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APPLICATION OF GIS AND REMOTE SENSING IN FLOOD HAZARD AND RISK ASSESSMENT MAPPING IN OWERRI ZONE, IMO STATE.

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ABSTRACT

Flood is a water related natural hazard that affects a wide range of human activities. This researched work was aimed to produce flood hazard and risk map that indicate areas of very high and low risk in Owerri Zone comprising nine local government areas of Imo State. Flood hazard mapping and risk assessment of Owerri Zone, Imo State was investigated using flood causative factors (rainfall intensity, slope, flow accumulation, variation in elevation and landuse). Remote Sensing and Geographic Information Systems were used as tools in analyzing flood causative factors.GIS spatial analyses and weighting involving integration of remote sensing and weighted linear combination (WLC) method of multi-criteria decision making (MCDM) were employed in assessing interaction and contributions to flooding by the causative factors contributing to flood hazard. Flood hazard and risk maps were produced and classified into various hazard levels. Flood hazard map result showed that high hazardous areas occurred on the southern part of the study areaoccupying about 58.6% of total area while low hazardous potential areas were found on the extreme northern part of the study area at 15.5% of total study area. Similarly, flood risk map result showed major dominance of extreme risk of high flood hazard in major towns in Owerri Municipal, Owerri West, Mbaitolu and Owerri North LGAs. Low risked areas were on towns covering AhiazuMbaise, Ezinihite Mbaise, Ngor Okpala and Aboh Mbaise LGAs. It is recommended that Government should integrate flood causative factors in urban planning while ensuring proper channelization of runoff from residential, commercial and public areas to safe and stable discharge points normally on any nearby river or stream.

Keyword: Flood, Hazard, Risk, Flood Causative Factors, weighted linear combination, WLC

1.0 INTRODUCTION

1.1 Background to the Study

Flood hazard has been a recurrent phenomenon in the world today. Seasonally, several reports of Stream and River banks overflow, coastal, flash and urban flood events are common causing damages to properties and loss of lives. Combined factors of human-induced impact on land uses through urbanization and deforestation etc and climatic changes without proper planning for sustainabilityhas increased flood risk to hazard (Sevim &Sigdem, 2015; Anueyiagu, 2022). Heavy downpour on low land areas where there are significant land use changes resulting to urbanization has increased the imperviousness nature of the earth which promotes higher surface runoff volume that triggers flooding once soil saturation is reached. Works by Sani, Noordin and Ranya, (2010); Woubet and Dagnachew (2011); Shantosh, (2011); and Sevim and Sigdem (2015),identified five significant flood causative factors as Slope, rainfall intensity, Land use, elevation and stream drainage pattern (flow accumulation).

Hence, increasing activities of man in harnessing environmental resources for economic benefit and improving on livelihood needs have resulted tounwarranted encroachment on flood plain areas which led to huge loss of life and damages to properties, causing the flooding which naturally has benefit to become a natural environmental disaster in most cities of the World (Bradshaw *et al.*, 2007; Nicholas, 2015; Anueyiagu 2022).

In the recent decades, there has been increase in the incidence of flooding event recorded in most countries making flood hazard as one of the most expensive and global natural disaster affecting man in his environment (Daniela, Usman and Costas 2017).Dilley *et al.* (2005) estimated that more than one-third of the world's land area is flood prone affecting over 82 percent of the world's population. Similarly, UNDP (2004) reported about 196 million people in more than 90 countries were exposed to catastrophic flooding, and that some 170,000 deaths were associated with floods worldwide between 1980 and 2000

Nigerian States are not free from Flood hazards. Itodo, (2012) and Ume (2012) have documented flooding inGurku, Nasarawa State to have claimed two lives and submerged over 50 residential houses and shops. Similarly, Amangabara and Obenado, (2015) reported a national flood hazard of 2012 as the most catastrophic, submerging three major States in the Niger Delta leading to evacuation of more than half a million as internally displaced persons from the Nigeria Delta Region.

In Imo State, Duru and Chibo, (2014) documented six Local Government Areas mostly from Owerri Zone as being affected by flood menace, varying from various degrees of flood types (Flash, River, Urban and Seasonal). Communities suffer different levels of devastations with obvious damages to goods, properties, farmlands, animals, leading to spread of disease and contamination of the water supply resulting to significant social, economic, and environmental impacts

In this study, flood hazard and risk maps were produced through assessment of flood causative factors (variation in elevation, flow accumulation, slope, land use and rainfall intensity) using geographic information system (GIS). This involves integration of Remote Sensing tool and weighted linear combination (WLC) aspect of Multi-Criteria Analysis (MCA) method to identify flood vulnerable areas in the study area through generation of ranked criterion values and maps based on interaction of flood causative factors.

1.2 Aim and Objectives of the Study

The aim of this study is to produce flood hazard and risk map that indicate areas of very high and low risk in four local government areas of Imo State.

2.0 MATERIALS AND METHODS

2.1 Study Area

Study area (Fig 1) is one of the three senatorial (Owerri Zone) zones of Imo State Nigeria. Owerri Zone comprises nine Local Government Areas (Owerri West, Owerri North, Owerri Municipal, AhiazuMbaise, Ikeduru, Aboh Mbaise, Mbaitolu, EzinihiteMbaise and Ngor Okpala). The study area habours the capital of Imo State in Nigeria with an estimated population projection of about3,967,071as at 2022.Study area is bordered by Abia State to the east, Imo East (Okigwe Zone) and Imo West (Orlu Zone) respectively to the North, Rivers State to the South and Imo West (Orlu Zone) to the West. It lies within latitude 5° 12' to 5° 40'Nand longitude 6° 50' to 7° 22E.

Owerri Zone falls under humid and semi-hot equatorial climatic type that experiences heavy downpour that promotes both urban flooding and sediment transport of sloped areas (Amangabara, 2014). It has two major seasons (Rainy season and Dry season). Rainy season begins in April and lasts until October while dry season period ranges from November to March. It has an annual rainfall varying from 1,500mm to 2,200mm and average annual temperature above 20 °C (68.0 °F) and an annual relative humidity of 75% (Nimet, 2015).

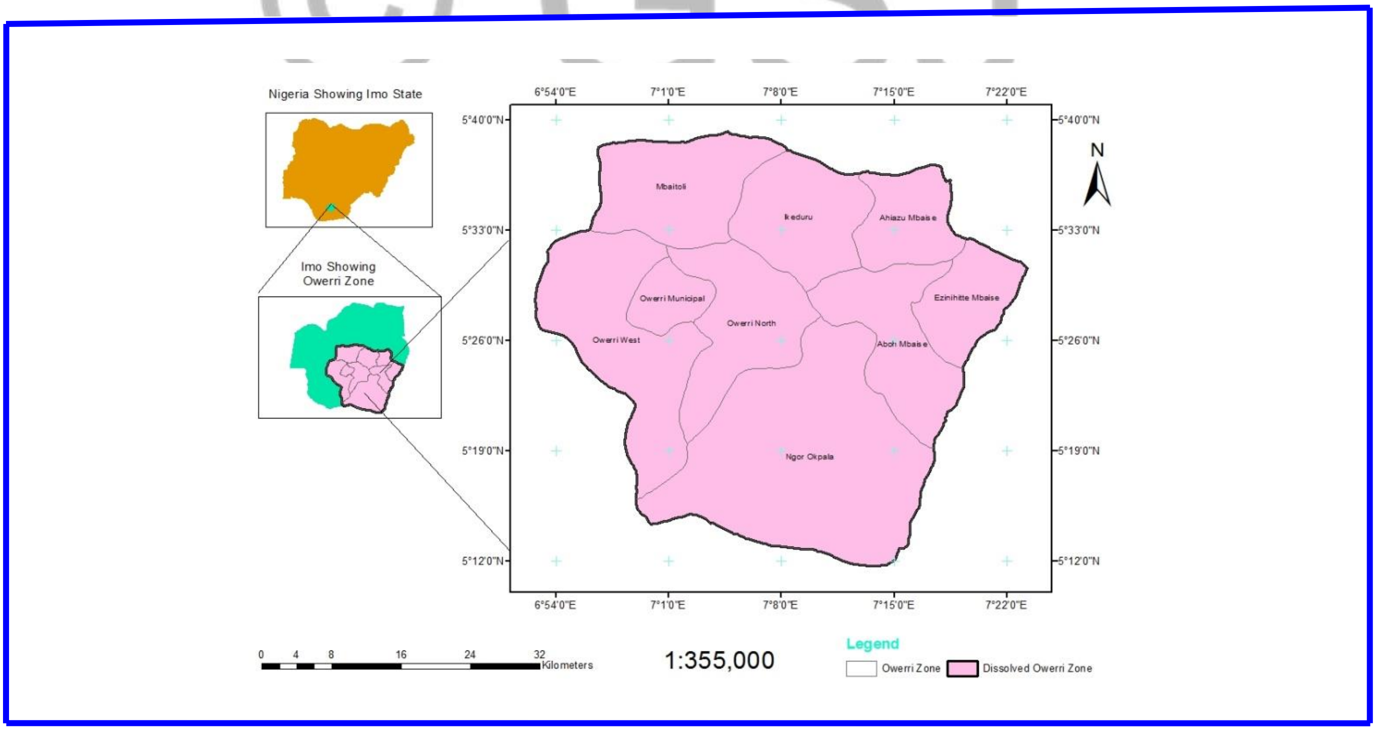


Fig 1 Study area map (Owerri Zone)

2.2 Flood Factors Processing

2.2.1 Flow accumulation processing

Delineated DEM of the study area was imported into ArcGIS software and processed through fill sink and flow direction analysis withArchydro Terrain Processing extension software for ARCGIS. Flow accumulation (fig 2) was processed by computing the accumulated number of cells upstream in the flow direction.

2.2.2 Variation in Elevation and Slope Processing

Elevation and overland slope covering the study area are two major variables likely influencing the rate at which runoff moves over a landscape, as the elevation changes, the velocity of the concentrated water changes (Zhang *et al*., 2007). The elevation and slope of the study area (Fig 3 & 4) were derived from the DEM data using the surface analysis tool in spatial analyst toolbox of ArcGIS software.

2.2.3 Land Use/Land Cover processing

Landuse land cover classification (fig 5) was derived from downloaded landsat imagery from Global Land Cover Facility after composited on ENVI (version 5.0) software to form a colour composite of the study area. Various region of interest such as Built-up, vegetated, agricultural, open space etc were created to form the basis for classification using maximum likelihood.

2.2.4 Rainfall Intensity Processing

Rainfall data was procured from various gauging stations within and outside the study area for proper understanding of rainfall variation. Rainfall intensity was calculated as the ration of rainfall amount to the duration collected fromthe gauging stations with the coordinate (x, y and z). Estimated rainfall intensity (fig6) was typed in as an attribute of the locations and used for interpolated to obtain rainfall intensity map of the study area.

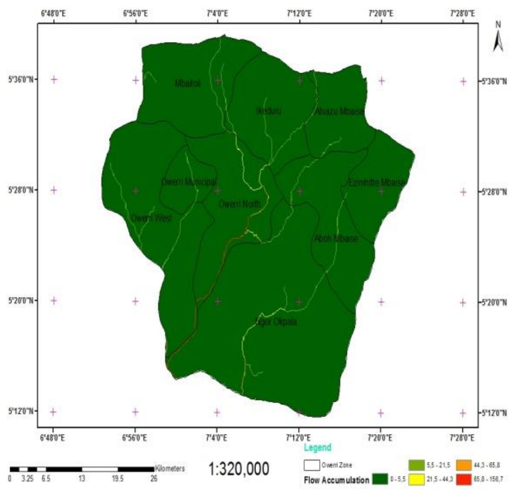


Fig 2 Flow Accumulation

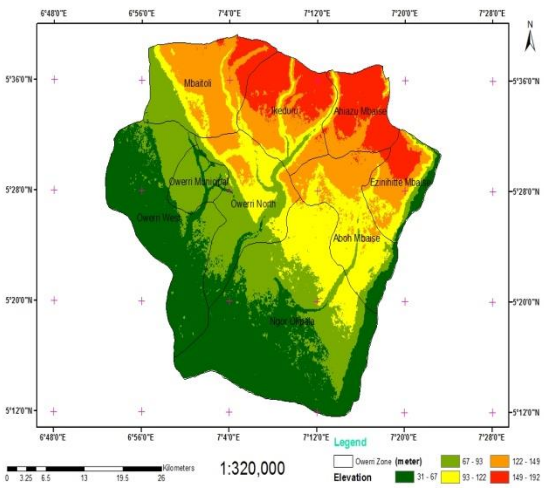
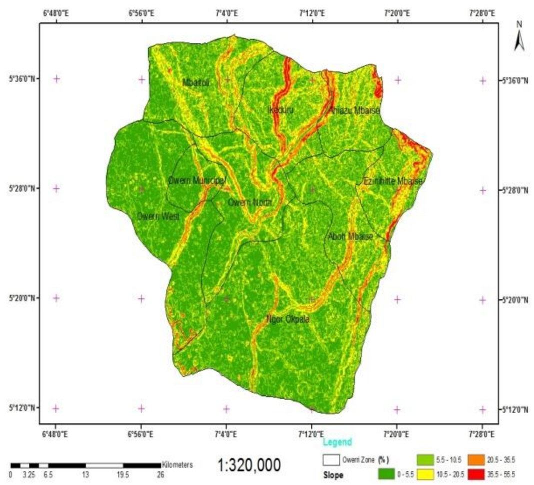


Fig 3 Elevation



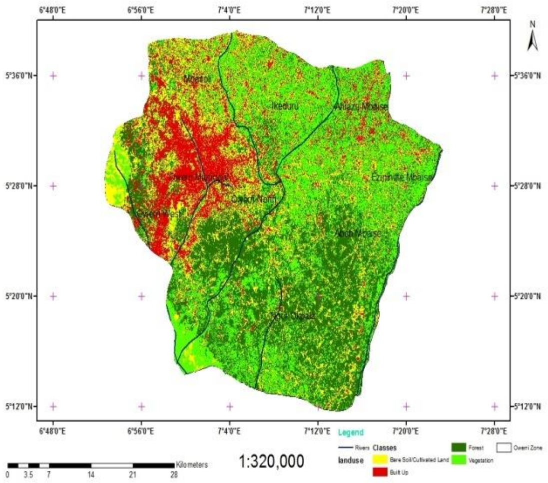


Fig 4. Slope **Fig 5. Landuse**

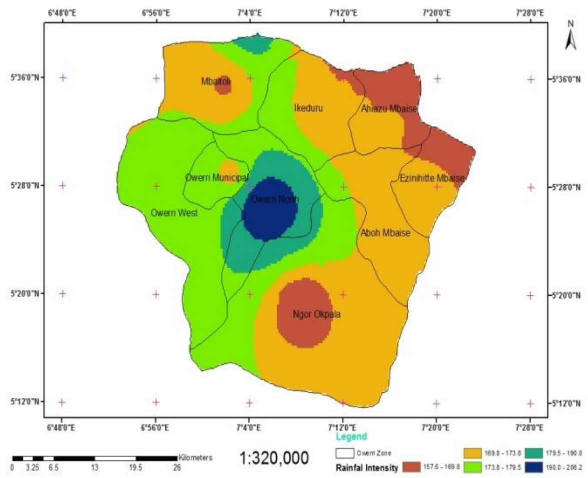


Fig 6. Rainfall Intensity

2.3 Criteria for Flood Hazard Mapping Using Multi-Criteria Analysis

2.3.1 Weighted overlay for Flood Hazard Mapping

Multi-Criteria Analysis is applied in producing and combining spatial data describing causative factors. In the first part, the flood hazard factors were produced in a numerically map layer describing the study area. All criteria (flood hazard factor maps) were combined by weighted linear combination (WLC) where continuous criteria (factors) were standardized to a common data model that was in raster layer with a common resolution.

Thus, in order to measure these effects, one (1) point is assigned to primary effect while half (0.5) point is assigned to secondary effect. With these effects, a factor rate is estimated as the sum of impacts on the others (1). Varying weighting values were applied to different factors because they have different impacts in contributing to flood hazard. This weighting approach has been applied by many scholars, (Shaban, Khawile and Abdullah 2006; Selvin and Cigdem, 2015; Eastman, 2015) in flood hazard mapping.

In the second part Ranking Method was used (Table 2). In Ranking Method, every criterion under consideration is ranked in the order of universally acceptable flood risk influence. To generate criterion values for each evaluation unit, each factor was weighted according to the estimated significance for causing flooding. With ranking method, 1 was the least important and 10 was the most important factor (ESRI, 2002; Shaban, Khawile and Abdullah 2006; Selvin and Cigdem, 2015, Eastman, 2015; Anueyiagu, 2022). The criterion maps in raster grids were mathematical processed and applied to the Map Calculator and combined by means of a weighted overlay in ArcGIS environment to produce the flood hazard map of the study (Fig7).

The weighted overlay tool of ArcGIS software combined the weight and ratio of each susceptibility factor through multiplying of their calculated ratio to determine its total weight using; very high-10, high-8, moderate-5, low-2 and very low-1 as adopted. The ratio of the flood hazard factors according to their weight on hazard formation adopted was based on; Flow accumulation 15%, slope 20%, elevation 35%, rainfall intensity 15% and land use 15% (Table 3).

Table 1 weighted values estimations from mutual effects of factors

	Interaction between Factors	Rates	Outcome
Flow Accumulation	1 major + 1 Minor	(1 x 1) + (1 x 0.5) =	1.5 points
Slope	2 major + 0 Minor	(2 x 1) + (0 x 0.5) =	2.0points
Land Use	1 major + 1 Minor	(1 x 1) + (1 x 0.5) =	1.5 points
Rainfall Intensity	1 major + 1 Minor	(1 x 1) + (1 x 0.5) =	1.5 points
Elevation	3 major + 1 Minor	(3 x 1) + (1 x 0.5) =	3.5 points

2.3.3 Flood Risk Assessment

Among the five flood hazard factors, landuse is the only elements at risk. Flood risk assessment and mapping were derived from the byproduct of element at risk and flood hazard map produced (Islam, and Sado, 2000; Joy and Xi, 2003;Woubet and Dagnachew, 2011; Anueyiagu, 2022). Land use land cover factor standing as the element at risk was combined with the flood hazard map of the study area to produce the flood risk map (Fig8) using GIS and Remote Sensing Technique (Table 3)

Table 2 Weighting Factors and their classifications

Factor	Domain	Descriptive level	Proposed weight (a)	Ratio (b)	Weighted ratio (a*b)	Total weight	Percentage (%)
Flow Accumulation	0-4917 4917-19054 19054-39338 39338-68842 68842-156740	Lowest Low Moderate High Highest	1 2 5 8 10	1.5	1.5 3 7.5 12 15	39	15
Slope	40.5-60.5 25.5-40.5 15.5-25.5 5.5-15.5	Lowest Low Moderate High Highest	1 2 5 8 10	2.0	2.0 4 10 16 20	52	20
Elevation	194-350 138-194 90-138 47-90 1-47	Lowest Low Moderate High Highest	1 2 5 8 10	3.5	3.5 7 17.5 28 35	91	35
Rainfall Intensity	156-167 167-172 172-178 178-189	Lowest Low Moderate High Highest	1 2 5 8 10	1.5	1.5 3 7.5 12 15	39	15
Land use	Forested Vegetated Bare/cultivated Built up Water body	Lowest Low Moderate High Highest	1 2 5 8 10	1.5	1.5 3 7.5 12 15	39	15
Total						**260**	**100**

Table 3 Flood Risk Assessment

Elements at Risk	**Domain**	**Descriptive level**	**Proposed weight**	**Ratio**	**Weighted ratio**	**Total weight**	**Percentage (%)**
Flood Hazard Map	Very less hazard Less hazard Moderate hazard High hazard Very high hazard	Lowest Low Moderate High Highest	1 2 5 8 10	5	5 10 25 40 50	130	50
Land use	Forested Vegetated Cultivated/bare Built-up waterbody	Lowest Low Moderate High Highest	1 2 5 8 10	5	5 10 25 40 50	130	50
Total						**260**	**100**

3.0 Results AndEvaluation

3.1 Flood Hazard

Flood hazard map (Fig 7 and Table 4) classified into various levels of hazard potentials for the study area showed that high and very high hazardous areas are found in the southern part of the study area at 588km^2 and 526.9km^2, representing about 30.9% and 27.7% respectively of total area. Moderate potential cuts across north and northeastern part at an area of 492.7km^2, occupying 25.9% of total area. Low and lowest hazardous potential areas are found around the extreme northern part of the study area at 69.1km^{2}and 225.8km^2 maintaining about 3.6% and 11.9% respectively, of total land area. Thus, the ratio of various hazards potential classes showed that for every 27.8km^2 of land in the study area exposed to flood hazard event, there are 7.7km^2 of very high hazard area, 8.6km^2 of high hazard area, 7.2km^2 of moderate, 3.3 of low hazard and 1km^2 of very less hazard areas.

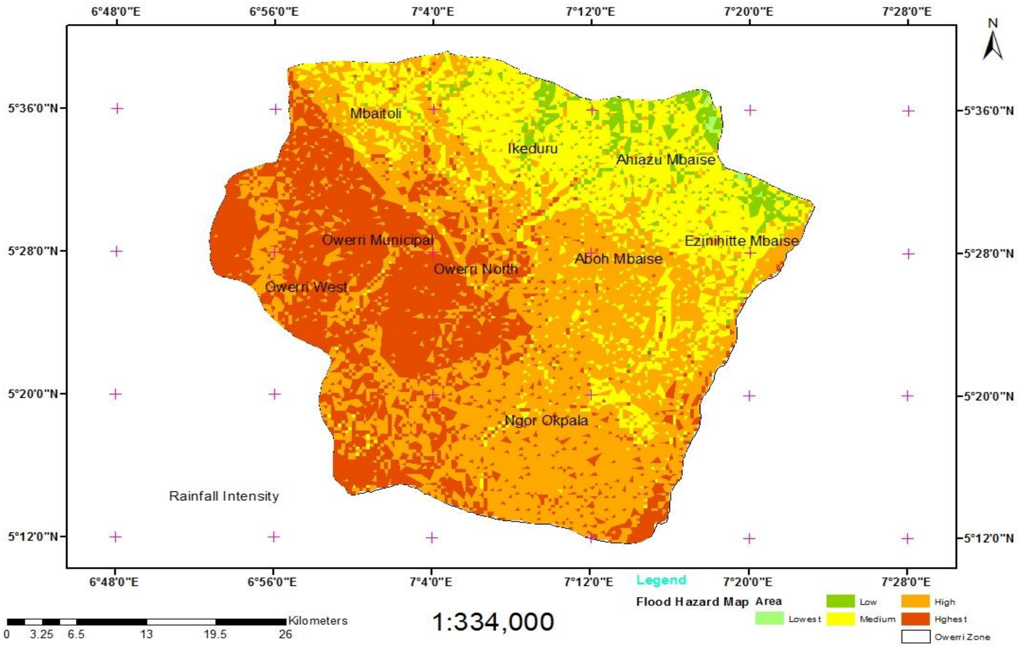


Fig 7 Flood hazard map of Owerri Zone

Table4 Flood hazard classification

Class	Area (km^2)	Percentage	Cumulative	Ratio
Very Less hazard	69.1	3.6		1
Les hazard	225.8	11.9		3.3
Moderate	492.7	25.9		7.2
High	588.0	30.9		8.6
Highest	526.9	27.7		7.7
	1902.5	100.0		27.8

3.2 Flood Risk Assessment

Flood risk assessment was carried out for Owerri Zone, Imo State by integrating already produced flood hazard layer map with the two elements at risk (land use). Vulnerability was assumed to be one. These three factors were made to be equally important in the Weighted Overlay process of ArcGIS software environment.

The weighted overlay tool of ArcGIS software combined the weight and ratio of each causative factor through multiplying of their calculated ratio to determine its total weight using; very high-10, high-8, moderate-5, low-2 and very low-1. The ratio of the flood causative factors according to their scaled weight on hazard formation was based on; flood hazard 50% and land use 50%.

Flood risk map (Table 4 and Fig. 8) showed that major part of Owerri Municipal and minor part of Owerri West, Mbaitolu and Owerri North LGAs are exposed to extreme risk of high flood hazard, moderate risked area dominating minor sections of the entire nine (9) LGAs while low risked areas were observed on the northeast and southern part of the study area covering Ngor Okpala, Ahiazu, Aboh, and Ezinihite LGAs.

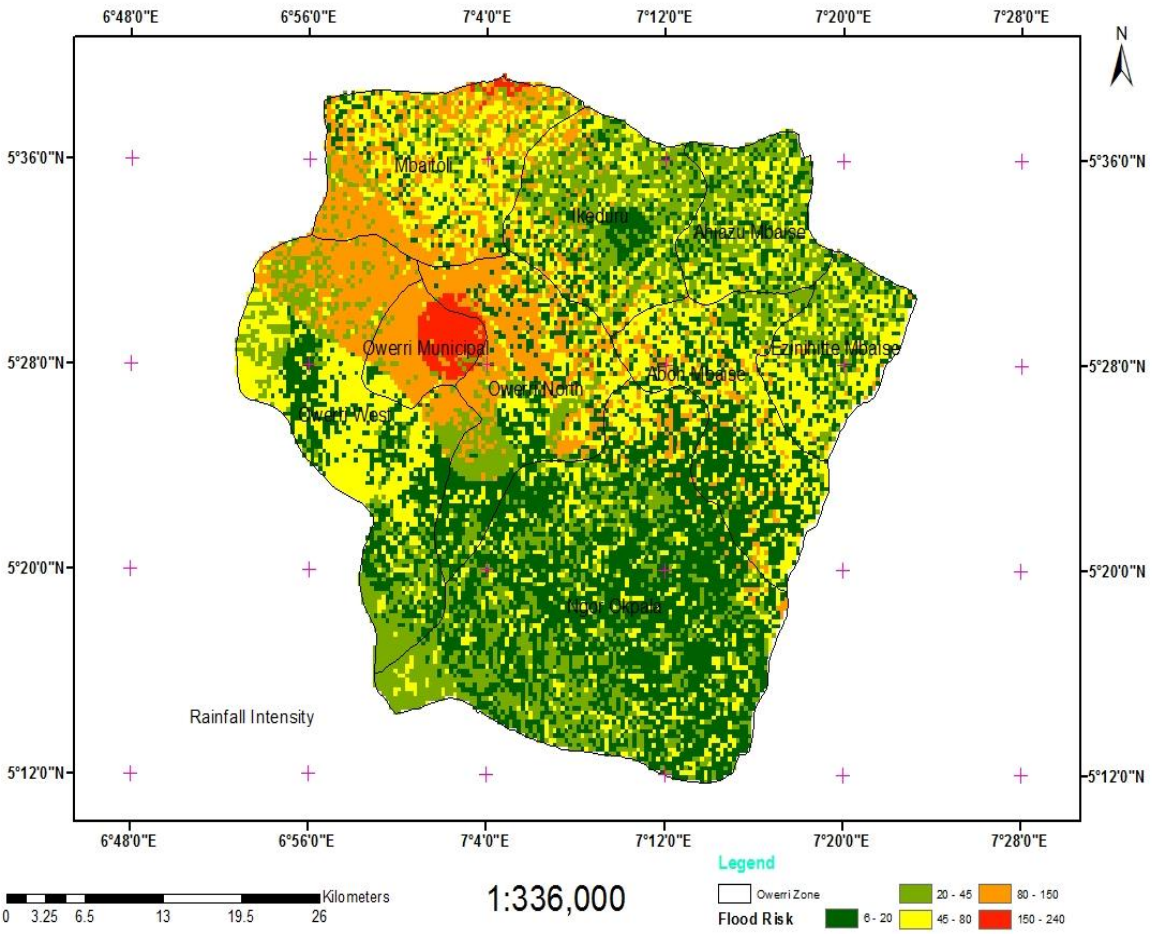


Fig 8 Flood Risk Map of Owerri Zone

Table 4 Flood risk analysis result

Flood Risk	Area	Percentage	Cumulative
Very less	479.4	25.2	25.2
Less	338.6	17.8	43
Moderate	401.4	21.1	64.1
High	462.3	24.3	88.4
Very high	220.7	11.6	100
	1902.5	100.0	

3.3 Discussion of Findings

The choice of five flood causative factors (Fig 2-6) for assessment and mapping of flood hazard and risk were based on spot assessment of flood inundated areas in the study area and reviewed literature on flood major causative factors (Woubet and Dagnachew 2011; Selvin and Cigdem, 2015; Amangabara and Obenade (2015); Anueyiagu 2022). Among several factors contributing to flood development, Shaban *et al* (2006); Selvin and Cigdem, (2015) and Eastman (2015), singled out variation in elevation and slope emanating from topographic factors as major contributors. They observed in simplest terms, that flat lands and riverine areas characterized with low topography are more vulnerable to flood inundations than steep slope and undulated grounds, for reasons that rise in sea level and flash/urban flood concentrate and percolate on low land areas as floodplains. Flood hazard is generally a function of topographic attributes with slope, elevation, flow accumulation, land use and rainfall intensity playing vital rules in determining flood plains (Amangabara and Obenade (2015); Anueyiagu 2022).

Flood hazard and risk results (Fig 7-8) showed strong measure of agreement with findings from Duru and Chibo, (2014); Amangabara and Obenade (2015) and Anueyiagu (2022) studies on the entire State (Imo) and beyond where severe socioeconomic implications were reported among flood inundated communities justifying flooding as the second most common environmental disaster next to gully erosion in Imo State. Incidence of flood disasters are common mostly during peak rainy season (July and September) ravaging human assets, agricultural lands, and public infrastructures. Communities in the study area suffered from different levels of devastations resulting from various types and forms of flooding.

4.0 Conclusion

The essence of flood hazard and risk assessment and mapping in the study area is unveil vital component of flood mitigation measures and land use planning issues capable of getting communities prepared to respond to dangers of flooding as they are happening so as to protect the public health and safety of citizens during emergencies. Thus, the need for proper management and control of flood hazards are of vital importance in returning normalcy to the land where sustainable development objectives can be actualized while boosting the economy of the State

The study integrated relevant flood causative factors in a spatial database framework of GIS to evolve a flood hazard and risk maps for Owerri Zone in Imo State using Multi-Criteria Analysis (MCA) technique involving integration of Remote Sensing technology and combination of analytical hierarchical process (AHP) and weighted linear combination (WLC) aspect of Multi-Criteria Analysis (MCA) method in identifying flood vulnerabilities in the study area through generation of ranked criterion values and maps based on interaction of flood causative factors.

Satellite Remote Sensing and GIS techniques have emerged as a powerful tool to deal with various aspects of flood management in prevention, warning, preparedness and relief management of flood disaster. They have greater role to play as an improvement over the existing methodologies

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