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## Multi-Criteria Evaluation for Flood Suitability Areas of Lokoja Metropolis of Kogi State Nigeria Using Geospatial Techniques

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### **Abstract:**

*Flooding is one of the most common and devastating natural disasters in the world. It has claimed many lives and property worth lots of money. Flood has rendered millions of people homeless and has also threatened the ecological biodiversity. The aim of this study is to utilize geospatial techniques in mapping areas which are suitable for safety in the flood zone areas of Lokoja metropolis. Mapping of areas suitable to prevent flood zones is fundamental in flood risk management as it identifies locations which are suitable for effective management and planning. Multi – criteria process which involves the combination of independent parameter inputs such as distance from river, elevation, land use, slope and soil were considered for analyses. Different maps such as the slope map, elevation map, and soil map were produced using ArcGIS 10.5 software. The result of the study shows areas of more suitable and less suitable areas for residents to reside within Lokoja metropolis. The study further shows that geospatial techniques can be effectively utilized in mitigating and monitoring the effect of flooding in Nigeria's confluence town. Owing to this, it is recommended that artificial levee and drainage system should be constructed along areas vulnerable to flooding. Water bodies should also be dredged as a preventive and remedial measure in the study area.*

**Keywords:** *Flooding, geospatial mapping, Lokoja, multi – criteria evaluation, vulnerability*

### **1. Introduction**

Flooding is one of the world's most frequent and widespread environmental hazards and of various types and magnitude (Sanyal, 2004). It has caused great damage and disruption to economic livelihood, businesses, infrastructure, services and public health (Ikhuria et al 2012). Nwafor (2006) defined flooding as a natural hazard which occurs as an extreme hydrological (runoff) event. European Commission (2007) defined flood as a natural phenomenon which results in the temporary submerging with water of a land that does not occur under normal conditions. Flooding is the accumulation of excess water which rises to overflow the land which is not normally submerged (Mukhopadhyay, 2010). This include overflow from water bodies such as rivers, lake, sea as well as overflow from heavy rainfall, snow melt and dam break, in which water escape out of its natural boundaries (Leinster, 2009). Flooding is rated as one of the most devastating natural hazards, which leads to significant economic and social damages than any other natural phenomenon (Disaster Management Support Group, DMSG, 2001). According to Mohammed (2018), flood is a hazard that result from extreme meteorological events such as heavy rainfall, causing rivers and oceans to overflow their banks and can have far – reaching effects on the people and the environment. It can also be caused by conventional or frontal storms whereby a lot of rainfall is experienced in a short duration of time. Ahmed et al (2011), stated that intensity and duration of rainfall are the most influencing factors for flood hazard. Globally, several flood cases have been documented. In India, one hundred and twenty five people have been recorded to be killed owing to flood and over 12 million others were displaced in 2007 Flood disaster that hit Bihar, Uttar Pradesh and Assam province (Isa et al 2015). Cinque et al (2003) stated that flood is a hazard that can be avoided, minimized by building more dams or by constructing more flood defence systems or by utilizing modern technologies and appropriate urban planning in flood risk area.

In Nigeria, flooding has caused significant harm to livelihood and properties worth millions of Naira. It occurs sequel to extensive rainfall, drainage blockages and dam failures (Jeb and Aggarwal, 2008). Flood is a common feature in Nigeria, especially during the urban flooding which occurs in towns, on flat or low – lying terrain where little or no provision has been made for surface drainage or where the existing drainage has been blocked with refuse, eroded soil sediments and municipal waste (Folorunsho and Awosika, 2001). Flooding in Nigeria is dated back to 1960 in Ibadan city, when Ogunpa river over-flew its banks, causing a considerable damage to lives and properties (Adegbola and Jolayemi 2012; Agbola et al, 2012). Since then, the occurrence of floods has spread nationwide. In 2012, the national Emergency Management Agency (NEMA) recorded that about 1.3 million Nigerians have been displaced owing to flood and 431 died

from various flood occurrences. In the same year, about 30 Nigerian states were affected by flood (IRIN 2012). Some of the states which were badly affected by the flood include Kano, Niger, Jigawa, Kaduna, Adamawa, Benue, Kogi and some southern parts of Nigeria (Adeoye, Ayanlade, Babatimehim, 2009). In Nigeria, Kogi state is the most affected state, owing to its location at the confluence of the country's major rivers (River Niger and Benue). The state had experienced a serious flood disaster in 2012 and 2018, which destroyed thousands of hectares of farmlands, livestock and loss of aquatic animals. The Kogi state flooding came owing to water release from Ladgo dam in Cameroon into river Benue; Shiroro and Kanji dam also release water into river Niger as well as climate change (NEMA, 2018). Several scientific studies have suggested that climate change is most likely to cause shifts in the global pattern and intensity of flood events in many areas, which increases the exposure of populations to severe flooding and that the impact of future changes in the climate extremes are expected to fall disproportionately.

Remote sensing and GIS techniques can be effectively utilized in mapping the spatial component of flood for management. It offers a synoptic view of the spatial distribution and dynamic of hydrological phenomena which includes flood. Remote sensing and GIS are used to measure, monitor and map out the extent of flood affected areas, as well as provide a quantifiable estimate of the land area and infrastructure which is affected by flood (Izinyonet al, 2011). While Remote Sensing has become important in providing reliable and timely information on environmental issues such as flood monitoring, GIS is utilized in producing interactive map overlays which quickly illustrate areas, which are in danger of flooding (Awal, 2003). Nigeria has been slow to realize the potential of remote sensing and GIS in mapping areas associated with flooding. This fact has been confirmed owing to the response to the recent flood disasters which have affected more than 23 states in the country, which had claimed several lives and properties worth a lot of money and which also threatened the ecological biodiversity.



*Figure 1: Situation Due to 2018 Flooding in Lokoja  
(Source: [www.kogiflood.worldpress.com/](http://www.kogiflood.worldpress.com/), 2018)*

## 2. Study Area

### 2.1. Location and Extent

Lokoja is a medium sized urban area in the central part of Nigeria. It is the administrative and the commercial capital of Kogi state and the Kogi Local Government Area. The study area, Lokoja is located between latitude  $7^{\circ}45'27.56''N$  and  $7^{\circ}51'04.34''N$  of the equator and longitudes  $6^{\circ}41'55.64''$  and  $6^{\circ}45'36.58''E$  of the Greenwich Meridian (Adeoye, 2012). It is located at the confluence of the Niger River and the Benue River in Central Nigeria and at altitudes between 45 – 125 meters above sea level; which is towards the North – South and the foot of the Patti Ridge, which reaches its altitude of 400 meters above sea level. Lokoja in Kogi State shares boundary with Niger, Kwara, Nassarawa and the Federal capital Territory to the North. To the East, it is bounded by the Benue State, to the South by Adavi and Okehi LGAs respectively and to the west by Kabba LGA. The study area is well accessible through state and federal highways which are interconnected with each other. It is also well connected by water transport and is the gate way and transit point between the North, East, West and the Southern part of Nigeria.

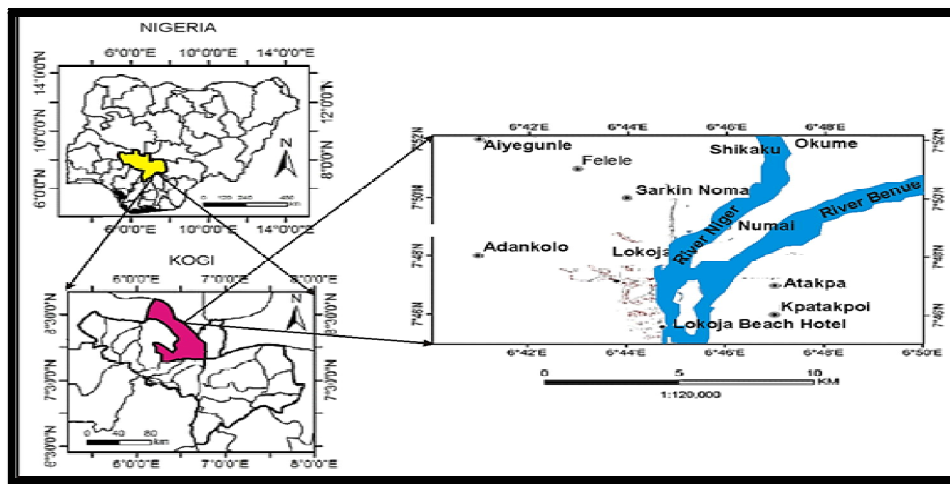


Figure 2: Location and Extent Map of Lokoja  
Source: Author, 2018 Map of Lokoja

## 2.2. Climate, Vegetation and Soil

The climate in the study area is that of the tropical hinterland of Nigeria (Iweana, 2012). Lokoja is characterized by two seasons: The rainy season and the dry season. The rainy season last from April to October, while the dry season last from November to March. The annual rainfall in the study area is between 1016mm and 1524mm with a mean annual temperature of about 26°C during the raining season and 35°C during the dry season. The relative humidity in the study area ranges from 55 – 65% during the dry season and from 70 – 80% during the raining season (Iloje, 1980). The vegetation of the study area is classified as Guinea Savanna of Nigeria. It is characterized by tall grasses and scattered short deciduous trees. The vegetation is green in the rainy season with fresh leaves and dry during the dry season. The beginning of the raining season marks the beginning of the growth of grasses in the area. Within the study area, the flood plains of the Niger and Benue river valleys have hydromorphic soils which contain a mixture of coarse alluvial and colluvial deposits. The alluvial soils, which is along the valleys of the rivers are basically sandy while the adjoining laterite soils are weathered and reddish, sticky and permeable. Generally, the soils are characterized by a sandy surface horizon overlying a clay accumulation.

## 2.3. Topography and Geology

The topography of Lokoja is fairly flat for most part of the area. The area slopes most from the mountain area towards the River Niger, while flat – topped hills are also common in most part of the study area (Ojo, 1995). Within the study area, the most striking relief feature is the Mount Patti, which has an altitude of about 1,500m above the sea level with a flat top, which is almost half of the size of Lokoja area. Several intermittent valleys exist, of which most of them have streams which criss – cross the breadth of the area. Within the study area, the basement complex rock is the major geological grouping which exist. This formation consists of fine to medium – grained sand stone, clays, carbonaceous silts and colitic iron stones (Ojo, 1995).

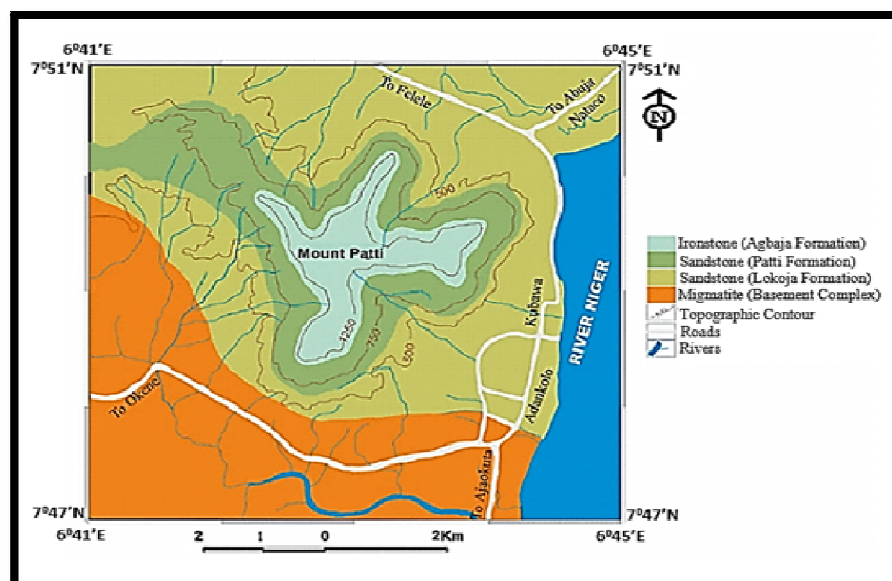


Figure 3: Geological Map of Lokoja (Modified from Federal Surveys of Nigeria, 1963, Sheets 141 Lokoja NW, NE)

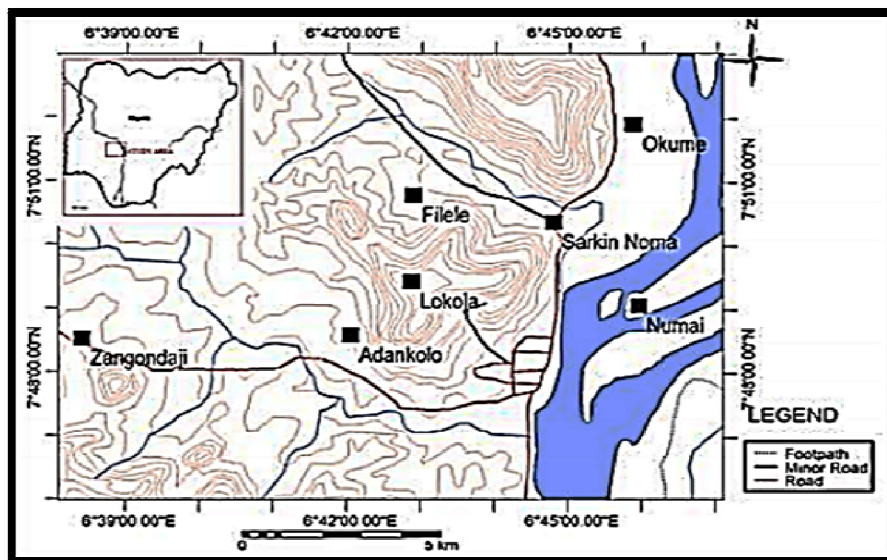


Figure 4: Topographic Map of Lokoja  
Source: Topographic Map of Nigeria, Lokoja Sheet 62 (1967)

### 3. Materials and Methods

This section is concerned with the type of data utilized in the study, the source of the data and the methods of collection, the devices used during the data collection, procedures used for the analysis; the criteria used in the analysis so as to achieve a conclusion.

#### 3.1. Data Sources and Data Acquisition

The data utilized for this study were obtained from both the primary and secondary sources (see table 1). The primary sources involved the use of the GPS receiver to obtain the coordinates of the communities affected with flood in the study area. Photographs were also obtained with the use of the digital camera. The secondary data used are as follows:

- Landsat 8 OTI/LIRS with spatial resolution of 30m was obtained from United States Geological Survey at path and row of 189/55. This was utilized to generate the land use and Land cover map of the study area.
- ASTER DEM acquired from Global Land Cover Facility was used in generating the slope map, elevation map and drainage map of the study area.
- Soil map was sourced from Kogi State Ministry of Agriculture, and was used in obtaining the soil information of the study area.
- Rainfall data was sourced from Nigeria Meteorological Agency (NIMET), Kogi State. This was utilized in generating the rainfall distribution pattern within the study area;
- Google Earth image was sourced from the Google Earth, 2018.

Data	Data Source	Data Source types	Year acquired
Landsat 8 OTI/LIRS	USGS	Secondary	2018
ASTER DEM	GLCF	Secondary	2018
Soil Map	Ministry of Agriculture, Kogi State.	Secondary	2018
Pictures	Field Work	Primary	2018
GPS - Coordinates	Field Work	Primary	2018
Rainfall Data	NIMET	Secondary	2017
Google Earth Image	Google Earth	Secondary	2018
Water bodies	NASRDA	Secondary	2017

Table 1: Data Sources and Data Acquisition

#### 3.2. Field Work and Ground Truthing

In the study, field work was carried out to validate the extent of flood as captured by the satellite imageries and to identify other areas inundated by the flood. The GPS receiver, Sony digital camera, printed copies of the satellite imageries and the base map were utilized as the field tools to delineate inundated areas. The means of transport was by road. The GPS coordinates and photographs of affected communities were acquired and plotted on the maps for emergency management. A survey of the affected communities in the flood disaster was carried out during the field work.

#### 3.3. Terrain Analysis of the Study Area

Knowledge of the terrain helps the researchers to have a good interpretation of the direction of the flowing water, as water flows by gravity naturally. The Digital Elevation Model (DEM), was utilized where all the sink were filled for the



creation of the flow direction grid model. The flow accumulation grid of surface water was created using the flow direction grid model in the ArcGIS 10.5 software.

### 3.4. Processing of the Data

This study was conducted based on Multi – Criteria Evaluation method. The zonation was carried out by using parameter inputs such as distance from river, elevation, land use, slope and soil were utilized for analyses.

#### 3.4.1. Proximity to River

River overflow is important in the initiation of a flood event. The inundation emanates from the river and expands into surrounding areas. Flood susceptibility is highest in areas by river banks and decreases as the distance increases, thus emphasizing the importance of distance from river risk assessment. Flood susceptibility is highest in places close to the river banks and decreases as the distance increases, thus emphasizing the importance of distance from the river in flood assessment.

#### 3.4.2. Generation of Drainage Density

The distance to drainage is considered an important factor in flood modelling. Thus, regions close to drainage is more prone to flooding than areas further away from drainage. The drainage density of the study area was produced from ASTER DEM by utilizing the spatial analysis tool on ArcGIS 10.5 software.

#### 3.4.3. Generation of Soil Map

Soil is important as they control the amount of water which infiltrate into the soil, and hence the amount of water which becomes flow. The structure and infiltration capacity of soils also have an important impact on the efficiency of the soil to act as sponge and soak up water. The chance of flood increases with decrease in soil infiltration capacity which causes increase in surface run – off. In the study, the soil map of Nigeria was scanned and imported into ArcGIS environment, where it is geo-referenced using UTM Zone 32 North with datum 1984. The study area “Lokoja” was subset from the soil map of Nigeria and the soil types were digitized.

#### 3.4.4. Generation of Land-Use/Land Cover Map

The land use/land cover map was extracted from Landsat 8 OLI satellite image covering the study area. The satellite image was geo-referenced using the Universal Traverse Mercator (UTM) Zone 32 North with datum WGS 1984. The maximum likelihood algorithm of supervised classification was adopted using ERDAS IMAGINE 9.5 and later analyzed using Arc Map spatial analyst tools to classify the Land-use/Land cover of the study area into suitable and not suitable zones for flooding in Lokoja. The Land-use/Land cover map was checked by field visit using the GPS.

#### 3.4.5. Generation of Rainfall Map

Heavy rainfalls are one of the major causes of flooding. Heavy rainfall increases the amount of discharge from rivers and cause overflowing as compared to little rainfall. In the study, the rainfall intensity map was prepared by using the Inverse Distance Weighted (IDW) method in ArcGIS spatial analyst tools and which was based on the NIMET data of 2018.

#### 3.4.6. Generation of Slope and Elevation maps

Elevation is important in the spread of flooding. This is so said, because, water flows from the higher to the lower elevations and where other factors that gear flooding are to be involved, the chances of flooding would still be slim where the elevation is high enough. Elevation also influences the intensity of the run – off and low elevations are more susceptible to flooding. The slope parameter is another independent parameter that can accelerate run – off. Areas with less steep slopes flood quicker than areas with steeper slopes, and which are features of high elevated areas. In the study, the elevation layer was created from the DEM using the Inverse Distance Weighting (IDW) interpolation tool in ArcMap and the slope layer was produced using the slope 3D analyst tool in ArcMap. Owing to the undulating nature of the area, the slope gradient varies.

#### 3.4.7. Weighted Overlay Analysis

The weighted overlay analysis determines its role in the final map. Here, the suitability parameters (Land use/Land cover, Elevation, Slope and proximity to infrastructure) are compared against each other, weighted and overlaid.

## **4. Results**

This section expounds the results of the parameters which is examined for flood vulnerability area and suitability within Lokoja area.

### *4.1. Flood Plain Vulnerability*

#### 4.1.1. Based on Elevation

In the study, the area was calculated by utilizing the spatial analyst tool of ArcGIS 10.5. Thus, the study shows that areas less than 150m above the mean sea level which represent 53.32% of the study area, are not suitable for residents,

indicating that they are prone to flooding with the remaining 46.68% area are suitable for residents and are not liable to flooding (see figure 5).

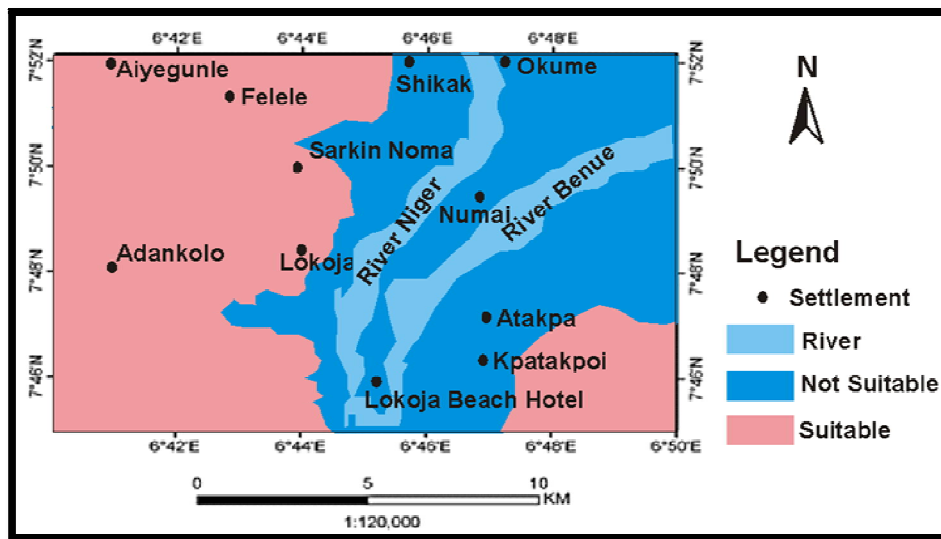


Figure 5: Areas within Lokoja Vulnerable to Flooding Based on Elevation

Flood Plain based on Elevation	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	154.84	53.32
Suitable	135.56	46.68
Total	290.40	100

Table 2: Flood Plain Based on Elevation

4.1.2.Flood Plain Based on Nearest to River Body

The study shows that areas within 23.17% of the study area, are not suitable for residents, indicating that the areas are prone to flood with 76.83% suitable and are not liable to flooding (see figure 6). In the study, Flood plain based map (nearest to River body) was calculated by utilizing the spatial analyst tool of ArcGIS 10.5. Figure 6 shows the flood plain with Lokoja, which is based on its proximity/nearest to the river channel.

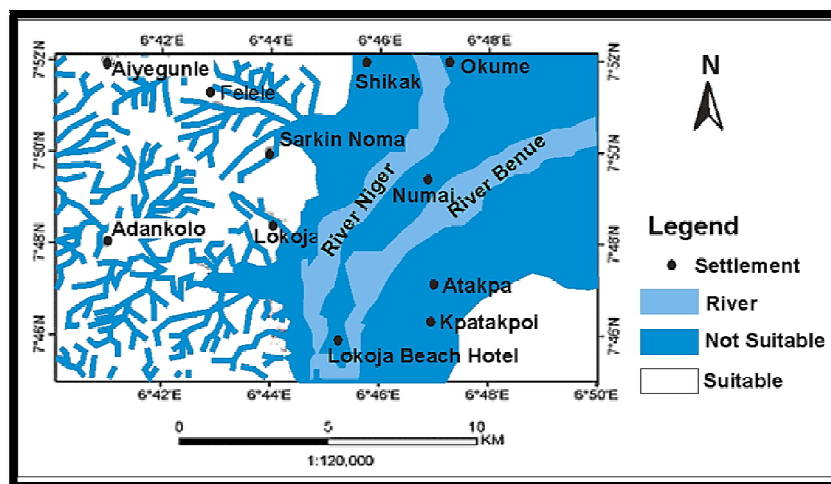


Figure 6: Flood Plain Based on Nearest to River Body

Flood Plain Based on Proximity to River Channel	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	67.29	23.17
Suitable	223.11	76.83
Total	290.40	100

Table 3: Flood Plain Based on Proximity to River Channel

Within the study area, some buildings are vulnerable to flooding, while others are not. Out of a total of 2505 building that was digitized, based on 80m buffer around the streams for settlement, 807 buildings are vulnerable to flood while 1698 are not vulnerable.

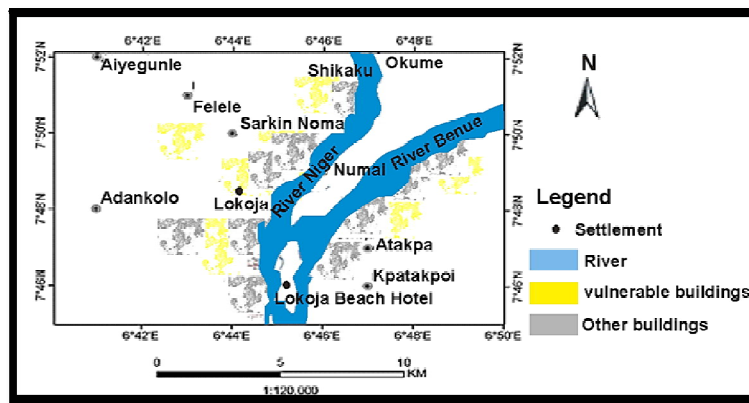


Figure 7: Buildings Vulnerable to Flooding within Lokoja

4.2. Biophysical Suitability of Lokoja for Re-Settlement

Within the study area, the analysis for land –use and land – cover suitability area (forest, rock outcrop) reveals that 70.05% of the area is suitable while the Not suitable areas (water body, built – up and wet – land) within the study area and representing 29.95% are not suitable.

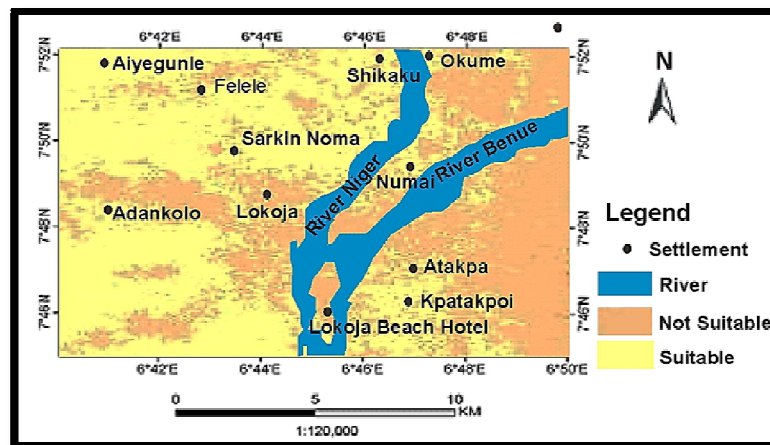


Figure 8: Land Use and Land Cover Suitability Map

LULC Suitability	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	86.97	29.95
Suitable	203.43	70.05
Total	290.40	100

Table 4: Land – Use and Land – Cover Suitability

4.3. Topography Suitability

4.3.1. Elevation

Results from the elevation suitability reveals that 91.10% of Lokoja and which is less than 500m above the mean sea level is suitable for human settlement, as majority of the study lies on lowland while 8.9% are of the area not suitable.

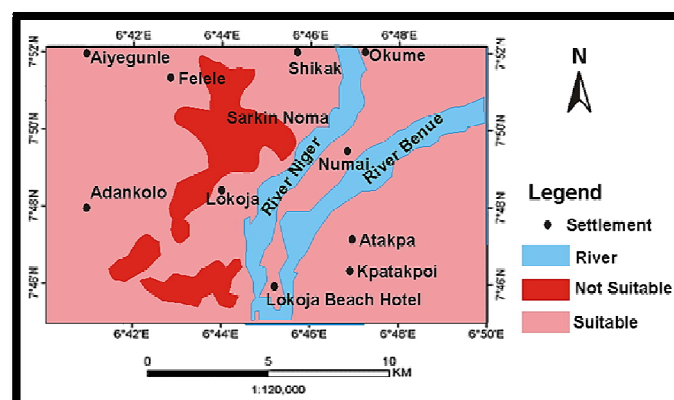


Figure 9: Topography Suitability Based on Elevation

Elevation Suitability	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	25.85	8.9
Suitable	264.55	91.10
Total	290.40	100

Table 5: Elevation Suitability

4.3.2. Nearest to Infrastructure (Roads and Streams)

Within the study area, 59.23% of the area is accessible by the major roads and streams within 2.5km while 40.77% of the area is not within 2.5km from the major roads and streams.

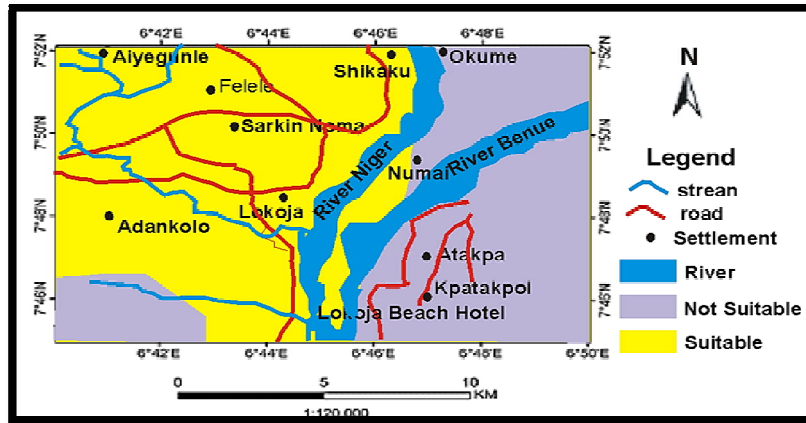


Figure 10: Topography Suitability based on Nearest to Infrastructure

Infrastructure Suitability	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	67.29	23.17
Suitable	223.11	76.83
<b>Total</b>	<b>290.40</b>	<b>100</b>

Table 6: Area Nearest to Infrastructure (Roads and Streams)

4.3.3. Slope

Analysis from the study reveals that slope suitability indicates that 84.42% of Lokoja is suitable, indicating that the study area has low land while 15.58% of the area is not suitable.

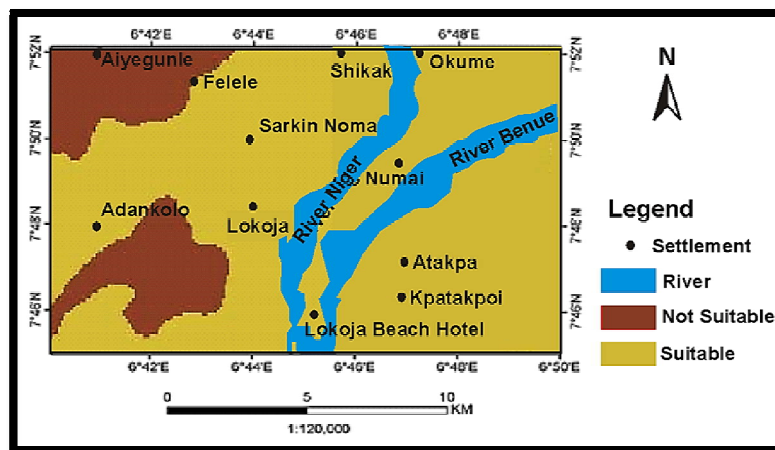


Figure 11: Topography Suitability Based on Slope

Slope Suitability	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	45.24	15.58
Suitable	245.16	84.42
Total	290.40	100

Table 7: Suitability Based on Slope

4.4. Weighted Overlay Analysis

From the study, it is observed that the land cover suitability factor was assigned 35.26%, 28.96% is flood plain delineation owing to elevation. Slope was 18.11%, infrastructure is 14.11% and elevation was 3.56%. Land cover suitability and flood plain elevation were the most important parameters. Thus, the results of the overall weighted overlay



of the suitability parameters (figures 9, 10 and 11) shows that 81.23% is not suitable for settlement while 18.77% is suitable for settlement.

Settlement suitability	Area (Km <sup>2</sup> )	Percentage (%)
Not Suitable	86.97	81.23
Suitable	203.43	18.77
<i>Total</i>	<i>290.40</i>	<i>100</i>

Table 8: Settlement Suitability

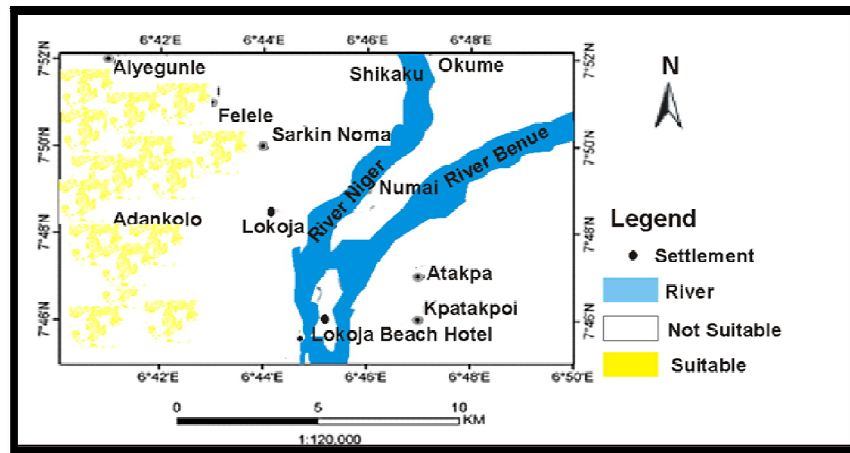


Figure 12: Overall Weighted Suitability Map for Settlement

## 5. Conclusion and Recommendations

### 5.1. Conclusion

In this study, Geospatial techniques was adopted to show areas more highly suitable and less suitable for flooding in Lokoja. Multi – criteria analysis for flood suitability in Lokoja Metropolis was carried out in a GIS environment. In the multi – criteria analysis, Weighted Linear Combination which involved the ranking of each contribution factor was utilized. The datasets for this study are those whose spatial references can be determined. These datasets were satellite imagery, soil map and metrological data. The study concluded by proffering a number of recommendations to address the issues of flooding in the study area.

### 5.2. Summary of Findings

Findings from the study, shows that:

- Within the study area, zones less than 150m above the mean sea level which represent 53.32% of the study area, are not suitable for residents, since they are prone to flooding while 46.68% area are suitable for residents.
- Areas within 23.17% of Lokoja are not suitable for residents owing to flood while 76.83% are safe for residents, suitable and are not liable to flooding.
- Out of a total of 2505 buildings that was digitized, and within 80m buffer around the streams for settlement, 807 buildings are vulnerable to flood while 1698 are not vulnerable.
- Within the study area, the analysis for land –use and land – cover suitability area (forest, rock outcrop) reveals that 70.05% of the area is suitable for residents while the 29.95% land use/land cover (water body, built – up and wet – land) are not suitable.
- The elevation suitability reveals that 91.10% of Lokoja and which is less than 500m above the mean sea level is suitable for human settlement while 8.9% are of the area not suitable.
- Within the study area, 59.23% of the area is accessible by the major roads and streams within 2.5km while 40.77% of the area is not within 2.5km from the major roads and streams.
- Slope suitability is 84.42% which indicates that the study area has low land while 15.58% of the area is not suitable.

### 5.3. Recommendations

Based on the findings from the study, the following recommendations are made:

- There is need for an improved land use planning within the study area
- Residents are advised to avoid indiscriminate dumping of refuse within flood zones, as this could result to flood disaster;
- Levee should be erected along areas prone to flooding in the study area
- Drainage systems should be established and existing ones widened in some areas prone to flooding.
- Buildings should not be erected along the flood plain zones

- Dredging should be done on the surrounding water bodies to deepen their depth
- The Kogi State Waste Management Board should ensure active regular collection of waste so as to avoid dumping of waste into the available drainage systems;
- Afforestation should be encourage in areas prone to flooding

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