

Flood Vulnerability Mapping of Lokoja Metropolis Using Geographical Information System Techniques

ONUIGBO I.C.¹, IBRAHIM P.O.^{1*}, AGADA D.U.¹, NWOSE I.A.¹, ABIMBOLA I.I.²

¹Department of Surveying Geoinformatics, Federal University of Technology Minna, Niger State

²Department of Surveying Geoinformatics, Kwara State Polytechnic, Ilorin

*Corresponding author: piusibrahim@gmail.com

Abstract Adequate geographic information on flood vulnerability is required to be able to prepare for flood disasters. This study applies Geographical information System Techniques to produce flood vulnerability map of Lokoja metropolis due to its confluence nature and its potential to cause devastating effect to the surrounding communities. This study is aimed at mapping flood vulnerable areas within Lokoja metropolis, for an effective flood disaster management and proper planning. Satellites imageries MODIS of 2011 and 2012, SPOT 5 of 2011, location map of Lokoja Metropolis, SRTM DEM, rainfall data, water discharge/gauge data, and GPS coordinates; acquired during field survey were integrated to map areas vulnerable to flooding. In this study Rank Sum method alongside Principal Component Analysis (PCA) is used to calculate the weight of factors that contributed to flooding within Lokoja metropolis. The study is limited to environmental factors such as hydrology, slope, soil type, drainage density, landform and landuse/landcover. Different maps were generated; composite map of the study area, flood extent map, flood plain map, slope map, flow direction map, flow accumulation map, Triangular irregular network, flood vulnerability map and also pie chart showing percentage area impacted, histogram showing the pattern of rainfall within Lokoja metropolis was generated. The approach resulted in four classes of flood vulnerability ranging from not vulnerable, less vulnerable, more vulnerable and most vulnerable areas. The area not vulnerable accounted for 20.25%, less vulnerable area accounted for 34.57%, more vulnerable area accounted for 28.57%, and the most vulnerable area accounted for 16.61%. The study concludes by proffering a number of recommendations aimed at addressing the issue of flooding within Lokoja metropolis. The recommendations includes; construction of levee along areas that are vulnerable to flooding, widening and construction of standard drainages around Lokoja metropolis, dredging of surrounding water bodies to deepen their depth, among others.

Keywords: flood, Lokoja, GIS, metropolis, vulnerability, rank, techniques

Cite This Article: ONUIGBO I.C., IBRAHIM P.O., SAMAILA-IJA H.A., NWOSE I.A., AGADA D.U., and ABIMBOLA I.I., "Flood Vulnerability Mapping of Lokoja Metropolis Using Geographical Information System Techniques." *Journal of Geosciences and Geomatics*, vol. 5, no. 5 (2017): 229-242. doi: 10.12691/jgg-5-5-2.

1. Introduction

Remote sensing data from satellite image offers an opportunity for improved observation and added systematic analysis of various factors affecting groundwater. Again GIS is one of the most important tools for integrating and analyzing spatial information and multidisciplinary database of any resource for planning of resource development environmental protection, scientific researchers and investigations [2].

Lokoja, Kogi State is both a highland/mountainous and lowland state. The river Niger in most cases and the flow of seasonal streams used to have undisturbed flow under cool vegetation from the Mount Patti and environ has since not only been exposed but its courses have always been blocked by construction and refuse from different land uses. The drainage systems originate from the centrally situated highlands and make their way down to the peripheral or outlying lowlands, especially during the rainy season (April-October). During rains, the water

becomes so much that it leads to excess water occupying and eventually submerging the streets. The state metropolis experiences majorly riverine flooding and sometimes flash floods depending on geology and the drainage pattern of the area [1]. On the other hand, much of the flood disasters in Lokoja metropolises are attributed to rivers that overflow or burst their banks and inundate downstream plain lands. The 2012 flood that assaulted Sarkin-Noma, Gadumo, Kporoka, Jingbe, Galilee, Kpata, Ganaja village and Saudana areas is a typical manifestation of riverine floods. Therefore, owing to its topographic and altitudinal characteristics, flooding, as a natural phenomenon, is not new to Lokoja [1]. They have been occurring at different places and times with varying magnitude. Scientific studies suggest that climate change is likely to cause shifts in the global pattern and intensity of flood events in some regions, thereby increasing the exposure of populations to severe flooding and that the impacts of future changes in climate extremes are expected to fall disproportionately on the poor [3].

Certain sections of society are particularly vulnerable, especially the poor who have to resort to living in areas

that are at high risk from natural disasters, such as flooding, landslides, etc. [4]. Flood hazard comprises many aspects which include structural and erosion damage, contamination of food and water, disruption of socio economic activity including transport and communication, as well as loss of life and property [5]. According to IPCC [6], flood hazards are natural phenomena, but damage and losses from floods are the consequence of human action. Flash flooding/urban flooding destroys the produce e.g. crop, rice paddy, fruit tree and vegetables thereby posing the risk of hunger to those engaged in subsistence farming and great loss to those engaged at a commercial scale [7]. Some of the causal factors of flood disasters in Nigeria have been attributed to land inundation from heavy rainfall, Dam failure/release of dams' water, climate change, and blockage of drainages with refuse, construction of buildings across drainages, inadequate drainage networks, and population increase in urban areas [8].

It is generally understood that there is a relationship between urbanization and hydrological characteristics; decreased infiltration, increase in run-off, increase in frequency and flood height. All disasters have spatial component; adequate geographic information on hazards and areas vulnerable to hazards is required to be able to prepare for disasters [28]. Hazard risk vulnerability mapping is considered as one of the most important steps in disaster risk reduction because it identifies areas

vulnerable to disaster so as to plan for disaster risk management [28]. Remote sensing offers a synoptic view of the spatial distribution and dynamic of hydrological phenomena such as flood and erosion. They are used to measure and monitor the extent of flooded areas, provide a quantifiable estimate of the land area and infrastructure affected by flooding and erosion [9]. Nigeria has been slow to realize the potential possessed by remote sensing and GIS in flood disaster management [28].

1.1. Study Area

1.1.1. Location of Lokoja

Lokoja is located between latitude $7^{\circ} 45' 27.56''$ N and $7^{\circ} 51' 04.34''$ N and Longitude $6^{\circ} 41' 55.64'$ E and $6^{\circ} 45' 36.58''$ E of the equator. It is situated on the western bank of the confluence of Rivers Niger and Benue at an altitude between 45-125 metres above sea level towards the north-south and the foot of the Patti Ridge, which reaches its altitude of 400 metres above sea level. Lokoja used to be a small urban centre and the headquarters of Kogi Local Government until 1991 when it became the head quarter of a new State. This town which had at some point in its rich history been the Capital of the Northern Protectorate and later Nigeria is presently the headquarters of Lokoja Local Government Area and the Capital of Kogi State.

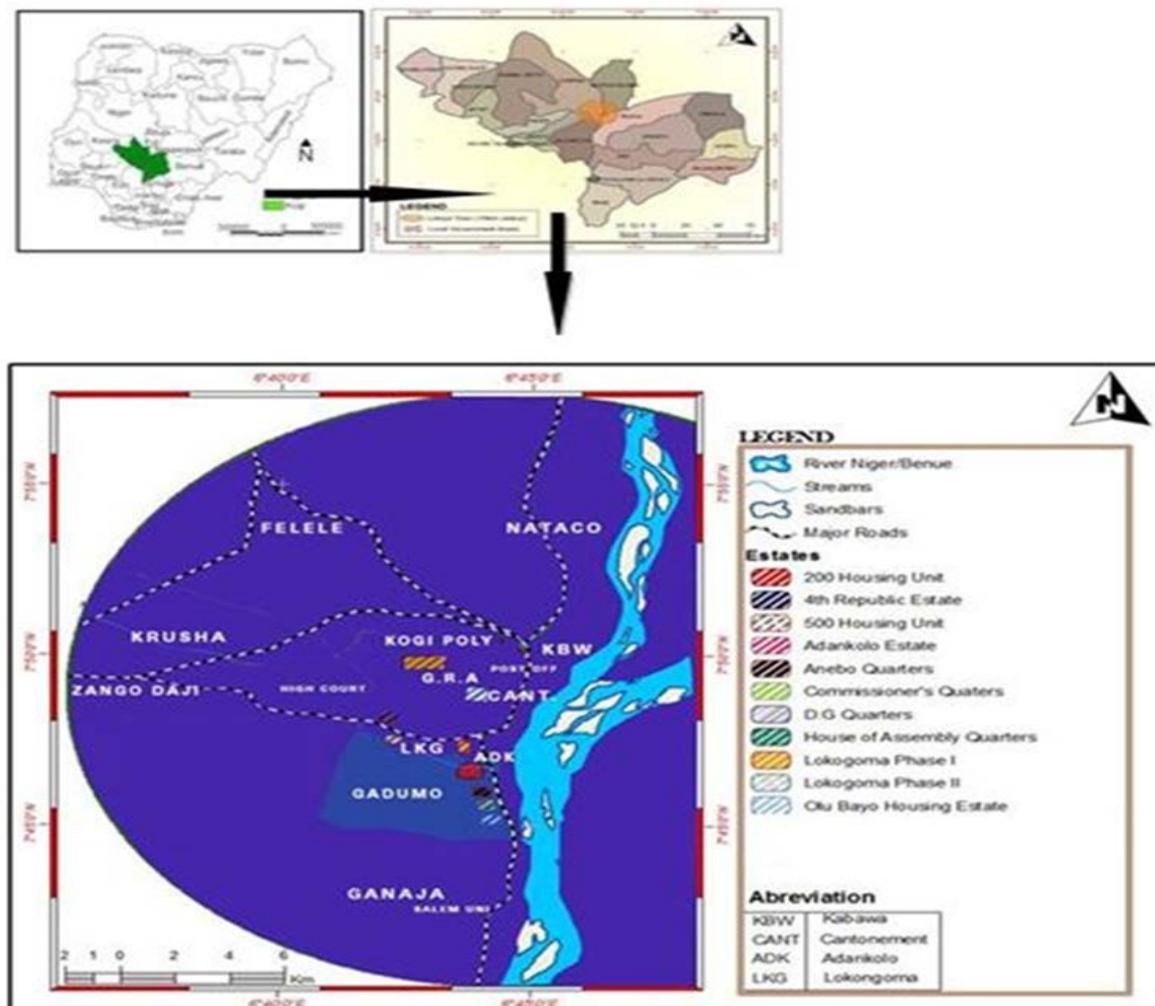


Figure 1. Location of the Study Area. (Source: Author's Lab Work, 2016)

2. Methodology

In order to carry out this research methodologically, data acquisition is the primary operation as far as digital mapping or GIS is an operation is concerned. Figure 2.1. Shows the step by step procedures carried out to arrive at the desired result. GIS and remote sensing techniques were used in mapping flood vulnerability areas within Lokoja metropolis. Table 2.1. Shows the primary and secondary data used to execute this work.

2.1. Data Acquisition

All data used for this research work, comprises of both secondary and primary data sets as shown in Table 2.1. The type of data needs depends upon the user requirements. Geometric data are usually collected in digital form from a variety sources. For this project, the following data were collected and used with the application of GIS and

Remote Sensing techniques in the mapping of the flood vulnerable areas within Lokoja metropolis.

2.2. Acquisition of Satellite Imagery

The satellite imagery used are SPOT-5 of 2011 and MODIS of 2011 and 2012. SPOT-5 satellite is a high resolution satellite operated by space imaging. The satellite imagery was chosen because of its spectral characteristics. The Moderate Resolution Imaging Spectroradiometer (MODIS) in surface reflectance with 250m resolution of Lokoja of 2011 and 2012 downloaded from NASA website; <http://modis.gsfc.nasa.gov>. The MODIS images comprises of visible and infrared channels which makes it possible to distinguish between water and land. The images used were for two years; the first was acquired in October, 2011 and the actual river width and the second was acquired in October, 2012 during the peak of the flood menace in Lokoja.

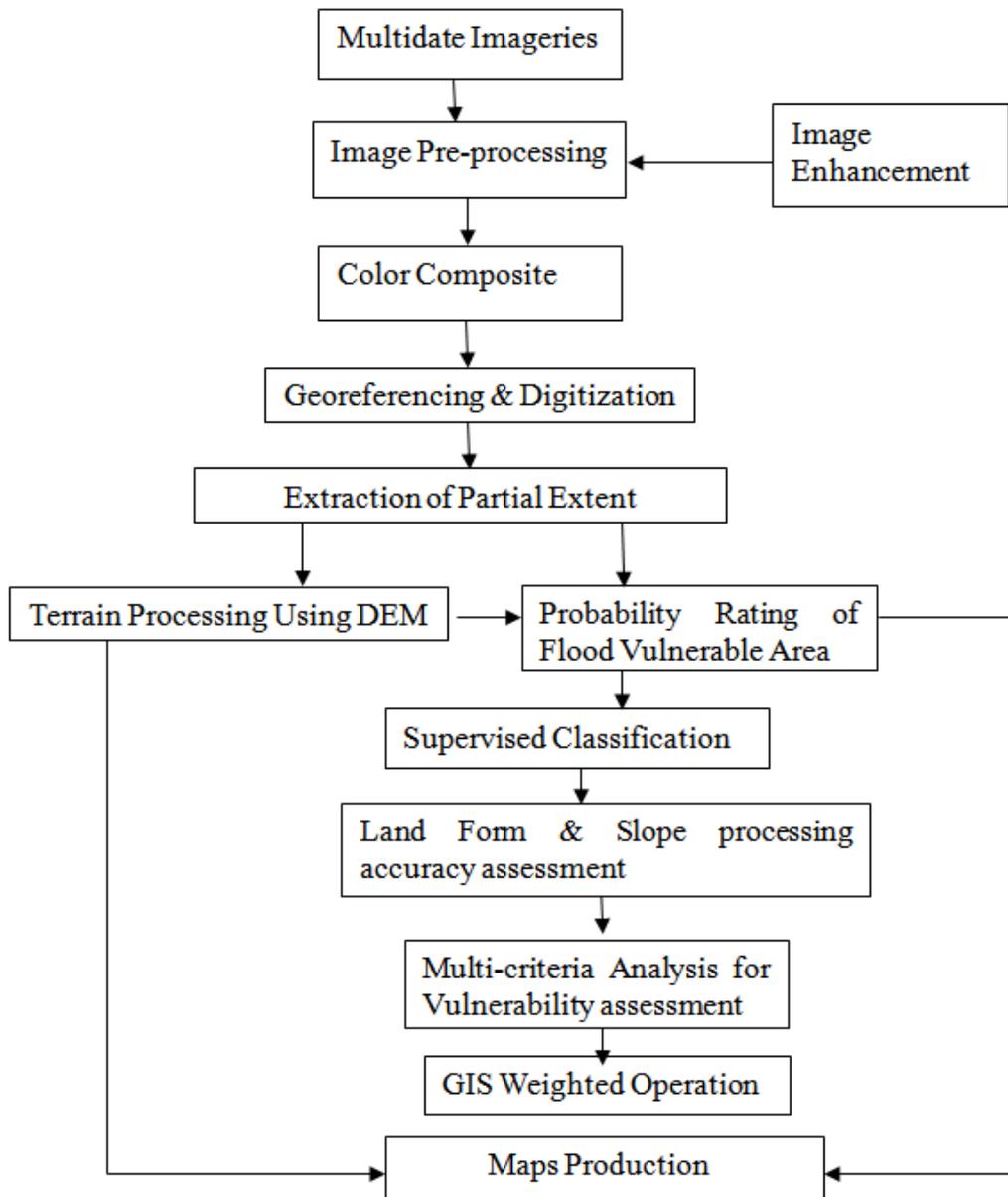


Figure 2.1. Flow Chart of the Research Methodology (Source: Author's Lab Work, 2016)

Table 2.1. Primary Data

Data	Accuracy	Sources
2011 SPOT-5 imagery Covering Lokoja Metropolis	4.5m resolution	Acquired from GIS Department, Kogi State Ministry of Lands, Housing and Urban Development
SRTM DEM of Lokoja Metropolis	90m resolution	Downloaded from the United State Geological Survey (USGS)
MODIS Surface reflectance	250m resolution	Obtained from NASA website http://modis.gsfc.nasa.gov
Rainfall fall data (1995-2014)		NIMET Lokoja Station
Peak discharge/gauge data (1995-2014)		Nigeria Inland Water Ways (NIWA)
GPS Coordinates		

Table 2.2. 20 Years Rainfall Value (Monthly) of Lokoja from 1995-2014

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
1995	0	0	80	202.1	168.2	106.3	402.2	200	16.2	200	12.4	0
1996	0	0	88.7	112.4	188.9	93.9	301.4	201.4	80.4	206.4	18.6	0
1997	0	10.3	0.3	168.8	108.2	107.5	164.8	235.6	322.3	122.9	0	0
1998	1.8	0	169.3	116.5	304.1	76.1	126.6	303.3	267.6	3.5	0	0
1999	0	0	TR	20.9	98.2	227.9	169.9	107.9	206.4	149.8	0	0
2000	TR	0	TR	162.6	97.2	155.2	97.2	190.1	216.6	91.8	TR	0
2001	0	0	4	112	77.3	125.1	198.3	157.9	252.1	46.2	0	0
2002	0	0	2.9	162.2	79.6	93.2	325.9	298	193.4	139	1.8	0
2003	0	15.3	9.4	38.5	92.7	180.9	271.4	53.1	163.7	147.1	14.7	0
2004	0	TR	3.4	157.5	246	168.4	225.5	78.6	252.1	203.1	0	0
2005	0	32.7	TR	93.4	134.3	170.5	60.9	132.9	143.5	167.5	3.4	0
2006	12	19.3	40.9	61.8	370	62.1	303.9	352.8	290.6	169.3	0	0
2007	0	0	11.6	82.3	277.3	184.5	231.8	225	246	240.7	2.2	0
2008	0	0	21.8	163.6	161.6	166.3	213.8	274.7	170.2	87.8	0	3.9
2009	10	0	5	243.6	108.4	220.1	212.8	369.8	255.8	206.4	0	0
2010	0	0	0	132.8	125	104.4	225.6	133	148.2	167.3	7.4	0
2011	0	TR	TR	65.7	147.3	163.2	128	160.9	191.1	147.9	0	0
2012	0	11.8	0	86.2	253.7	157.7	268.2	180.6	148.4	209.7	2.2	0
2013	0	47	29.5	138.1	254.2	124.3	225.1	123.9	139.2	217.8	0	0
2014	0	25.1	10.6	197	206	183.4	194.5	274.4	192	190.5	46	7

Source: Nigerian Meteorological Center, Kogi State, 2016

2.3. Acquisition of Elevation Data, Meteorological Data, and Hydrological Data

The shuttle Radar Topographic Mission (SRTM) of the study area used, is the digital elevation model (DEM). In addition to the satellite data was the topographic map of Lokoja (sheet 247NE, NW, SE, and SW). The rain fall data covering the period of twenty years (1995-2014) and the hydrological dataset were also obtained. All these data set were gotten from each of the Lokoja branch office. Table 2.2 and Table 2.3 shows the data used respectively.

Also, the soil raster map data of the Nigerian soil map was use to extract soil information of the study area. It is generally accepted that soil types in Nigeria are grossly influenced by the climate and vegetation zone of the country. This is expected because of the degree of available moisture in the soil, is an important factor in soil reactions.

Immediately the data were acquired and prepared they were taken to the GIS environment for further data processing, where the following were done; image pre-processing, filtering, colour composite, georeferencing and digitization, extracting the spatial extent of the flooded areas, terrain processing using DEM, probability rating of flooding in flood vulnerable area and classification of 2011 spot-5 image, training sample, classification and processing of soil, land form processing and classification, processing of drainage density and classification, slope processing and

classification, GIS weighted operation and multi-criteria analysis for flood vulnerability assessment and processing of hydrological data for flood frequency.

Table 2.3. Annual Discharge (peak) and Gauge Data of Lokoja Gauge Station (1995-2014)

Year	Discharge in Cummeccs	Water Level
1995	17713	8.8
1996	19914	9.4
1997	15548	8.2
1998	23491	10.5
1999	23090	10.36
2000	18225	8.94
2001	18885	9.12
2002	17012	8.62
2003	19025	9.16
2004	16098	8.36
2005	13792	7.66
2006	19389	9.26
2007	19941	9.41
2008	20426	9.55
2009	20534	9.58
2010	21272	9.79
2011	17139	8.65
2012	30676	12.85
2013	11468	5.68
2014	17512	8.75

The following parameters were considered during data processing to achieve maximum accuracy as shown in Table 2.4, Table 2.5, Table 2.6, Table 2.7 and Table 2.8.

The Pramojaneer formula used in calculating drainage density was adopted;

$$\text{Drainage density} = L / A$$

Where; L is the total length of drainage channel in watershed in km

A is the Total area of watershed in km^2

The calculation was done in Arc-map. The data used for this calculation are the length of the main stream and the area of the river respectively.

Table 2.4. Training Sample

Training Sample	Code
River	1
Farm Land	2
Heavy Forest	3
Swamp	4
Hill	5
Light Forest	6
Built-up Area	7
Bare Land	8

Table 2.5. Classification of Soil Types around the Study Area.

Class	Soil classification	Weight
1	Shallow soil, poorly drained soil with high percentage of silt >60%	4
2	Shallow soil, clayey poorly drained soil with high percentage of silt 40-60%	3
3	Poorly drained soil with high percentage of fine sandy soil 20-40%	2
4	Poorly drained soil with high percentage of silt and fine soil <20%	1

Table 2.6. Attached Weight to Drainage Density

Class	Drainage Density	Weight
1	<1	5
2	1-3	4
3	3-5	3
4	>5	2

Table 2.7. Composite Index Computation Using Rank Sum Method

Factors	Inverse	Weight	Normalized	Criteria
Slope	1	5	0.33	33.33
Drainage	2	4	0.27	26.67
Landform	3	3	0.20	20.00
Landuse/landcover	4	2	0.13	13.33
Soil	5	1	0.07	6.67
		15		100

Further insight to flood frequency is provided by the return period analysis using the Weibull equation;

$$P = m / n + 1 \quad (1)$$

Where m is the rank from lowest to the highest (ascending order), P is an estimate of the probability of the value being equal to or less than the ranked value.

For the probability expressed in percentage;

$$P = m / n + 1 \times 100 \quad (2)$$

Table 2.8. Return period using Weibull Formula

Discharge (Cummeecs)	Discharge in Descending Order	Rank (m)	P = m/(n+1)	Probability (%)	Return period (1/p)
17713	30676	1	0.041	4.17	24.39
19914	23491	2	0.082	8.17	12.25
15548	23090	3	0.125	12.50	8.00
23491	21272	4	0.180	17.96	5.56
23090	20534	5	0.232	23.22	4.31
18225	20426	6	0.280	28.00	3.57
18885	19941	7	0.334	33.43	2.99
17012	19914	8	0.383	38.25	2.61
19025	19389	9	0.441	44.14	2.26
16098	19025	10	0.499	49.94	2.00
13792	18885	11	0.553	55.32	1.81
19389	18225	12	0.624	62.42	1.60
19941	17713	13	0.695	69.47	1.44
20426	17512	14	0.777	77.73	1.29
20534	17139	15	0.827	82.69	1.21
21272	17012	16	0.888	88.83	1.12
17139	16098	17	0.934	93.40	1.07
30676	15548	18	0.962	96.20	1.61
11468	11468	19	0.984	98.40	1.02
17512	13792	20	0.995	99.50	1.00

3. Result and Discussion

3.1. Result

The results are presented in form of maps, charts and statistical tables as obtained from the step wise processing of the DEM, MODIS, SPOT images and non-spatial data of the study area. The statistical tables include the Landcover of Lokoja metropolis, wet and dry area in Lokoja metropolis between 2011 and 2012 as obtained from the MODIS image, and flood extent of Lokoja metropolis as obtained from the 2012 MODIS image. Presented below are the various maps, tables, and charts showing the output of the techniques in order in which they were carried out.

3.2. Discussion of Results

Table 3.1 and Figure 3.3 shows the delineation as well as mapping of the flood actual extent of Lokoja metropolis from the MODIS image and field validation data. The classification of the MODIS satellite image of both 2011 and 2012 shows the true representation of the flood extent in Lokoja metropolis. The derived statistical table (Table 3.1) showed that flood the flood extent in the study area accounted for the large land cover of about 37.19% and about 230062500m² of the total area while the River only accounted for 5.06% and about 31312500m². The land on the other hand including the built up area, farm land, vegetation cover and others accounted for a total of 57.75% and about 357250000m² of the total area. This result shows that the flood incident in Lokoja metropolis (2012) engulfed a good portion of the land mass (See Pie Chart; Figure 3.3).

Figure 3.4 shows the variation in heights in 3D map format. From the map it can be seen that areas ranging from 26 to 58 and 58 to 123 are relatively low and fairly flat; its suffice to say that such areas are vulnerable to flooding as run-off from the higher elevations tend to accumulate at the area of lower concentrations and when rivers over flow their banks. Areas ranging from 155 and above are not vulnerable to flooding. Considering the height variation, Lokoja metropolis can be considered to be low except for the surroundings as shown in Figure 3.4. Its then suffice to say that the flood menace in Lokoja metropolis can partly be attributed to poor drainage system.

Figure 3.5. the slope map of Lokoja metropolis. The slope map identifies the overall rate of downwards movement of water, in other words, the higher the elevations, the faster the downward flow of water. It can be seen from Figure 3.5 that the low slope areas range

from 0 to 4.44 to degrees, the moderate slope areas range from 4.44 to 13.85 degrees and high slope areas ranging from 13.85 to 34.28 degrees. One of the important factors to be considered in determining areas vulnerable to flooding is the steepness of the slope. The calculations of the slope angle of the DEM reveals that areas within and without the stream buffer have varying slope angles. Therefore, it's possible that some areas within the stream buffer zone are well above water level than the other areas and such areas are said to be less vulnerable to flooding than the later. The Figure 3.5 clearly shows the slope steepness of the area reclassified into three categories. The lower the slope angles of a particular area, the closer to water level. Therefore, areas within the slope angle of 0 – 4.44 and within the stream buffer zone were classified to be the most vulnerable to flooding which can arise from the event of sudden release of Dams or heavy rainfall.

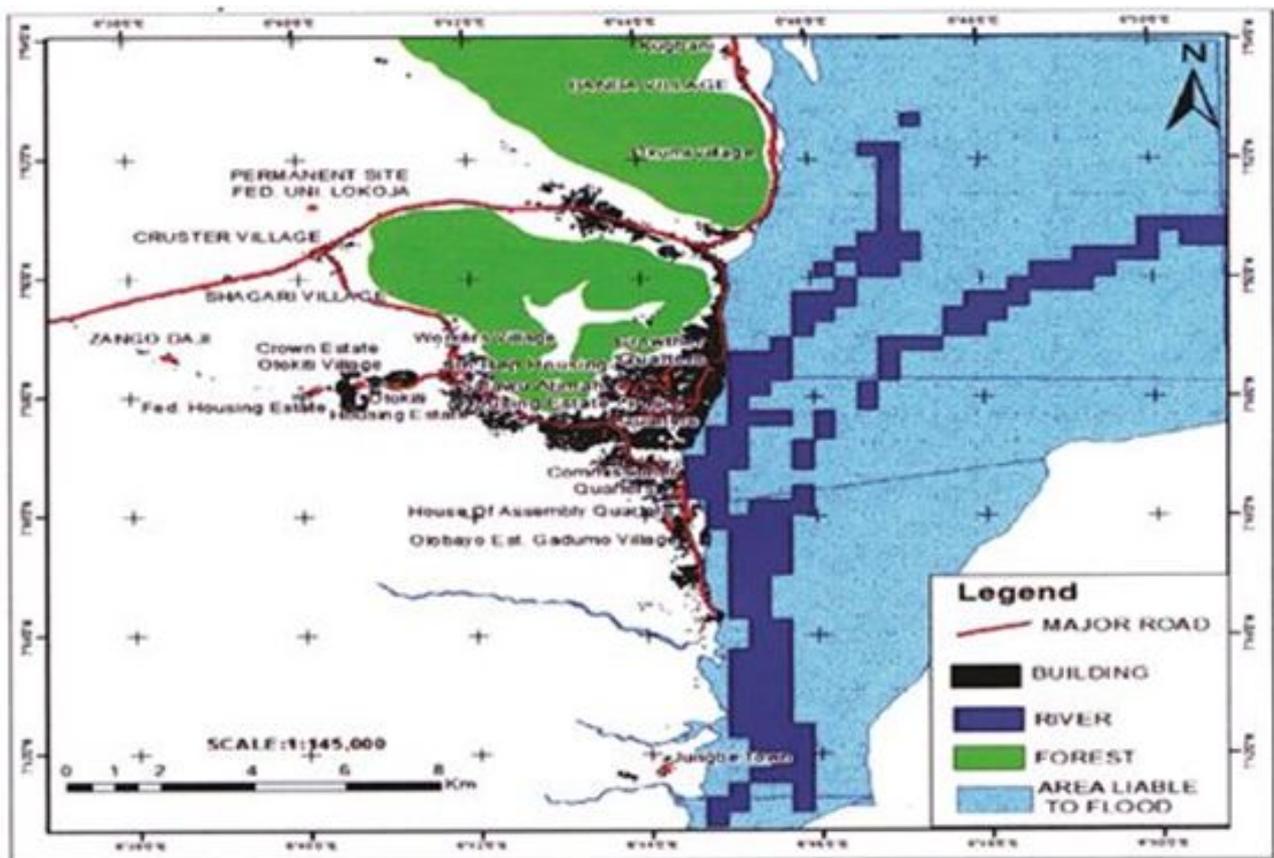


Figure 3.1. Composite Map of the Study Area (Source: Authors Lab Work, 2016)

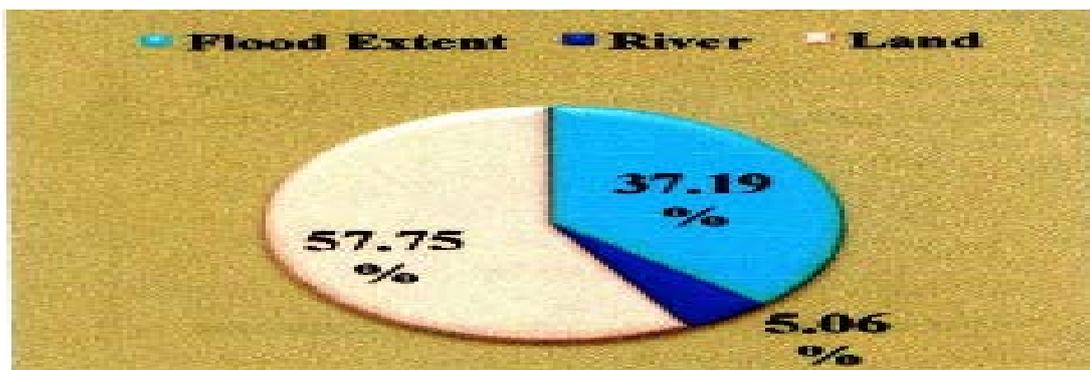


Figure 3.2. Percentage Area Impacted (Source: Authors Lab Work, 2016)

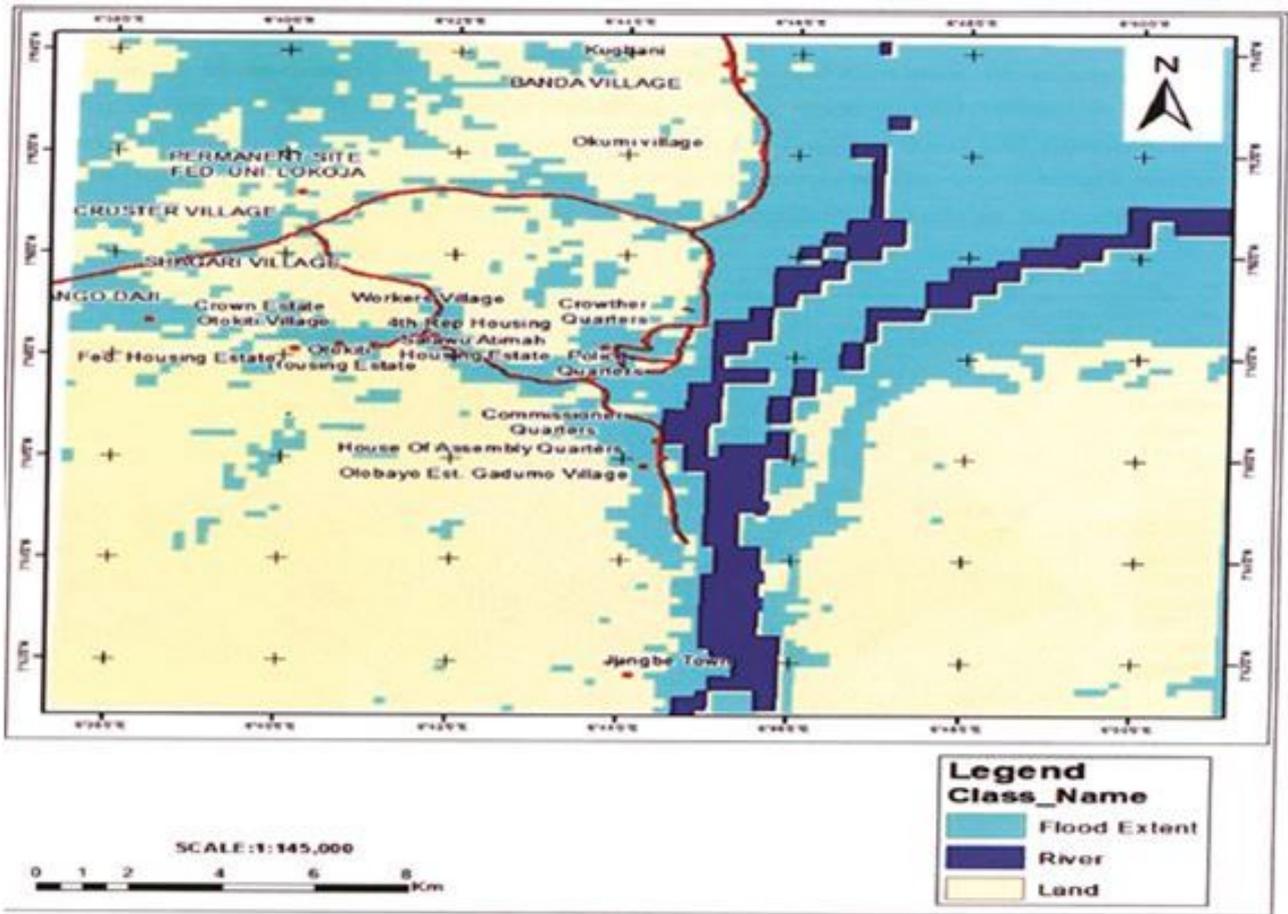


Figure 3.3. Flood Extent Map of Lokoja Metropolis (Source: Authors Lab Work, 2016)

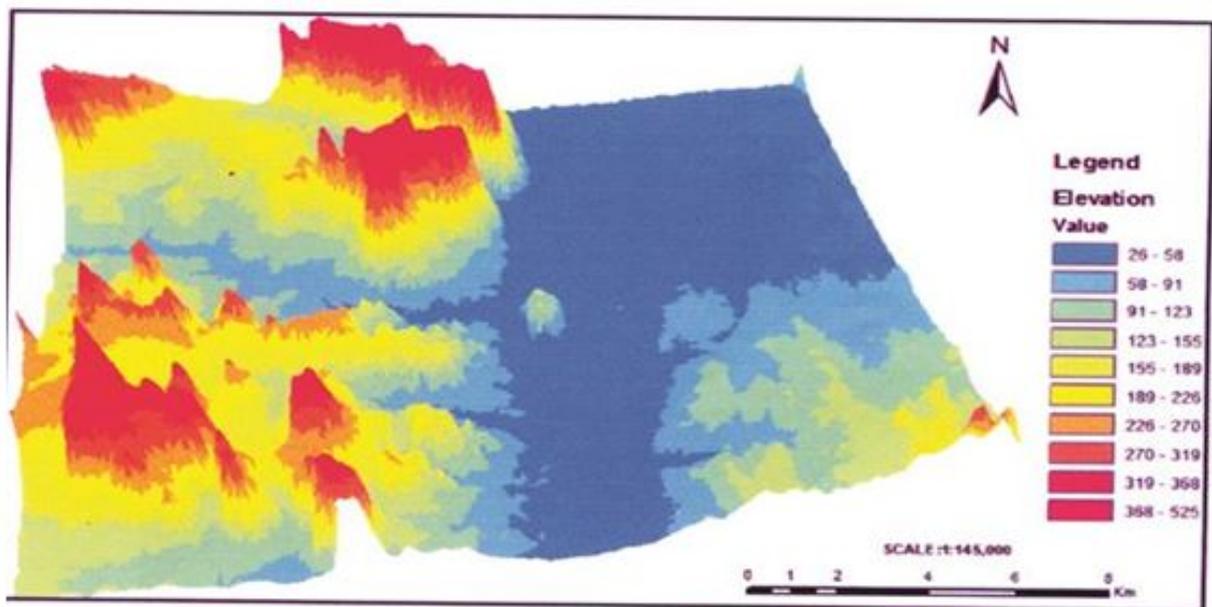


Figure 3.4. 3D Flood Plain Map of Lokoja Metropolis (Source: Authors Lab Work, 2016)

Figure 3.6. depicts that the flow direction/Pattern across the state is seemingly from North to South around the metropolis while it is uniformly distributed in other areas, with Crutcher village, and some areas like Zango, Gada, Lokongoma, and others are naturally drained into places like Gadumo, Ganaja, and other surroundings natural drain channels. The slope map shown in Figure 3.5 further substantiates the above claim. The flow

accumulation shown in Figure 3.9, gives a first order initial idea of the areas vulnerable to flooding within Lokoja metropolis. Areas like Crutcher village, Zango, part of Lokongoma, Otokiti, and other parts very close to the above places listed stand as being above flood level. Others are ranked as either “Less Vulnerable”, “More Vulnerable”, or “Most Vulnerable to flooding respectively.

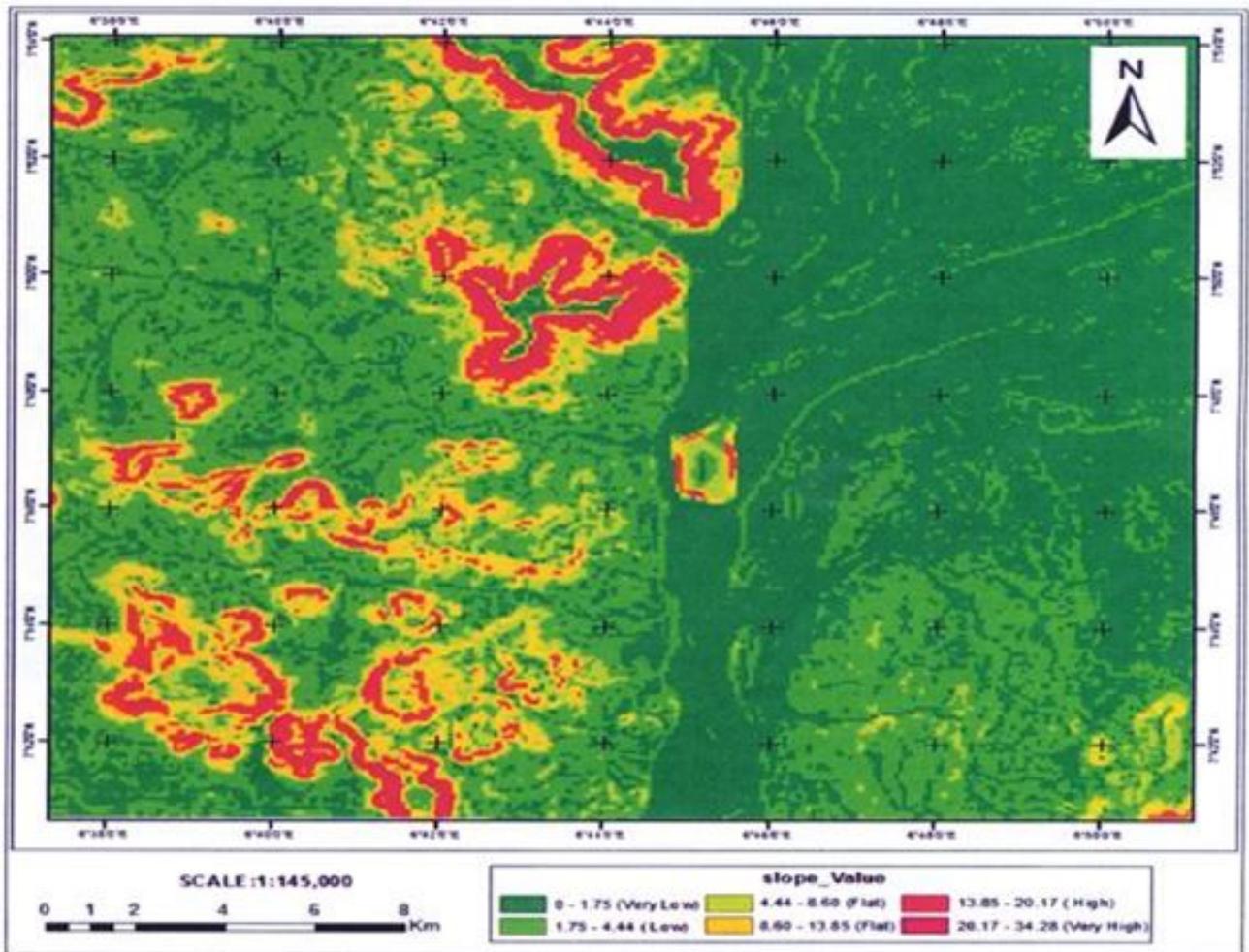


Figure 3.5. Slope Map of Lokoja Metropolis (Source: Authors Lab Work, 2016)

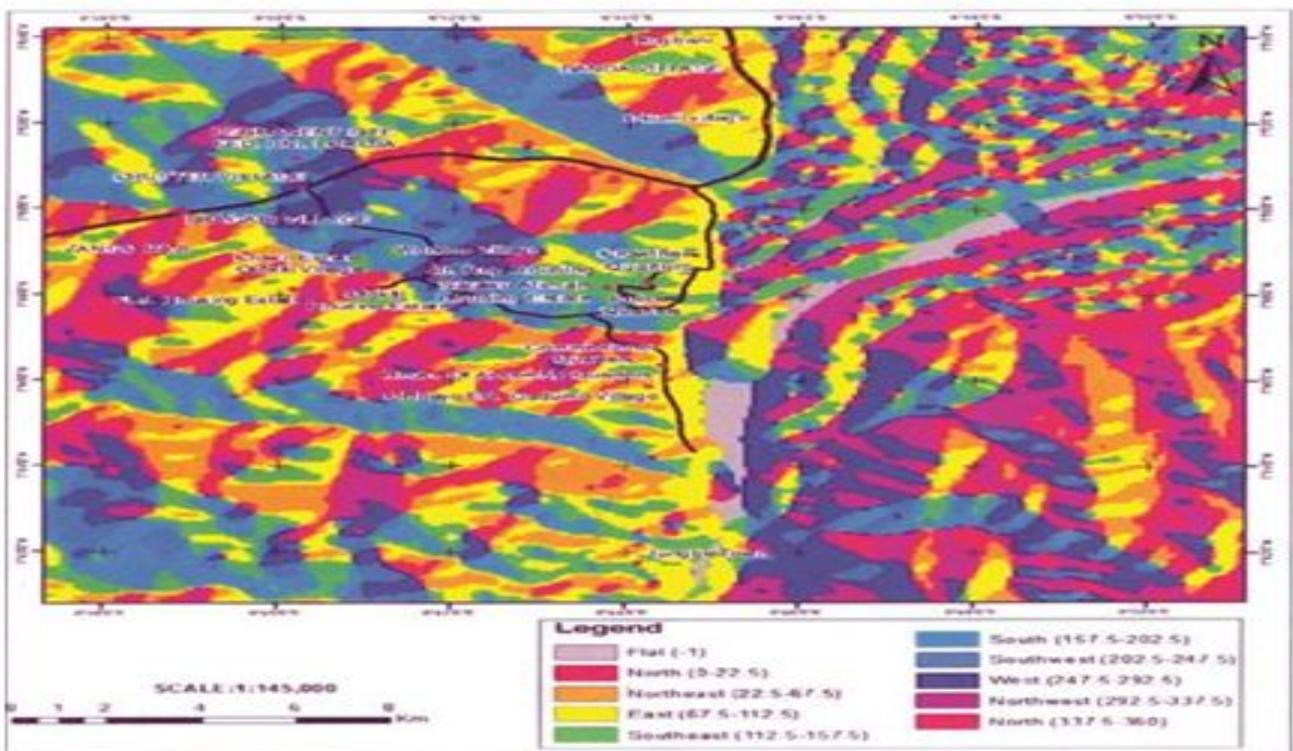


Figure 3.6. Flow Direction Map of Lokoja Metropolis (Source: Authors Lab Work, 2016)

Table 3.1. Areal extent of land use/land cover in 2012

Value	Pixel Count	Class Name	Area (m ²)	Area (%)
1	3681	Flood Extent	230062500	37.19
2	501	River	31312500	5.06
3	5716	Land	357250000	57.75
Total			618625000	100

Table 3.2. Wet and Dry Area in Lokoja Metropolis

Class Name	Area in 2011 (m ²)	Area in 2012 (m ²)	Area in 2011 (%)	Area in 2012 (%)
Wet	31312500	258000000	4.91	40.47
Dry	606187500	379500000	95.09	59.53
Total	637500000	637500000	100	100

Table 3.3. Flood vulnerability in Lokoja Metropolis

Vulnerability	Weight	Pixel Count	Area (m ²)	Area (%)
Not Vulnerable	1	132833	119549700	20.25
Less Vulnerable	2	226770	204093000	34.57
More Vulnerable	3	187389	168650100	28.57
Most Vulnerable	4	108932	98038800	16.61
Total			590331600	100.00

Table 3.4. 20 Years Rainfall Value (Monthly) of Lokoja from 1995-2014

YEARS	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC	Total RF	Mean RF
1995	0	0	80	202.1	168.2	106.3	402.2	200	16.2	200	12.4	0	1387.4	115.617
1996	0	0	88.7	112.4	188.9	93.9	301.4	201.4	80.4	206.4	18.6	0	1292.1	107.675
1997	0	10.3	0.3	168.8	108.2	107.5	164.8	235.6	322.3	122.9	0	0	1240.7	103.392
1998	1.8	0	169.3	116.5	304.1	76.1	126.6	303.3	267.6	3.5	0	0	1368.8	114.067
1999	0	0	TR	20.9	98.2	227.9	169.9	107.9	206.4	149.8	0	0	981	81.750
2000	TR	0	TR	162.6	97.2	155.2	97.2	190.1	216.6	91.8	TR	0	1010.7	84.225
2001	0	0	4	112	77.3	125.1	198.3	157.9	252.1	46.2	0	0	972.9	81.075
2002	0	0	2.9	162.2	79.6	93.2	325.9	298	193.4	139	1.8	0	1296	108.000
2003	0	15.3	9.4	38.5	92.7	180.9	271.4	53.1	163.7	147.1	14.7	0	986.8	82.233
2004	0	TR	3.4	157.5	246	168.4	225.5	78.6	252.1	203.1	0	0	1334.6	111.217
2005	0	32.7	TR	93.4	134.3	170.5	60.9	132.9	143.5	167.5	3.4	0	939.1	78.258
2006	12	19.3	40.9	61.8	370	62.1	303.9	352.8	290.6	169.3	0	0	1683.1	140.258
2007	0	0	11.6	82.3	277.3	184.5	231.8	225	246	240.7	2.2	0	1501.4	125.117
2008	0	0	21.8	163.6	161.6	166.3	213.8	274.7	170.2	87.8	0	3.9	1263.7	105.308
2009	10	0	5	243.6	108.4	220.1	212.8	369.8	255.8	206.4	0	0	1632	136.000
2010	0	0	0	132.8	125	104.4	225.6	133	148.2	167.3	7.4	0	1043.7	86.975
2011	0	TR	TR	65.7	147.3	163.2	128	160.9	191.1	147.9	0	0	1004.1	83.675
2012	0	11.8	0	86.2	253.7	157.7	268.2	180.6	148.4	209.7	2.2	0	1318.5	109.875
2013	0	47	29.5	138.1	254.2	124.3	225.1	123.9	139.2	217.8	0	0	1299.1	108.258
2014	0	25.1	10.6	197	206	183.4	194.5	274.4	192	190.5	46	7	1526.5	127.208

The Triangular Irregular Network (TIN) of the study area shown in Figure 3.8 further buttressed on the fact that some areas are more vulnerable than the other. From the map, the areas ranging from 35-83.889m are considered to be the most vulnerable areas to flooding, areas with height ranging from 83.889-132.778m are considered to be more vulnerable to flooding, areas ranging from 132.778-181.667m are considered as areas less vulnerable to flooding, while areas with heights ranging from 181.667 and above are considered as areas not vulnerable to flooding. More also, the presence of excess water may be as a result of reduction in capacity of natural water course, this obstruct the natural water flow and deregulate topography thereby leading to local depression.

The Pre and during flood mapping as well as the analysis of the study area using the MODIS Satellite imageries (2011 and 2012) as shown in Figure 3.9 serve as reality check. From Figure 3.9, almost all the areas

considered to be dry in 2011 were converted to wet areas in 2012. It can be seen in Table 3.2 that the wet area accounted for 4.91% in 2011 which is the size of part of River Niger and Benue increased to 40.47% in 2012. These clearly show that the flood took over the area and therefore reduced the dry area from 95.09% in 2011 to 59.53% in 2012. This result attest to the fact that there was a very serious flood disaster in 2012 which took over areas considered to be dry by the communities living in such zones.

The rainfall data analysis carried out shows that over the years, the rainfall amount in the study area is inconsistency. There has been a variation in the rainfall pattern over the years. The mean monthly rainfall is 104.2cm while the mean annual rainfall is 1224.11cm. (See Table 3.4). Table 3.4 shows that year 2006 recorded the highest mean rainfall to be 140.258 and year 2005 recorded the lowest mean rainfall of 78.258.

Finally, in order to create the flood risk map of Lokoja Metropolis as shown in Figure 3.10 rank sum method was used and each factor is weighted according to the estimated significance for causing flooding. From the GIS weighted analysis which result is shown in Table 2.6, factors that influences the flood were ranged from one to four and was categorized from Not vulnerable to Most vulnerable. A composite flood risk index (FRI) is computed using the overlay analysis and raster calculator in the Arc GIS 9.3 software. Areas considered not to be vulnerable accounted for 20.25% of the total area, area considered to be less vulnerable accounted for 34.57%, area said to be more vulnerable accounted for 28.57% while area considered to be the most vulnerable accounted for 16% of the total area.

4. Conclusion and Recommendations

4.1. Conclusion

Geographical Information System and Remote Sensing techniques were adopted in this work and they are in phases in order to map out areas vulnerable to flood. The research identified the factors that contributed much to the flooding within Lokoja metropolis. Multi criteria analysis for flood vulnerability was carried out in a GIS environment. In the multi criteria analysis, Weighted Linear Combination which involves the ranking of each contributing factor was used. The datasets for this work are those whose spatial references can be determined. These datasets are satellite images (Both high and medium resolution), topographic maps, soil map, hydrological and meteorological data. The study has raised awareness on areas that are vulnerable to flood and their magnitudes. The study fully appraised the role of GIS and Remote Sensing Techniques in decision making process. The study concludes by proffering a number of recommendations aimed at addressing the issue of flooding within Lokoja metropolis.

4.2. Summary of Findings

The various phases of analysis carried out above have given an in-depth understanding of the areas that are vulnerable to flood within Lokoja metropolis and the factor that has played the major impact. This insight will pre-empt the recommendations of the study on how flood could be controlled and properly managed. The key findings are itemized below.

- i. Lokoja metropolis is linked with Lagdo dam in Cameroon, Jebba Dam, Kainji Dam and Shiroro Dam in Niger State, Nigeria.
- ii. The water level as revealed by the research is on the high side at the time of flood (See Table 3.4).
- iii. The research also showed that the flood extent in the study area accounted for the large land cover of about 37.19% and about 230062500m² of the total area while the River only accounted for 5.06% and about 31312500m². The land on the other hand including the built up area, farm land, vegetation cover and others accounted for a total of 57.75% and about 357250000m² of the total area (See Table 3.1).

- iv. The study also revealed that the low slope areas range from 0 to 4.44 degrees, the moderate slope areas range from 4.44 to 13.85 degrees and high slope areas ranging from 13.85 to 34.28 degrees (See Figure 3.5).
- v. Areas ranging from 35-83.889m are considered to be the most vulnerable areas to flooding, areas with height ranging from 83.889-132.778m are considered to be more vulnerable to flooding, areas ranging from 132.778-181.667m are considered as areas less vulnerable to flooding, while areas with heights ranging from 181.667 and above are considered as areas not vulnerable to flooding (See Figure 3.8).
- vi. Five contributing factors were examined (soil, landuse/landcover, topography, slope and mean annual rainfall) (MAR)). The impact of each of the above contributing factors as revealed by the Principal Component Analysis (PCA) shows a very close representation of the reality. This is because the flood vulnerability class progression in the PCA corresponded with the areas of observable impact as earlier visited on the field when compared with the PCA values. The contributing percentage for the factors going by the overall result in the PCA are soil (38.65%), landuse/landcover (32.59%), topography (16.02%), slope (9.19%), and MAR (3.55%) (Appedix A).
- vii. The research also revealed that areas considered not to be vulnerable accounted for 20.25% of the total area, area considered to be less vulnerable accounted for 34.57%, area said to be more vulnerable accounted for 28.57% while area considered to be the most vulnerable accounted for 16% of the total area (See Figure 3.10 and Table 3.3).

4.3. Recommendations

Based on the findings of this study, it is important to strictly adhere to the following recommendations:

- i. Levee project should be encouraged by Kogi State Government along areas that are vulnerable to flood.
- ii. Widening of some of the existing drainages in some areas and construction of standard ones to cut across the entire Lokoja metropolis should be encouraged and putting into considerations areas that are most vulnerable to flooding within Lokoja Metropolis.
- iii. There should be a form of co-operation between Kogi State Government and Niger State Government and also between Nigeria and Cameroon on the management of Kainji Dam, Jeba Dam, and Shiroro Dam all in Niger State and Lagdo Dam in Cameroon.
- iv. The government of Kogi State should totally discourage the building of houses along the flood plains.
- v. The Kogi State Waste Management Board should ensure active regular collection of waste to avoid dumping of waste into the available drainages.
- vi. The government of Kogi State should carry out dredging on the surrounding water bodies to deepen their depth.

References

- [1] Aderoju, O. M., Jantiku, J., Fagbemiro, O. A., Aliyu, I., Nwadike, B. K., Ajonye, S. E., and Salman, K. S. (2014). Geospatial assessment of 2012 flood disaster in Kogi State. *Journal of Environmental Science, Toxicology And Food Technology*, PP 74-84. www.iosrjournals.org (accessed 27th October, 2015).
- [2] Biswas, A., Jana, A., Mandal, A. (2013). Application of remote sensing, GIS and MIF technique for elucidation of groundwater potential zones from a part of Orissa coastal tract, Eastern India. *Research Journal of Recent Sciences*, 2(11), 42-49.
- [3] Few, R. (2003). Flooding, Vulnerability and Coping Strategies: Local responses to global threats. *Progress Development Studies*, 3, pp 43-58.
- [4] Price R. K., & Z. Vojinovic (2008). Urban flood disaster management, *Urban Water Journal*, 5:3, 259-276.
- [5] Hewitt, K. and Burton, I., (1971). The hazardousness of a place: A regional geology of damaging events, University of Toronto, Department of Geography Research Publication, 5, pp 154-155.
- [6] IPCC (2007) Climate Change Impacts, adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Inter governmental Panel on Climate Change, (pp. 77-103). Cambridge, UK; Cambridge University Press.
- [7] Adeoye, N. O., Ayanlade, A. and Babatimehin, O., (2009). Climate change and menace of floods in Nigerian Cities, Socio-economic implications, *Advances in Natural and Applied Sciences*, 3(3), 369-377.
- [8] Adeoye, A., and Rustum, R. (2011). Lagos (Nigeria) flooding and influence of urban planning. *Journal of Urban Design and Planning*, 164, 175-187.
- [9] Izinyon, O. and Ehirorbo, J., (2011), Measurements and documentation for flood and erosion monitoring and control in the Niger Delta states of Nigeria, TSo7e Engineering Survey, Marrakech, Morocco.
- [10] Adeoye, N.O. (2012). Spatio-temporal analysis of Landuse/cover change of Lokoja- a Confluence town. *Journal of Geography and Geology*, vol.4 no 4; 2012, pp 40-51, published by Canadian Center of Science and education.
- [11] African Research Bulletin (ARB) (2010) "policy and practice, economic trends, BENIN: Counting the cost of Floods", African Research Bulletin: Economic, financial and Technical Series, 47(11), Pp 18902-18903, Black Well Publishing ltd.
- [12] Brooks, N., Adger, W.N., and Kelly, P.M. (2005), The determinant of vulnerability and adaptive capacity at the national level and the implication for adaptation. *Global Environmental Change* vol 15, pp 151-163.
- [13] Chidinma, B. O., Vincent, N. O., (2015), Mapping of flood prone areas in Surulere, Lagos, Nigeria: A GIS Approach. *Journal of Geographic Information System*, 7, pp 158-176. <http://www.scirp.org/journal/jgis> (accessed 18th Jan., 2016).
- [14] Eguaroje, O. E., Alaga T. A., Ogbole J. O., Omolere S., Alwadood J., Kolawole I. S. et al. (2015). *Flood vulnerability assessment of Ibadan City, Oyo State, Nigeria. World Environment*, 5(4): 149-159..
- [15] IPCC (2001): Climate change 2001: *impacts, adaptation, and vulnerability, summary for policymakers* (A Report of working group II of the IPCC). Geneva, Switzerland.
- [16] Isma'il, M., and Iyortim, O. S., Application of Remote Sensing (RS) and Geographic Information Systems (GIS) in flood vulnerability mapping. *International Journal of Geomatics and Geosciences* Vol. 3, 3, pp 618-62. www.sciencedirect.com (accessed Nov., 30th, 2015)
- [17] Greenlee, D. D. (1987). "Raster and Vector Processing for Scanned Linework." *Photogrammetric Engineering and Remote Sensing* 53 (10): pp 1383-1387.
- [18] Ifatimehin, O., and Ufuah, M., (2006), *An analysis of urban expansion and loss of vegetation in Lokoja using GIS techniques*, Zaria Geographic vol 17, pp 28-36.
- [19] Eastman, J.R. (2001) IDRISI, Guide to GIS Image processing, vol. 2, pp 56-57. www.gyml.unibas.ch/go/17/pdf2/guide2 (assessed 28th sept. 2015).
- [20] Eludoyin, O.S. and Weli, V. (2010). Spatial analysis of flood vulnerability levels in Port Harcourt metropolis using Geographic Information Systems (GIS). <http://creativecommons.org/licenses/by/4.0/> (accessed 11th Jan., 2016).
- [21] Etuenovbe, A. (2011). *The devastating effect of flooding in Nigeria*. Paper presented at the Bridging the Gap between Cultures, FIG working week, Morocco, Africa.
- [22] Jeb, D.N., and Aggarwal, S.P (2008), "Flood in Inundation Hazard Modelling of the River Kaduna using Remote Sensing and Geographic Information Systems", *Journal of Applied Sciences Research*, 4 (12), pp 1822-1833.
- [23] Jenson, S. K., and J. O. Domingue. 1988. "Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis." *Photogrammetric Engineering and Remote Sensing* 54 (11): 1593-1600.
- [24] Kebede, Bishaw, *Application of GIS and Remote Sensing Techniques for Flood Hazard and Risk Assessment*. Proceeding of the 2012 Berlin Conference on the Human Dimensions of Global Environmental Change.
- [25] Klingebiel, A. A., E. H. Horvath, W. U. Reybold, D. G. Moore, E. A. Fosnight, and T. R. Loveland, 1988. *A Guide for the Use of Digital Elevation Model Data for Making Soil Surveys*: U.S. Geological Survey Open-File Report 88-102, 18 p. (in press).
- [26] Koppen, W. (19336). *The Geographic System of Climate.*, Berlin, Germany: Borntraeger Science Publishers.
- [27] Lillesand, T.M., Keifer, R., and Jonathan, W.C., (2007): Remote sensing and image interpretation. Sixth Edition: John Wiley & Sons, Inc.
- [28] Ismail, M., and Opeluwa, I.S. (2013). Application of Remote Sensing (RS) and Geographic Information Systems (GIS) in flood vulnerability mapping: Case study of River Kaduna, *Journal Of Geomatics and Geosciences*. Volume 3, No 3, 2013.
- [29] Maguire, O.J. (1991). An overview and definition of GIS. *Geographical information systems: principles and applications*, 1, 9-20.
- [30] Mark, D. M. 1988. "Network Models in Geomorphology." *Modelling Geomorphological Systems*, ed. M. G. Anderson. New York: John Wiley. 73-97.
- [31] Midgeley, S.J.E, Davies, R.A.G., and Chesterman, S. (2011, November). *Climate Risk and vulnerability mapping: status quo (2008) and future (2050)*. Paper presented at Regional Climate Change programme Southern Africa (RCCP), UK Department for international Development (DFID), One World Sustainable Investments, Cape Town, South Africa.
- [32] National Aeronautic and Space Administration NASA (2011f), "Flooding in Nigeria", NASA Earth Observatory available at <http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=46322>.
- [33] National Emergency Management Agency, NEMA (2013). A Publication of Punch Newspaper, November, 18, 2013.
- [34] Odumosu, O.J., Ajayi, O.G., and Adesina, E. (2014). *Modeling Surface Runoff and Mapping Flood Vulnerability in Lagos State from Digital Elevation Model*; Paper presented at 2014 FIG Congress; Engaging Challenges-Enhancing the Relevance, Kuala Lumpur, Malaysia 16-21 June 2014.
- [35] Ojeh, V. N., and Ugboma, P. (2012). *Flood Hazard in Urban Niger Delta: A case study Abraka Town, Delta State, Nigeria*. *International Journal of Environmental Research*, 1, 23-29.
- [36] Olayemi, J.O., Oluibukun, G. A., and Ekundayo, A. (2014). *Modeling surface runoff and mapping flood vulnerability of Lagos State from Digital Elevation Model*. paper presented at the FIG congress Kuala Lumpur, Malaysia.
- [37] Nwilo, P.C., D., Nihinlola, O., and Ayila, E. A. (2012). Flood modeling and vulnerability Assessment of settlements in the Adamawa State floodplain using GIS and Cellular Framework Approach ; *Global Journal of HUMAN SOCIAL SCIENCE* Volume 12 Issue 3 2012 Global Journals Inc. (US).
- [38] Peucker, T. K., and Douglas, D. H., 1975. Detection of surface-specific points by local parallel processing of discrete terrain elevation data: *Computer Graphics and Image Processing*, Vol. 4, pp. 375-387.
- [39] Shantosh, K. (2011). GIS based flood hazard mapping and vulnerability assessment of people in Kankai (East Nepal, Pakistan) due to climate change. www.library.witpress.com (accessed 23rd Aug, 2015).
- [40] Tarboton, D. G., R. L. Bras, and I. Rodriguez-Iturbe. (1991). "On the Extraction of Channel Networks from Digital Elevation Data." *Hydrological Processes* 5: 81-100.

- [41] Thecla, I. A., and Chinedu, O., (2015). Spatial analysis of vulnerability to flooding in Port Harcourt Metropolis, Nigeria. (accessed 23rd Aug, 2015). [Http://www.creativecommons.org/licenses/](http://www.creativecommons.org/licenses/)
- [42] U.S. Geological Survey, (1987). Digital Elevation Models: U.S. Geological Survey Data User's Guide 5, 38 p. 23.
- [43] Ward, R. C. (1978) *Floods: A geographical perspective*. London, England: The Macmillan Press.
- [44] Wikipedia, the free encyclopedia (2007): flood. <http://en.wikipedia.org> (accessed 26th Sept, 2015).
- [45] Worrall, L. (Ed.). (1990). *Geographic Information Systems: Developments and Applications (Vol.1) Burns and Dates'*.

Appendix A

Principal Component Analysis

```

pca_new - notepad
File Edit Format View Help
# Data file produced by Principal Components
# Input raster(s):
#   w_soil1_prj.tif\Band_1
#   w_landuse_prj_good.tif\Band_1
#   w_topo_prj.tif\band_1
#   slope_low_prj.tif\Band_1
#   w_innodation2012_proj.tif\Band_1
# The number of components = 5

output raster(s): pca_NEW

# COVARIANCE MATRIX
# Layer SOIL LANDUSE TOPOGRAPHIC SLOPE FLOODED AREA
#-----
# SOIL 1.69807 0.06890 0.05095 0.03084 0.09921
# LANDUSE 0.06890 1.12374 0.23607 0.18681 0.34015
# TOPOGRAPHIC 0.05095 0.23607 0.57585 0.07498 0.29014
# SLOPE 0.03084 0.18681 0.07498 0.20950 0.14623
# FLOODED AREA 0.09921 0.34015 0.29014 0.14623 1.02453
#-----

# CORRELATION MATRIX
# Layer SOIL LANDUSE TOPOGRAPHIC SLOPE FLOODED AREA
#-----
# SOIL 1.00000 0.04988 0.05153 0.05171 0.07522
# LANDUSE 0.04988 1.00000 0.29346 0.38501 0.31701
# TOPOGRAPHIC 0.05153 0.29346 1.00000 0.21587 0.37773
# SLOPE 0.05171 0.38501 0.21587 1.00000 0.31563
# FLOODED AREA 0.07522 0.31701 0.37773 0.31563 1.00000
#-----

# EIGENVALUES AND EIGENVECTORS
# Number of Input Layers 5 Number of Principal Component Layers 5
# PC Layer SOIL LANDUSE TOPOGRAPHIC SLOPE FLOODED AREA
#-----
# Eigenvalues 1.79028 1.50968 0.74183 0.42563 0.16427
# Eigenvectors
# Input Layer
# SOIL 0.82091 -0.57028 -0.02927 -0.00071 -0.00585
# LANDUSE 0.37314 0.57485 -0.70189 -0.12273 -0.13031
# TOPOGRAPHIC 0.20135 0.27969 0.17975 0.92111 -0.02196
# SLOPE 0.10372 0.14100 -0.03376 -0.03545 0.98334
# FLOODED AREA 0.36820 0.49620 0.68778 -0.36775 -0.09963
#-----

# PERCENT AND ACCUMULATIVE EIGENVALUES
# PC Layer EigenValue Percent of EigenValues Accumulative of EigenValues
# SOIL 1.79028 38.6529 38.6529
# LANDUSE 1.50968 32.5945 71.2474
# TOPOGRAPHIC 0.74183 16.0164 87.2638
# SLOPE 0.42563 9.1896 96.4533
# FLOODED AREA 0.16427 3.5467 100.0000
#-----
    
```