Assessment of the Pattern of Flood Vulnerability in Nsukka and Environs using Geospatial Techniques

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Abstract

Flood vulnerability assessment is valuable tool that helps to reduce flood risk by identifying flood hotspots and improving adaptation. This study assessed the pattern of flood vulnerability in Nsukka and Environs using Geographic Information System (GIS) and remote sensing techniques. ArcGIS 10.2, Google earth pro and Surfer software were used to generate the flood vulnerability pattern using the Digital Elevation Model (DEM) and slope map of the study area. The Boolean operation was used to overlay the DEM and slope map to generate the flood vulnerability map. The results show that the elevation of Nsukka and environs ranges from 390.57m to 457.78m while the slope ranges from 0.83 to 89.99 degrees. The flood vulnerability map classified the study area into two namely; vulnerable and non vulnerable areas. The results revealed Nsukka and environs are generally not highly vulnerable to flooding asmajority (92.2%) of the study area is not vulnerable to flooding while only a small proportion (7.8%) is vulnerable to flooding. The reason for the low vulnerability to flooding has been linked to generally high elevation of the study area. However, it has been recommended that other factors such as settlement pattern, land use, socio-economic and adaptive capacity variables be incorporated for a comprehensive flood vulnerability assessment to determine flood flashpoints. This will aidcoordinated spatial planning of Nsukka and Environs as delineating floodable and non-floodable areas will prevent people from building in flood-prone areas. It would help policy makers formulate policies to combat urban flooding in the study area as well as promote the achievement of Sustainable Development Goal 11 that emphasizes on making communities safe, inclusive and sustainable.

Keywords: flood, vulnerability, GIS, Nsukka, DEM

1. INTRODUCTION

Floods are among the most devastating natural disasters and seriously affect people's lives and property annually (Dilley *et al.*,2005;. Nwilo *et al.*, 2012). Flooding is a general temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff (Jeb and Aggarwal, 2008; Essien *et al.*,2018). The European Commission Directive (2007) has defined flood as a natural phenomenon that results in the temporary submerging with water of a land that does not occur under normal conditions.

Globally, flooding is considered to be one of the worst natural disasters in the world as it is responsible for a third of all-natural problems and half of the damages on facilities around the globe (Ohl and Tapsell, 2000; Jeb and Aggarwal, 2008; Nwilo *et al.*,2012; Essien *et al.*,2018) making it difficult for any country to be immune to flooding.Wadsworth (1999) in *Nwilo et al.*(2012) declared that 80% of federal disasters in the US were related to flooding and Wang *et al.* (2010) opined that urban flooding has more devastating effects.

Floods have been noted to occur naturally and have the potential to lead to fatal effects such as displacement of people, loss oflives and properties, and damage to the environment (Adeoye *et al.,* 2009; Akukwe *et al.,* 2018). However, floods can also be caused by anthropogenic activities and human interventions in the natural processes such as an increase in settlement areas, population growth and economic assets over low lying plains prone to flooding leading to alterations in the natural drainage and river basin) patterns, deforestation and climate change (Jeb and Aggarwal, 2008; Adeoye *et al.*, 2009; Nwilo *et al.*, 2012; Essien *et al.,* 2018). The rapid development, growth and population explosion that occur in urban areas compounds the impacts of climate change to worsen the risks of flooding (United Nations, 2005; Carter and Parker,2009; Nkwunonwo *et al.*, 2014). Urban centres are typically covered with impervious surfaces, reducing infiltration of rainwater and producing more runoff (Chen *et al.*,2009) due to urbanization. Certain anthropogenic activities such as the building of houses along the floodplain, indiscriminate disposal of wastes and poor or clogged drainage systems have been noted to precipitate urban flooding (Aderogba, 2012; Aladelokun and Ajayi 2014; Hula and Udoh, 2015; Ikechukwu, 2015; Oluwatayo and Olatunji, 2015). These anthropogenic activities are propelled by uncoordinated urbanization resulting from population increase, rural-urban migration and poor knowledge about environmental issues such as flooding. Unfortunately, inadequate understanding of the impacts of flooding in many areas hinder the prediction of the magnitude of flood damage especially in developing countries (Thumerer *et al*.,2000; Moussa and Bocquillon, 2009; Fewtrell *et al*.,2011).

In Nigeria, floods cause almost 90 percent of damages resulting from natural hazards and the effect of flooding have increased in the last three decades especially in urban centres (Adeoye *et al.*,2009; Nwilo *et al.*, 2012; Essien *et al.,* 2018). Annually, more than 700,000 hectares of arable land and built-up areas are damaged due to flooding in Nigeria (Jeb and Aggarwal, 2008; Ishaya *et al.*,2015). In 2012, Nigeria experienced the worst flood in history as the United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA, 2012; Nigeria Hydrological Services Agency, 2020) noted the flood to be the worst flood in the past 40 years where 33 out of the 36 States of the country were affected. The 2012 flood affected more than 7.7 million people with more than 2.1 million registered as Internally Displaced Persons and 363 people reported dead and about 600,000 homes destroyed in Nigeria (Benue State Emergency Management Agency, 2017). The above shows that a greater percentage of areas and people are vulnerable to flooding in Nigeria. Since the 2012 revealed that most areas in Nigeria are vulnerable flooding, and urban centres are noted as flood hotspots (Essien *et al.*, 2018), there is need to assess the pattern of flooding in Nsukka and environs

2. LITERATURE REVIEW

The term“vulnerability”has different contextual meanings. According to social scientists, vulnerability is combination of socio-economic factors that influence the ability of people to cope with change or stress while climate scientists view itas the probability of occurrence and impacts of weather and climate-associated events such as flooding (Vincent, 2004; Wisner *et al.*, 2004; Fussel and Klein, 2006; Yusuf and Francisco, 2009; Hinkel, 2011; Malone and Engle, 2011) in Akukwe and Ogbodo (2015). According to IPCC (2007:11), “vulnerability is defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes”, and this definition has been adopted in this study. Thus, in this study, vulnerability refers to susceptibility and exposure to flooding with respect to elevation and slope of Nsukka and environs.

Vulnerability assessment is relevant as it has become a valuable tool that helps to reduce damages and improving well being since it tackles issues that bother on, what is vulnerability, what/who is vulnerable, and what are they vulnerable to? (Malone and Engle, 2011). Since hazards are difficult to totally control, concerted efforts are needed to reduce risk, and this can only be achieved by reducing the vulnerability of the exposed environments or communities to those hazards (Cardona, 2004). Hence, the adverse effects of flooding can be minimzed through the use of vulnerability maps that aid in spatial planning and sustainable urbanization, and as noted by Malone and Engle (2011), vulnerability has emerged as a bridge between impacts on the one hand and the need for adaptive changes on the other hand.

Studies on flood vulnerability have been undertaken in various regions of the world using various methods, though the use of Geographic Information Systems (GIS) is more common and reliable (Lumbroso, 2020). For instance, Park, Yang and Kim (2016) assessed social and economic vulnerability to natural disasters in Seoul, South Korea using indicator-based model and their results showed variability of vulnerability within same borough and the vulnerability assessment helped to prioritized disaster prevention projects in different areas. In Portugal, Fernandez et al.(2016) applied a geographic information system-based multicriteria decision analysis (GIS-MCDA) to social vulnerability in Portugal where their assessment showed what and who was at risk, thereby indicating where impact-reduction strategies should be implemented. In the same vein, Mayhuraet al. (2017) assessed the spatial variation of social vulnerability to flood hazards in Muzarabani district, Zimbabweusing the principal component analysis (PCA) and GIS tool, with five categories of flood vulnerability ranging from 1 (very low vulnerability) to 5 (highly vulnerable).

Nonetheless, several studies have also been carried out on mapping flood vulnerability using GIS where the use of spatial tools have been argued to be a reliable method for assessing flood vulnerability (Lumbroso,2020). For instance, Nkwunonwo *et al.*(2014) assessed the development of a simplified model for urban flood risk mitigation in Lagos

Metropolis where they used the social vulnerability index and land use map to assess the vulnerability of the Lagos metropolis to floods. Their results revealed that two-thirds of the Lagos was highly vulnerable to flood hazard, with Ajeromi-Ifeledun Local Government Area being the most vulnerable. They advocated controlled urban expansion and conducting a regular flood risk assessment to minimize impacts of floods.In the same vein, Emmanuel *et al.*(2015) worked on the Flood hazard analysis and damage assessment of the 2012 Flood in Anambra State, Nigeria where GIS and remote sensing were applied to identify the areas vulnerable to flood hazards and the extent of damage that resulted from the 2012 flood hazard in the study area. Their results showed a spatial variations in flood hazard levels with varying economic impact of the 2012 flood disaster as well as population exposed to different levels of risk in Anambra State. They recommended improved land use and a regular flood risk mapping for hazard prediction in Anambra State.In line with the above, Ogbonna *et al.*(2015) in their spatial assessment of flood vulnerability in Aba Environs', used GIS and rainfall data to predict the likelihood of flood occurrence in various areas of Aba Urban. Their results revealed that virtually all parts of Aba Urban were vulnerable to flooding with a constant rainfall trend. However, they concluded that topography, poor drainage infrastructure and non-compliance with building, planning and environmental regulations rather than rainfall trend were the key cause of flood problem in Aba Urban. Similarly, Okwu-Delunzu *et al.*(2017) worked on spatial assessment of flood vulnerability in Anambra East using GIS and remote sensing to map flood-prone areas. Their results revealed that 71% of Anambra East was liable to flood risks with agricultural land use having the highest probability of being affect by flood hazard. Recently, increased flood episodes have been recorded in Nsukka and environs due main to excessive run off which is in agreement with the findings of Ihinegbu *et al.*(2019) who noted that flood occurrence in Alor Uno was due to the excess runoff from Nsukka Urban.

However, the above review shows that scholars have attempted to assess the flood vulnerability of various urban centres in Nigeria, yet, there is dearth of literature on the pattern of flood vulnerability in Nsukka. Since vulnerability analysis is an integral part of disaster risk reduction, there is need to examine the pattern of flood vulnerability in Nsukka and Environs using geospatial technique. This would help inform spatial planning and flood management in the study area.

3. METHODOLOGY

3.1 Study Area

The study area, Nsukka and Environs is located in Nsukka Local Government Area (LGA), Enugu State of Nigeria. It is the hub of Nsukka LGA (see Figure 1). Geographically, the study area is located between Latitude 6^0 47'38"N and 6^0 53' 16"N and Longitude 7^0 19' 37"E and 7^0 24' 43"E. Nsukka and Environs' is divided into Nru, Nkpunano, Ihe, Owerre, University of Nigeria (UNN) and Government Reserved Area (GRA) (see Figure 2).

Nsukka and Environs is located within the Southeastern region of Nigeria. The climate of the study area according to Koppen's climate classification is thetropical wet and dry climate or Aw climate thatreceives an average annual rainfall amount of about 1800mm (Anyadike, 2002). The temperatures are high throughout the year with an average value of 27°C.The average relative humidity ranges between 60-70% in January and 80-90% in July (Anyadike, 2002). Two main seasons are experienced in the study area namely; the

Rainy and Dry seasons. The rainy season is about 8 months (from March to October) while the dry season is 4 months and usually runs from November to February (Anyadike, 2002; Phil-Eze, 2004). Flooding in the study area is usually experienced during the rainy season.

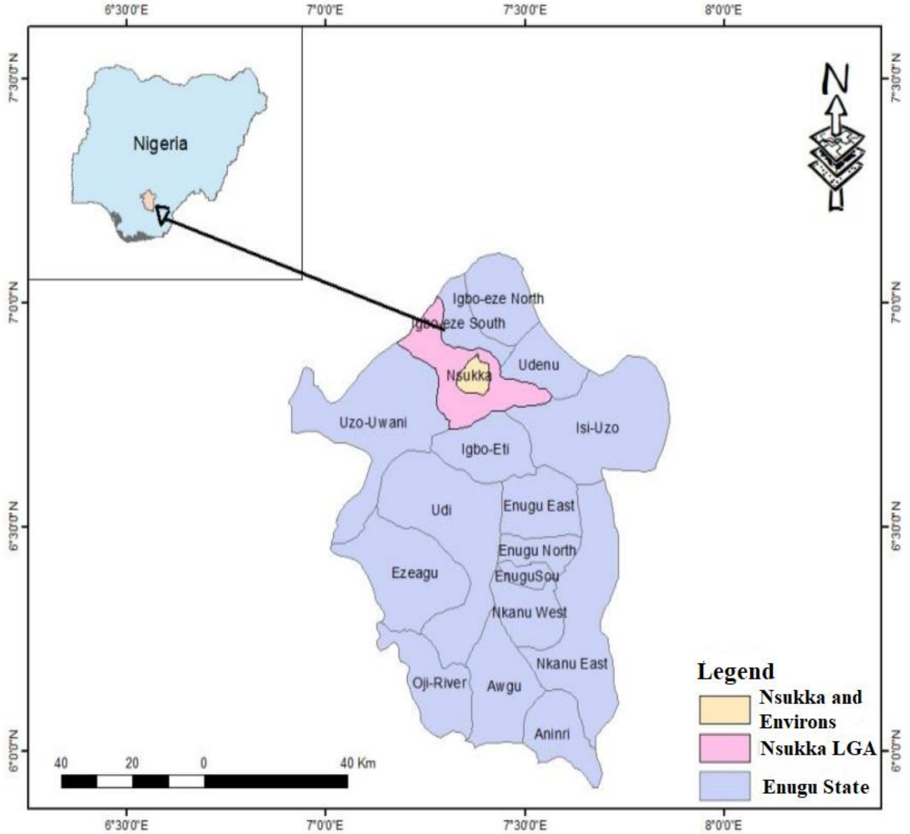

Figure 1: Enugu State showing Nsukka and Environs
Source: Department of Geography, University of Nigeria

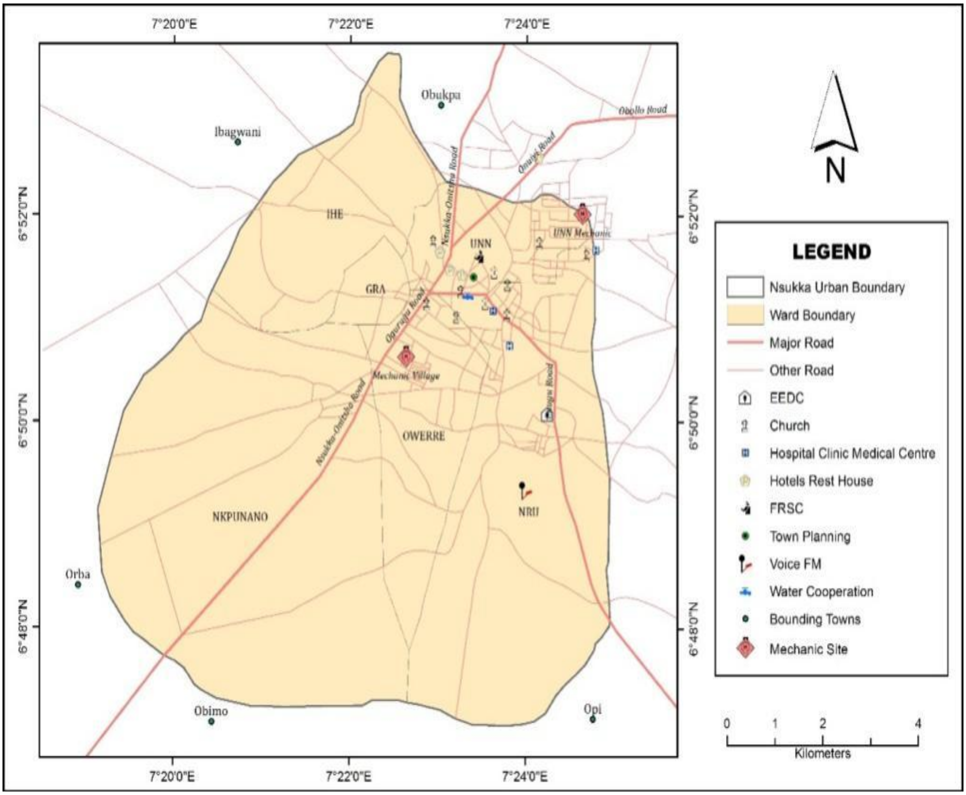

Figure 2: Nsukka and Environs Map
Source: Department of Geography, University of Nigeria

The relief is predominantly undulating cuesta landscapes of above 350 meters high within the Nsukka-Okigwe cuesta (Ofomata, 2002). The Nsukka-Okigwe cuesta is made up of the Enugu escarpments formed by the resistant sandstone in the lower coal measures and in the lower parts of the false bedded sandstone. Another typical feature of this relief is the dry valleys and residual hills (Ofomata, 2002).
The geology according to Umeji (2002)is characterized by cretaceous sedimentary formations comprising sandstones, shales, limestone and coal with pronounced degree of laterization process resulting in iron enrichment.

The vegetation of the study areas lies mainly within the rainforest-savanna eco-tone comprising more than 60% grass. The predominant grass species are Andropogon, Hyparrhenia and Pennisetum purpureum (Phil-Eze 2001; Anyadike, 2002). *Elaeis guineensis* (Oil palm tree),*Dacroydes edulis* (African pear), *Mangifera indica* (Mango),*milicia excelsa* (iroko tree), *Psidium guajava* (Guava), *Gmelina arborea* (Gmelina tree), coconut,bread fruit, kola nut and bitter kola nut trees are among the dominant tree species found in the study area (Phil-Eze, 2001).

3.2 Data Sources

The study employed the use of google imagery. Google imagery of 2019 of the study was downloaded from Google Earth with a 10m radiometric resolution. The coordinates of different locations in the study area were obtained with the aid of a hand-held Global Positioning System (GARMIN CAN310). The hand-held GPS was also used for ground-truthing. Google Earth Pro was used to generate the height information for the Digital Elevation Model (DEM) and this was exported in excel format. The base map of the study area was obtained from the GIS Unit of the Department of Geography, University of Nigeria, Nsukka, Nigeria.

3.3 Data Analysis

The DEM was produced using Surfer II. First, the longitudes, latitudes and elevations of various points in the study area were obtained using Google Earth Pro and were exported in Excel format. The exported excel file was then imported into Surfer for the generation of the DEM. The same Excel file was imported into the spatial analyst tool of ArcGIS 10.2 to produce a slope map of the study area. To generate the pattern of flood vulnerability map of the study area, the spatial analyst tool, Boolean operation, in ArcGIS 10.2 was used. The Boolean operation was used to detect the area where the topography is simultaneously low slope and low Elevation using the logical expression “And”. The Boolean equation was written as follow: Flood map: (Slope < 86 degree and DEM < 435 m). The slope less than 86 degree and DEM less than 435 m was considered as the lowest terrain surface vulnerable to flood (see Figures 3 and 4). Therefore, the output map was our flood vulnerability map of the study area.

4. RESULTS AND DISCUSSION

4.1 Digital Elevation Model

The DEM in Figure 3 indicates that communities such as Nru Nsukka, Umuoyo, Iheagu have high elevation and are more prone to runoff during high precipitation. Areas with elevations ranging from 424.17 to 457.78 including Owerre, GRA, UNN and Nkpunamo are considered as flat terrain. Areas ranging from 424.17 downwards are lower in elevation and therefore are more prone to flooding as runoff from higher elevations tends to concentrate at lower elevations such as Ihe, parts of Alor Uno and Onuiyi. The DEM classification of Nsukka and Environs’ was based on the elevation of the study area which ranges from 390.57 to 491.38. However, the results reveal that the elevation in Nsukka is generally high with the lowest areas being 390.57m above sea levels. This suggests that the study area is prone to high runoff during precipitation and this correlates with the findings of Ihinegbu *et al.*(2019) which argued that flood occurrence in Alor Uno Community was due to the massive runoff from Nsukka Urban. The DEM also indicates that the highest elevations are in the Southeastern part of the study area while the lowest elevations are in the Northwestern part (see Fig. 3).

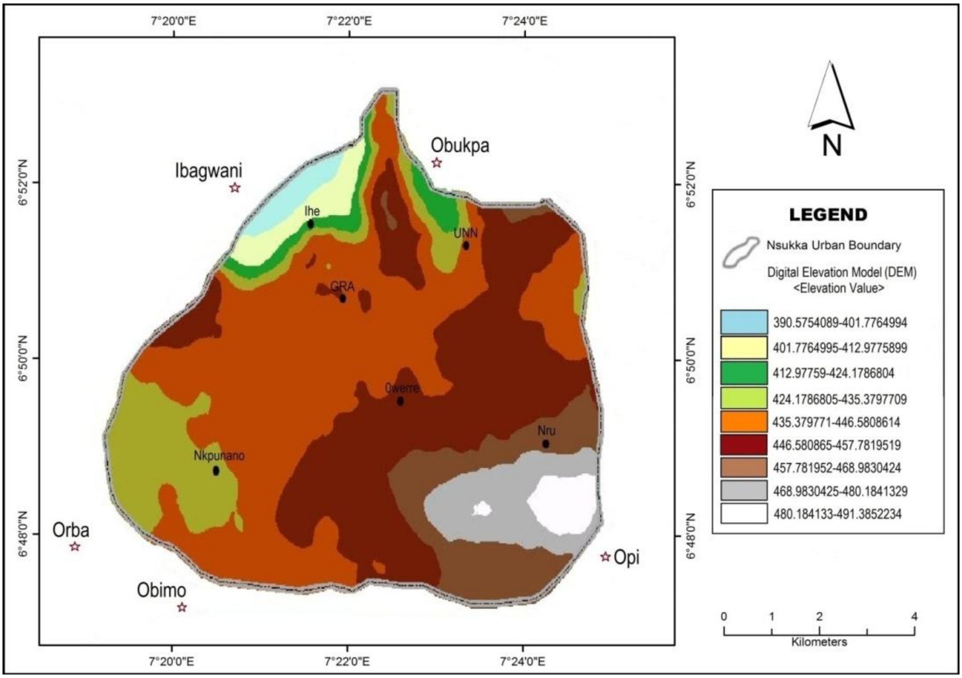

Figure3: Digital Elevation Model of Nsukka and Environs
Source: Authors' analysis (2020)

4.2 Slope of the Study Area

Figure 4 shows the slope of the various communities in Nsukka. The majority of the communities are classified as high slope areas. Generally, areas with a lower slope is highly vulnerable to flooding while areas of high slope are the least vulnerable to flooding. The slope map shows that low slope areas (0.83 – 76.00^0) are flood-prone. Areas ranging from 76.00 to 86.49^0 (moderate slope areas) are less vulnerable to flood while high slope areas (86.49 – 89.99^0) are not vulnerable to flood. The slope map also indicates that the majority of parts of the study area are not vulnerable to flood.

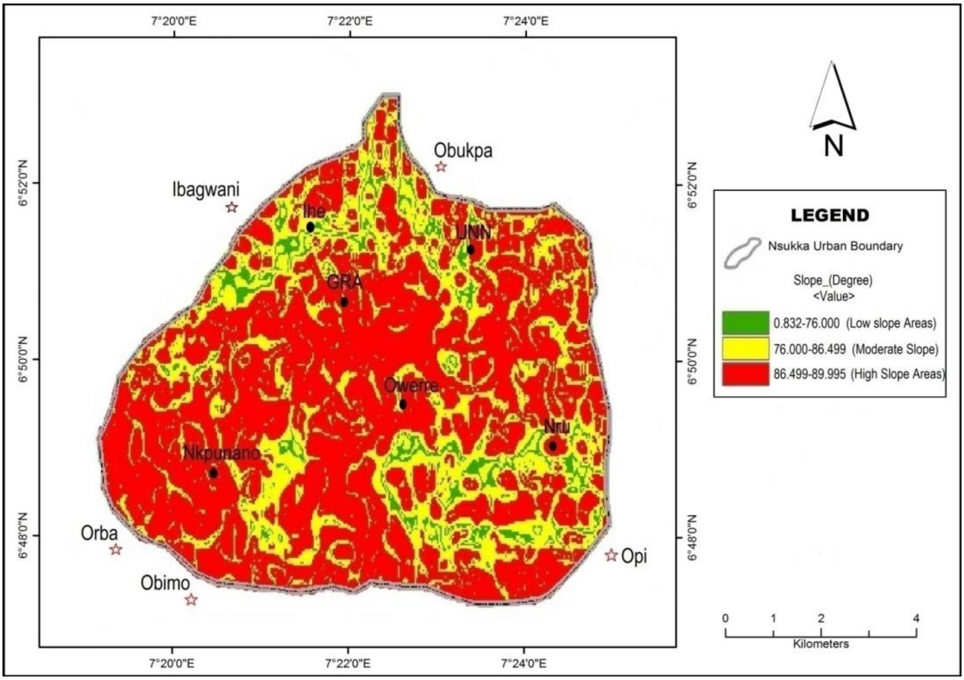

Figure 4: Slope map of Nsukka and Environs
Source: Authors analysis (2020)

4.3 Pattern of Flood Vulnerability

Vulnerability assessment is vitalto a successful disaster risk reduction since it helps in the identification of flood hotspots. A combination of elevation and slope of the study area was used to produce the flood vulnerability map of Nsukka (Fig. 5). This combination also generated a table where areas were classified as floodable and non-floodable, that is vulnerable and not vulnerable to flooding respectively. The flood vulnerability map in figure 5, and Table 1 shows that 4.947 SqKm (7.85%) of the study area was vulnerable to flood while 58.069 SqKm (92.15%) was not vulnerable to flood. Areas of low slope and elevation are the areas vulnerable to flood e.g around UNN, Ihe Nsukka. This means that only a small proportion of the study area was liable to flood. This can be justified by figures 3 and 4 which suggests a general pattern of high elevation and slope across the study area. However, thefinding of this study is not in agreement with results of many scholars (including Njoku *et al.*,2013; Ogbonna *et al.*,2015) as areas of relatively low elevation and slope in their study areas were not vulnerable to flood. Nonetheless, the observed low vulnerability to flooding in the study area is due to the generally high elevation and slope across the study area.

Table 1: Flood vulnerability in Nsukka Urban

Vulnerability	Pixels	Area (SqKm)	Percentage (%)
Floodable	6623	4.947	7.85
Non-Floodable	77708	58.069	92.15
Total	**84331**	**63.016**	**100.00**

Source: Authors' computation, 2020

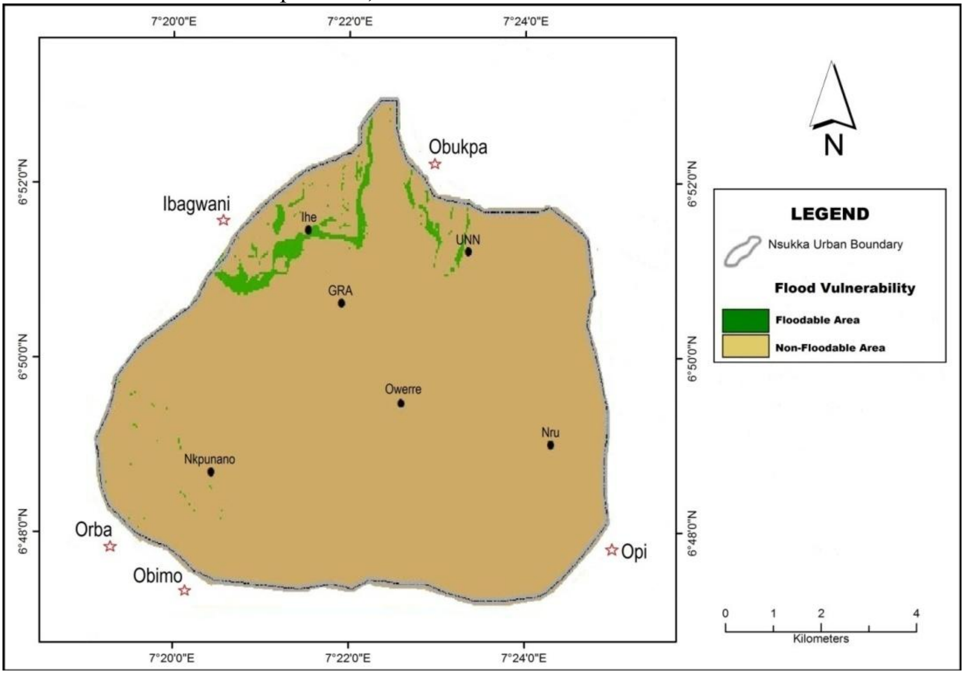

Figure 5: Pattern of Flood Vulnerability in Nsukka and Environs
Source: Authors analysis (2020)

5. CONCLUSION

The study investigated the pattern of flood vulnerability in Nsukka and Environs using geospatial technique.Flooding is a major environmental hazard that requires strategies that will minimize the impacts associated with it. Thus, the importance of GIS and remote sensing in assessing flood vulnerability has been demonstrated in the study area. A flood vulnerability map was produced using topographic variables (slope and elevation), and the results revealed that Nsukka is generally not highly vulnerable to flooding due to its high elevation and slope. This vulnerability map is a vital tool that is necessary in spatial planning and flood management plans as it shows floodable and non-floodable areas. Though, only topographic variables were considered in producing the flooding vulnerability map, it is important to note that human factors (settlement pattern, land use, socio-economic and adaptive capacity among others) should also be taken into consideration in further studies.

6. RECOMMENDATION

The following are recommended;

a. the vulnerability map be used for spatial planning in order to properly zone land use and control urbanization in Nsukka as well as in flood risk management. The Town Planning Department of Nsukka Local Government Area needs to utilize this vulnerability map since the delineated floodable and non-floodable areas will deter people from erecting structures in floodable areas. In addition, other geospatial technique should be applied to update land use planning of the study area.

b. Socio-economic, adaptive capacity, settlement pattern land use factors should be taken into consideration to upscale the flood vulnerability assessment to determine flood flashpoints. A comprehensive flood vulnerability assessment would help formulate policies to combat urban flooding; the common type of flooding experienced in the study areas. Consequently, it will promote the achievement of Sustainable Development Goal 11 with emphasis on making communities safe, inclusive and sustainable.

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