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The Application of Geospatial Techniques in Flood Risk and Vulnerability Mapping for Disaster Management at Lokoja, Kogi State, Nigeria

Suleiman, Y. M, M. B Matazu, Davids, A. A and Mozie, Mabel Chioma
Laboratory of Remote Sensing and Meteorology
Department of Geography, Federal University of Technology, Minna, Nigeria.
Email: suleimanym2u@yahoo.co.uk

Abstract
A flood risk and vulnerability assessment of Lokoja town in Nigeria was investigated. The objective is to identify the risk lives and vulnerability level of the settlement to flood disasters. Geospatial techniques using remote sensing data and GIS was utilised in the analysis. Results indicate that the substantial part of the settlement falls within the high flood risk zone. The mapping identified three zones with respect to vulnerability level. Buildings within 30 meters buffer distance from the river banks and flood plains are classified as highly vulnerable, 50 meters buffer distance is moderately vulnerable and 70 meters above as safe zones. Building challenges, rainfall impact and water releases from hydropower dam were identified as major causes of floods in the study area. It is recommended that continuous inventorying of hydroclimatic variables at dam reservoirs be intensified and adherence to site selection for building should continuously be enforced to reduce the risk levels and safeguard the settlement from flood disasters.
Keywords: Flood Mapping, Vulnerability, Risk, Rainfall, Drainage Basin, Buffer Distance

1. Introduction

Floods are major disasters affecting many countries of the world annually, especially in most flood plain areas. Floods do not only damage properties and endanger the lives of human and animals but also produce other secondary effects like outbreak of diseases such as cholera and malaria as well. Flooding is commonly caused by heavy downpours of rains on flat ground, reservoir failure, volcano, melting of snow and or glaciers etc. Flood risk is not just based on history; but on a number of factors: rainfall, river flow and tidal-surge data, topography, flood control measures, and changes due to construction of building and development on flood plain areas.

Flooding is caused by several factors and is invariably preceded by heavy rainfall. The other causes of flooding are moderate to severe winds over water, unusual high tides, tsunamis due to undersea earthquakes, breaks or failures of dams, levees, retention ponds or lakes, or other infrastructure that retains surface water. Flooding can be aggravated by impervious surfaces or by other natural and man-made hazards which destroy soil, vegetation that can absorb rainfall.

Although flooding is a natural occurrence, man-made changes to the land can also be a factor. Development does not cause flooding but can make it worse. In cities and suburbs, pavement and rooftops prevent some rainfall from being absorbed by the soil. This can increase the amount of runoff flowing into low-lying areas or the storm drain system.

The town of Lokoja as a settlement on a river bank is not an exception. It has witnessed several devastating floods, occurring almost on an annual basis, in its recent history, especially from 1991, due to rapid and uncontrolled urbanization of the town (Mabel, 2014). The release of waters from Ladgo dam in Cameroon into the River Benue flood plain, and similar releases from Kainji, Jebba and Shiroro dam on the Niger river were largely responsible for the 2012 flooding in Nigeria, of which Lokoja, a confluence town of Rivers Niger and Benue was adversely affected.

The significance of the year 2012 flood disaster in Nigeria lies in the fact that they were unprecedented in the past forty years. Most parts of the central states of Nigeria and other adjoining states along the rivers Niger and Benue were devastated by these floods, causing huge destruction to the rural and urban infrastructures (farmlands/crops, roads, buildings, drainages, bridges, power lines, etc) and socio- economic lives of the areas.

Floods occur when the soil, stream channels and manmade reservoirs cannot absorb or contain all the water. A flood that occurs suddenly, with little or no prior signs, is called a flash flood and is due to intense rainfall over a relatively small area, it is inevitable, resulting from the natural rainfall-runoff process. It is a natural phenomenon and its magnitude is periodic. The periodicity of floods implies that every year some area surrounding the river (on both sides) is flooded. Every other period, (two, five, ten, fifty, one hundred and even a thousand years) is associated with increasing areas around the river which gets inundated.

Flood disaster management like other disasters management can be grouped into phases; the preparedness phase where activities such as prediction and risk zone identification or vulnerable mapping are taken up long before the event occurs, the prevention phase where activities such as forecasting, early warning, monitoring and preparation of contingency plans are made before or during the event, and the response and mitigation phase where activities are undertaken after the disaster and this includes damage assessment and relief management (Van Western *et al.*, 1993).

Mitigation of flood disaster can be successful only when detailed knowledge is obtained on the expected frequency, character, and magnitude of events in an area as well as the vulnerability of the people, buildings, infrastructures and economic activities in a potential dangerous area (Van Western and Hosfstee, 1993). However, Ifatimehin *et al.* (2009, Ifatimehin and Ufuah (2006) reported that this detailed knowledge is always lacking in most urban centers of the developing world especially Nigeria.

One way to mitigate the effects of flood is to ensure that all areas that are vulnerable are identified and adequate precautionary measures taken to ensure adequate preparedness, effective response, quick recovery and effective prevention. Before these could be done, information is required on important indices of flood risk identification which are elevation, slope orientation, proximity of built-up areas to drainages, network of drains, presence of buffers, extent of inundation, cultural practices as well as attitudes and perceptions (ICPR, 2002). To get information on most of these, and identify areas that are vulnerable to floods, reliable techniques of collecting and analyzing geospatial information are required. In this regard, an integrated approach of the knowledge of remote sensing and GIS can be used to investigate and map out areas that are less or more vulnerable to flooding.

The periodic flood events in the study area therefore necessitated the need for proper monitoring and evaluation of its causes of flood and solutions to the problems. The objective of this study is to apply Geospatial techniques in mapping flood risk and vulnerable areas of Lokoja town for disaster management.

2. The Study Area

Lokoja, the study area is located between latitude 7°45´27.56´N and 7°51´04.34´´N and longitude 6°41´55.64´E and 6°45´36.58´´E, with a total land area of 29,833km^2. It shares political boundaries with Niger, Kwara, Nassarawa States respectively and the Federal Capital Territory to the North; Benue State to the East; Adavi and Okehi Local Government Areas by the South and Kabba Bunu (LGA) by West (Wikipedia, 2012).

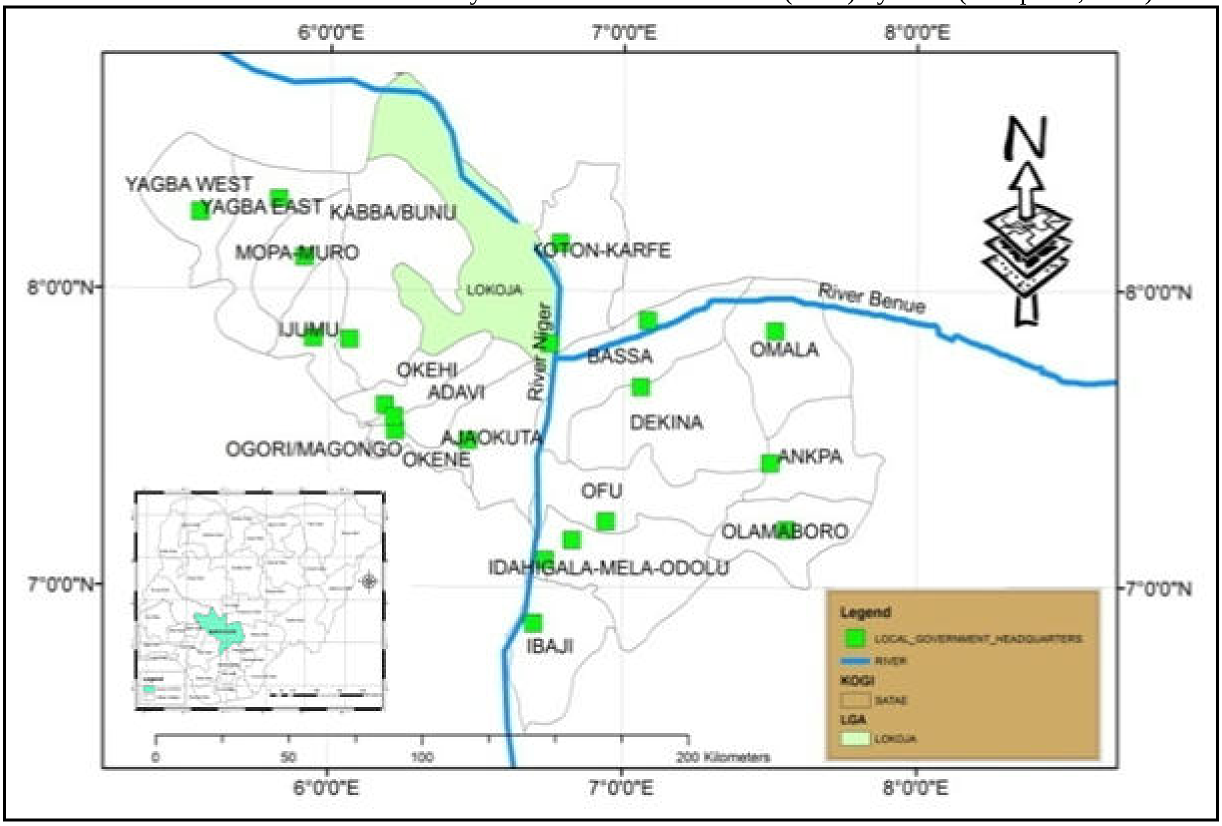

Figure 1: The Study Area Coverage (Lokoja) Kogi State, Nigeria

The annual rainfall in the area is between 1000 mm and 1500 mm with its mean annual temperature not falling below 27°C. The Onset of rains is March/April and Cessation is late October. The rest of the months; November to March is dry.

The general relief is undulating and characterized by high hills. The Niger-Benue trough is a Y-shaped lowland area which divides the sub-humid zone into three parts. The land rises from about 300 meters along the Niger - Benue Confluence, gradually reaching up to 600 meters above the sea level in the uplands. Lokoja is drained by Rivers Niger and Benue and their tributaries. It has been deeply dissected by erosion into tabular hills separated by river valleys. The flood plains of the Niger and Benue river valleys at Lokoja, is made up of hydromorphic soils which is a mixture of coarse alluvial and colloidal deposits. The alluvial soils along the valleys of the rivers are sandy, while the adjoining lateritic soils are deeply weathered and grey or reddish in colour. The soils are generally characterized by a sandy surface horizon overlying a weakly structured clay accumulation.

3. Materials and Methods

(a) The Secondary data which includes the Satellite imageries, Satellite Radar Topographic Mission (SRTM) data, Topographic maps, and Global Positioning Satellites (GPS) points collected were utilised for this study. Satellite images of Landsat Enhanced Thematic Mapper (ETM) + of 1st January 2006, by mosaicking of two scenes to obtain the Area of Interest (AOI) i.e. path 189 and row 54 &55 also Images of October 13, 2012, and October 20, 2008 of the study area captured by Moderate Resolution Imaging Spectrodiometer (MODIS) on Natural Aeronautic and Space Administration (NASA)'s Terra Satellite. The MODIS images comprise of visible and infrared channels to better distinguish between water and land. The Geodetic/Geographical data, the settlement and Road route map was extracted from the Administrative Map using Georeferencing and Digitization Procedures.

(b) Image Processing was carried out using the Earth Resource Data Analysis Software (ERDAS) 9.2 to mosaic the Landsat ETM+ Path 189 Row 54 and Row 55 respectively which was later stacked into band 4,3,2 False Colour combination as it best depict vegetation, water and land. The Arc GIS 10.1 was used to perform the Supervised Classification of the Study Area to determine the Land Use and Land Cover of the terrain before flood.

(c) The Arc hydro tools; an extension of the Environmental Systems Research Institute (ESRI) was used to preprocess the Digital Elevation Image of the Study Area by producing the agreed Digital Elevation Model (DEM) and other Operation as Sink and Flow Accumulation. Data Projection and Georeferencing. Images preprocessed in other software's were imported in the Arc GIS 10.1 software where the area of interest was extracted via the clipping process in the Arc tool box. The AOI raster and Vector feature of the Lokoja town were then re-projected to WGS 1984 Universal Transverse Mercator (UTM) Zone 32 N. Mercator (UTM) and Georeferenced.

(d) Field Data Integration. Geodetic data was collected and this was done to validate the flood extent obtained from the Satellite imagery of the Study Area. This was carried out to validate the flood extent as captured by the Satellite imageries. The point data was collected by a Garmin GPS - Map 76 Mark Receiver, Canon digital Camera, Printed Copies of Satellite imageries and Base Maps were used as the field tools to identify and delineate inundated areas.

(e) Spatial Analysis Techniques. The analysis of the inundated areas was conducted via query by location i.e. Proximity Analysis. This was done by selecting some of river channel, and shape files of the settlement to determine areas that were adversely affect by floods. The Buffering was categorized into various ranges along the basin at distances of 0 – 150 m, 150 – 250 m, 350 - above to represent the highly vulnerable, moderately vulnerable and safe-zone regions of the Study Area (Ojigi, 2013).

This operation was carried out in ArcGIS software by loading all features layer (Point, Line and polygon) that cover the flood Inundated region to determine the actual spatial coverage and extent of the flood. The zoning of flood vulnerable areas was categorized into three zones (highly vulnerable, moderately vulnerable and safe-zone regions). This zoning was based on the proximity of communities along the River basin as well the elevation of the terrain of the study area which was taken into consideration.

4. Results and Discussion

Table 1: Mean Monthly Rainfall and Evaporation Statistics of Lokoja

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Rainfall (mm)	0	4	332	86	115	213	190	317	298	123	9	0	**1427**
Evaporation (mm)	130	124	113	104	81	63	30	48	51	72	95	113	**1053**
Difference in Values	-130	-120	-81	-18	34	150	160	269	247	51	-86	-113	**374**

Source: Suleiman (2013)

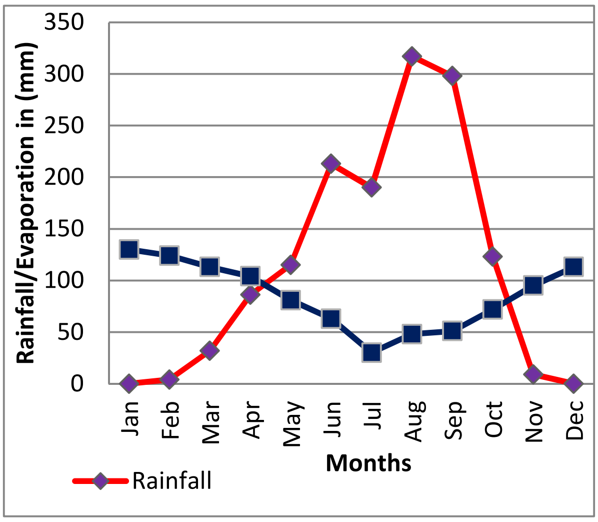

Figure 2: Monthly Moisture Distribution at Lokoja

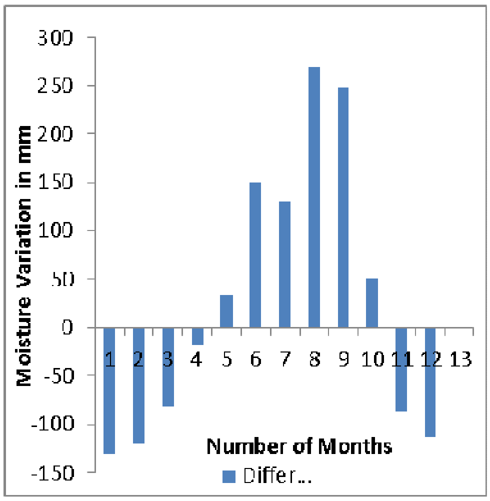

Figure 3: Variation in Rainfall Distribution at Lokoja

Table 1 and Figure 2 indicate that highest rainfall is normally recorded in the month of August/September. Correspondingly, evaporative losses are much lower between May and October and thus signifying moisture surplus.

Figure 3 illustrate the seasonal variation in the moisture availability over Lokoja. The months of November to April of any hydrological year also suffers moisture deficit. These are dry season months in the Study Area. About 6 months; May to October are also characterised by moisture surpluses corresponding with wet season period at Lokoja.

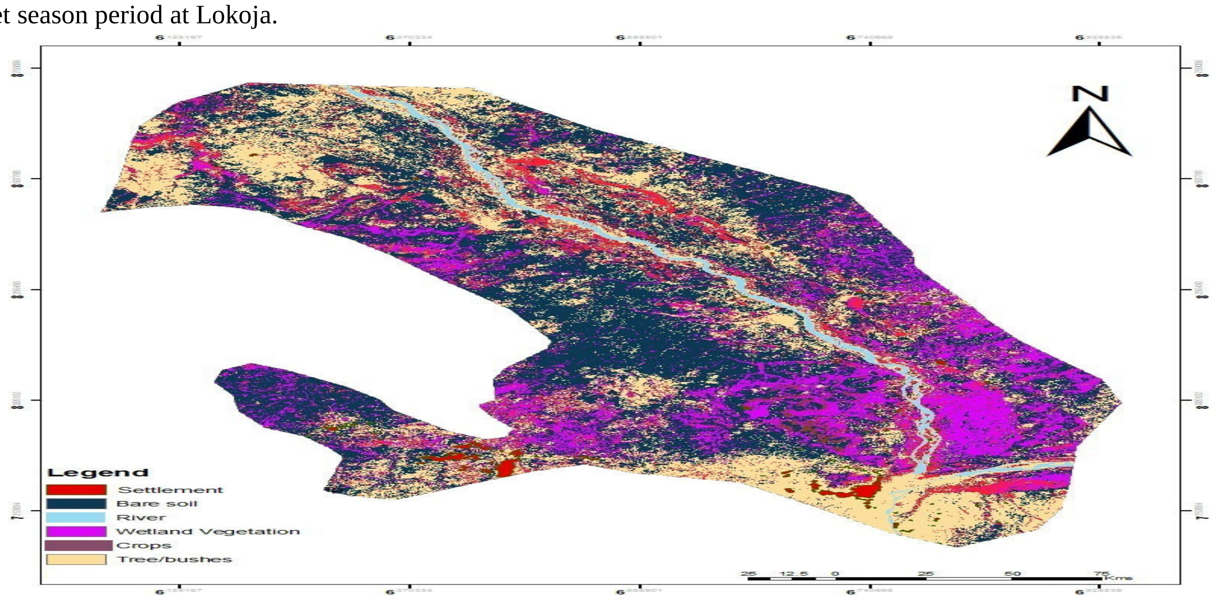

Figure 4: Classified Land use / Land cover of the Study Area

Figure 4 illustrates landuse / land cover classification of Lokoja and environs. Six major features were identified; namely Bare Soil, Settlement, Wetland Vegetation, Crops, and Forest/trees.

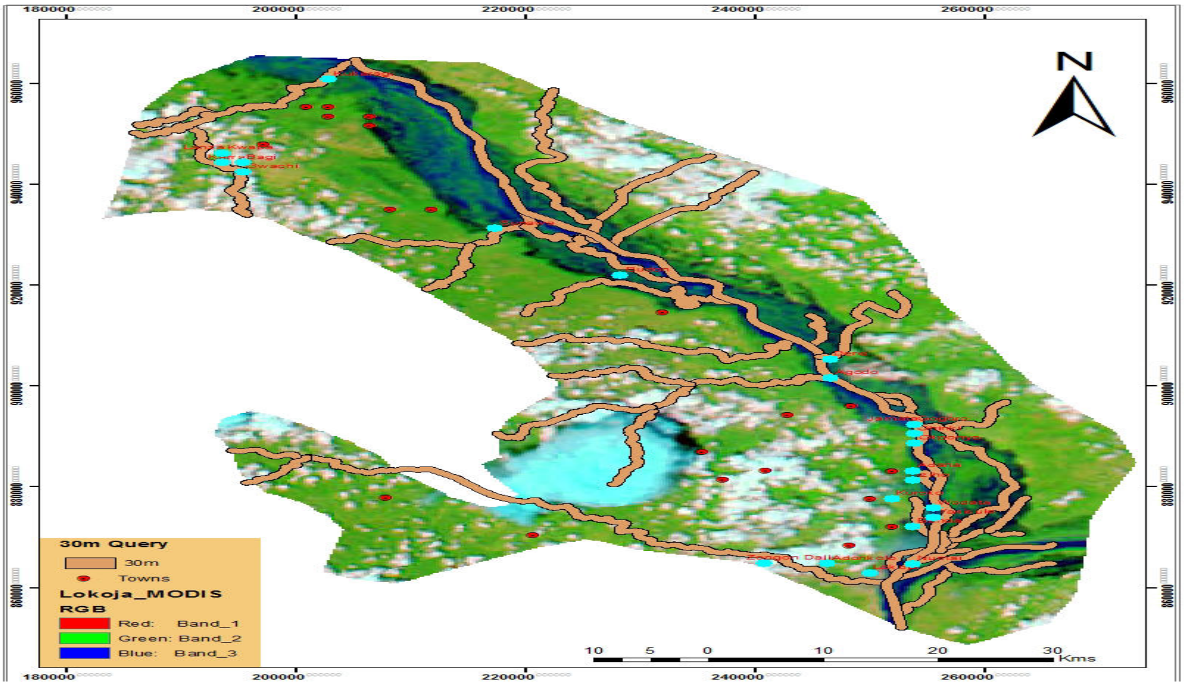

Figure 5: 30 Meter Buffer Distance along Drainage Lines

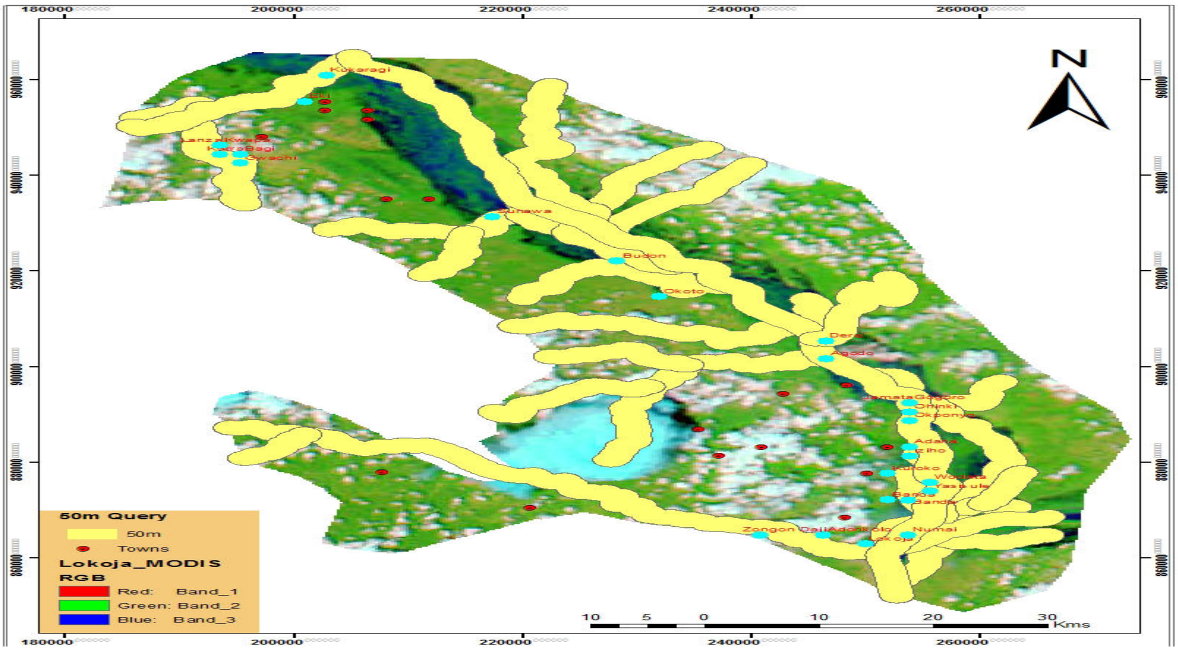

Figure 6: 50 Meter Buffer Distance along Drainage Lines

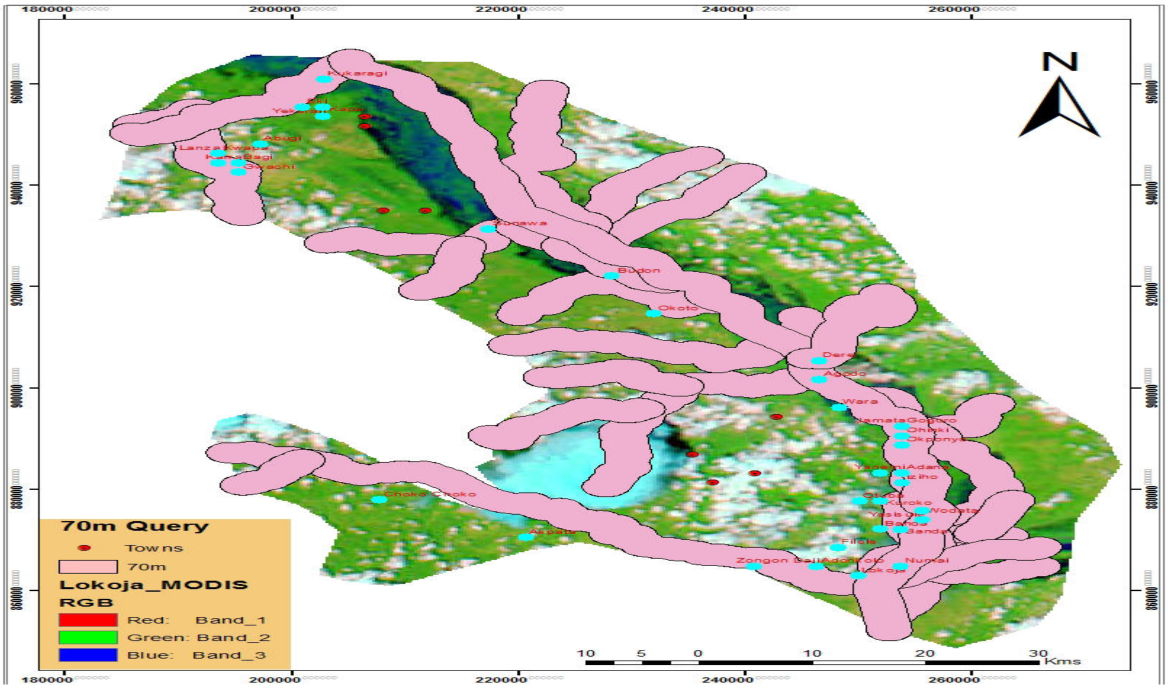

Figure 7: 70 Meter Buffer Distance along Drainage Lines

Figures 5, 6 and 7 shows a multiple ring buffer of the drainage basin in the following criteria 30 m, 50 and 70 m respectively. This was performed to determine flood risk extent in accordance with Space Standards for Urban Development and areas liable to flood along the river channel in the Study Area

Table 2: Buffer Distance and Number of Submerged Towns

Buffer Distance	Number of Submerged Households	% of the Total
30 m	24	27.27
50 m	27	30.68
70 m	37	42.05
Total	**88**	**100**

Table 2 indicates that that out of the 83 households, about 24 are highly vulnerable to flood at 30 meters, 27 are moderately vulnerable at 50 meters and 37 are less vulnerable at 70 meters.

Figure 8 is the Flood Vulnerability map and depicts key areas that are at risk of flood and those that are not. Three Zones are identifiable:

(a) Highly Vulnerable. These are areas closest to the Confluence of Rivers Niger and Benue and of low relief. This includes Sunawa, Dare, Wara and Filele.

(b) Moderately Vulnerable. These areas are far away from the river and have higher concentration of human population and economic activities. These areas include Gwachi and western side of Patti hill along Abuja-Lokoja road, and

(c) Safe Zones. These are areas on higher relief compared to the other zones. Places located in this class include Tajimi, Chokochoko, Akpata and areas around mount Patti.

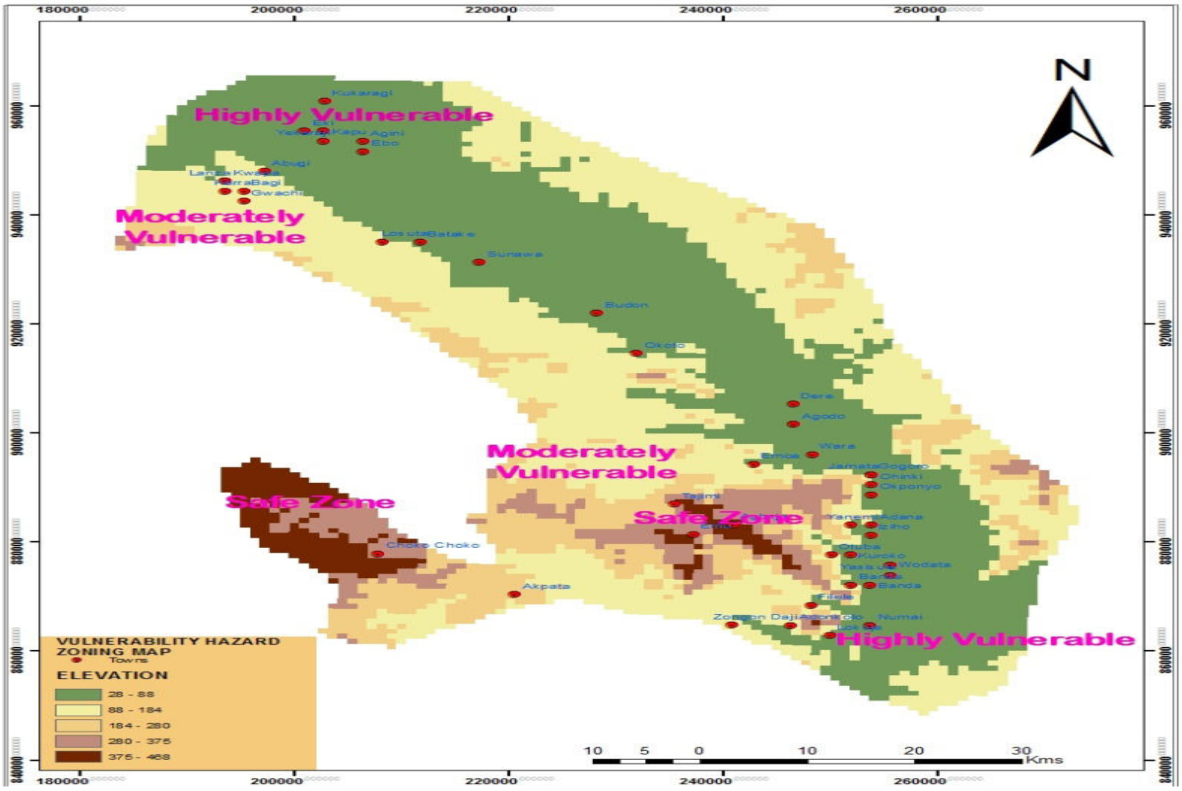

Figure 8: Flood Vulnerability Map of the Study Area

Table 3: Vulnerability Level of Locations within Lokoja

Vulnerability Level	Number of Locations	% of the Total
Highly Vulnerable	24	57.14
Moderately Vulnerable	14	33.33
Safe Zone	4	9.53
Total	**42**	**100**

The incidence of floods in the study area is caused by a combination of natural and human induced activities along the floodplains. Lokoja happens to be the confluence of the two largest rivers in Nigeria; Rivers Niger and Benue. The size and importance of these rivers coupled with increasingly growing human activities like building, dam construction, excavation of sand along the river bank increase the risk of flood disasters.

A buffering operation was carried out to assess the effect of floods and how far away from the river channel people could erect their buildings. The result indicates that at 30 meters from the river 24 households were inundated. At 50 meters m buffer, 27 households were susceptible and at 70 meters buffer from the river, 36 households are at risk. This signifies that houses should not be built less than 75 meters from the river banks. After this operation, the communities were then grouped using the standard flood risk zoning method. At the end we have highly vulnerable areas, moderately vulnerable and safe zones. From the analysis, those safe zones are areas of elevated landform; they are relatively high and can hardly be inundated by flood waters in case of excess discharge from the river drainage. The safe areas are recommended for people to live to avoid the risk of flood disaster.

5. Conclusion and Recommendations

The DEM generated and the image drape shows that Lokoja town is not only a river side settlement but also a hill side settlement. It is a fast growing settlement owing to its status as the administrative and commercial nerve centre of Kogi State, Nigeria. It is also the 'gateway' settlement to the highly populated southeast and southwest Nigeria and as such serve as both a resort and stop over settlement for most travelers and business people. This is resulting in increased physical planning problems as buildings are constructed on every available space including the marginal flood plains and river banks. This results in the blockage of river channels and drainage lines; and investigation of surface runoff leading to floods. Coupled with urban development problems is the variability of climate resulting in the increased rainfall and inflow into the hydropower dam reservoirs. This, most often is beyond the capacity of these dams to cope with excess water in their reservoirs. To save the dam structures from collapse, massive water releases are made with devastating flood consequences to the downstream environment. Lokoja being at downstream settlements is therefore at high risk of floods. Careful appraisal of the flood events and the affected environment using Geospatial techniques becomes expedient for effective flood disaster management.

It is therefore recommended that on going dredging of the Niger River at Lokoja being intensified to pave way for free flow of water, strict adherence to urban development laws and procedures particularly in the choice of sites be enforced and there should be continuous monitoring of the hydroclimatic variables at the hydropower dam reservoirs to issue early warnings and safeguard downstream environments from devastating extreme weather events like floods.

REFERENCES

ICPR (2002). Non-structural Flood Plain Management: Measures and Their Effectiveness. *Koblenz: International Commission for the Protection of the Rhine (ICPR).*

Ifatimehin and Ufuah, M.E. (2006). Analysis of Urban Expansion and Loss of Vegetation in Lokoja using GIS Techniques. *Zaria Geographers, 17(1): 28-36.*

Ifatimehin, O.O., Musa, S.D. and Adeyemi, J.O. (2009). An Analysis of the Changing Land Use and Its Impact on the Environment, Anyingba Town, Nigeria. *Journal of Sustainable Development in Africa 10 (4): 357-364.*

Mozie, M.C. (2014). Flood Risk and Vulnerability Mapping of Lokoja, Nigeria. Unpublished B.Tech. Project, Department of Geography, Federal University of Technology, Minna.

Ojigi, M.L., Emmanuel, E. Achema and Alade, T.A. (2012). Geospatial Analysis of Landslide Vulnerability in Kuje and Environs, Abuja, Nigeria, 2012.

Suleiman, Y.M. (2013): Impact of Climate on Hydropower Generation in the Lower Niger River Basin, Nigeria. Unpublished Ph.D. Thesis, Department of Geography and Environmental Management, University of Ilorin, Nigeria.

Van Western, C.J.I., Van Duren, H.M.G. Kruse, and M.T.J. Terlien (1993). GIZZIS: Training Package for Geographic Information Systems in Slope Instability Zonation. International Institute for Aerospace Survey and Earth Science (ITC), 15 (1): 245 pp. Enschede, The Netherlands.