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Spatial Assessment of Flood Vulnerability in Anambra East Local Government Area, Nigeria Using GIS and Remote Sensing

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ODVU and OCE designed the study, performed the statistical analysis and wrote the protocol. Author ODVU wrote the first draft of the manuscript. Author LS managed the analyses of the study. Author OCE managed the literature searches. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

This study aimed at spatial assessment of flood vulnerability in Anambra East and environs. In carrying out this work, Remote Sensing (RS) and Geographic Information System (GIS) were employed. Data from Google image and Shuttle Radar Topography Mission (SRTM) of 2012 was used. ArcGIS 10.1 and other GIS softwares were employed in image processing. The procedure consists of mapping of flood prone area and modeling of digital elevation. Analysis of land use and land cover indicated that agricultural land used or farmland was highest (41.7%), followed by forest 27.26% and built up area 22.75%. Flood vulnerability assessment showed that 71% of the study area was liable to flooding. This calls for immediate interventions and initiatives to discourage inhabitants from occupying the flood prone areas, relocate and avoid liable areas particularly river banks. In this regard land use planning should be followed appropriately and where necessary.

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Keywords: Flood; GIS; vulnerability; topography; land use planning.

1. INTRODUCTION

Various definitions have been given to flood. This includes abnormally high stream flow that overtops the natural or artificial banks of a stream [1] too much water in the wrong place [2], a natural hazard which occurs as an extreme hydrological event [3] and the flow of water above the carrying capacity of the channel [4]. Generally, floods happen on flat or low lying areas with hydraulically smooth or saturated surfaces [5]. Floods are environmental hazards caused by both natural and anthropogenic factors [6], although it is generally accepted that rainfall is the dominant cause of flooding worldwide [7]. The effects of floods are wide, and are particularly serious in developing countries where the prevailing coping strategy is resilience [8,3]. These include environmental and socio economic effects [9,10,11,12,13] Floods can be quite beneficial. Actually, nature benefits are more from natural floods than from not having them at all. What makes natural floods a disaster is when flood waters occur in area populated by humans and in areas of significant human development. Otherwise, when left in its natural state, the benefits of floods outweigh the adverse effects [14].

The major approach to flood mitigation has been the structural approach. Non structural mitigation strategies such as land use planning, forecast and the application of Geographic Information System (GIS) and Remote Sensing are however crucial and are gaining attention [15]. In Nigeria and elsewhere, GIS and remote sensing techniques have been applied in the assessment of flood vulnerability and risks. Advancements in RS and GIS and computer applications are very useful in flood management particularly in the mapping of flood risk areas [16]. In recent time, vulnerability assessment has been done using GIS and remote sensing in addition to socio economic surveys [17]. Vulnerability has environmental and socioeconomic dimensions [18,19] implies liability to suffer loss and increases with decreasing ability to cope with, resist, and recover from or adapt to imposed stress factors such as flood disasters [20,21].

Flooding is one of the most serious environmental problems in Anambra state, It is also one of the most devastating environmental hazards in the state, claiming more lives and causing damages to property and infrastructure more than any other natural phenomena [22]. This is especially so as over 30 percent of the inhabitants of the area live in the riverine communities including the study area [23]. The floods of 2012 inundated over 70% of the study area flooded, turning inhabitants into refugees and depriving them of their sources of livelihood. Other problems resulting from flooding in the area include forced migration of people, destruction of household properties, destruction of farm produce which threatens food security, causing hunger to the victims, over-crowding, spread of communicable disease and water borne disease, crime rate and conflict increases as people resort to different social vices to survive. This study aims at assessing the topography of the area to evaluate its contribution to flooding in the study area.

Several studies on spatial assessment of flood vulnerability have been carried out in Nigeria including that of [6] and [24]. Similar study in the area in recent times on assessment of 2012 flooding was carried out by [25] on Flood hazard analysis and damage assessment of 2012 flood In Anambra State Using GIS and Remote Sensing and by [23] On assessment of environmental effects of 2012 floods in Umuleri, This study therefore aimed at spatial assessment of areas vulnerable to flooding in Anambra East, using GIS and remote sensing techniques. This will help guide land use planners, general environmental and disaster management policy makers and stakeholders in the study area in creating awareness and increasing their level of preparedness.

2. METHODOLOGY

2.1 Study Area

The study area is Anambra East Local Government area of Anambra state. It lies within latitude 540° 0' 0'' N and longitude 727° 0' 0'' E and latitude 648° 0' 0'' N and longitude 637° 0' 0'' E (Figure 1), covering a land area of 4416 sq. km. The study area has a tropical wet and dry climate [11], with mean annual temperature of about 27ºC. The study area is made up of depositional lowlands with pockets of lakes, ponds and levees. It also has a variety of land forms despite the fact that they are dominated by flat and low lying land generally less than 120m above sea level. The relief of the study area is undulating and descends towards the water bodies. The study area has abundant water resources that area being exploited by the habitants. It is draind by Omabala River, the Nkisi River, the Idemili River and the Nwangele creek, all are tributaries of River Niger. The area has three geological formations namely the alluvia in the North Western part, Imo Clay shale in the Eastern parts and the Bende-Ameki in the South. It usually experiences an average eight months of rainfall between March and October and four months of dry season between November and February. On average, rainfall amounts vary between 1800 and 2000 mm annually.

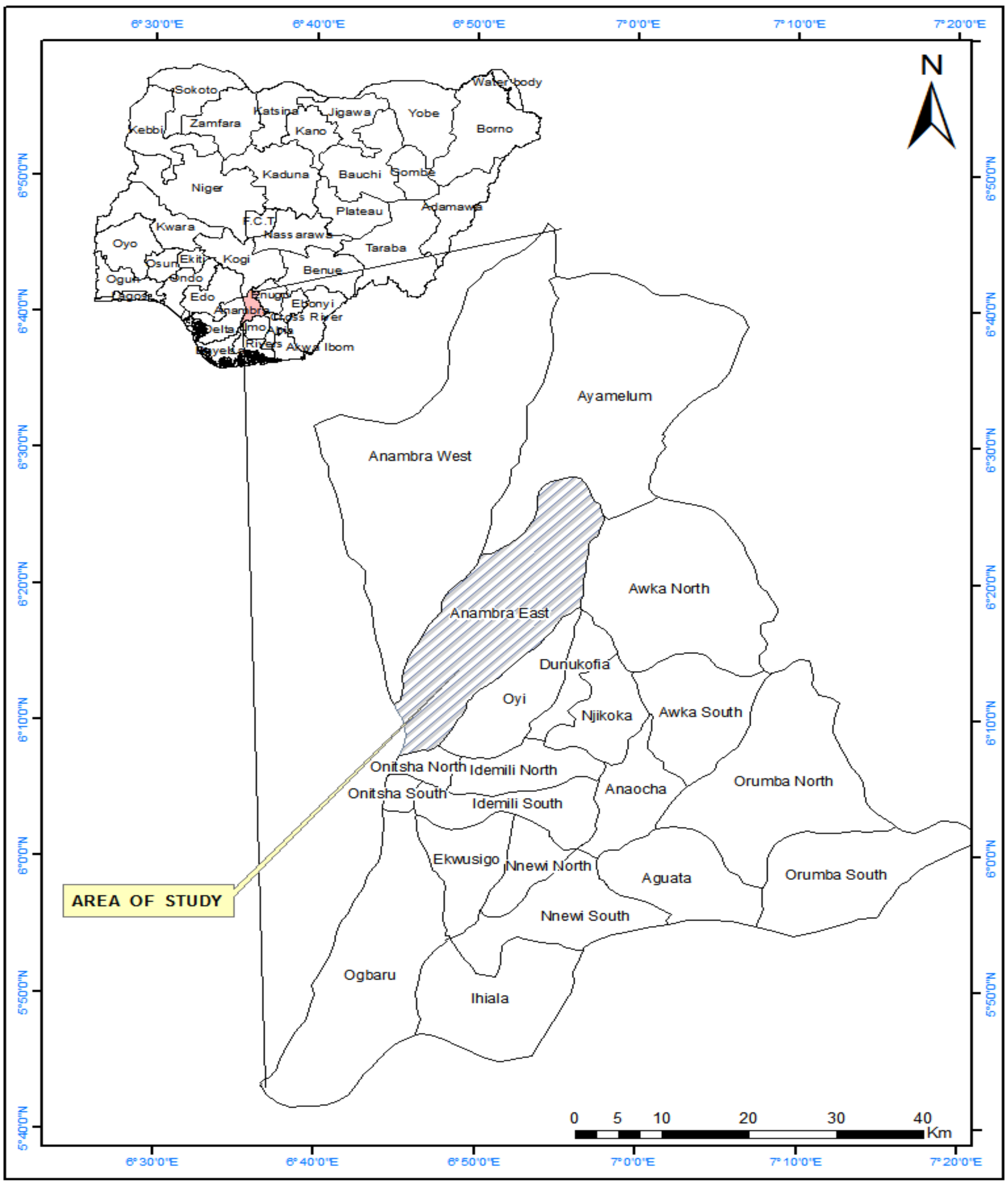

Figure 1. Map of the study area

Source: Produced from Administrative Geospatial data of Nigeria, http://www.diva-gis.org

2.2 Data Sources

Existing google imagery 2014 of the study was downloaded from the Google Earth with radiometric resolution of 10 m. A Shuttle Radar Topographic Mission (SRTM) satellite data of the same Area with 90 m resolution was obtained Global Land Cover Facility web site. (http://www.landcover.org/), Coordinates of different locations in the study area was obtained by the use of the GARMIN CAN310 hand held GPS (WGS84 32N Minna datum). Having had the base maps (topographical sheets and satellite imagery), the study area was extracted from Administrative map of Nigeria.

2.3 Data Collection

Arc GIS 10 spatial analyst extension was used to generate the height information from SRTM DEM (Digital Elevation Model) and handheld global positioning system (GPS) was used for ground truthing. The data were collected in degree, minute, second and imported into Microsoft Excel where the data was converted to degree decimal and transferred to Geographical Information System environment in Data Base Format (DBF) before point map was generated.

2.4 Data Analysis

2.4.1Terrain processing

The SRTM satellite data of the study area was processed using Arc Gis 10.1. The Hydrology toolset was used to generate the hydrological attributes such as, flow direction, flow accumulation, streams and the drainage basin of the study area. Terrain features such as slope, the contour and Digital Terrain Model (DTM) were generated using surface toolset. Data was derived from Shuttle Radar Topographic Mission (SRTM) data obtained from satellite imageries.

2.4.2 Use land cover classification

Supervised (full Gaussian) classification using the maximum likelihood algorithm in Erdas Imagine 9.1 was used to generate three main land use land cover classes from google image Figure 3: (1) Built up area, (2) Farm land and (3) Forest and River. These land use land cover classes were derived from google image of 2014 for the study areas.

2.4.3 Flood vulnerability analysis

The flood vulnerability area map was generated by using the Boolean operation in Arc Gis Raster calculation tool. The Boolean operation was used to detect the area where the topographic is simultaneously low slope and low Elevation using the logical expression "And", the syntax is written as follow: Flood map: (Slope < 3 degree and DEM < 86 m) see (Figure 4). The slope less than 3 degree and DEM less than 86 m was considered as the lowest terrain surface vulnerable to flood. The output map result to the flood vulnerability map.

3. DATA ANALYSIS

3.1 Geographical Relief of the Study Area

The essential geographic relief attributes examined in this study were digital terrain model, slope, water flow direction and contour.

3.2 Digital Terrain Model (DTM)

Figure 2 indicates that Aguleri, Ikenga and Umuleri have high elevation are therefore more affected by run off drainage during high precipitation. Lower areas from 170.333 to 86.666 including parts of Nsugbe and Nkwelle are considered as flat terrain. Areas ranging from **86.666** downward are lower in elevation; these areas are prone to flooding as run-off from the areas of higher elevations tends to concentrate at lower elevations such as Onitsha, parts of Umuleri, Nando and Igbariam.

3.3 Topography of the Study Area

Contour lines (Figure 3) connects areas of equal elevation were generated at 20 m intervals. The spot height tells the direction in which water flows through. From the map, contour of the study area ranges from 20-420.

3.4 Slope of the Study Area

The slope map (Figure 4) indicates that low slope areas (0 to 121) are flood prone. Moderate slope areas (1.121 to 3.035) are less vulnerable to flood while high slope areas ranging from 3.005 to 11.861 are not vulnerable to flood.

3.4 Land Use/ Land Cover of Study Area

Four land use classes (Built up area, Farm Land, Forest and River) were identified. The built up area accounted, for 22.75% of total area while farm land accounted for 41.75% suggesting agriculture was an important economic activity in the study area. Forests accounted for 27.26% while rivers covered 8.25%, (Figures 5 and 6).

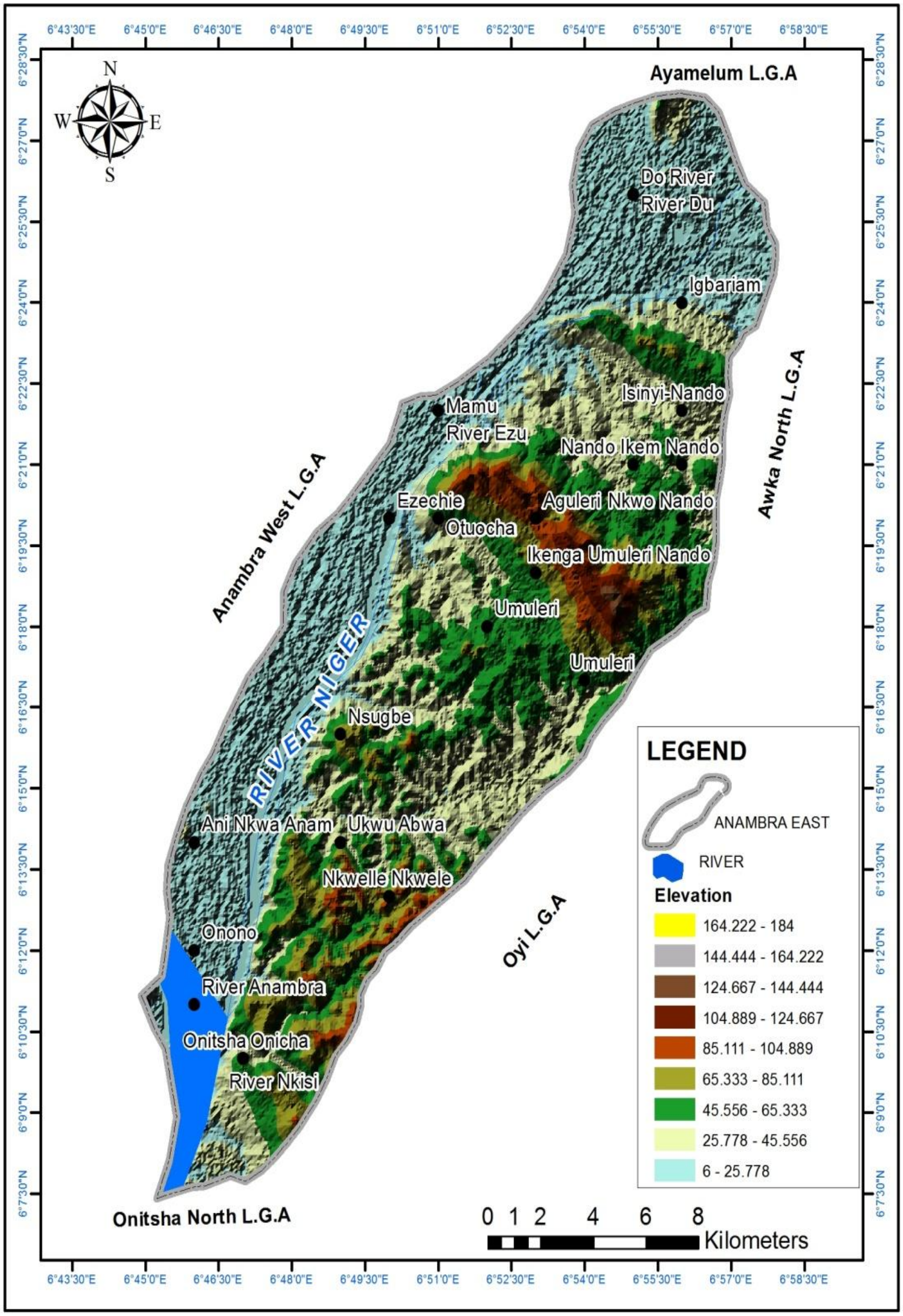

Figure 2. Digital terrain model of Anambra East L.G.A
(Correction affected: Authors has concentrated on only Anambra East and boundary LGAs also inserted)

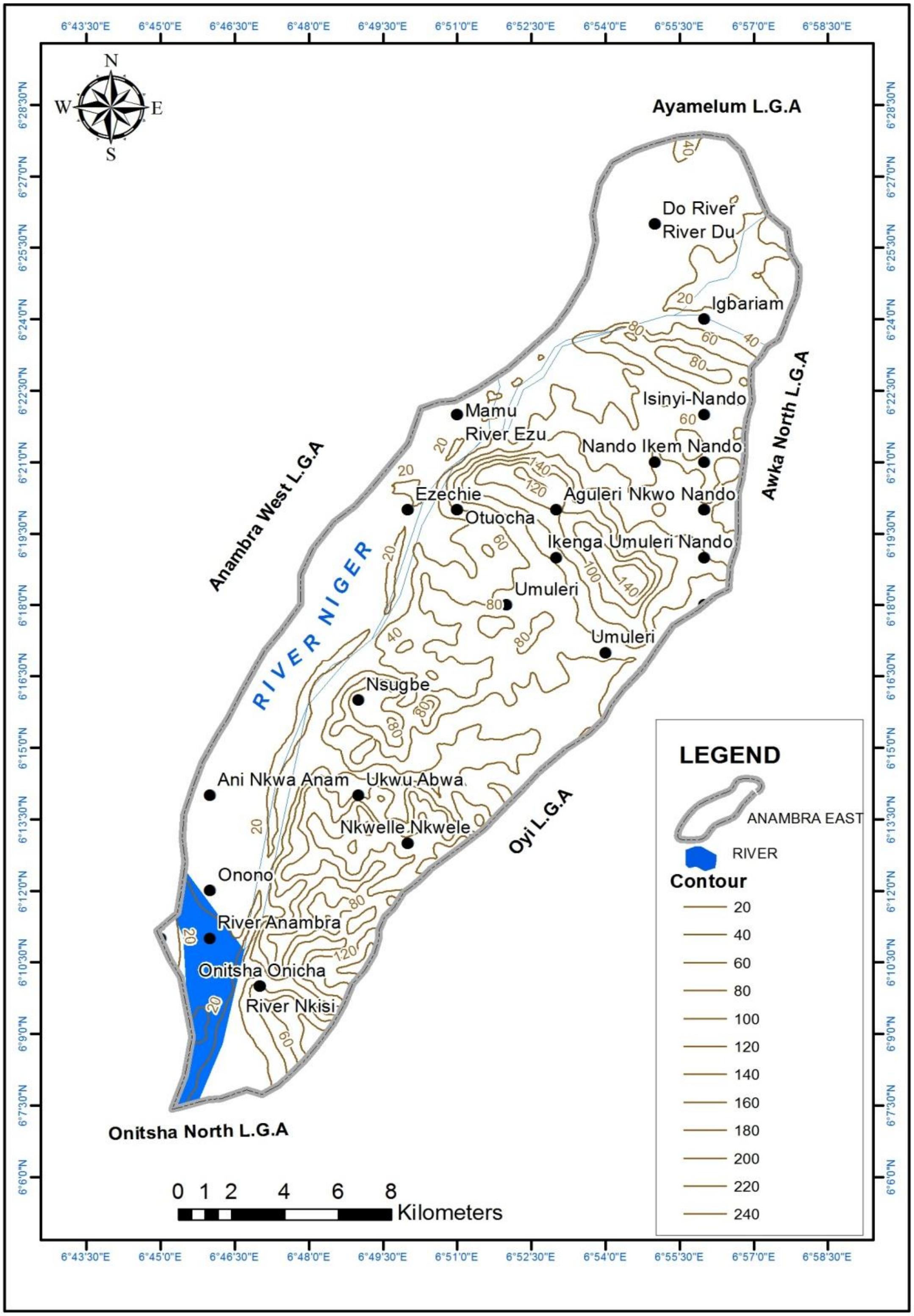

Figure 3. Contour map of Anambra East L.G.A

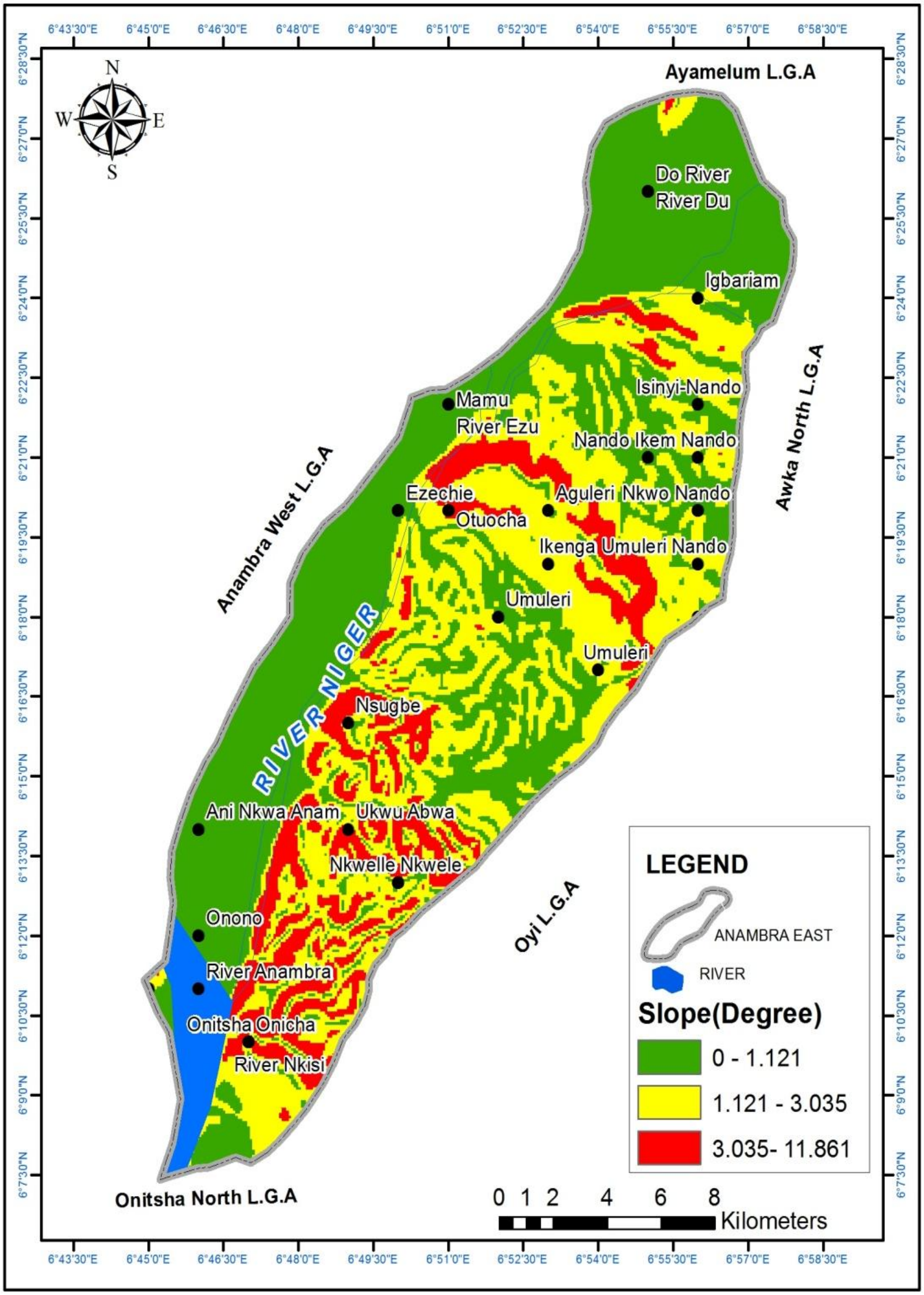

Figure 4. The slope map of Anambra East L.G.A

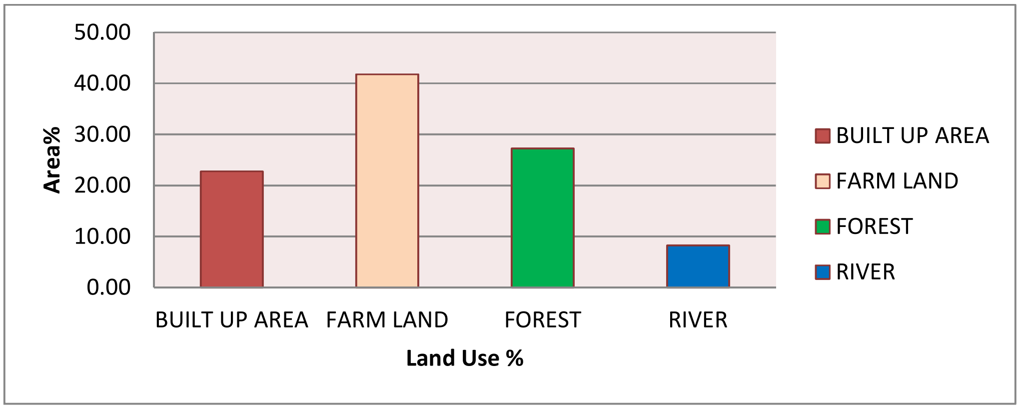

Figure 5. Histogram of land use / land cover of Anambra East L.G.A

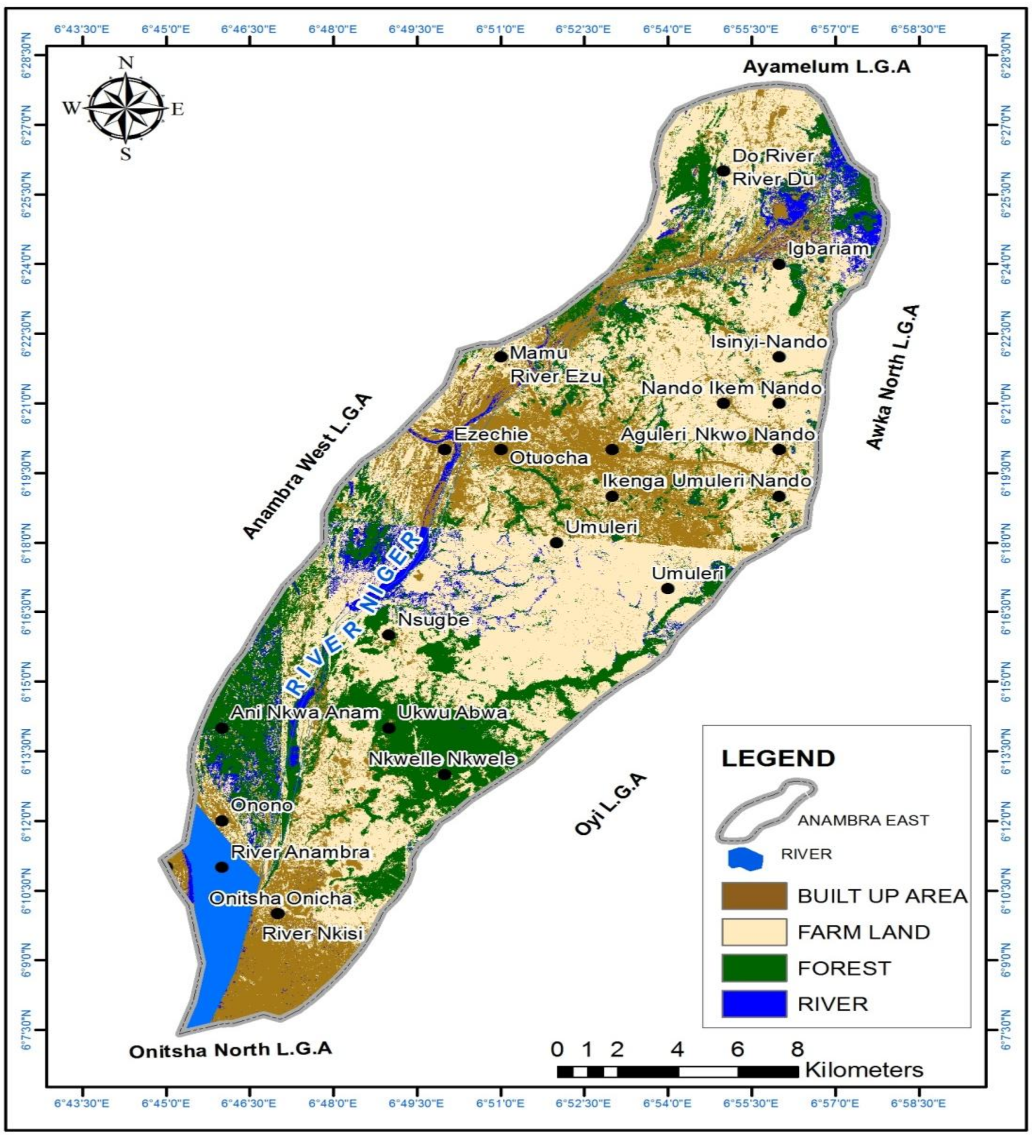

Figure 6. Land use land cover map of Anambra East L.G.A

4. RESULTS

4.1 Flood Vulnerabilty

Figure 7 shows that 288927000 m^2 (76.24%) of the study area was liable to flood whereas the remaining 23.76%, equivalent to 90023400 m^2 of the study area was not. This means that 76.24% of the study area has very high flood risk, which needs immediate and sustained interventions to protect the area from flood menace. Areas of low elevation and low slope as earlier described are areas vulnerable to flood.

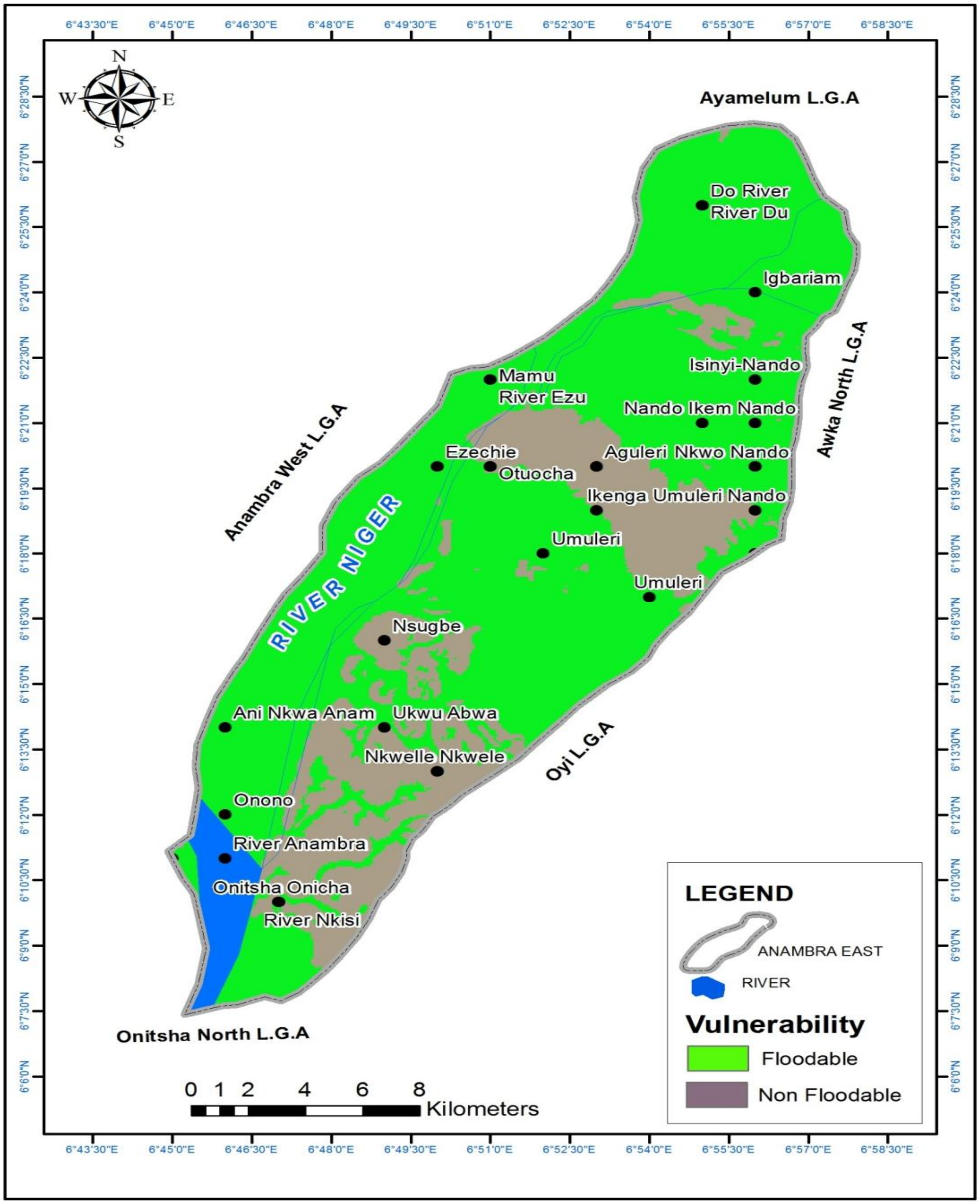

Figure 7. Flood vulnerability map of Anambra East L.G.A

Table 1. Table of flood vulnerability in Anambra East L.G.A

Vulnerability	Pixels	Area	Percentage
Floodable	35670	288,927,000	76.24
Non Floodable	11114	90,023,400	23.76
Total Area	**46784**	**378950400**	**100.00**

4.2 Discussion

The study shows that flood hazards occur in areas of low elevation. This is because run off occurs from areas of higher elevation to areas of lower elevation. This study essentially emphasized the strong influence the topography of the study area has on flood vulnerability. Although other factors, particularly ineffective land use planning and inertia among inhabitants might play key roles. The flooding of river and drainage channels following heavy rainfall is the most common form of flooding in the study area. Floods in the study area usually cover a large spatial extent and may last for weeks or even months. The findings of this study agree with those of many others including [26,24]. Therefore it is very important that areas of lower elevation should be given special consideration in land use planning.

5. CONCLUSION

Flooding is a major environmental problem in the study, accounting for loss of lives and property. While topographic considerations and rainfall may be assumed to be the key natural causes, land use types are also crucial factors causing flooding in the area, since most part of the land is used for Agricultural purposes. The application of GIS and RS in the spatial assessment of flood vulnerability is a very important non structural mitigation strategy for flood. This is so since it will help improve level of preparedness as well as guide policy and intervention in this regard. The study area requires proper land use mapping and planning to mitigate the flood menace. The construction of good drainage systems with adequate carrying capacity should be encouraged. It is also necessary to discourage inhabitants where possible from occupying flood prone areas, especially, if flood resistant structures and warning systems are not available.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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