Gombe Journal of Geography and Environmental Studies (GOJGES)

Vol. 2 No.3 Jun. 2022

e-ISSN: 2714-321X

p-ISSN: 2714-3201

http://www.gojgesjournal.com

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 2 No.3 Jun. 2022, e-ISSN: 2714-21X; p-SSN: 2714-3201

ASSESSING THE IMPACT OF TOPOGRAHY ON FLOOD VULNERABILITY IN MAKURDI LOCAL GOVERNMENT AREA, BENUE STATE, NIGERIA

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Abstract

Flood is one of the major global environmental problems that need urgent attention. The present study focused on the assessment of the impact of topography on flood vulnerability in Makurdi Local Government Area. Makurdi Local Government Area is located along River Benue and annually subjected to excessive floods especially when the spill ways of Lagdo Dam at the upstream of River Benue in Cameroon Republic are opened. Topography has been identified as a strong criterion for the determination of flood vulnerability of an area. The study used the Advanced Space Borne Thermal Emission and Reflectance (ASTERGDEM V2) data with 30m resolution for mapping the topography and generation of rivers/streams within the Local Government Area. Topographical Map of the area was also used for extraction of names and locations of desired features such as villages or rivers. Political Map of Makurdi Local Government Area was used for demarcation of ward boundaries. The topography of the area was generated by creating TIN map using contour 200m interval of the area through ArcGIS 10.7.1 and converted to raster map. The topography map was classified into four flood vulnerability classes: extremely, highly, moderately, and low vulnerable areas. The eleven wards in Makurdi LGA were created using polygon feature of the ArcGIS 10.7.1. Calculation of flood vulnerability in each ward was achieved by extracting each of the wards as a polygon and using the 'clip' extraction module of the Arc Toolbox of ArcGIS 10.7.1 to delineate each of the vulnerability classes from each of the wards within the LGA. The results revealed that large parts about (67%) of Makurdi LGA land area are within the low relief which subject the area to frequent floods. Seven wards (Central South Mission, Wailomaya, Bar, Central Market and Modern Market, North Bank II and Mbalagh), out of the eleven wards had more than 80% of their land areas within extremely and highly vulnerable areas to floods. It was recommended that developmental structures in the low terrain areas within the LGA should be discouraged through public awareness and enforcement of laws by the concerned authorities.

Keywords: Flood vulnerability, Topography, Geospatial Technique, Makurdi LGA.

1.1 Introduction

Flooding is considered to be one of the most destructive and frequently occurring natural disasters in the world. The impacts of flood on communities and its effects on sustainable development are overwhelming in recent years. As the world's population increases at an alarming rate with increase in infrastructural development, more lives and properties are becoming vulnerable to the risk of flood hazards whenever extreme flood events occur (Olanrewaju *et al.*, 2019). In the report of Organization for Economic Co-operation and Development (OECD 2016), The United Nations International Strategy for Disaster Risk Reduction (UNISDR) reported a 35% increase in flood risk on the world

economy which is driven by the increasing exposure of the people and economic assets experienced in the last decade. In Nigeria, flood accounts for the highest occurring natural hazards causing severe damage to lives and properties (Terwase and Terese, 2013).

According to EM-DAT: International Disaster Database on Nigerian disaster, in 2012 alone, about 7 million lives were affected by the widely spread flood, while 363 deaths and $500,000 worth of economic damages were recorded. Flood in Nigeria is becoming a yearly event as it occurs in the form of coastal floods, river flood and urban flood. Flood vulnerability describes the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of flood (UNISDR, 2017). Vulnerability assessments are performed on those elements that are determined to exhibit a certain degree of exposure to a natural hazard. Physical vulnerability represents the potential direct impact of a natural hazard on the built environment and people (Papathoma *et al.,* 2021).

The effects of floods in Benue floodplains in general and Makurdi LGA in particular cannot be overemphasized. In September 2012, the sudden release of water from Lagdo dam in Cameroon caused flooding that affected 33,000 people, displaced 189 people, and killed one person, with an unspecified number of houses 'submerged' (Nigeria Post-Disaster Needs Assessment, 2013). The frequency and intensity of flood in Makurdi LGA in recent years has been at the mercy of the opening of Lagdo Dam in Cameroon. Floods in Makurdi LGA has resulted into collapse of so many houses, loss of materials worth several millions of Naira, displacement of many of the inhabitants, loss of livelihoods like crops and fishing ground, displacement and forceful migration of people. Individuals, organizations and government at all levels have all put their hands on deck to ameliorate the hydrological hazards but not without the problem of inadequate data and information (as provided in this study) as the basis of delineating and quantifications of flood risk zones and communities liable to flood (NEMA, 2013; Abah, 2013; Ajene and Ogorry 2016).

Since Makurdi LGA is located along River Benue and which is always susceptible to floods, the various factors that are responsible for the vulnerability have been examined by numerous authors Abah (2013); Acha and Aishetu (2018); Adekola and Lamond (2018); Brian (2021). The nature of the topography of an area has been identified as a major determinant of flood vulnerability and hence, numerous studies have been carried out to assess the impact of topography on flood hazard (Shettima *et al.,* 2019). In the work of Xie and Zhao (2013) the relationship between topographic relief and flood disaster, with the support of GIS technology was examined and conclusion was made that the lower the terrain, the more vulnerable to flood hazard. Hawker *et al*., (2018), investigated the implications of simulating global Digital Elevation Models for flood inundation concluded that an ensemble of the MERIT DEM simulated gives inundation estimates closer to a light detection and ranging-based benchmark. Shettima *et al.,* (2019) used remotely sensed data and GIS techniques to assess the impact of topography

on flood vulnerability of the terrian of Maiduguri. The study revealed that the impact of topography on excessive flooding in the low relief of the core of Maiduguri urban was enormous. The assessment of topography as a criteria in the investigation of flood vulnerability especailly based on the wards within the LGA has not been given the desired attention. This study therefore, was designed to use geospatial techniques in the mapping, quantification and analysis of the impact of only topography among other vulnerability criteria or factors on flood vulnerability in Makurdi LGA. It is expected that the findings will help policy makers (especially urban planners) through the provision of information and reliable data to formulate policies that will minimize flood impacts due to the topography of the area.

2.1 The Study Area

Makurdi metropolis which is also known as Makurdi LGA is the political headquarters and capital of Makurdi LGA and Benue State respectively. The extent of Makurdi LGA is determined by 16 km radius from the General Post Office in Makurdi metropolis (Ajene and Ogorry, 2016). The latitudinal location of Makurdi falls between 7°35′ 30″ N and 7° 53′ 00″ N, and 8°22′ 00″ E and 8°40′ 00″ E (Fig. 1). Makurdi LGA (as determined in this study using GIS technique) covered a total land area of about 820.66 km^2. However, at present, only 135.47 km^2 (17.63%) of the LGA have been developed (Fig. 1). Table 1 shows the land area and the percentages of each of the eleven wards in the LGA.

Table 1 The land area and percentages of the wards in Makurdi

Wards	Area (km^2)	Percentage
Agan	136.64	16.67
Ankpa/Wadata	10.21	1.24
Bar	112.17	13.67
Central South Mission	15.23	1.86
Clerk/Market	9.88	1.20
Fidi	203.23	24.76
Mbalagh	198.14	24.13
Modern Market	97.06	11.83
North Bank 1	4.59	0.56
North Bank 2	16.8	2.05
Wailomaya	16.71	2.04
Total	**820.66**	**100**

Source: Calculated from Makurdi wards (Ministry of Survey, Makurdi)

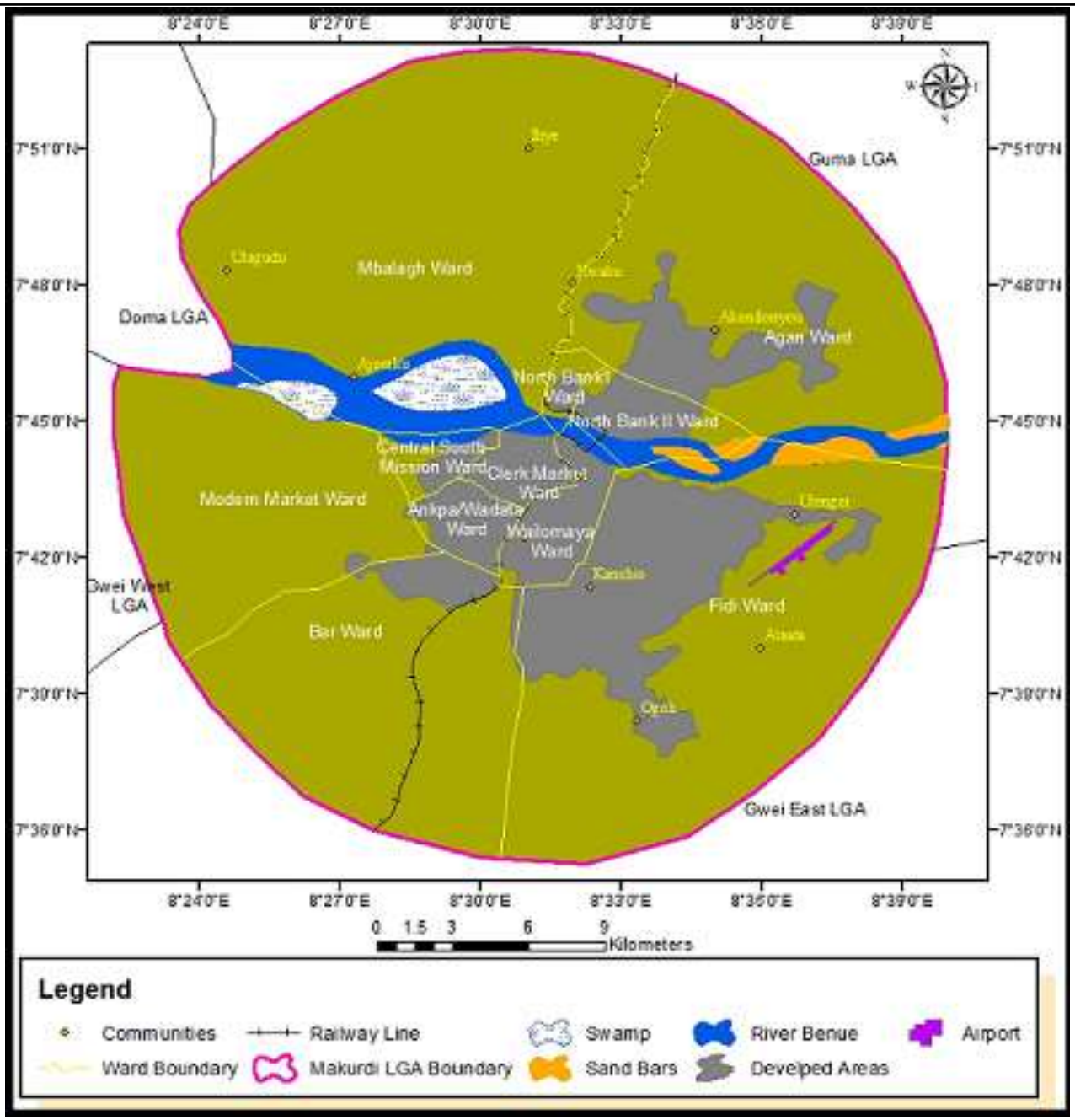

Figure 1 The Study Area
Source: digitized from Map of Makurdi (Ministry of Land and Survey, Makurdi) and Google Earth

Generally, the relief of Makurdi ranges from 30.85 to 179 m above sea level (Fig. 2). The relief was classified into four (4) in this study, high, moderate, low and very low relief. The land areas and percentages of each of the relief classes of Makurdi LGA are presented in Table 2.

Table 2: Land areas and percentages of the relief classes of Makurdi

Relief Classes	Area (km^2)	Percentages
High	87.87	10.72
Moderate	189.79	23.15
Low	310.92	37.92
Very Low	231.28	28.21
Total	**819.86**	**100**

Source: Calculated from the DEM map in Arc GIS environment

The low and the very low relief areas cover about 66.13% of the total land area of Makurdi LGA. Since low terrain is liable to floods (Abah 2013; Ikusemoran *et al.*, 2013), this large percentage of low relief areas within the LGA coupled with close proximity to River Benue cause the annual inundation of most parts of the town during flood as large parts of the town are in low relief areas. The high relief is the highest part of Makurdi LGA. The elevation of the high relief ranges from 131.1 to 179 m above sea level (Fig. 2). The high relief zone which covers a very small portion of Makurdi LGA are mainly found in Fidi and Agan wards in the south and northern part of River Benue respectively. The low relief surrounds the valley of River Benue (Fig. 2). The elevation of the low relief zone ranges from 85.1 to 106 m above sea level. The zone covers large area of the following wards; Mbalagh, Modern Market, Fidi, Bar, Agan and the core of Makurdi especially Clerk/Market. Low relief zone is the largest relief zone, more than the combine land area of the high and moderate relief zone. This zone is a relatively low elevation area with tendency to be flooded in the event of heavy down pour that may cause the River Benue to overflow its banks. River Benue which is the second largest river in Nigeria runs through the central part of Makurdi LGA which subjects most parts of the town to be marshy especially during the rainy season. The relief and drainage of Makurdi LGA is shown in Fig. 2

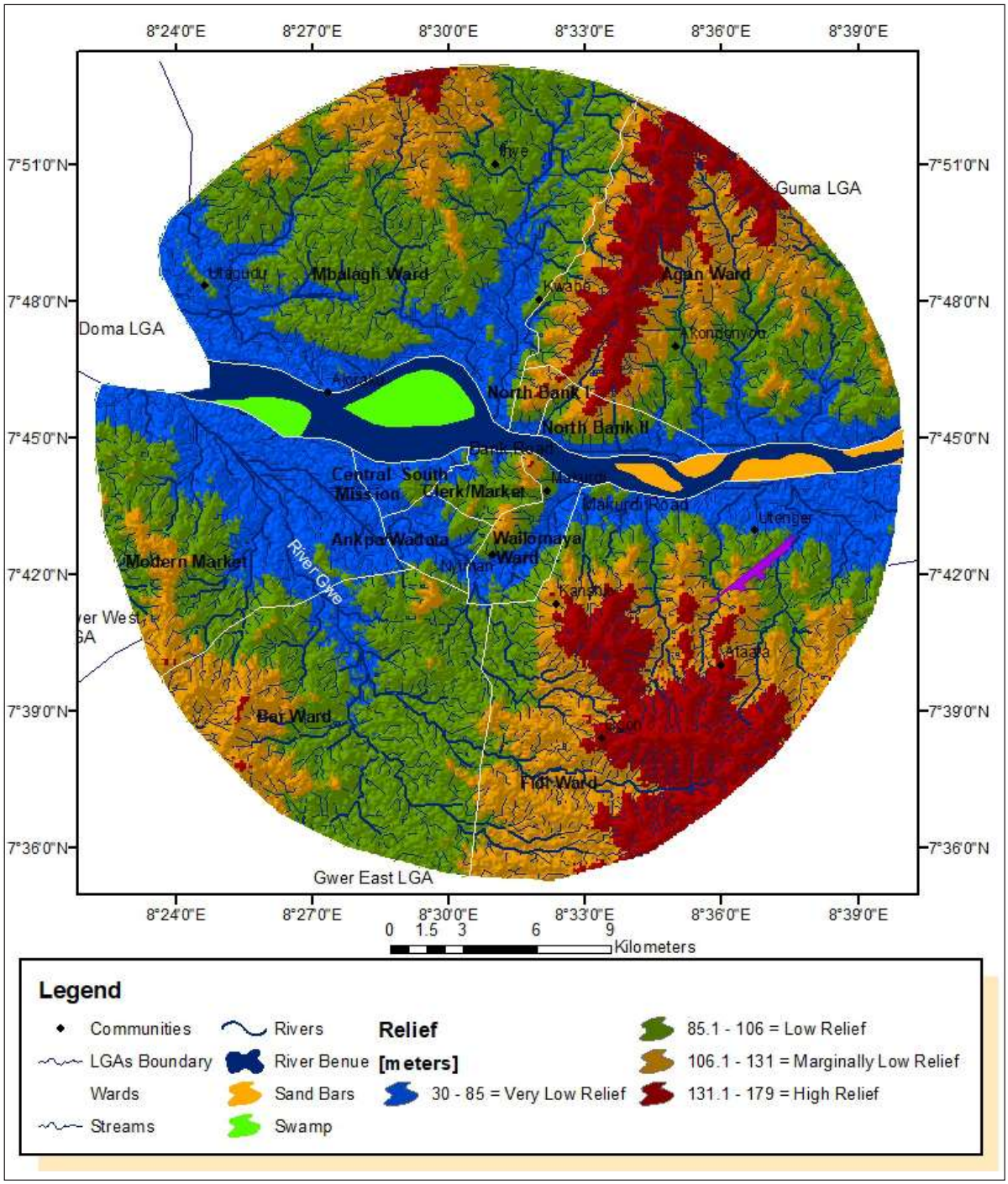

Figure 2 The relief and drainage of Makurdi LGA
Source: Generated from SRTM DEM Data

Other than River Benue, there are other tributaries that run from both sides of the River Benue and empty their water into the Benue River. Among these numerous streams River Gwer is a major one. Makurdi is located within the tropical sub humid climate which is dominated by two distinct seasons; the wet season which occurs from April till October; and the dry season that starts in November and ends in March (Abah 2013, Hilakaan and Ogwuche 2015, Hemba *et al.*, 2017). Hemba *et al.*, (2017), classified the temperature periods in Makurdi into three; (i) cool dry season from November to January, (ii) hot dry season from February to April, and (iii) hot wet season from May to October. Hilakaan and Ogwuche (2015) observed that the mean monthly relative humidity in Makurdi LGA varies between 43% in January and 81% in July-August. Abah (2013) and Hemba *et al.*, (2017) noted that the soils of Makurdi LGA were of two types; the hydromorphic soils which are developed on alluvium sediments in the valley of River Benue, and the red ferrasols which are developed on sedimentary rocks outside the immediate valley of River Benue. According to NPC, (2007) population and projected (2023), Makurdi LGA has a total of 612,382 people. The dominant ethnic groups are the Tivs, other existing tribes include Idomas, Etilos, Jukuns and Igede.

3.0 Methodology

Among the data that were used for this study are: Advanced Space Borne Thermal Emission and Reflectance (ASTERGDEM V2) data with 30m resolution was obtained from earthexplorer.usgs.gov for generation of topography and rivers/streams within the LGA. Topographical Map obtained from Ministry of Survey, Makurdi were used for extraction of names and locations of desired features such as villages or rivers. Google Earth Pro was also used for identification and spatial locations of features like, rail line and rivers. Political Map of Makurdi LGA was obtained from Ministry of Land & Survey, Makurdi for demarcation of ward boundaries in Makurdi LGA.

The assessment of flood vulnerability of Makurdi LGA based only on topography, involves the following steps:

(i) Generation of elevation map by creating the TIN map using contour 200 m interval of the area using ArcGIS 10.7.1 . The created TIN map was converted to raster map.

(iii) Classifications of the raster elevation maps into four flood vulnerability classes: extremely, highly, moderately, and low vulnerable areas.

(iv) Demarcation of the eleven wards in Makurdi LGA using polygon feature of the ArcGIS

(v) Overlay of interested features like ward boundary so as to examine the vulnerability of each of the wards.

(vi) Calculation of flood vulnerability in each ward was achieved by extracting each of the wards as a polygon and using the 'clip' extraction module of the ArcTool box of ArcGIS 10.7.1 to delineate each of the vulnerability classes from each of the wards within the LGA. The calculation module of ArcGIS software was then used to calculate the land area in each of the extracted classes. The percentages of each extracted land area was determined through the use of Microsoft Excel.

4.0 Results and Discussion

4.1 Impact of topography on flood vulnerability in Makurdi LGA

Fig. 3 shows the flood vulnerability of Makurdi LGA based only on the topography of the area. The topography in Fig. 3 shows that the valleys of River Benue and other important rivers in the LGA fall in extremely vulnerable areas. The areas that were found to be extremely vulnerable to flood in Fig. 3 have also been identified by some researchers like Abah (2013); Mamodu *et al.*, (2015) and Brian (2021).

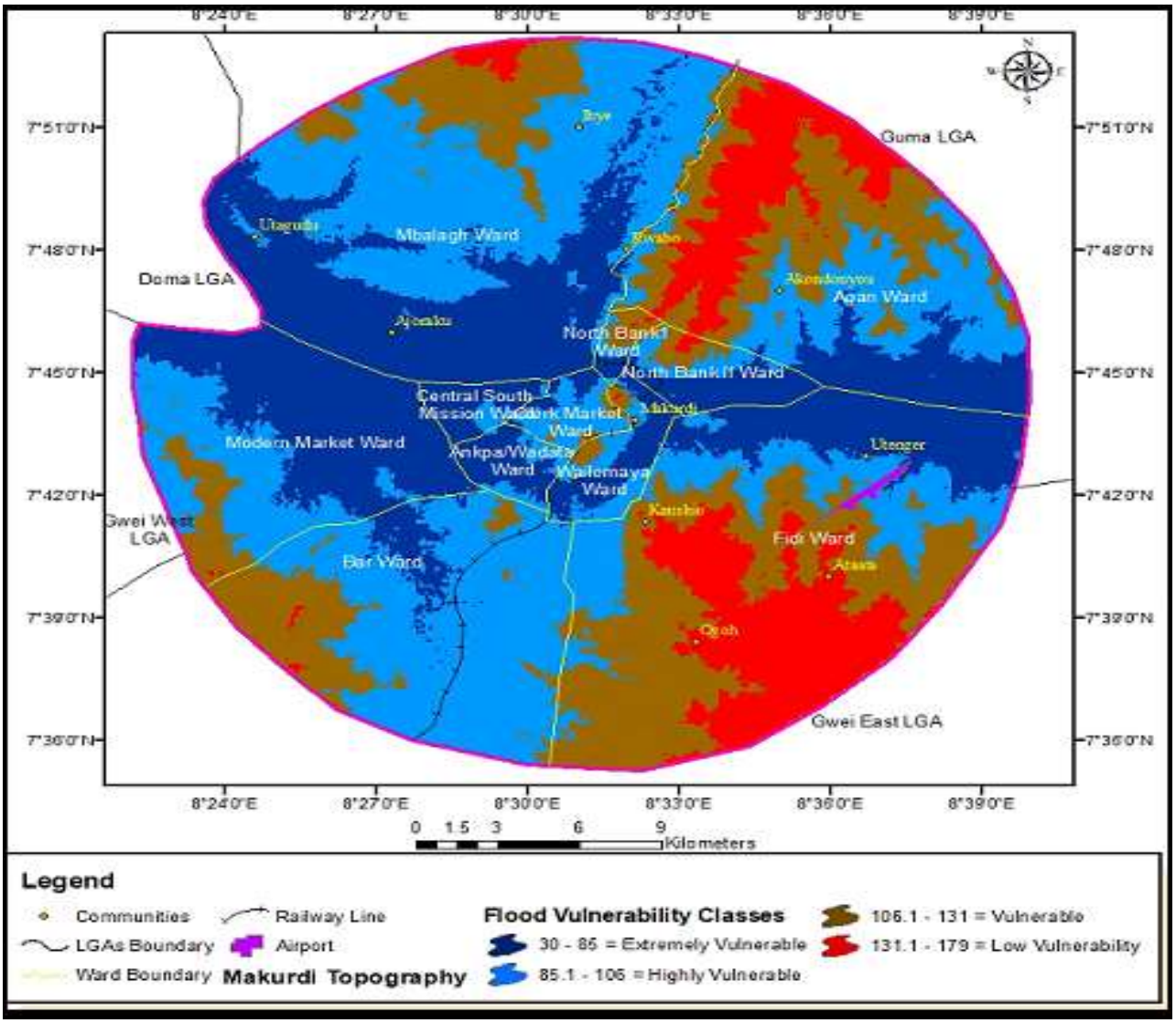

Figure 3 Flood vulnerability based on topography only.
Source: Generated from SRTM DEM Data

The high relief regions of Mbalagh and Agan wards and Fidi wards in the north and south of River Benue respectively are less vulnerable to floods than the low relief areas. Makurdi, Utenger, Ihye, Ajoraku, Utagudu and Nyiman are some of the main communities that are located in extreme flood vulnerable areas. Unfortunately, the high relief areas cover the least land area in the LGA as shown in Table 2 where only 10.72% of the total land areas of the LGA are high relief. This finding conforms with that of Acha and Aishetu (2018) who also reported high relief as the least terrain in the Metropolis. The use of topography as the only criteria for modeling flood vulnerability has been carried out by so many authors (Ikusemoran *et al.*, 2013, Shettima *et al.*, 2019). Table 3 shows the flood vulnerability among the wards in Makurdi LGA as well as the percentages of each vulnerability classes in each wards based solely on the topography of the LGA. It was revealed in Table 3 that Central South Mission ward has its entire land area within extremely and highly vulnerable areas, Wailomaya, Bar, Central Market and Modern Market wards all have more than 90% of their land areas within extremely or highly vulnerable areas. While North Bank II and Mbalagh have more than 80% of the land in extremely or highly vulnerable areas to flood. Out of the eleven wards in the LGA, only three wards (Fidi, Agan and North Bank I) recorded less than 50% of their land areas within extremely and highly vulnerable areas. Collectively, Table 3 revealed that 66.19% of the total land area of Makurdi LGA falls in either extremely or highly vulnerable areas. This finding show that large part of Makurdi LGA is located mainly in low terrain areas which subject the LGA to frequent flooding. Only Agan and Fidi wards among the eleven (11) LGAs have more than 20% of their land areas in low vulnerability terrain. This finding conforms to the earlier works of NEMA, (2013); Abah,
(2013) where extremely and highly vulnerable areas were the main flood areas in the LGA.

Table 3 Flood vulnerability based on Topography among the wards in Makurdi LGA

Wards	Extreme Vulnerability (km^2)	% of LGA	High Vulnerability (km^2)	% of LGA	Moderate Vulnerable (km^2)	% of LGA	Low Vulnerability (km^2)	% of LGA	Total (km^2)
Agan	19.07	13.96	39.36	28.81	45.49	33.29	32.72	23.95	136.64
Ankpa/Wadata	7.37	72.18	2.31	22.62	0.03	0.29	0	0.00	10.21
Bar	8.23	7.34	80.32	71.61	23.25	20.73	0.37	0.33	112.17
Central S/Mission	13.43	91.46	1.30	8.54	0	0.00	0	0.00	15.23
Clerk/Market	2.63	26.62	6.35	64.27	0.9	9.11	0	0.00	9.88
Fidi	37.38	18.39	38.41	18.90	76.09	37.44	51.35	25.27	203.23
Mbalagh	66.93	33.78	100.59	50.77	27.67	13.96	2.95	1.49	198.14
Modern Market	57.39	59.13	30.49	31.41	9.11	9.39	0.07	0.07	97.06
North Bank I	1.25	27.23	0.98	21.35	2.23	48.58	0.16	3.49	4.59
North Bank II	9.46	56.31	3.91	23.27	2.91	17.32	0.52	3.10	16.8
Wailomaya	9.02	56.69	6.04	37.96	0.81	9.63	0.04	0.24	15.91
Total	**232.66 (28.37%)**		**310.06 (37.82%)**		**188.49 (23%)**		**88.18 (10.77%)**		**819.86**

***Based on total land area**
Source: Researcher, (2020)

5.0 Conclusion

The impact of only topography as a criterion in the assessment of flood vulnerability in Makurdi LGA has been demonstrated in this study. It was revealed in the study that large parts (66.13%) of the LGA are in the low or very low terrain, while only 10.72% are on high topography. Therefore, the low terrain of large parts of Makurdi LGA, subject the LGA to frequent flooding. Out of the eleven wards within the LGA, the whole land areas of Central South Mission Ward falls within extremely and highly vulnerable areas, while Wailomaya, Bar, Central Market, Modern Market, North Bank II and Mbalagh Wards all have more than 80% of their land areas within extremely or highly vulnerable areas. Only three wards (Fidi, Agan and North Bank I) recorded less than 50% of their land areas within extremely and highly vulnerable areas. Collectively, about 66.19% of the total land area of Makurdi LGA falls in either extremely or highly vulnerable areas. Most of the identified areas vulnerable to flood due to topography have been mentioned by numerous authors who have carried out research on flood vulnerability of the LGA which suggest that topography impacts on flood vulnerability. The integration of multi-criteria for flood vulnerability assessment of the LGA is suggested for further studies.

5.1 Recommendations

The following recommendations are made from the findings of the study:

(i) Developmental structures in the low terrain areas within the LGA should be discouraged through public awareness and enforcement of laws by the concerned authorities.

(ii) More attention should be placed on the wards in the low terrain areas during policy making for flood control and management

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