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A GIS Multi-Criteria Evaluation for Flood Risk-Vulnerability Mapping of Ikom Local Government Area, Cross River State

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JE and AOA designed the study and wrote the protocol. Author ACU managed the literature searches. Author FOO conceptualized the work and reviewed related literatures while author CGN performed and reported the spatial analyses. All authors read and approved the final manuscript.

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ABSTRACT

Flooding is a significant hydrological hazard in the world and has elicited responses from government and non-government agencies alike due to the damages it portends. This study was formulated on this backdrop, with the objective of designing a flood risk-vulnerability map of Ikom Local Government Area. The types of data employed were majorly secondary. Interviews were also primarily adopted. The multi-criteria assessment meant a systematic combination of independent parameter inputs (distance from river, rainfall intensity, elevation, land use, slope and soil; abbreviated as "DRELSS") for the analyses. Analytical processes such as buffering, slope generation, interpolation, classification, reclassification and the weighted overlay were used in the ArcMap platform. The methods were all based on existing literature, authors expert understanding and standard analytical procedures. The flood risk-vulnerability map produced from the analysis

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shows 5 risk zones (very high, high, moderate, low and very low-risk zones). From the analysis, it was discovered that areas close to the rivers were more prone to flooding. A total of 7 communities were within very high-risk zone, which also covers 28 square kilometers (sq km) while 16 communities were in high risk zones within an acreage of 305 sq km, both only making up a significant 16 percent of the total Ikom land area, most of which had built-up human activities. A follow-up ground-truthing exercise bolstered the findings of flood occurrence in the deduced communities. The necessity of a multi-criteria flood risk-vulnerability evaluation in Ikom, like any other area, is thus indispensable as it provides for precaution, preparedness and post-hazard planning. The findings herewith are no doubt vital to the government, urban planners, insurers, emergency services and the likes.

Keywords: Flood; risk; vulnerability; GIS; remote sensing; multi-criteria evaluation; weighted overlay.

1. INTRODUCTION

Flooding is one of the most overwhelming and frequently occurring natural hazards in the world. It is a significant issue at the frontline of environmental discuss in the world today due to the trails of damages it leaves behind. The damages caused by this natural hydrological hazard ranges from socio-economic damages to loss of lives and properties. These have drawn the attention of the government, non-governmental organizations, private organizations and individuals to seek a strategic remedy to the damages created by this devastating phenomenon. More so, impacts of a flood disaster on the society and its effect on sustainable development are overwhelming in recent. This is geared to increasing climate change, accompanied with excessive rainfalls and its devastating consequences remain indelible in the lives of many people and the environment [1].

Flooding occurs when water overflows or inundates land that is usually dry. This can happen in a multitude of natural and anthropogenic ways. Most common is when rivers overflow their banks, excessive rain, a ruptured dam or rapid ice melting in the mountains [2]. Notably, most flood destruction is attributable to humans' desire to occupy areas vulnerable to flooding such as picturesque coastlines, river valleys or floodplains. Aggravating the problem is a tendency for developers to backfill and build on wetlands that would otherwise act as natural flood buffers [2]. Also, there is a tendency for land and housing to be cheaper to acquire in the areas that are floodplains, thus the unavoidable residence in such high-risk areas. In other cases, people are ignorant of the physical vulnerability of certain areas and are taken unaware when the flood comes.

The problem of flooding is universal. For instance, in the United States, where flood mitigation and prediction are advanced, floods do about $6 billion worth of damage and kill about 140 people every year [2]. A 2007 report by the Organization for Economic Cooperation and Development found that coastal flooding alone does some $3 trillion damage worldwide and in China's Yellow River valley, where some of the world's worst floods have occurred, millions of people have perished in floods in the last century [2]. In Europe, [3] noted that climate change is increasing flood risk with nearly 1 million people expected to be affected by flooding in the near future with significant economic damage in the range of hundreds of billions of Euros per year. Flooding has been attributed to global warming. "As humans continue to emit greenhouse gases like carbon dioxide, the world continues to warm. The warming is seen everywhere, in the atmosphere, oceans, with rising water levels and melting ice and it is known conclusively that humans are causing the warming" [3].

In addition, the United Nations Office for Disaster Risk Reduction (UNISDR) and the Belgian-based Centre for Research on Epidemiology of Disasters (CRED) stated that between 1995 and 2015, flooding had the highest percentage of natural disasters by disaster type with 3062 occurrences (43 percent). This was followed by storm (2018 incidents-28 percent), then earthquake (562 events-8 percent), extreme temperature (405 occurrences-6 percent), landslide (387 occurrences-5 percent), drought (334 incidents-5 percent), wildfire (251 events-4 percent) and volcanic activity having the least with 111 occurrences which makes up only 2 percent. The report further revealed that in the last 20 years, 157,000 people have died as a result of floods. The report also says that between 1995 and 2015, 3062 flood disasters affected 2.3 billion people all over the world, accounting for 56 percent of all those affected by weather-related disasters [4]. It was likewise reported that during the period of 1996 to 2005, there were 290 flood-disasters in Africa alone, which left 8,183 people dead and 23 million people affected, and which caused economic losses of $1.9 billion [5].

Nigeria is not left out. In the past decade, thousands of lives and properties worth millions of Naira have been lost directly or indirectly from flooding every year. Nigeria has witnessed diverse flood events in the past years and due to the high level of vulnerability and lack of coping capacity of the people, with the fast occurrence of extreme events resulting from climate change [1]. The devastating flood occurrence and its multidimensional impact on the masses have been a great concern to Nigeria and the world as a whole. The 2012 flood event is a special case. It was believed to have resulted from the combination of Lagdo Dam effect and rainfall intensity. Cross River state amongst other states were affected by the 2012 flood incident which has been characterized as the most devastating since the last 4 decades. An estimate of 1.3 million people was displaced and about 431 people lost their lives with over 1525 square kilometers of farmland destroyed [6]. Specifically, Cross River State is a frequent sufferer from flooding. The 2012 flood disaster affected 212 communities in Cross River State, killed 13, displaced 49,918, destroyed 1,800 houses, 82,361 farms and so on [7]. Also, in 2017 [8] reported that 25000 people were affected in a particular flood event in Boki Local Government Area (LGA). Also, between July and August 2017, the state was reported to have witnessed 217 flood cases with 15 mortalities in 21 communities of 12 LGAs (Obudu, Yala, Ogoja, Boki, Etung, Ikom, Obubra, Abi, Biase, Akamkpa, Odukpani and Calabar South) [9]. In the same vein, in 2012, Ikom LGA (Alisse and Osokora communities) were visited by flood waters rendering scores of villagers homeless and farmless. A total of 43 buildings were destroyed, most of which were built close to the river bank, making it easier for water to overrun them [10].

The problems that arise from lack of knowledge on flood mitigation and prediction especially in Nigeria and the developing world at large cannot be overemphasized. Still, answers have not been provided to questions on the remedy to the recurrent flooding in Nigeria [11]. It is no more questionable that a thorough knowledge of flood vulnerability is essential for developing an effective flood mitigation strategy for the areas susceptible to the menace. The need for modelling flood vulnerability was stressed by the Director General (DG) of the Nigerian Hydrological Services. He noted that "…*while the trends in climate variations prevail, there is need to carry out comprehensive flood hazard mapping for areas considered at risk in Nigeria*…" [11]. The UNISDR and CRED also emphasized that "…*in view of the serious health and socio-economic impacts of flooding, flood control should be regarded as a developmental issue as well as humanitarian concern and priority be given to cost-effective mitigation measures in poor regions at high risk of recurrent flooding…"* [4].

On the other hand, a widely accepted definition of risk was offered by [12] and cited by [13] as the probability of a loss that depends on three elements; hazard, vulnerability and exposure. [14] also suggested that hazard and vulnerability cannot exist independently of each other. Hence any changes in hazard and/or vulnerability will influence the extent of the risk. Furthermore, [14] pointed out that since hazards cannot be modified; efforts aimed at reducing risk to a hazard can only be focused on reducing the vulnerability of the exposed communities or environments to that hazard. More so, vulnerability is a state of conditions and processes resulting from physical, social, economic and environmental factors that increase the liability of a community about the impact of hazards [15].

The better way to thus define flood risk is the definition of risk as an outcome of hazard, that is, the physical and statistical aspects of the actual flooding (for example, the return period of the flood, extent and depth of inundation) and the vulnerability, that is the exposure of people and assets to floods and the susceptibility of the elements. Flood risk is thus a combination of hazard (potential damage), vulnerability (probability of flooding occurrence) and impact of exposure [16]. In this study risk and vulnerability are used pari-passu because of the focus of the work on the vulnerability element of risk (potential spatial reach of flood when it occurs and communities most likely to experience inundation).

The strategies to combat the problem of flooding are not far-fetched. It is not enough for the Nigeria Meteorological Agency (NIMET) to predict that flooding would occur. There is need for site specific prediction of the communities that are particularly at risk so that proactive measures can be initiated before the inundation. Today, several strategies and technologies have been designed to combat the problem of flooding, and at the forefront of these technologies are the Geographic Information System (GIS) and Remote Sensing (RS) technologies. The application of GIS and RS technologies in evaluating flood risk region and assessing potential damages caused by flooding has helped urban and town planners manage flood incidence in the least cost and real-time manner.

Vulnerability assessments have been undertaken to understand the potential for loss, traditionally they focused on the nature of the hazard and who and what is exposed [16]. Different studies have addressed contemporary vulnerability of different communities worldwide to flooding from the natural hazards perspective of understanding exposure and the number of people and structures affected [16,17,6,18]. Particularly, flood risk-vulnerability mapping using GIS and RS has been employed in several cases through different criteria and methodologies. GIS and RS are considered as key tools by many researchers to map the spatial distribution of flood risk. The multi-criteria evaluation (MCE) methodology is vastly used where several criteria are defined and compared side by side in predicting possible flood risk zones.

The MCE method has been applied in several studies since 80 per cent of data used by decision makers is geographically related [19]. [20] and [21] also adopted GIS MCE techniques for flood risk evaluation. They integrated several sets of data to derive zones of flood vulnerability. Other authors [22,23,24] also emphasized the importance of the weighted overlay technique which has gained popularity in the spatial flood risk-vulnerability mapping process. This study was thus designed to evaluate flood risk-vulnerability in Ikom LGA of Cross River State, specifically to show the different flood risk-vulnerability zones within the area using the spatial MCE method. The overall aim of the study was to generate a composite flood risk-vulnerability map that can aid decision makers take proactive measures towards flood mitigation.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Ikom LGA, one of the 18 LGAs of Cross River State. It stretches between longitudes $8^{\circ}00^{1}$ and $9^{0}00^{1}$ E and latitudes $5^{0}40^{1}$ and $6^{\circ}30^{1}$ N. Ikom is bounded in the north-east by Boki LGA, in the east by Etung LGA, in the North West by Ogoja LGA and in the south by Obubra LGA, all in Cross River State as shown in Fig. 1. The study area has a land mass of about 2102 square kilometers (sqkm) with generally undulating terrain with monotonous depressions which contain water most of the time. The climate of the area is a typical tropical climate with distinct rainy and dry seasons. The dry season stretches from November to March while the rainy season is from April to October. The mean annual rainfall is about 2900mm. The LGA had a population of 162383 people as at December 2006 (National Population Commission, 2006).

2.2 Sources of Data

The methods adopted for this study were exclusively geospatial with majorly secondary datasets. The MCE approach was adopted, combining different datasets in a bid to develop a flood risk-vulnerability map of Ikom LGA. The study was based on secondary data as follows:

i. 2017 Satellite imagery: downloaded from United States Geological Survey (USGS) Google Earth platform
ii. DEM: acquired from elevation data downloaded from USGS Google Earth platform and processed with *TCX Converter* elevation generator tool
iii. Slope and elevation map: processed from the DEM
iv. Rainfall data: acquired from 2017 NIMET Seasonal Rainfall Prediction [25].
v. LGA boundary and communities: acquired from the Office of the Surveyor General, Cross River State.
vi. Water bodies shapefiles and roads: digitized from the satellite imagery.
vii. Soil map: the soil map of Ikom LGA was based on the soil inventory described in [26], which was an extract from a compilation of the soil map of Nigeria by the Center for World Food Studies (1996).

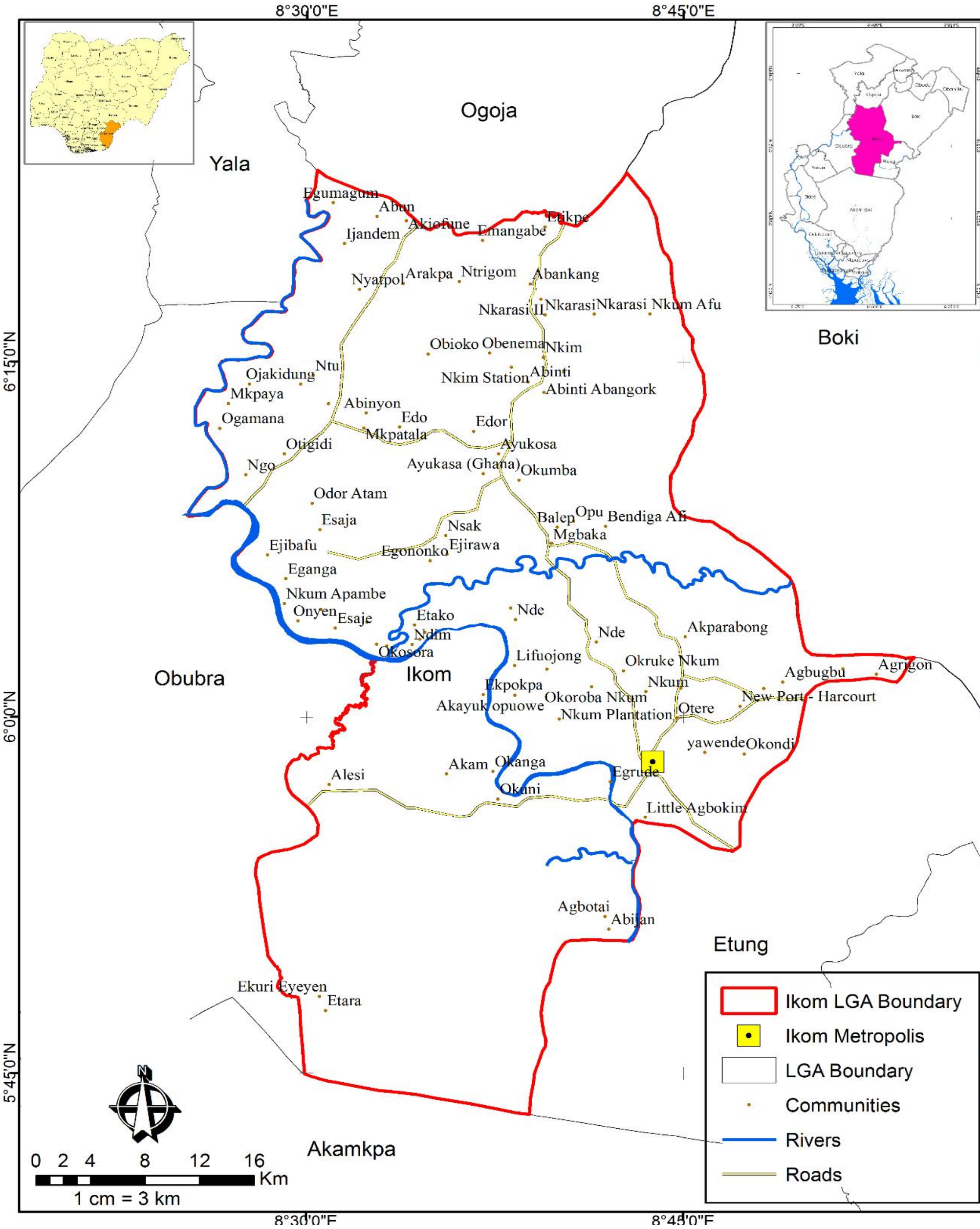

Fig. 1. Map of Ikom LGA

More so, to buttress the eventual findings from the study, interviews were subsequently used to accrue information on flood occurrence at some communities in proximity to rivers in the area. A total of 4 communities were visited in November (2017) which was during the dry season period.

2.3 Parameter Inputs

To generate a flood risk map for Nigeria, the area selection of effective parameters is vital. Although it is difficult to choose factors unanimously to be applied in flood risk assessments, some important variables have a definitive role in flood risk mapping as mentioned by [27]. Authors over time have used the multi-criteria methodology combining different parameters because it provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent, qualitative as well as quantitative information [28]. The selection of parameters for this study was mainly theoretical based on their relevance to flood hazards as documented in literature. [6] considered DEM (elevation), flow accumulation, slope map, population density, land use and proximity to the river as the parameters. In the same vein, [29] developed a model which performs a multi-criteria analysis incorporating seven criteria–parameters: flow accumulation, rainfall intensity, geology, land use, slope, elevation and distance from the drainage network. [30] also considered precipitation, slope, land use and soil type while [31] used slope, soil, demography, drainage density, rainfall distribution, and landuse.

An assessment of the parameters adopted by different authors show similarities in the geospatial datasets adopted. Thus, for this study, independent parameters such as distance from river (D), rainfall intensity (R), elevation (E), landuse (L), slope (S) and soil (S) were considered, hence the acronym “DRELSS” which summarizes the methodology for this study.

i. **Distance from rivers:** River overflows are crucial for the initiation of a flood event. Often the inundation emanates from river and expands into surroundings areas. Flood susceptibility is highest in areas by river banks and decreases as the distance increases, thus emphasizing the importance of distance from river in flood risk assessment [29]. The Cross River is the major river that passes through Ikom, as well as its tributaries. The Cross River was buffered with an initial interval of 1000 m (Fig. 2) while the smaller tributaries from 500 m (Fig. 3). This was because the larger water body portends higher flood risk due it its larger volume and the possibility of its waters to cover a larger expanse during a deluge.
ii. **Rainfall:** The rainfall intensity zones map (Fig. 4) was also generated using the *IDW* based on the NIMET data of 2017. Floods are related to extremities in precipitation. A combination of precipitation characteristics (the amount of rainfall, intensity, duration and spatial distribution) influences the flood events. Heavy rainfall increases the amount of discharge from rivers and causes overflowing [32]. As depicted on Fig. 4, there is a slightly higher intensity of rainfall in the southern corner of the area (> 2000 mm) and the intensity reduces northwards where there are values less than 2000 mm.
iii. **Elevation:** Elevation plays a vital role on the spread of flooding. Water flows from higher to lower elevations and where other factors that gear flooding are at play, the chances of flood occurrence would still be slim where the elevation is high enough. Elevation also influences the intensity of runoff. In all, areas with low elevations are more susceptible to flooding. The elevation layer (Fig. 5) was derived from the DEM using the Inverse Distance Weighting (IDW) interpolation tool in ArcMap. It shows that Ikom has a rather undulating terrain with heights ranging from less than 50 m at the river basins to as much as 862 m in the southern corner of the area.
iv. **Landuse:** Water infiltration has significant influence on the occurrence of floods. Areas covered by vegetation, especially forests have low flood susceptibility because forests have high infiltration rates. On the other hand, surface runoff is very high in areas that are built-up because of impervious surfaces [27,33]. Following from this, land use/land cover is a very important factor for flood risk-vulnerability mapping. The maximum likelihood algorithm of supervised classification in ArcMap software was adopted to classify the land use in Ikom LGA into 4 classes (dense forest, built-up areas, rivers and farmlands/shrubs/farmlands) as shown on Fig. 6. There is a dense forest which is part of the Cross River National Park in the southern and eastern edge of the area. The built-up areas are also notably neighbours to the water bodies. Farmlands, shrubs and bare lands however occupy a larger portion of the LGA.
v. **Slope:** This is another independent parameter which can accelerate the soil erosion and surface runoff as well as vertical percolation. Areas with less steep slopes may flood quicker than areas with steeper slopes and such steep slopes are features of high elevated areas. The slope layer (Fig. 7) was also generated using the *slope* 3D analyst tool in ArcMap. The output was given in percentage. Because of the undulating nature of the area, the slope gradient also varies significantly.
vi. **Soil:** Soil water infiltration is used as a flood prediction parameter because of its influence on runoff. The rate of water

infiltration depends on external factors and soil properties, which vary based on the type of soil [32]. The geology of flood hazard areas is an important criterion, because it may amplify/extenuate the magnitude of flood events. Permeable formations favor water infiltration and on the contrary, impermeable surfaces favor surface runoff. Therefore, karstic formations and lacustrine deposits (clays, marbles and loam) have been rated to support flood occurrence more than alluvial and continental deposits due to their higher infiltration capacity [29]. Particularly, the Rhodic Nitisol (a common clay family) is prone to erosion due to its low structural stability, slacking and surface caking [34]. Ikom is dominated by 3 major soil categories; the Acrisol (acidic clay), Humic Nitisol (humus clay) and the Rodic Nitisol (ferralitic clay) (Fig. 8). Of these 3 types, only the humus clay is less susceptible to flooding because it allows for some degree of infiltration of runoff.

2.4 Classification and Reclassification Process

The classification was done using the *natural breaks* grading method in the same ArcMap platform. After classifying each factor to properly symbolize the scenario, they were further reclassified to enable further analyses. The inverse ranking was applied. The class with the least flood susceptibility or influence in flood initiation was assigned a value of 1, the next level of flood risk induction was assigned 2, and so on [30]. The ranking is user defined, supported by literatures and also depending on their significance or influence on flood risk [27]. The ranks were further grouped into a rating index of high and low risk groups.

The classes of the distance from the rivers were defined from testimonies of residents on the history of floods in the study area during the reconnaissance survey. The residents reported the point where the yearly flooding invades to.

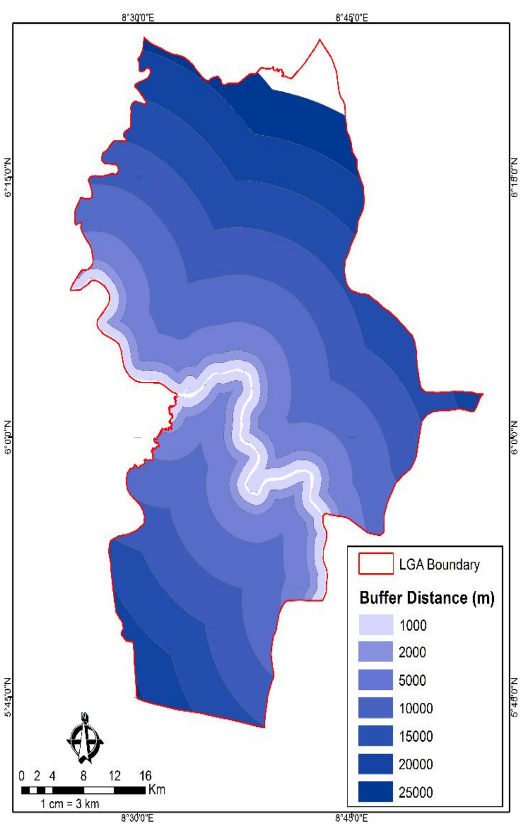

Fig. 2. Buffer from major river

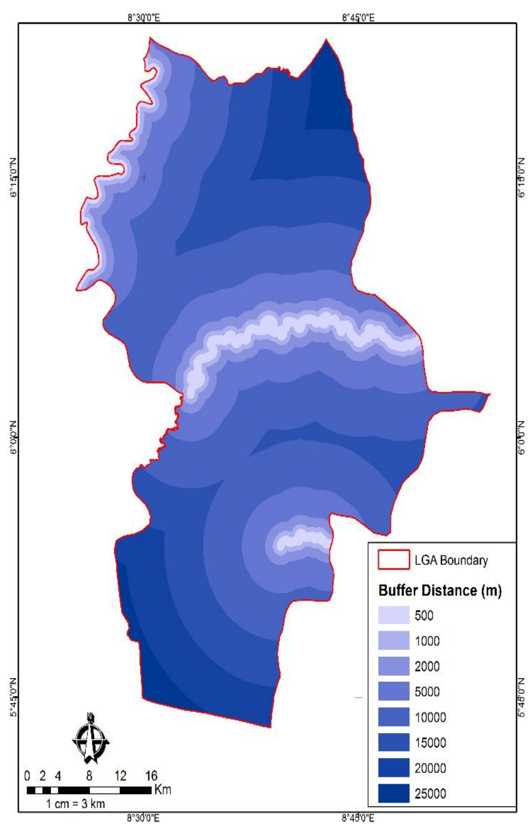

Fig. 3. Buffer from minor rivers

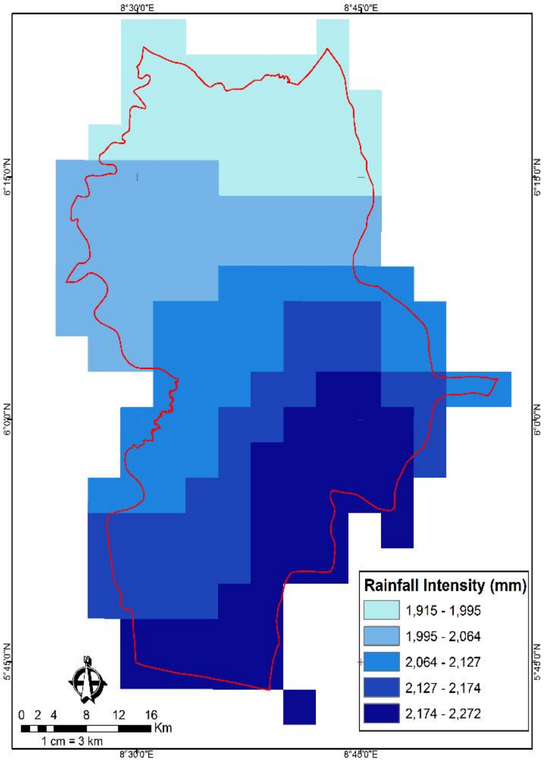

Fig. 4. 2017 Rainfall intensity in Ikom LGA

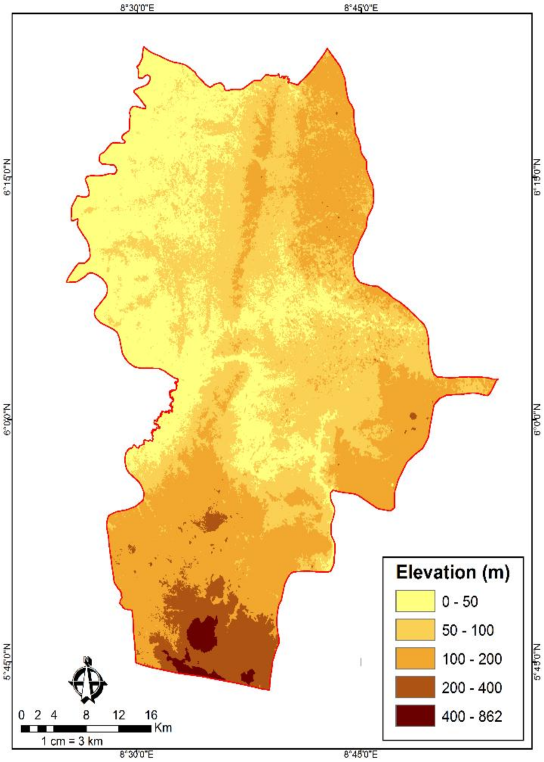

Fig. 5. Elevation classes of Ikom LGA

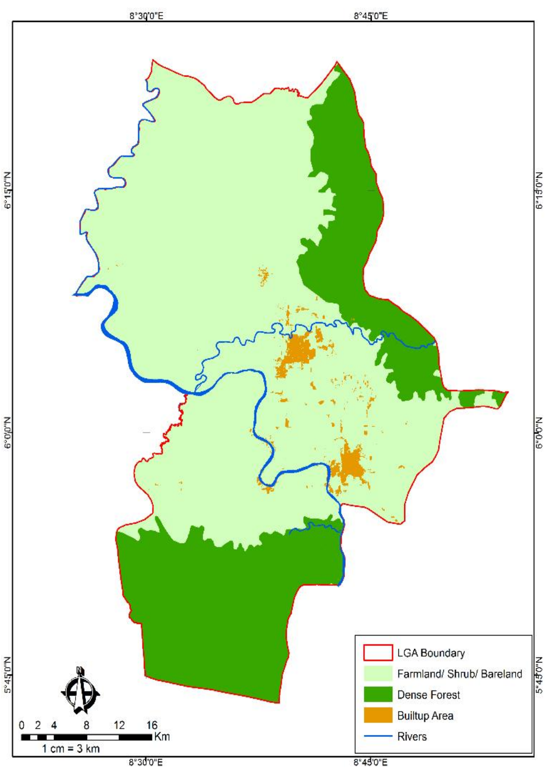

Fig. 6. Land use/ Land cover characteristics of Ikom (2017)

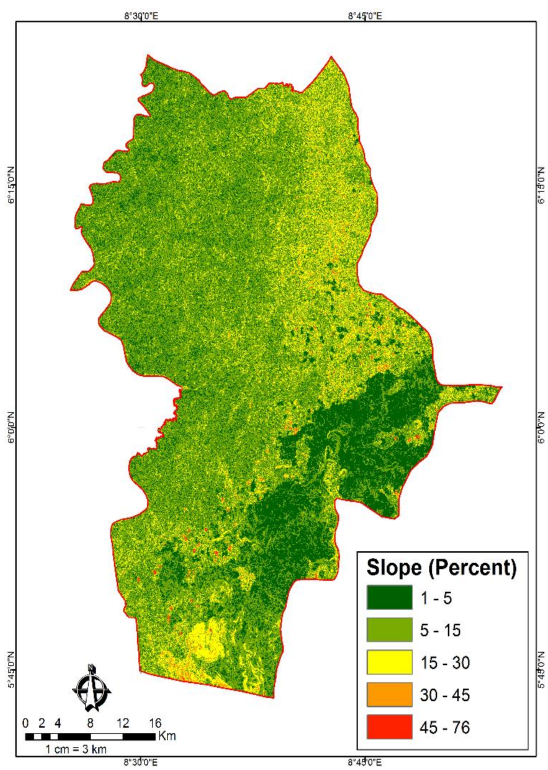

Fig. 7. Slope map of Ikom LGA

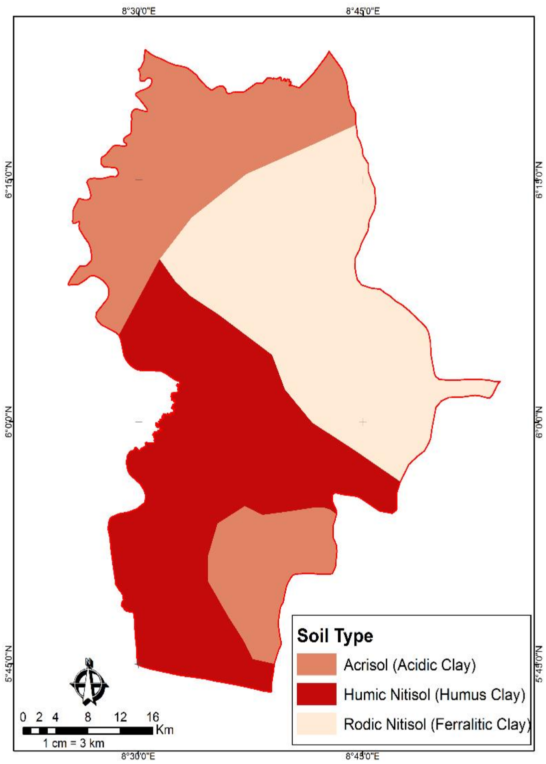

Fig. 8. Soil map of Ikom LGA

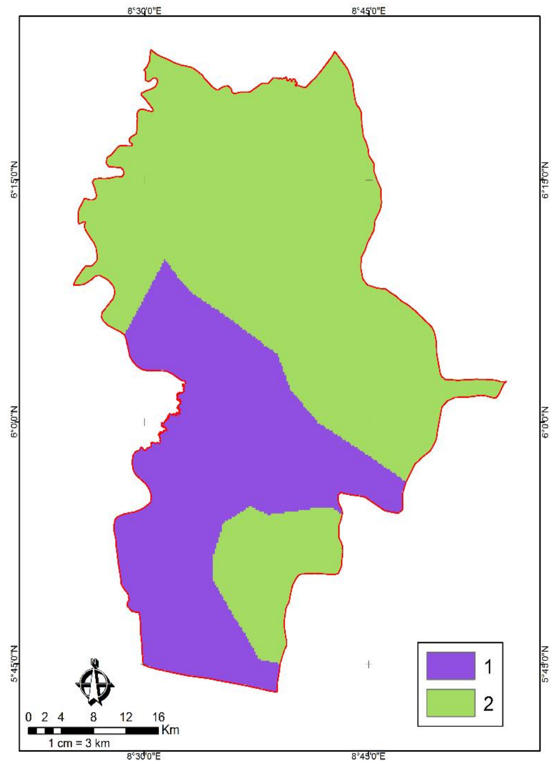

Fig. 9. Reclassified soil map of Ikom LGA

The distance from the river to the observed point was measured to guide in defining the intervals for the buffer from the rivers. The buffers from the large and smaller rivers are shown in Figs. 2 and 3. For [29], the initial buffer from the river was 200 m and for [35], an initial buffer of 30 m from the river was sufficient. Whereas [27] started buffering from a distance of 100 m from the river. The reclassification process in this study replaced the buffer distances less than 500 m and 1000 m with value 7 being the most susceptible areas from smaller and larger rivers respectively and value 1 for the farthest buffer offset from the river (Table 1). Additionally, because the river buffers were in vector data format, and whereas the analysis requires all the layers to be in raster form, the buffer outputs were converted to raster using the ArcMap *feature to raster* tool.

Further, the elevation layer (Fig. 5) was initially classified into 5 classes from the low elevation areas (0-50 m) to the very high areas (400-862 m). As portrayed on Fig. 10, the elevation layer was reclassified to 5 classes with new values (1-5) for each class, 1 representing the highest elevation with the least flood susceptibility and 5 for areas with high susceptibility (Table 1). Likewise, the slope classes were initially 5 groups, from the least percent to the highest (Fig. 7). The slope was then reclassified into 5 groups (Fig. 12) with 1 representing the steepest slope (45-76 percent) and 5 for the less steep slope gradient (1-5 percent) which is more susceptible to flood risk (Table 1). This classification follows from [27] who considered slope gradients less than 10 percent as most susceptible while [36] espoused slopes less than 1.3 percent as most vulnerable.

The parameters of land use and soil types were classified similarly to previous studies with modifications according to the characteristics unique to Ikom LGA [37]. The landuse was reclassified into 3. Value 3 for the dense forest which is least susceptible, 2 for farmlands/ shrubs/ bare lands and 1 for the most susceptible (built up areas) (Table 1). Also, soil types were reclassified into only 2 classes (Fig. 9). Class 1 for the humus clay that does not encourage flooding and class 2 for the acidic and ferralitic clay that makes flooding possible (Table 1). Similarly, rainfall was reclassified into 5 categories as shown on Fig. 11, from the least

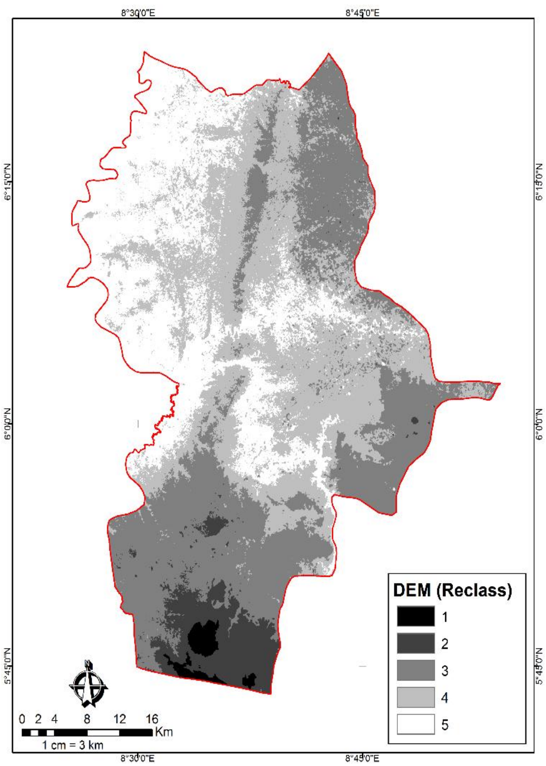

Fig. 10. Reclassification of elevation

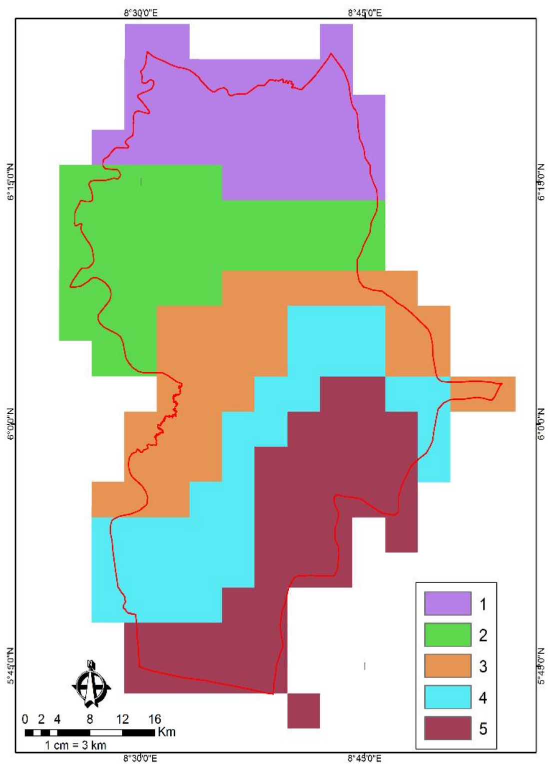

Fig. 11. Reclassification of rainfall intensity

Table 1. MCDA parameters

Parameters	Class	Reclass (Rates)	Rating Index	Weight (W)
Distance from rivers (m)	<500, <1000	7	High risk	25
	1000-2000	6	Low risk	
	2000-5000	5		
	5000-10000	4		
	10000-15000	3		
	15000-20000	2		
	20000-25000	1		
Rainfall intensity (mm)	2174-2272	5	High risk	16
	2127-2174	4		
	2064-2127	3		
	1995-2064	2	Low risk	
	1915-1995	1		
Elevation (m)	0-50	5	High risk	22
	50-100	4		
	100-200	3	Low risk	
	200-400	2		
	400-862	1		
Landuse	Built-up areas	3	High risk	5
	Farmland/shrub/bare land	2	Low risk	
	Dense forest	1		
Slope (percent)	01-.05	5	High risk	22
	.05-15	4		
	15-30	3	Low risk	
	30-45	2		
	45-76	1		
Soil types	Acidic and ferralitic clay	2	High risk	10
	Humus clay	1	Low risk	

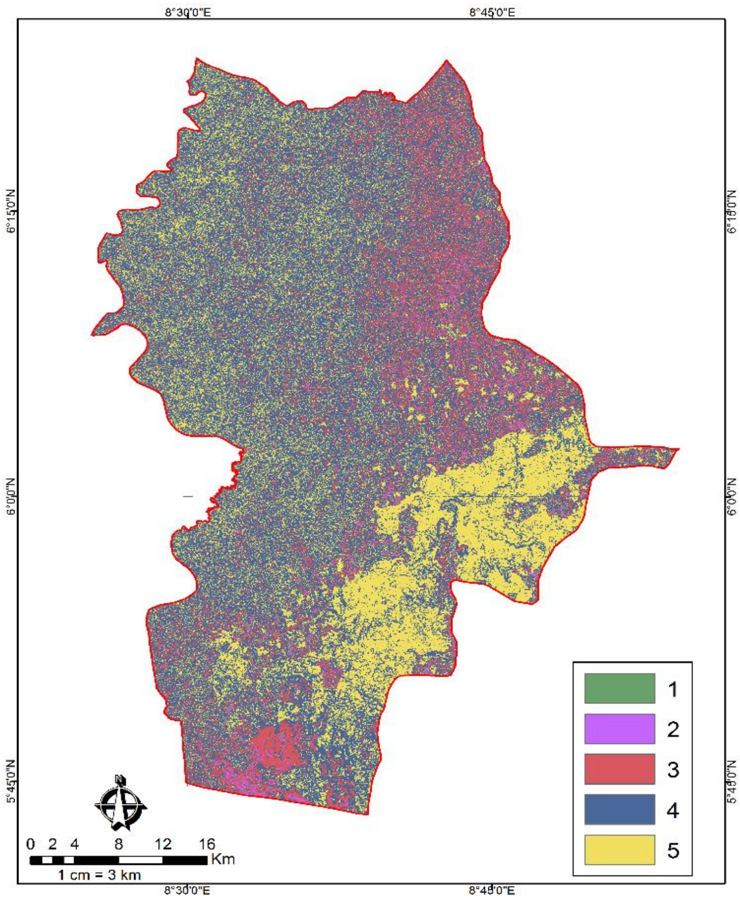

Fig. 12. Reclassification of slope

rain intensity reclassed as 1 to the highest rain intensity as 5 (Table 1).

2.5 Weighting Process

The weight of each factor determines its role in the final result. The weight assigned for each parameter is usually based on expert understanding of the relevance of each factor and sometimes backed by analytical processes and literatures. While [27] assigned the highest weight to distance from river followed by slope, [32] considered slope ahead of distance from river and other parameters. Also, [37] considered the influence of slope second to soil type.

For this study, reconnaissance survey showed that inundation mostly occurs during the rainy season in low lying areas by the rivers. Thus 3 factors are most pertinent- distance from rivers, topography (elevation and slope) and rainfall. Going by this, with inclination to the choices of previous authors, distance to river was assigned the highest weight (25) followed by topography (elevation-22, slope- 22) and rainfall (16). Soil type was assigned a weight of 10 and landuse, the least (5). As depicted in Table 1, the total weight (W) sums up to 100 to enable execution of the weighted overlay analysis. The weighted overlay unions several raster layers using a common measurement scale and weighs each raster according to its assigned importance.

3. RESULTS AND DISCUSSION

3.1 Flood Risk-Vulnerability Zones in Ikom LGA

The weighted overlay tool was used to integrate the rates and weights (Table 1) and to generate a flood risk-vulnerability map of Ikom LGA (Figs. 13 and 14). The flood risk map was classified into 5 zones from the very low risk to the low risk, the moderate risk, high risk, and very high-risk zones. The very low risk and low risk zones are locations where chances of flood occurrences are about zero except a reenactment of the Biblical deluge. For the moderate risk, the chances are low as well. Flooding in the moderate risk zone can be triggered by extreme anthropogenic events, for example, draining of excessive water from a nearby dam during the peak of the rainy season. The high and very high-risk areas refer to the areas where flood can occur without much ado, for example due to mere seasonal as well as sporadic rainfall.

Fig. 13 shows that a substantial portion of the study area are susceptible to flooding, although some of the high and very high-risk areas are yet to be habited. The colour variations on the map shows the various flood risk-vulnerability levels in the area. A further output portrayed in Fig. 14 depicts the parts of the area susceptible to flooding and an overlay of anthropogenic activities such as roads and built-up areas. As a ripple effect of the proximity to the Cross River and its tributaries, elevations and other factors considered, the central parts of the LGA are deduced to be most susceptible to flooding. Because of the importance of water, people have settled in very close proximity to the river, most of which are unsafe to reside or do business.

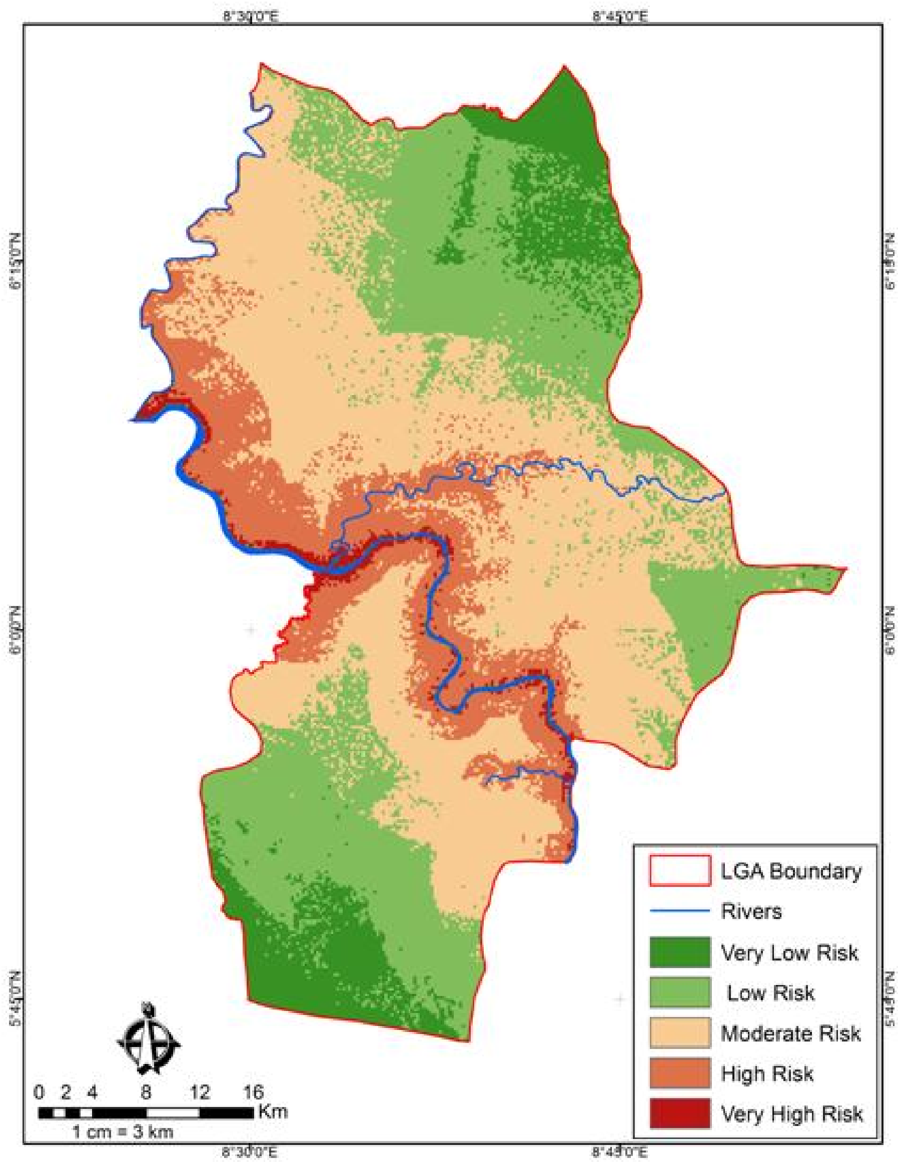

Fig. 13. Flood risk-vulnerability map of Ikom LGA

The findings illustrated in Table 2 reveals that out of the total 2102 sq km that makes up Ikom LGA, the very high flood risk-vulnerability zone covers an area of 1.5 sq km while the high-risk zone is 14.5 sq km. The values for the high and very high-risk zones seem small compared to the total area coverage of the area However, because floods happen mostly in low lands, and in an area with an undulating terrain and viable water bodies, people tend to settle at the low lands, especially closer to the river. This is the case in Ikom LGA. Fig. 14 shows areas of built-up landuse within high and very high flood risk zones. The communities within the high-risk zone includes; Mkpaya, Ogamana, Ngo, Odor Atam, Esaja, Ejibafu, Eganga, Onyen Orangha, Esaje, Etako, Ekamntonofo, Nde, Iifuojong, Ekpokpa, Akayuk Opuowe, Little Agbokim and Abijang while the very high-risk zone consists of Ndim, Abaragba, Osokora, Nkum Apambe, Okanga, Okuni and Egrude.

Table 2. Area coverage of risk level zones

Risk level	Area coverage (sq km)	Percentage
Very low risk zone	258	12.2
Low risk zone	626	29.7
Moderate risk zone	885	42.1
High risk zone	305	14.5
Very high-risk zone	28	1.5
Total	2102	100

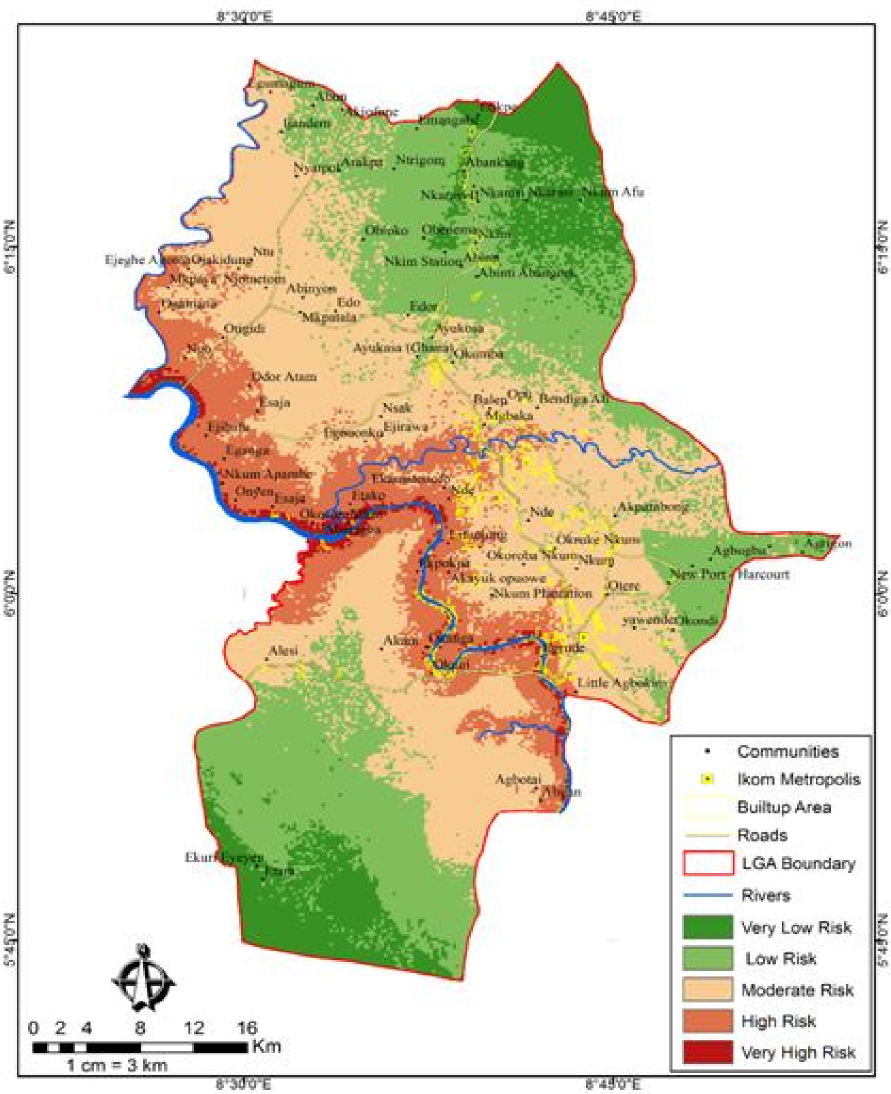

Fig. 14. Flood risk-vulnerability map with anthropogenic features in Ikom LGA

Plate 1. Abijang community

Plate 2. Oyen Orangha community

Plate 3. Okuni community

Plate 4. Abaragba community

A follow-up ground truthing exercise to 4 communities in the deduced high and very high flood risk zones in Ikom LGA buttressed that in reality, flooding was a problem as there were relics of flooding with the residents testifying to its wrath. At Abijang community, the residents noted that water encroached mostly into their farmlands and a few houses. Plate 1 shows one of the houses at close proximity to the river that was said to get flooded during major flood events. The scenario was similar at Oyen Orangha community where the banks of the river showed graduation of the water level at different times (Plate 2). The residents lamented the effects of inundation on their livelihood especially at the peak of the rainy season. At Okuni community, the pedestrian stairs visible on Plate 3 was said to get totally submerged during the rainy season with the water ascending and inundating everything in its path up to the Calabar-Katsina Ala highway which is 120 m from the river. In the same vein, Abaragba community, like the others visited showed vestiges of flooding which was established by the residents interviewed (Plate 4).

4. CONCLUSION AND RECOMMENDATIONS

The study outlined the use of GIS and MCE in decision-making. The multi-criteria design meant an integration of a variety of evaluation techniques and data in a GIS platform and an eventual presentation of the outputs in a holistic manner which will aid better decision making. The parameters (DRELSS) selected for deriving various vulnerability indices of areas at risk of flooding in Ikom LGA were major driving factors that must be considered in any flood risk assessment. The flood risk-vulnerability map showed spatial differences in the risk levels within the area. The map provides a tool for instigating effective implementation of mitigation/disaster reduction measures that would decrease the vulnerability and risk faced by the people in Ikom LGA, especially residents living in the high and very high flood risk zones.

Due to the already escalating effects of flooding in Ikom LGA, the design and adoption of the comprehensive flood risk-vulnerability map is timely. The final output from this study is an indispensable tool for relevant government agencies such as the town planning department and emergency services. Estate developers, insurers, construction companies and the likes are not left out from the end users of the findings. When predictions are made as to the occurrence of flooding, site specific preparedness or evacuation warning should be given to residents who reside, farm or do other businesses within the deduced flood risk zones. Efforts should also be asserted by the government to restrict accommodation within deduced flood risk zones and relocation can be arranged for those already resident in danger zones.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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