan of the two States. Ensuring the enforcement of existing town planning laws and constant monitoring of the Urban space is highly needed.

REFERENCES

[1] Adegbola, A.A. and J.K. Jolayemi, (2012). Historical rainfall-runoff modeling of river Ogun,

[2] Ibadan, Nigeria. Ind. J. Sci. Technol., 5: 2725-2728. DOI: 10.17485/ijst/2012/v5i5/30450.

[3] Aderogba, K.A., (2012). Qualitative studies of recent floods and sustainable growth and Development of Cities and Towns in Nigeria. International Journal of Academic Research in Economics and Management Sciences. Vol. 1, No 3.

[4] Afangideh I., Ekpe A., Offiong A. (2013). Implications of Changing Rainfall Pattern on Building Loss in Calabar. International Journal of Innovative Environmental Research. 1(2): 10-18.

[5] Agbola, B., Ajayi, O. Taiwo, O. and Wahab, B., (2012). The August 2011 flood in Ibadan, Nigeria; Anthropogenic Causes and Consequences. International Journal of Disaster Risk Sciences. Vol. 3 No 2.
[6] Alayande A.W. and Agunwamba J.C. (2010). The Impact of Urbanization on Kaduna River Flooding. Journal of American Science. Vol.6 No. 5, 28-35.
[7] Editor, G. (2012). Taming the floods in Lagos. The Guardian.
[8] Iyanda, I. A. (2003). River Niger Flood and Flood Management for sustainable Hydroelectric
[9] Power Generation at Kainji Dam. Federal University of Technology, Minna). McFeeters, S. K., (1996). The use of the normalized difference water index (NDWI) in the delineation of open water features. International journal of remote sensing, 17 (7), 1425-1432.
[10] IPCC (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change
[11] Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Field, C.B.V.Barros, T. F. Stocker, D. Qin, D. J.Dokken, K. L. Ebi, M. D. Mastrandrea, K.J. Mach, G.-K. Plattner, S. K. Allen,M. Tignor, and P.M. Midgley (eds.). Cambridge University Press, Cambridge, UK, and New York, NY, USA,582 pp.
[12] Komolafe, A.A., S.A.A. Adegboyega, A.Y.B.Anifowose, F.O. Akinluyi and D.R. Awoniran, (2014). Air pollution and climate change in Lagos, Nigeria: Needs for proactive approaches to risk management and adaptation. Am. J. Environ. Sci., 10: 412-423. DOI:10.3844/ajessp.2014.412.423.
[13] Middleton, N. (2003). An Introduction to Environmental Issues: The Global Casino.NewYork. pp 366-372. modeling environment for spatial decision support. International Journal of Geographical Information Science, 7(4).
[14] National Research Council (NRC, 2010). America’s Climate Choices: Panel on Advancing the Science of Climate Change. Advancing the Science of Climate, Washington, DC.
[15] Nobre A.D., Cuartas L.A., Hodnett M., Renno C., Rodrigues G.O., Silveira A., Waterloo M. and Saleska S. (2011a). Height above the nearest drainage –a hydrologically relevant new terrain model. Journal of Hydrology 404: 13-29, DOI: 10:1016/j.jhydrol.
[16] Salako, F.K., (2008). Rainfall variability and Kinetic energy in southern Nigeria. Climate change,8 151-164.