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Full Length Paper

Geospatial Assessment of Anthropogenic and Rainfall Implications for Flooding in Lokoja Kogi State, Nigeria

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The aim of this paper was to study the rainfall trend and investigate the implications of anthropogenic activities and rainfall for flooding at Lakota. 18 years annual rainfall data and 32 years hydrological (discharge and river stage) data of the study area were collected from Nigerian Meteorological Agency (NIMET) and National Inland Water Ways (NIWA) respectively. Other data used include pre-disaster and during disaster moderate resolution (MODIS) satellite image of 2012 flood within the study area, GPS coordinates of buildings within the areas ravaged by flood and data collected using questionnaires. Software used is ArcGIS10.1 and Microsoft Excel 2011 version. Proximity analysis in GISs environment was used to investigate the level of agreement of development to regulation standard while statistical parameters and least square regression analysis were respectively, used for investigation of 2012 rainfall intensity and rainfall trend analysis. Equation which approximates the linear relationship between rainfall amounts (the dependent variable (Y)) and the year (the independent variable (X) was developed using time series rainfall data. With the equation we were able to predict rainfall intensity from 2013 to 2025 and determined range of acceptable rainfall at 95% confidence limit. Furthermore, the technique was used to ascertain the contributions of rainfall to flooding in the study area. Result shows that 2012 flood rainfall intensity was higher than long term average and this contributed to increase in water level beyond average along the river Niger course resulting to higher water discharge within the study area. There is also an increasing trend in rainfall as could be seen from the linear trend in figurg4. The model of the linear trend is; Y = 9.032x – 16807, meaning that the area is getting wetter at the rate of 9.032mm. With this increase, there is enough water for the ground water storage and river flow which will increase flooding. Further analysis also revealed that illegal construction of buildings along the floodplain and its corresponding informal settlements resulted to huge economic loss and increase in the number of affected persons during 2012 flood within the study area.

Keywords; flood, informal settlement, rainfall intensity, Gis, MODIS

19.0 Introduction

Flood has been identified world wide as highly destructive. For safety purpose, hydrological and meteorological data such as flow rate and rainfall are used to predict flood event while developmental standards are established to control and regulate developments around the flood plain. Flooding is defined as the occurrence of large amount of water over an area that was usually dry (Olajuyigbe et al., 2012). Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (runoff) event. The impact of floods has been increased due to a number of factors, including rising sea level, intensive rainfall , increased developments and activities on the floodplain etc (Ologunorisa, 2004). In the period 1963 to 1992, the world suffered from 202 floods with more than

1,000,000 (one million) victims. Most of them are flash flood recorded as torrential rains, monsoon floods, headwater flood or landslide (Kwak, and Kondoh, 2008)). The largest flood catastrophe on the list was the flash flood in June 1991 with more than 5,000 victims in Afghanistan (Ramnoop, I995 and inyangorok,2011). In recent times there have been extreme climatic conditions due to climate change. As a result of this, the intensity of rainfall has increased tremendously causing floods in many areas and countries worldwide (Emmanuel *et al1 2017).* This has aggravated flooding potential in global communities especially in coastal areas. Nigeria as a nation is not left behind. In 2012, heavy rains and the release of water from Lagdo dam upstream River Benue in Republic of Cameroon resulted to serious floods in almost all the states in Nigeria. Anuforom (2012) opined that rainfall intensity of the year all over the country were generally higher than long term mean values. This according to him has led to serious flooding and opening of dams erected across rivers especially in rivers Niger and Benue. The event has been described as the worst floods Nigeria has seen in at least half a century. Nigeria hydrological agency noted that the level of river Niger in Lokoja on 29th September 2012, was at 12.84m and at a discharge of 31692 cubic meter per second while as of November 2012, It subsided to a level of 8.83m with a discharge of 17722 cubic meter per second. Although flood hazard is natural but it is generally acceptable that rainfall is the most common cause of flooding worldwide (Nwagbara, Ijeoma and Chima 2010). However, human modification and alteration of natural river right of way can accentuate the problem while the disastrous consequences are dependent on human activities and occupancy in the flood prone areas. The paper therefore seeks to investigate the effect of anthropogenic activities and rainfall implications for flooding in Lokoja local government areas of kogi state

Figure 1A: people displaced during 2012 flood in lokoja

Figure 1b: floode buildings during 2012 flood in lokoja

1.1 Aim and Objectives

The major aim of this study is to a investigate the implications of rainfall intensity and anthropogenic activities on flooding in Lokoja

1.1.1 Objectives

To investigate the the rainfall trend in the study area
To predict future rainfall intensity in the study area
To investigate the contribution of anthropogenic activities to 2012 flooding in the study area
To recommend a flooding reduction measures within the study area measures.

1.2 Study Area

Lokoja is the capital city of Kogi State in the North central part of Nigeria and is also a Local Government Area in Kogi State. It has a population of 195,261 based on the 2006 census with landmass measuring approximately 3180 km². Lokoja drives its name from two hausa words, a tree and a color. “Loko” which means Iroko and “Ja” which means “Red” so the word Lokoja means red Iroko tree. The area enjoys both wet and dry season with a total annual rainfall between 1000mm-1500mm. Mean annual temperature is about 27.7^{o}c and a relative humidity of 30% in dry season and 70% in wet season. Average daily wind speed is 89.9km/hr. wind speed is usually at its peak in March and April. The most important hydro-geological features are River Niger and the confluence of river Niger and River Benue. The largest river in Nigeria (river Niger) flows through Lokoja but it is under-utilized for transportation even irrigation.Table1 summarizes the climatic condition of Lokoja

Table 1; Climate data for Lokoja

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	28 (82)	31 (87)	32 (90)	32 (90)	31 (87)	28 (83)	27 (81)	27 (81)	27 (81)	28 (82)	29 (84)	29 (84)	29.1 (84.3)
Average low °C (°F)	26 (79)	31 (87)	31 (88)	31 (87)	29 (84)	27 (80)	26 (78)	26 (78)	26 (79)	26 (79)	27 (81)	27 (81)	27.8 (81.8)
Precipitation mm (inches)	5 (0.2)	10 (0.4)	41 (1.6)	97 (3.8)	150 (5.9)	155 (6.1)	168 (6.6)	170 (6.7)	211 (8.3)	122 (4.8)	13 (0.5)	3 (0.1)	1,145 (45)

Source: Weatherbase

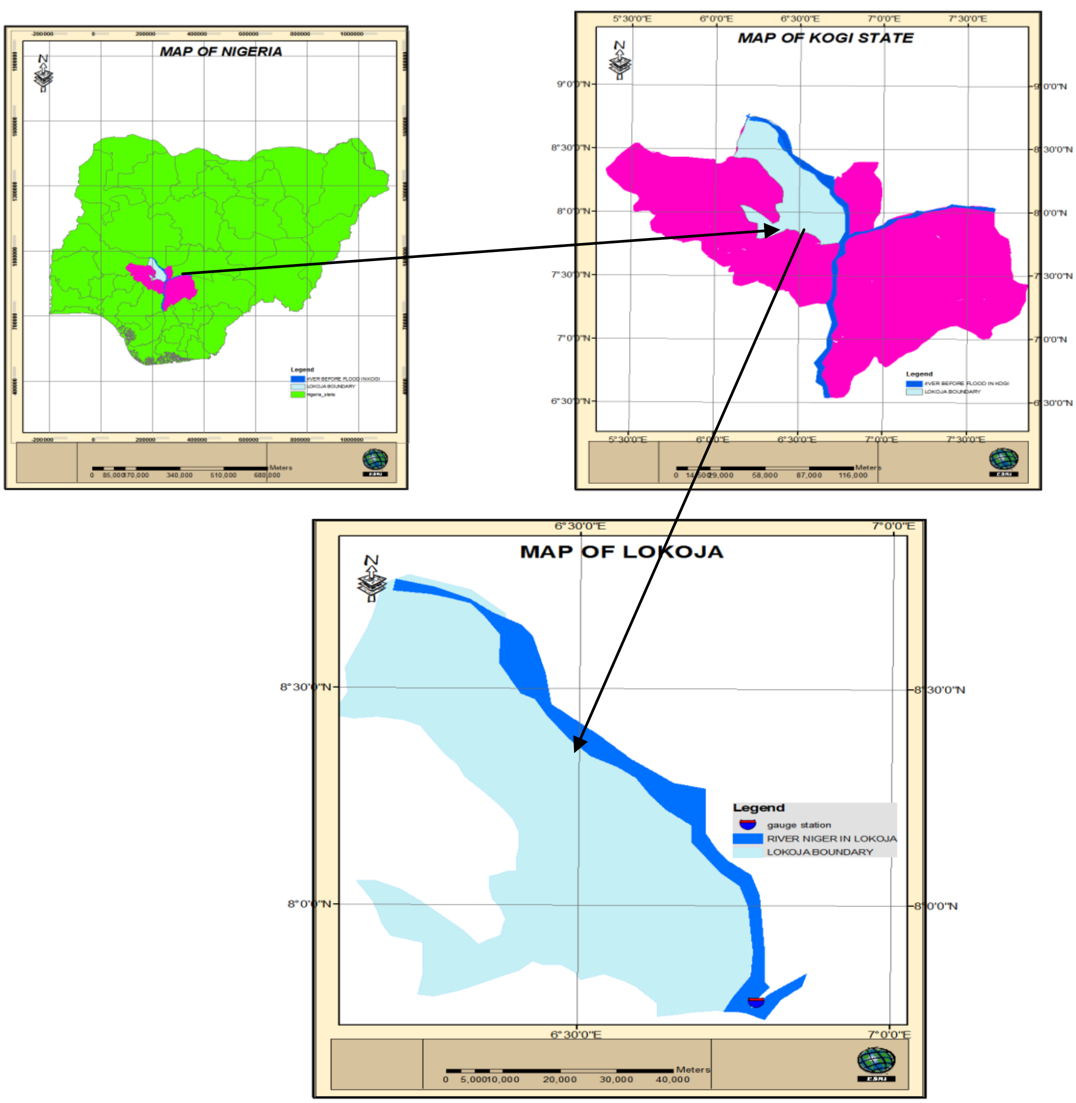

Figure 2: Ocation map of the study area

2.0 MATERIAL AND METHODS

A combination of social, geo-physical survey and geospatial techniques was use in capturing data for this study. Data from social survey was obtained from questionnaires, face to face interview and visitation to the relevant authorities. Data from geophysical technique was obtained by field data capture using hand held GPS for observations while geospatial technique involved integration of remote sensing data in GIS platform.. These instruments were focused on generating data on building plan approval, building setback from the river, respondent's age and income, coordinates of buildings around and within the flood plain and 2012 flood satellite image of the study area. Software used is ArcGIS10.1 and Microsoft excel.

2.1 Social Survey Technique.

Part of Data for this research was collected through the administration of questionnaires and face to face interview. A total of 500 questionnaires were randomly administered to respondents living in the flood prone areas. The questionnaires were administered on occupants of the houses around the floodplain. The questionnaires addressed income of the respondents, distances of the building from the floodplain, building plan approval, information regarding to other places that experience flood, causes and benefit of floods within the states. Other data in this category are 18 years (1995 -2012) annual discharge data of Lokoja gauging station collected from National Inland Water Ways (NIWA) Lokoja (Table4) and 32 years (1981-2012) historical annual rainfall of Lokoja (Table5) collected from Nigerian Meteorological Agency (NIMET) Oshodi Lagos.

2.2 Socio –Economic Trait of Respondents:

The age structure of the respondents shows that 3% of the sampled population is under 20 years, 27% is between the ages of 25-35years, 30% is between the ages of 35-45years 30% is between 45-55 years the remaining 10% is above the age of 55years. This age structure shows that the majority of the respondents are adult between the ages of 25 to 55 years. These set of people are the active proportion of the population who are likely to bear the burden of the flood menace. It shows that 87% of the sampled population constitute the working population as such their view cannot be jettisoned as far as the issue of flood is concerned in lokoja. The children and the aged relies on these set of people for their livelihood therefore any adverse impact of flooding on these set of people will surely have backward effect on the social and economic life of the general populace. Majority of the respondents are low income earners. A summary from the questionnaires revealed that over 56.4% of the residents earn less than N20,000 per months 23.4% earns between N20,000 – N30,0000, 12% earn between N30.000-N55000 while only 8.2% of the respondents earns above N55000. This signifies that majority of the respondents are low income earners who cannot afforded accommodation in a standards environment these set of people can only affords accommodation in flood prone area where accommodation is cheaper.

2.3 Rainfall analysis

The rainfall data was analysed to provide information on the role of rainfall in causing floods in Lokoja. i.e to provide evidence that 2012 rainfall in the study area was high enough to cause flooding. Data were analysed with the use of Trends Analytical Technique as well as least square regression statistical analysis. All statistical analysis were carried out using Microsoft Excel 2010 version. **T**he principle of regression states that if it is found that a relationship exists between events (variables) a mathematical model which approximate the best fit line or curve of the relatinship can can be established. This model can be used to predict the dependent variable given a set of independent variable. For two variable X and Y where Y is dependent on X, the best fit straight line takes the form of equation 1 below.

$$y = mx + c - - - \qquad \text{eq(1)}$$

$$where\ m = n\ \frac{\sum(xiyi - (\sum xi\ (\sum xyi}{n\ \sum x_1^2 - (\sum x\ )^2} \text{-----} \qquad \text{eq2}$$

$$C = \frac{(\sum y_i)(\sum xi^2) - (\sum xi)\ (\sum xy_i)}{n\ \sum x^2 - (\sum x\ )^2} \text{-----------} \qquad \text{eq3}$$

Where 'y' is the annual rainfall in (mm)
X is the year and 'n' is the total number of events

2.4 Flood extent mapping

To extract and map the flood-affected areas, the administrative maps of Lokoja was scanned and geo-referenced. Likewise the time series MODIS data were entered into the same environment and the dataset were projected to UTM coordinate system for on-screen digitalization. The true width of the river channel was extracted from pre-disaster imagery as polygons (shape file) and in the same process, the flood extent along the river channel in the study area, and the political boundary were also digitized as polygons within the ArcGIS10.1 window. Progressively, the Niger River layer and the flood extent layer were both overlaid on the political boundary of the study area. The coordinate of buildings locations within and around the floodplain captured with hand held GPS during field investigation were added as events in the flood extent map (fig5).

2.5 Proximity Analysis

Buffer was used to assess the conformity of these buildings setbacks to developmental regulation standard and the results obtained were validated by information derived from the questionnaires. Buffering is process by which zone of influence or interest is created around a geographic entity. It is often used to depict areas included or excluded by a spatial activity.

Criteria for Buffering

- Buildings must be at least 30m away from the course of the river (set back rule of town and regional planning 1986)
- 70m away from the river. This criterion was based on previous flood extent experienced in the areas
- 100m from the river: This criterion was included in this study to give room for eventualities. What if flood extends beyond the previous extent which area will be affected under such circumstance?

River Niger was buffered to the above distances and the co-ordinates of samples of buildings collected were plotted as events in ArcGIS environment. (fig6)

3.0 RESULT

Table 1 and Table2 are report from respondents showing building setback distances from the river and number of persons with building approval certificate respectively. Figure3 and table4 are hydrograph of river stage and hydrographic data between 1995 and 2012 within the study area respectively. Table5 reveals annual rainfall of Lokoja between 1995 and 2012 while and table6 is statistics deducted from table5. Figure 4 Reveals annual rainfall trend within the study area. Table7 is the range of acceptable rainfall within the study area at 95% confidence limit and Table8 contains the forecasted rainfall . Figure5 is 2012 flood extent map of the study area and Figure6 is the Buffer analysis used to investigate the conformity of building setbacks to developmental standard.

Table 2: Building set back from the flood plain

Setback	Frequency	Percent
2m -10m	250	50%
11m-20m	70	14%
21m-30m	50	10%
31m-40m	50	10%
40m- above	60	12%
no response	20	4%
total	500	100%

Table 3: Building Plan Approval

Approval	Frequency	Percent
formal approval	105	21%
no –approval	360	72%
no responses	35	7%
total	500	100%

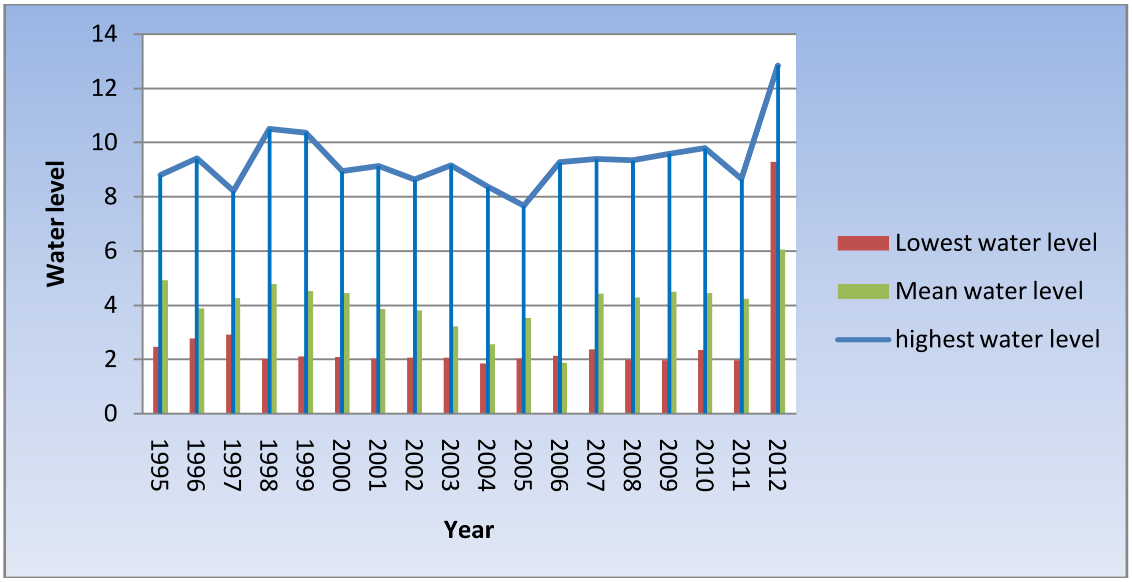

Figure 3: Hydrograph at Lokoja Gauge station between 1995 and 2012

Table 4: Yearly discharge and stage record of Niger River, between 1995 and 2012

Years	Minimum Discharge in m3/s	Maximum Discharge in m3/s	Range Discharge in m3/s Mean water level	Highest water level In m	Lowest water level In (m)	Mean water level In (m)
1995	3628	17713	14085	8.8	2.45	4.91
1996	2811	19914	17103	9.4	2.77	3.87
1997	2700	15548	12848	8.2	2.91	4.25
1998	2664	23491	20827	10.5	2.01	4.78
1999	3756	23090	19334	10.36	2.1	4.52
2000	3201	18225	15024	8.94	2.08	4.43
2001	2616	18885	16269	9.12	2.04	3.86
2002	2592	17012	14420	8.62	2.05	3.81
2003	2290	19025	16735	9.16	2.05	3.22
2004	2915	16098	13183	8.36	1.85	2.55
2005	1919	13792	10534	7.66	2.04	3.51
2007	1844	19389	11873	9.26	2.12	1.87
2007	2530	19941	17545	9.38	2.35	4.42
2008	2450	20426	17411	9.34	1.99	4.28
2009	2664	20534	17976	9.58	1.95	4.49
2010	3020	21272	17870	9.79	2.33	4.45
2011	2993	16912	18252	8.65	1.96	4.22
2012			13919	12.84	9.28	6.05

Source: Extracted from NIWA's gauge record in Lokoja

Table 5: Annual rainfall of Lokoja

YEAR	RAINFALL
1981	1144.6
1982	804.5
1983	853.7
1984	1147.7
1985	965.7
1986	1281
1987	1170.8
1988	1330.9
1989	1519.7
1990	1136.3
1991	1492.7
1992	1083.1
1993	995.6
1994	1194.9
1995	1291.1
1996	1240.7
1997	1410.5
1998	1031
1999	1767.1
2000	1010.7
2001	1003.8
2002	1276
2003	923.6
2004	1335.4
2005	939.4
2006	1684.1
2007	1501.4
2008	1239.5
2009	1653.3
2010	1076.1
2011	1356.941
2012	1365.972

Table 6: Statistical Data from annual rainfall data

Statistics	Values(mm)
Minimum	804.5mm
Maximum	1767.1mm
Mean	1225.9mm
Range	962.6mm

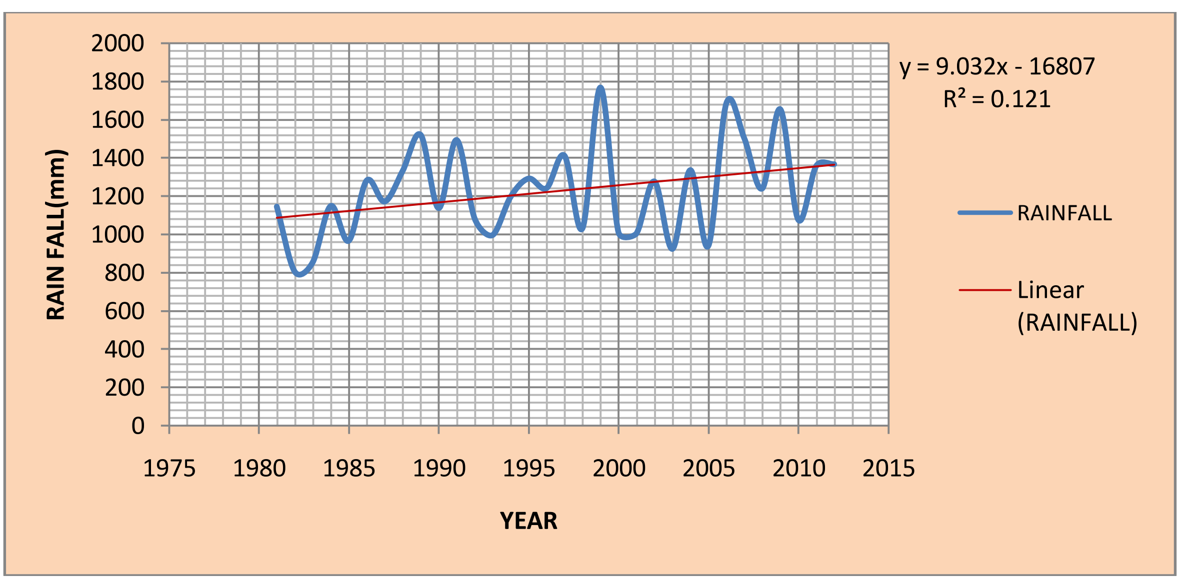

Figure 4: Trend Analysis Plot for Rainfall of the Study Area

The entire analysis produced a fitted trend equation of the manner shown below;
Y = 9.032x – 16807 which is similar to equation 1
In order to establish a confidential (prediction) interval for the forecasted annual rainfall the standard deviation of the annual rainfall for the previous flood years was computed using the formula below;

$$\partial = \sqrt{\frac{\sum(y - \breve{y})^2}{(n-1)}}$$

where y stands for rainfall

The expected rainfall can be calculated at 95% confidential level since the prediction is not 100% reliable. The confidential (prediction interval) was calculated using the formula below;

$$CI = Y + 1.96 * \frac{\partial}{\sqrt{n}}$$

Table 7: Range of Expected Rainfall At 95% Confidence

FROM CONFIDENCIAL INTERVAL
1682.967 – 1851.233
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1682.967 – 1851.233

Table 8: Forecasted Rainfall

PREDICTED YEAR (x)	FORECASTED RAINFALL (y)mm
2013	1375.02
2014	1384.052
2015	1393.085
2016	1402.117
2017	1411.149
2018	1420.181
2019	1429.214
2020	1438.246
2021	1447.278
2022	1456.311
2023	1465.343
2024	1474.375
2025	1483.408

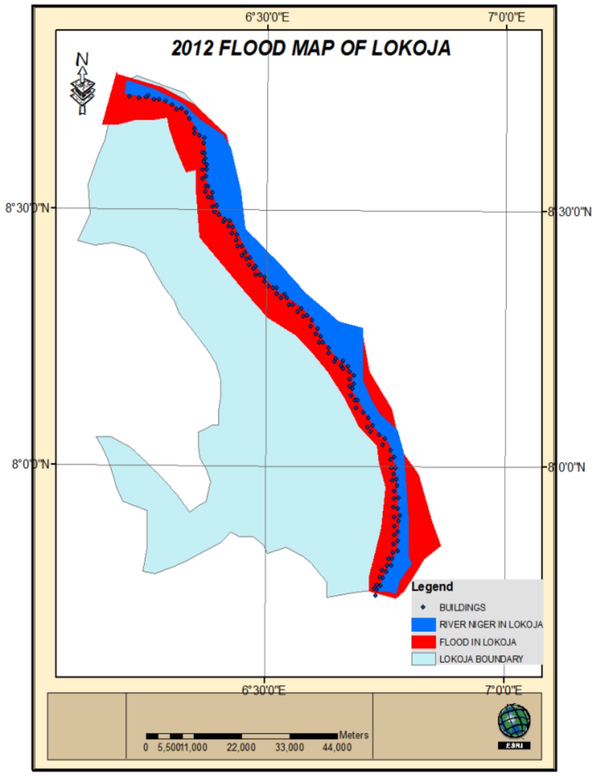

Figure 5: 2012 Flood map of Lokoja

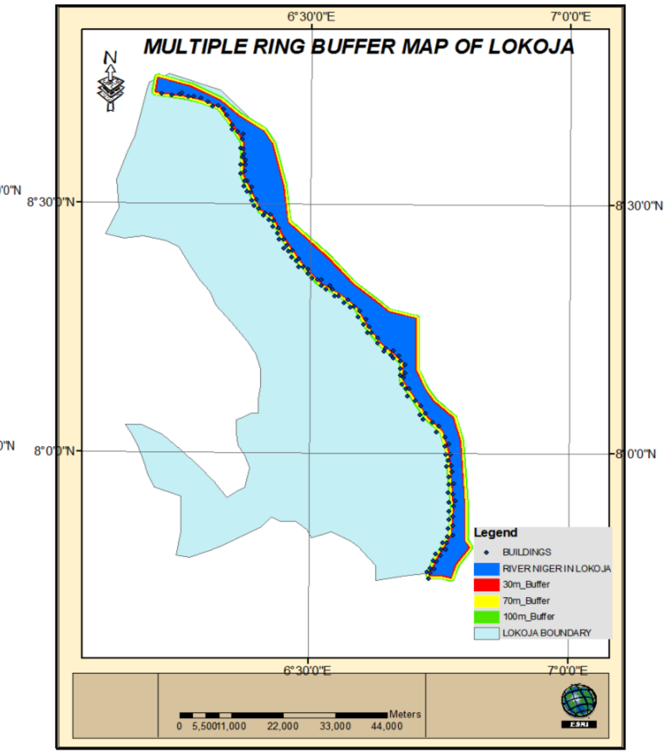

Figure 5: 2012 Flood map of Lokoja **Figure 6:** Buffer Analysis

3.1 DISCUSSION OF RESULT

Table 2 reveals a summary of report from respondents. It shows buildings setbacks from river Niger in the study area. This revealed that most buildings are located within the floodplain of the river. In general, 370 respondents attested that their building setbacks are between 2m to 30m from the river and this constitutes 74% of the sample population while 110 (22%) persons reported building setback of 31m and above. From Table3, it can be seen that only 21% of the sample population obtained building approval from the appropriate authority. Result from the buffer analysis also revealed that 75% of the sampled buildings observed less than 30m set back from the river while 25% of the sampled building observed less than 70m setback. This analysis therefore validates the information obtained from the questionnaires. The high level of informal settlement shows the weakness of developmental control mechanism within the study area. This reveals why the study area was rated among the worst affected zone during 2012 flood event in Nigeria.

3.2 Rinfall and Hydrological Analysis .

In this study, rainfall analysis was conducted to investigate the contribution of rainfall to the 2012 flood. Table6 contain the statistical parameters reduced from time series rainfall data.

The value of rainfall above the mean in 2012 was very alarming which can lead to flood. Table4 shows18 years (1995 – 2012) hydrological records (annual discharge data at Lokoja gauging station) and figure3 is a hydrograph summarizing the records. The hydrograph revealed that for a period of 18years, the lowest, mean and highest water levels in 2012 are higher than that of the previous years. It can also be seen, that the lowest water level in 2012 is above the highest water level in the previous years. Though not only the value of rainfall in 2012 was above average but it can be seen from the climatic data of the area (Table1) that maximum precipitation occurs between August and October. The high rainfall experienced coupled with the release of water from Lagdo dam which coincided with the time of maximum precipitation in 2012 is seen as a contributing factor to the flood. Table7 reveals range of expected rainfall while table8 shows the forecasted rainfall. From both tables, it is be concluded that the expected flood is likely not to be more severe than the previous years since the forecasted rainfall fall short of the lower range.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The study investigated the implications of anthropogenic activities and rainfall for flooding in Lokoja. Analysis was made using proximity of residence to drainage, i8 year's hydrological records, and 32 years rainfall trend of the study area. It was revealed that 2012 rainfall was higher than long term mean and therefore has a major contribution to 2012 flooding in the study area. Result also attested that informal settlement resulted to increase in number of affected persons and huge economic loss. The model developed revealed that the entire area is getting wetter by 9.032mm per year. Although, extensive and sustained rainfall generates excess discharge which results to overflowing of river banks and consequently, flooding of low lying areas but human modification and alteration of natural river right of way can accentuate the problem while the disastrous consequences are dependent on human activities and occupancy in the flood prone areas ,It was therefore concluded that these are the reasons the study area was extensively affected during 2012 flood event in Nigeria**.**

4.2 RECOMMENDATIONS

i. The authority should strengthen the developmental control mechanisms in the study area.
ii. State-of -The-arts flood warning systems shouldbe strategically located for earlier detection of flood.
iii. Environmental education should be intensified within the study area..
iv. Where alternative resettlement cannot be provided, building codes should be established to guide construction in the flood prone areas.

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