MULTI-CRITERIA DECISION ANALYSIS FOR ASSESSMENT OF FLOOD DISASTER RISK AND VULNERABILITY IN MAKURDI LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA

BY

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ABSTRACT

Makurdi Local Government Area (LGA) is often subjected to annual flood disaster due to its geographical location in terms of its low relief, proximity to River Benue as well as its location at the downstream of Lagdo Dam in Cameroon. Multi-Criteria Decision Analysis (MCDA) was adopted to investigate flood vulnerable areas and elements at risk in Makurdi LGA in Benue State. Topography, landuse and landcover, proximity to River Benue, rainfall and soil textures were integrated and weighted using Analytical Hierarchy Process (AHP) for the assessment of flood vulnerable areas in the Metropolis. Fidi ward was purposively sampled based on its large size and heterogeneous terrain for the assessment of the disaster risk and exposure in the city. Coordinates of one hundred and ninety-one (191) structures in Fidi ward were acquired using GPS Garmin 76 for the investigation of elements at risk in the community. Flood vulnerability of the community were classified into; extremely, highly, moderately and low vulnerability. The results revealed that the valleys of River Benue and other large rivers like River Gwe within the LGA were extremely or highly vulnerable to flood with collective land areas of about 59.91 km^2, while the low vulnerable areas were mainly on high relief areas. The wards at the core of the city with very high population were located within extremely or highly vulnerable areas. Other wards with high percentage of land area within extremely and highly vulnerable areas include: Ankpa/Wadata (98.93), Clerk/Market (98.18), Wailomaya (93.35) and North Bank II (92.44). Seventy (70) of the 191 sampled structures were water points, health centres or entrepreneurs which are the essential necessities for human survival. Fifty-one (51) of the 70 structures fell within either extremely or highly vulnerable areas. It was recommended that there should be constant update of geospatial data of the structures within the metropolis for monitoring and assessment of elements at risk for quick government intervention during flood. Relocation of the structures and people in the extremely vulnerable flood areas to safer zones should be enforced if other control methods fail.

Keywords: Analytical Hierarchy Process, Flood Disaster Risk, Flood vulnerability, Geospatial Techniques, Multi-Criteria Decision Analysis,

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. The increasing climate change, accompanied with excessive rainfall and its devastating consequences remain indelible in the lives of many people and the environment. These unpalatable experiences have placed many countries on hold in their struggle for physical development (World Meteorological Organization [WMO], 2021). As the world's population increases at an alarming rate with increasing infrastructural development especially in floodplain areas, more lives and properties are becoming vulnerable to the risk of flood hazards whenever extreme flood events occur (Olanrewaju et al., 2019). The reoccurring flooding in River Benue particularly in Makurdi which destroys a lot of farmlands and claims lives and properties continues to attract scholars to investigate the affected parts of the city. Flooding in Benue State in general and Makurdi LGA in particular have been attributed to release of water from Lagdo Dam in Cameroon (Nigeria Post-Disaster Needs Assessment, 2013), and climate change (Terwase & Terese 2013; Mngutyo & Ogwuche 2013). According to Ocheri & Okele (2012), floods usually halts activities in some schools, churches, markets and other socio-economic activities in Makurdi.

Flood vulnerability refers to the way flood hazard or disaster affects human life and property. Vulnerability to a given hazard depends on: proximity to a possible hazardous event, and population density (Kittiphong et al., 2019). Risk assessment involves; hazard assessment, location of buildings, highways, and other infrastructure in the areas subject to hazards, and potential exposure to the physical effects of a hazardous situation. It aids decision makers and scientists to compare and evaluate potential hazards (Baky et al., 2019).Effective management of floods can be monitored through integration of geospatial techniques (Yekeen et al., 2019). Multi Criteria Decision Analysis (MCDA) is a broad term used to describe a set of methods that can be applied to support the decision-making process by taking into account multiple and often conflicting criteria through a structured framework (Madruga de Brito & Evers 2016). Analytical Hierarchy Process (AHP) formulates the decision into a hierarchy of criteria and uniquely uses pair wise comparisons provided by experts' judgments to elicit preferences (Udezo & Ayeni, 2016).

Despite the yearly occurrence of flood disasters in recent times and the huge risk associated with them, much have not been done on the integration of several criteria to assess flood vulnerability that subject the LGA to annual flood disaster risks. Most of the existing works on flooding in Makurdi dwelt on causes, effects and control using qualitative techniques (Terwase & Terese 2013; Ahile & Ityavyar 2014; Marcellinus & Joseph 2015). Though some geospatial mapping of flood vulnerability zones in Makurdi have been carried out (Abah 2013; Mamodu et al., 2015); Acha & Aishetu 2018), but none of the studies investigated flood vulnerability and disaster risk based on the wards within Makurdi LGAs. Integration of some criteria for flood vulnerability zones and the use of MCDA and AHP for mapping flood risk zones as were carried out in this study was also not adopted in the existing ones. Furthermore, the assessment of elements at risk and disaster risk analysis, distinguish this work from the existing ones. It is against this background that geospatial technique was used to map vulnerable land areas, communities and facilities to floods while GIS-based MCDA and AHP methods were adopted for computing the priority weights of each criterion to rank and display vulnerable areas to flooding. Therefore, integration of remotely sensed data, GIS techniques and the application of MCDA and AHP for mapping flood risk zones were carried out to map the land areas and communities that are vulnerable to flood hazard and analysis of flood disaster risk.

THE STUDY AREA

Makurdi town is the political headquarters of Makurdi Local Government Area (LGA) and the capital of Benue State. It is situated within the Benue trough in the North Central geo-political zone of Nigeria. The extent of the present day Makurdi is a 16 km radius from the General Post Office along the Beach Road (Ajene & Ogorry 2016). Makurdi is located between Latitudes 7° 35′ 30″ N and 7° 53′ 00″ N of the Equator and Longitudes 8°22′ 00″ E and 7°39′ 00″ E of the Meridian (Fig.1). River Benue which is the second largest river in

Nigeria runs through the central part of Makurdi which makes most parts of the town to be marshy especially during the rainy season. The total land area of Makurdi as calculated using GIS technique in this work is about 819.86km^{2}which is close to that of Hilakaan & Ogwuche (2015) who quoted the land area as 804 km^2. Out of this total land area, only 32.81 km^2 and 102.66km^2 have been developed in the northern and southern part of River Benue respectively, which means a total land area of 135.47 km^2 of the town constituting (17.63%) of the total land area have been developed (Fig.1).

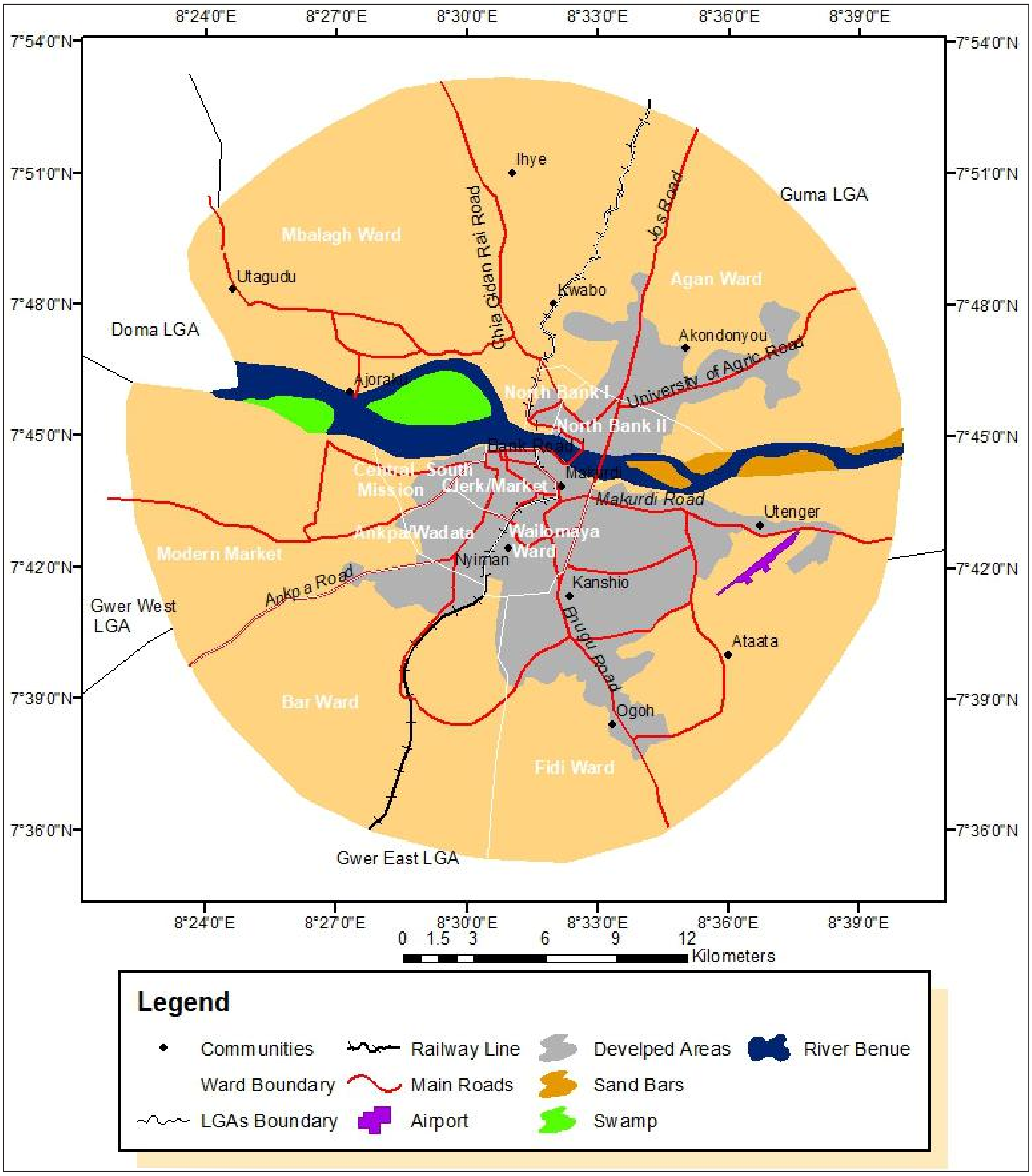


Figure 1: The Study Area

There are eleven (11) wards in Makurdi which include Agan, Ankpa/Wadata, Bar, Central South Mission, Clerk Market, Fidi, Mbalagh, Modern Market, North-Bank I, North Bank II and Wailomayo (Hilakaan & Ogwuche (2015). Generally, the relief of Makurdi ranges from 30.85 to 179 m above sea level. Therefore, the general low terrain of the area coupled with the close proximity to River Benue could lead to excessive flooding of most parts of the LGA. The major river in Makurdi is River Benue which runs from West to East and traversing Makurdi into almost two equal halves (Fig.1). 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 which include Kpege, Adaka, Asase, Idye, Urudu and Demekpe amongst others (Abah, 2013).

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 & 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 & Ogwuche (2015) observed that the mean monthly relative humidity in Makurdi varies between 43% in January and 81% in July-August. Abah (2013) and Hemba et al. (2017), opined that the soils of Makurdi 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. Makurdi town is located within the Guinea Savannah belt of Nigeria which is a transitional vegetation zone separating the forested belt in southern part of Nigeria from the savannah zone in northern Nigeria (Areola, 1983 in Hilakaan & Ogwuche (2015). Changes in land cover, and destruction of forest in the riverine areas have all contributed to flood risk (Ndoma, 2015).

According to NPC (2007), "the population of Makurdi LGA comprises 154,138 males and 146,239 females" respectively making a total of 300,377 people within the LGA. The dominant ethnic groups are the Tivs, other existing tribes include Idomas, Etilos, Jukuns and Egede. Most of the facilities and establishment such as Air Force Base, Naval Base, Airport, Benue State University, Makurdi Brewery, Ministry of Health, and many public facilities such as educational institutions, health and religious centers among others are all located in the southern part of River Benue within the town. Therefore, since most of the developed areas and facilities are located so close to River Benue, there is the need to assess flood vulnerability and disaster risk in the area.

METHODOLOGY

The data types that were acquired and utilized for this work are shown in Table 1. Rainfall, topography, proximity to water body, soil texture and land-use/land-cover have been identified as the main criteria for flood vulnerability assessment (National Disaster Management Framework (NDMF 2010); Elissavet, et al. (2019). The five criteria were integrated for this study. (i) Rainfall: The spatial pattern of rainfall was generated by using the mean rainfall spatial data of DivaGIS for fifty-one years (1950-2000). The mean annual rainfall of fifty-three (53) points of equal distance was acquired and Kriging module of point interpolation was used to map the spatial pattern of rainfall based on the rainfall values of the 53 points. The output map was classified into extremely vulnerable, highly vulnerable, vulnerable, marginally vulnerable and slightly vulnerable. (ii) Topography: The raster elevation map of Makurdi was also generated using the ASTERDEM V2 DEM data set and classified into four flood vulnerable classes.(iii) Proximity to River Benue: The buffering of the proximity module of ArcGIS was used to buffer the distances of Makurdi land area from River Benue. The distances of the intensity of the previous flood areas from River Benue were obtained from field observations and from the inhabitants during field work that was carried out on Thursday, August 4^{th}, 2021.

Table 1: Types, Description, Purposes and Sources of Data

Data Types	Description of Data	Purpose	Sources
Thermal Emission and Reflectance (ASTER)	AsterGDEMV2 Data (30m Resolution)	Generation of relief and drainage	earthexplorer.usgs.gov
Satellite Image	Landsat OLI/TIRS ofJanuary 31st 2021.	Generation of NDVI for assessment of vegetation cover	earthexplorer.usgs.gov
Rainfall Data	Mean annual rainfall spatial data from 1950-2000 of Makurdi	Creation of spatial pattern of mean annual rainfall	DivaGIS
Global Positioning System (GPS)	Gearman 76	For capturing of features and places of interest	
Political map of Makurdi LGA	Showing the eleven wards in the LGA	Delineation of the eleven wards	Ministry of Land and Survey, Makurdi

The buffer zones include; 3 kms, 5 kms and further than 5 kms buffer. (iv) Soil Texture: Based on the six available FAO based soil classifications within Makurdi LGA, each of the soil types were weighted based on the premise that clayey soils with less permeability for instance are more prone to floods than those whose textures are highly permeable (FAO, 2017). The weights of each of the six soil classes are shown in Table 3.5. (v) Landuse/Landcover: Landsat 8 (OLI) image of January 31st, 2021 was acquired and classified into the landuse and landcover using NDVI indices with the following formula (Tek, 2018): NDVI = (NIR – Red) / (NIR + Red), For Landsat 8 data as used in this study: NDVI = (Band 5 – Band 4) / (Band 5 + Band 4). The NDVI value varies from -1 to 1. Dense vegetation is delineated from the values of the NDVI because higher value of NDVI reflects high Near Infrared (NIR), that is, dense vegetation. Vegetation indices were used for the classification of the image based on the following: NDVI = -1 to 0 = water bodies, NDVI = 0.1or close to 1; = barren rocks and sand, NDVI = 0.2 to 0.5 = shrubs and grasslands and NDVI = 0.6 to 1.0 = dense vegetation. The following four LULC classes were classified: water body, built-up areas/bare surfaces, shrubs/woodland and forest.

Multi Criteria Decision Analysis was applied to integrate the five criteria using AHP for the weighting of the criteria. The assignment of the weights on each criterion was based on literature such as Guler & Zuhal (2018) and Shettima et al. (2019).The values of vulnerability from lowest of 1 and highest of four were assigned to each of the classified five maps. The five (5) criteria were integrated using MCDA method. The criteria were weighted using AHP methods of weighting (Saaty 2012). The matrix of the five criteria were generated, and the weights of the criteria are shown in the prioritization and weights matrix in Table 1.

Table 1: Prioritization and Weights Matrix of the Seven Criteria

	Topography	LULC	Proximity	Rainfall	Soil Texture	Weights	Weights %
Topography	0.444	0.511	0.383	0.348	0.375	0.412	41.22
LULC	0.222	0.255	0.383	0.348	0.250	0.292	29.17
Proximity	0.148	0.085	0.128	0.174	0.188	0.144	14.45
Rainfall	0.111	0.085	0.064	0.087	0.125	0.094	9.44
Soil Texture	0.074	0.064	0.043	0.043	0.063	0.057	5.73
	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	100.0000

In order to assess the areas vulnerable to floods in each of the eleven wards in Makurdi, the following steps were taken. The first step was the generation of the five criteria maps (rainfall, topography, landuse/landcover, soil texture and proximity to River Benue). Reclassification of the five criteria maps based on the values of the weights of each criterionin Table 1. Integration of the five criteria using the weighted sum of the multi criteria approach in ArcGIS10.7.1 after subjecting them to AHP analysis. Overlay the wards' boundaries, and other facilities such as roads, railway line and other important features. Extraction of each of the districts and calculation of the vulnerability classes of each ward that is, highly vulnerable, vulnerable, marginally vulnerable and slightly vulnerable.

The assessment of the elements at risk was carried out in only one ward from the eleven wards in Makurdi. The selected ward (Fidi) was purposively sampled (since residential houses were excluded) taking the following factors into consideration: (i) Fidi ward is the largest ward in Makurdi covering 24.76% of the total land area of Makurdi (ii) Fidi ward comprises of heterogeneous topography where all the topographical classes are found. The locations of the facilities in the heterogeneous terrain show the facilities in the different vulnerable classes. Coordinates of one hundred and ninety-one (191) facilities and features in Fidi ward were obtained and overlain on the flood vulnerability map from which the facilities that fall in flood risk areas are referred to as elements at risk.

RESULTS AND DISCUSSION

Figures 2a, 3a, 4a, 5a and 6 show the generated five criteria for this study while Figures 2b, 3b, 4b, 5b and 6show the classified images using the weights assigned to each of the criterion.

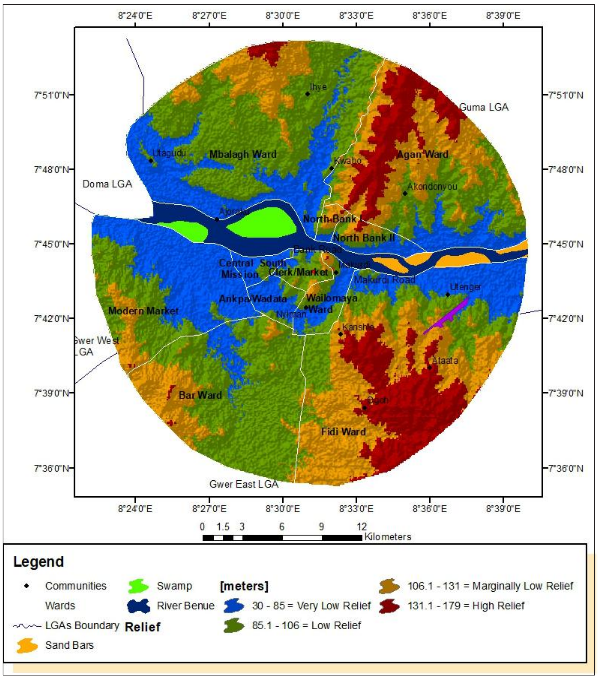


Figure 2a: Topography of Makurdi LGA

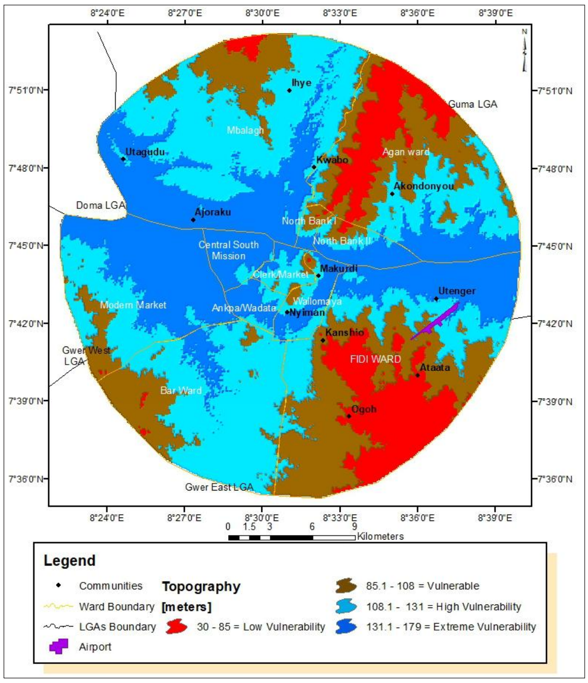


Figure 2b: Classified Topography of Makurdi LGA

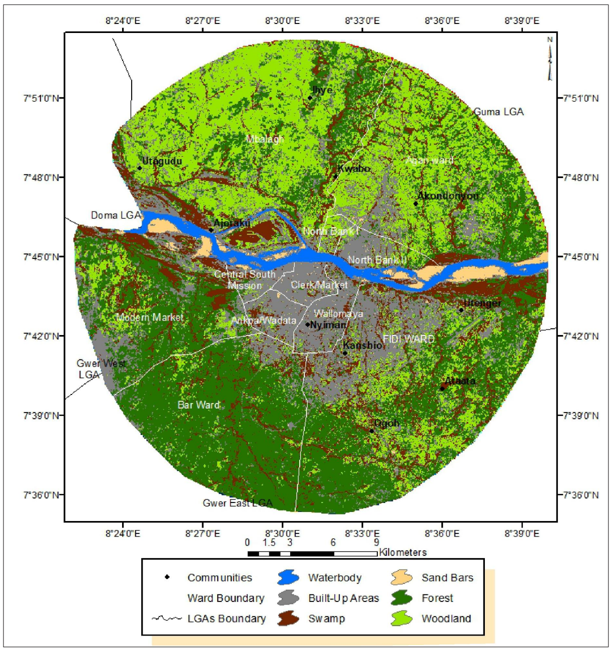


Figure 3a: LULC of Makurdi LGA

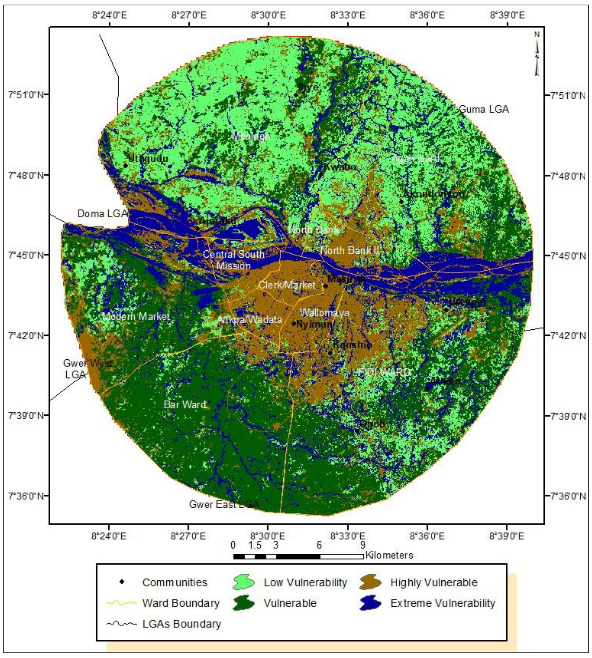
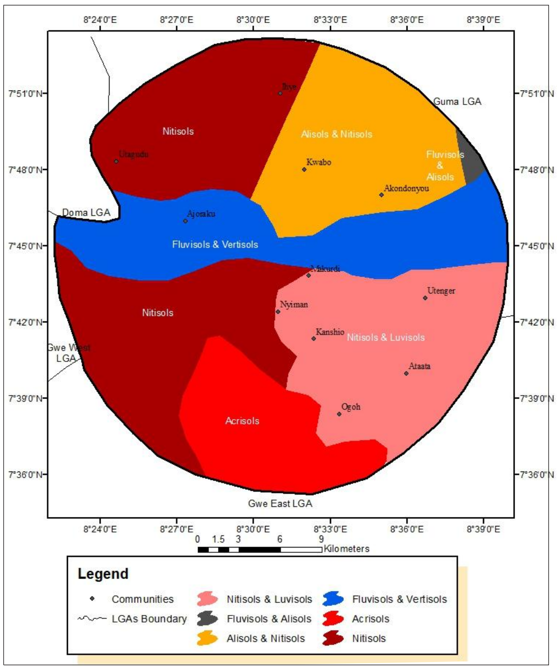


Figure 3b: Classified LULC of Makurdi LGA



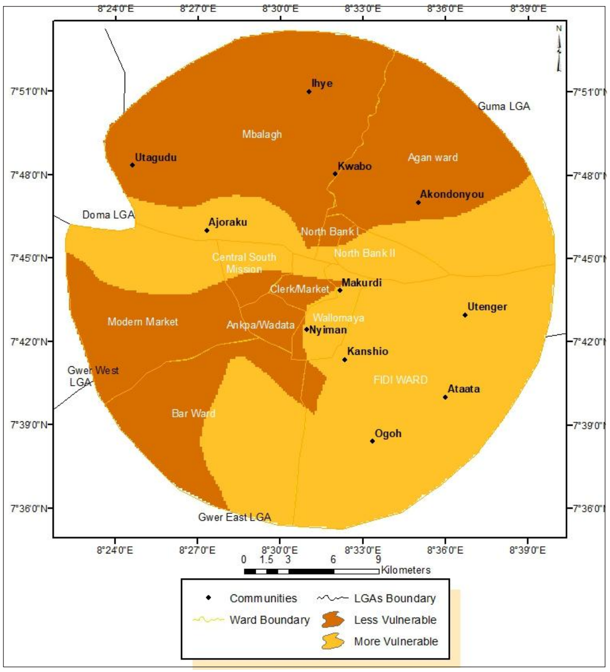
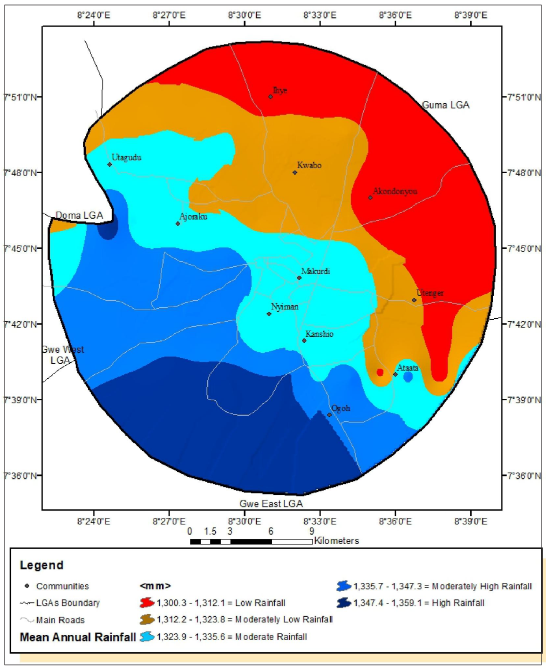


Figure 4a: Soil Texture in Makurdi LGA. Figure 4b: Classified Soil Texture in Makurdi LGA



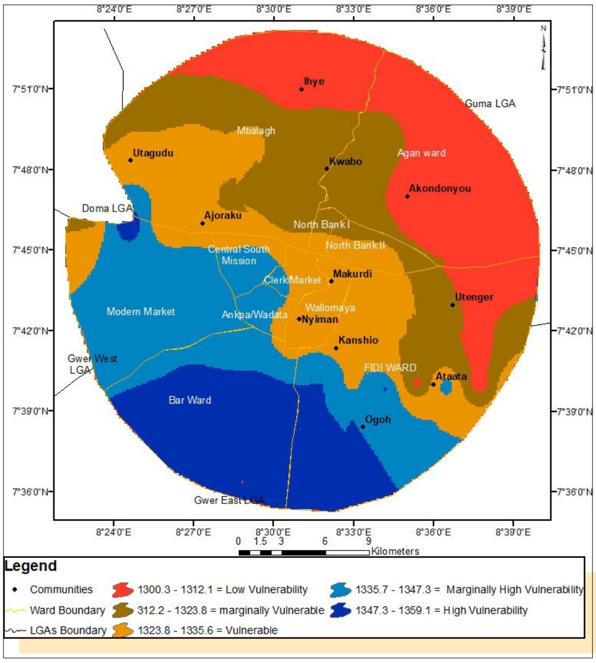


Figure 5a: Rainfall Pattern in Makurdi LGA. Figure 5b: Classified Rainfall Pattern Makurdi

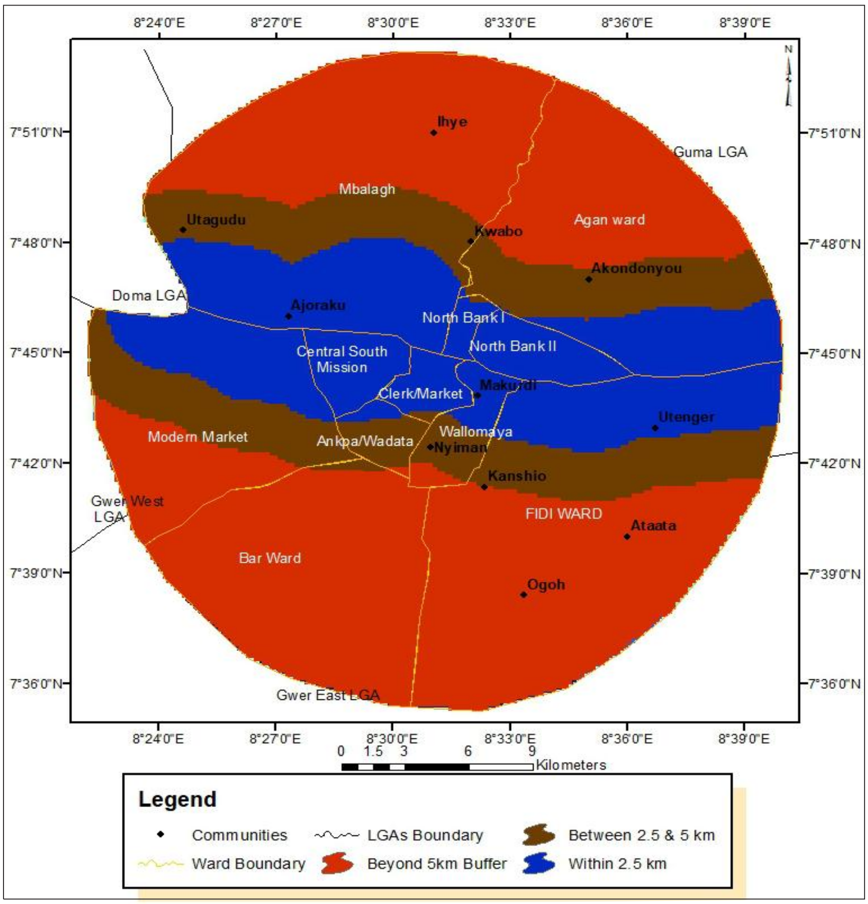


Figure 6: Generated and Classified Proximity to River Benue

Fig. 7 shows the flood vulnerability map based on the integration of the five criteria, while Tables 2 and 3 show flood vulnerability among the wards in Makurdi LGA and elements at risk and exposure based on vulnerability/proximity respectively

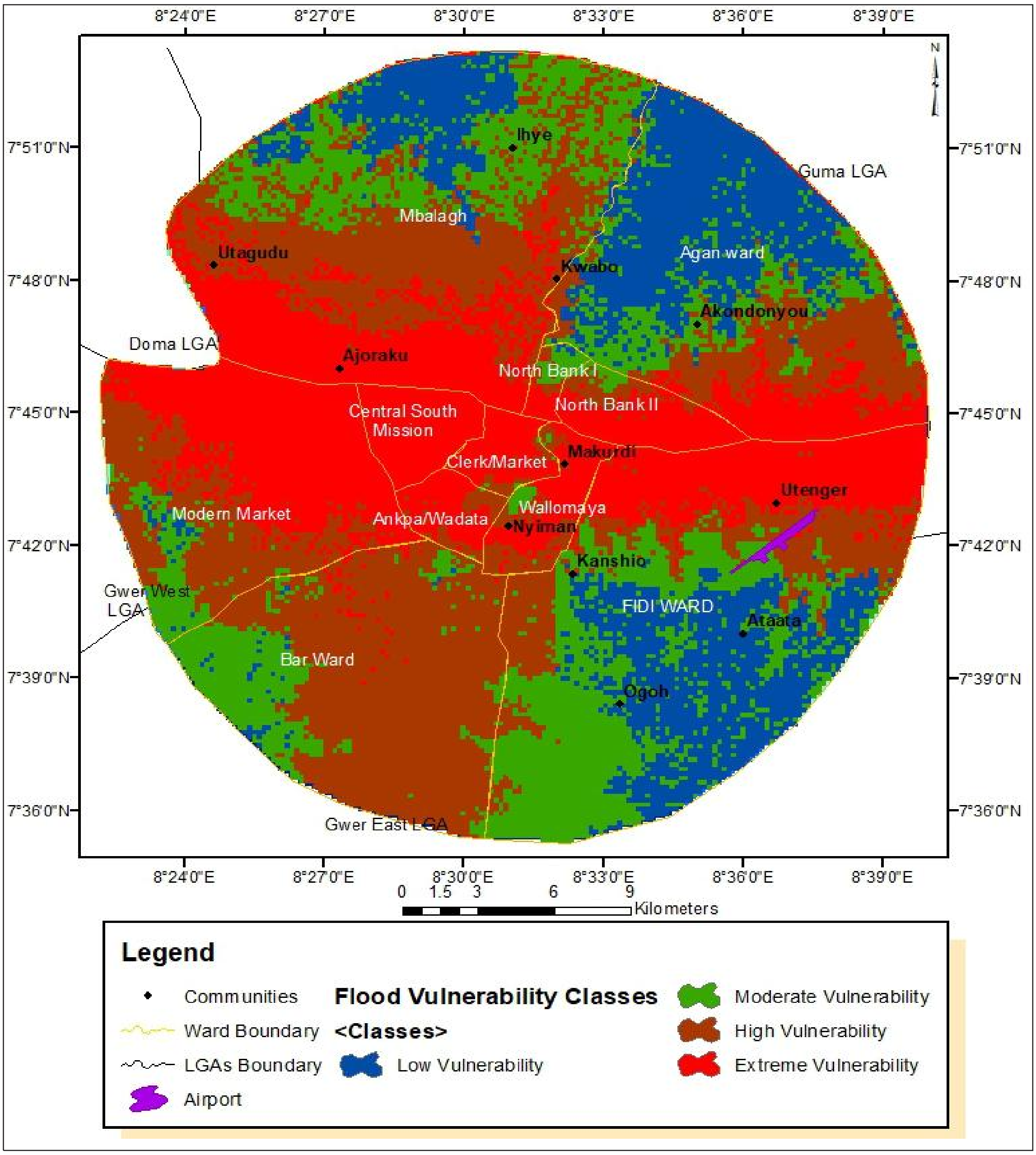


Fig.7: Flood vulnerability in Makurdi LGA

Table 2: Flood vulnerability among the wards in Makurdi LGA

Wards	Extreme Vulnerability (km^2)	%	High Vulnerability (km^2)	%	Vulnerable (km^2)	%	Low Vulnerability (km^2)	%	Total (km^2)
Agan	19.9	14.56	30.84	22.57	25.25	18.48	60.65	44.39	136.64
Ankpa/Wadata	7.51	73.56	2.59	25.37	0.11	1.08	0	0.00	10.21
Bar	2.73	2.43	85.12	75.88	23.16	20.65	1.16	1.03	112.17
Central S/Mission	15.23	100.00	0	0.00	0	0.00	0	0.00	15.23
Clerk/Market	8.37	84.72	1.33	13.46	0.18	1.82	0	0.00	9.88
Fidi	40.89	20.12	34.6	17.03	70.16	34.52	57.58	28.33	203.23
Mbalagh	49.7	25.08	72.13	36.40	49.25	24.86	27.06	13.66	198.14
Modern Market	53.27	54.88	33.63	34.65	9.15	9.43	1.01	1.04	97.06
North Bank I	1.76	38.34	0.93	20.26	1.71	37.25	0.19	4.14	4.59
North Bank II	12	71.43	3.53	21.01	1.27	7.56	0	0.00	16.8
Wailomaya	10.1	60.44	5.5	32.91	1.11	6.64	0	0.00	16.71
Total	**221.46**	**26.99***	**270.20**	**32.92***	**181.35**	**22.10***	**147.65**	**17.99***	**820.66**

***Based on total land area**

Table 3: Elements at Risk and exposure based on vulnerability and proximity

Elements	Extreme Vulnerability		High Vulnerability		ModeratelyLow Vulnerability		Low Vulnerability		0 – 2.5 kms Proximity		2.5 – 5 kms Proximity		Above 5 kms Proximity		**Total**
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Education	16	48.48	10	30.30	4	12.12	3	9.09	22	66.66	5	15.15	6	18.18	**33**
Electricity	2	40.00	2	40.00	1	20.00	0	0	2	40.00	3	60.00	0	0	**5**
Entrepreneur	29	80.56	6	16.67	1	2.78	0	0	30	83.33	5	13.89	1	2.78	**36**
Health	11	68.75	1	6.25	4	25.00	0	0	12	75.00	1	6.25	3	18.75	**16**
Industry	4	66.67	0	0	1	16.67	1	16.67	4	66.67	0	0	2	33.33	**6**
Public	3	25.00	3	25.00	5	41.67	1	8.33	3	25.00	6	50.00	3	25.00	**12**
Religious	21	60.00	6	17.14	5	14.29	3	8.57	24	68.58	2	5.71	9	25.71	**35**
Security	4	50.00	2	25.00	2	25.00	0	0	4	50.00	4	50.00	0	0	**8**
Transport	3	50.00	3	50.00	0	0	0	0	2	33.33	4	66.67	0	0	**6**
Tourism	5	62.50	2	25.00	1	12.50	0	0	5	62.50	3	37.5	0	0	**8**
Water	11	61.11	4	22.22	2	11.11	1	5.56	10	55.56	6	33.33	2	0	**18**

The integration of the five criteria using MCDA and AHP for weighting the criteria shows the vulnerability of land areas to flood as presented in Fig 7. The valleys of River Benue as well as the high rainfall parts of the South Western part of River Benue (Figs. 2b and 5b) were all either extremely or highly vulnerable to flood. The entire Central South Mission and large parts of Ankpa/Wadata, Wailomaya, Clerk/Market, Modern Market and North Bank II, Fidi, Agan, Bank North I and Mbalagh wards all fall within the extremely vulnerable areas. This finding is similar to that of Abah(2013) that Makurdi town is potentially susceptible to flooding in areas like Wurukum,Wadata, Ankpa, Hudco Quarters and parts of North Bank. Terwase and Terese (2013) also listed Wadata, Idye, Atsusa, Wurukum, Akpehe, Logo1 and Logo 2, Ankpa Quarters extension, Nyiman and Gyado villa as most vulnerable areas to flood in Makurdi.

Table 2 reveals that land areas within highly vulnerable areas had the highest percentage while extreme vulnerable land areas follow. Therefore, the collective land areas that are extremely or highly vulnerable areas cover a total land area of 59.91%. This finding means that large parts of the entire LGAare very vulnerable to flood which agrees with that of Abah (2013) that Makurdi is entirely potentially vulnerable to flood. Among the wards, Central South Mission was the most vulnerable ward because the entire land of the ward falls within extremely vulnerable areas. Other wards with high percentage of land area within extremely and highly vulnerable areas include: Ankpa/Wadata (98.93), Clerk/Market (98.18), Wailomaya (93.35) and North Bank II (92.44). Unfortunately, all these aforementioned wards are the core of the Metropolis with very high population (Abah, 2013). Therefore, there is the need to monitor the causes, effects and control measures of flood in these extremely and highly affected wards so as to minimize the impact whenever it turns to disaster.

Table 2 also reveals that none of the land areas in five (5) wards (South Central Mission, Ankpa/Wadata, Clerk/Market and Wailomaya) out of the eleven wards falls within low vulnerable areas. While two wards (Modern Market and Bar) had about only 1% of their land area within low vulnerable areas. Therefore, only Mbalagh, Agan and Fidi wards had more than 10% of their land area within low vulnerable areas which further substantiate that Makurdi Metropolis is generally vulnerable to flood. Extension of built-up areas into the floodplains, encroachment on water channels, river channel siltation, changes in vegetation and clearing of forest cover by man have all contributed to the frequent flood occurrence in the low terrain of the metropolis (Brian 2021).

Table 3 reveals the elements at risk and exposure where the three most important sectors (health, entrepreneur and water) all have more than 60% of their facilities within extreme vulnerable areas. Other than water facilities with 55.55%, health, tourism, education, religious and entrepreneur facilities had more than 60% of their facilities within 0-2.5 kilometers from River Benue. The implication of the findings in this section is that during floods, major means of livelihoods (entrepreneur), health, education and water are exposed and are at risk to flood. It was concluded in this section that since most of the elements at risk in Table 3, as generated from Fidi ward with less than 40% extremely or highly vulnerable areas as shown in (Table 2) were located in extreme flood areas and also within 0-2.5 kilometers from River Benue. Therefore the close proximity of most of the structures to River Benue as well as the low relief of the areas, naturally expose them to flood and make them at risk to flood.

CONCLUSION

Multi-criteria analysis for assessment of flood vulnerable areas as well as the identifications and analysis of elements at risk in Makurdi LGA using geospatial techniques have been demonstrated in this study. It has been established in this study that several factors are responsible for flood vulnerability in Makurdi LGA, among which topography, land use are and landcover, proximity to river, rainfall and soil texture. The wards at the core of the metropolis which constitute larger population are more vulnerable to floods due to their geographical location and the environmental factors such as low terrain, poor landuse, proximity to Benue River, constant and high rainfall among others.Most of the structures within the Metropolis were found to be exposed or at risk to flood since most of the elements were within either extremely or highly vulnerable areas to flood. Higher percentages of the structures were also found within the low terrain of the generally low relief areas and/or within close proximity to the devastating River Benue.

Based on the findings in this study, the following recommendations were proffered:

(i) Application of remotely sensed data and GIS techniques should be adopted for flood vulnerability and flood disaster risk monitoring and control because of the accuracy, reliability, time and cost saving of the technique.

(ii) Generation and constant update of geospatial data of the structures within the metropolis for monitoring and assessment of elements at risk for quick government intervention during flood is recommended

(iii) Where all the aforementioned recommendations cannot work, the structures and people within the frequently affected flood areas should be relocated to a safer ground.

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