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FLOOD HAZARD AND RISK ASSESSMENT IN IMO STATE USING GEOGRAPHIC INFORMATION SYSTEM

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Abstract

The study was aimed at producing flood hazard and risk maps for Imo State. Flood causative factors (rainfall intensity, slope, variation in elevation and land use) were assessed and analyzed using Remote Sensing and Geographic Information Systems tools through multicriteria decision making process. GIS spatial analysis and weighting involving integration of analytical hierarchical process (AHP) and weighted linear combination (WLC) method of multi-criteria decision making (MCDM) were employed in assessing interaction and contributions to flood hazard by the causative factors. Flood hazard and risk maps were produced and classified into various hazard levels. Flood hazard and risk maps showed very high hazardous areas on the southern part of the study area, justifying that those inhabitants in southern part of Imo State are more vulnerable to flood hazard than those in the northern part.

Key words: causative factors, flood hazard, GIS, spatial analysis, weighted overlay, multicriteria

1.0. Introduction

Flood is a natural phenomenon occurring globally at varying intensity on flood plain areas since time immemorial. In the recent decades, there has been increase in the incidence of flooding event recorded in most countries (Baidya *et al*. 2007; Daniela, Usman & Costas, 2017). However, the increasing activities of man through occupation, urbanization and encroachment on flood plain areas coupled with observed changes on climatic factors have resulted to a huge loss of life and damages to properties, causing floods to be termed as “natural environmental disaster” (Sevim & Sigdem, 2015; Daniela, Usman & Costas, 2017).

Flood hazard has been recorded as one of the most expensive natural disasters affecting man in his environment. The incidence of flooding is prominent in Riverine areas especial when rivers exceed their storage capacity leading to river banks overflow and filling adjacent low lands causing severe environmental and socio-economic consequences to inhabitants nearby (Itodo, and Daudu, 2012; Ume 2012; Amangabara & Obenado, 2015). Flooding, though a natural disaster is caused by combined factors of climatic change and human-induced land uses such as urbanization without proper planning for sustainability. These have been attributed as the most important factors leading to flood formation in the world today (Sevim & Sigdem, 2015). Heavy downpour at river banks or low land areas where there are significant land use changes such as deforestations and urbanizations have resulted to increased risk factor to flood hazard. Urbanization increases the imperviousness of the earth which promotes higher surface runoff volume that triggers flooding where soil saturation is reached. Works by Sani, Noordin and Ranya (2010); Woubet, (2011); and Sevim and Sigdem (2015) identified five significant flood risk factors as slope, rainfall intensity, land use, elevation and stream drainage pattern (flow accumulation).

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. Sneh (2013) reported flood menace involving huge losses to lives, properties, livelihood systems, infrastructure and public utilities affecting 40 million hectares out of a geographical area of 329 million hectares in India, claiming over 1600 lives annually and damages to crops, houses and public utilities.

Flood and its associated severe socioeconomic implications have been recorded across many States in Nigeria. While Itodo (2012) and Ume (2012) reported submerging of over 50 residential buildings by flood in Nasarawa State, Amangabara and Obenado (2015) highlighted submerging of uncountable houses in Bayelsa, Delta and Rivers State leading to evacuation of over half a million people to IDP camps from 2012 national flood events. The 2012 flood according to the National Emergency Management Agency (NEMA) affected 30 of the 36 States of Nigeria, 7 million peopled were affected in these States, 597, 476 houses were destroyed, 2.3 million displaced and 363 deaths were reported with large track of farmland and other means of livelihood destroyed, animals and other biodiversity were also gravely impacted upon. United Nations, Development partners and relevant Ministries, Departments and Agencies put the estimated total value of infrastructure, physical and durable assets destroyed at $9.6bn. The total value of losses across all sectors of economic activity was estimated at $7.3bn. The combined value of these damages and losses was put at US$16.9bn.

Duru and Chibo, (2014) have documented six Local Government Areas in Imo State as being affected by flood menace, varying from various degrees of flood types (Coastal, flash, River, Urban and Seasonal). Communities suffered different levels of devastations from various types of flooding occurring mostly during peak rainfall season. Overall implications of Imo flood incidence ranges from ravaging human activities, causing damages to goods, properties, farmlands, animals, disease spreads and contamination of the water supply resulting to significant social, economic, and environmental impacts.

Hence, the need for proper management and control of flood hazards are of vital importance for bringing normalcy to the land where sustainable development objectives can be actualized while boosting the economy of the State. However, this cannot be technically achieved without effective flood hazard and risk mapping (Ezemonye & Emeribe, 2011). Flood hazard and risk mapping are the vital component in flood mitigation measures and land use planning. This study attempts to integrate relevant flood risk factors in a spatial database framework (GIS) to evolve a flood hazard and risk map for Imo State using Multi-Criteria Analysis (MCA) technique. 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 (Awal, 2003; Sani, Noordin & Ranya, 2010). They are an improvement over the existing methodologies. Remote sensing, GIS technique and multi-criteria Analysis have successfully established its application globally in different areas of flood management such as flood inundation mapping, flood risk assessment, flood plain zoning and river morphological studies (Sani, 2008;Woubet & Dagnachew 2011; Selvin & Cigdem, 2015;Daniela, Usman & Costas 2018).In this study, flood hazard and risk were mapped using geographic information system (GIS) involving integration of Remote Sensing tool and combination of analytical hierarchical process (AHP) and weighted linear combination (WLC) aspect of Multi-Criteria Analysis (MCA) method. GIS spatially assesses flood causative factors and produces flood hazard and risk maps with the aim of providing flood control and reduction of damages.

2.0. Methodology

2.1. Study Area

The study area (Imo State) is located in Southeastern Nigeria with Owerri as its capital. It lies within latitudes 5°10'N and 5°60'N, and longitude 6°35'E and 7°30'E with an area of around 5,536 sq km (Fig 1). Imo State is bordered by Abia State on the East, River Niger and Delta State to the West, Anambra State on the North and Rivers State to the South. Imo state is an oil producing state with over 5.9million people and the population density varies from 230 to 1,400 people per square kilometer from 2019 projection (NPC, 2006).

The main cities in the study area are Owerri, Orlu and Okigwe, however, there are other notable towns in the State to include Isu, Oguta, Atta Ikeduru, Akokwa, Mbaise, Mbaitoli, Mbieri, Ohaji/Egbema, Orodo, Nkwerre, Ubulu, Ngor Okpala, Omuma, Mgbidi, Awo-Omamma, Izombe, Orsu, and Amaigbo, Umuowa Orlu, Isu and Umuozu.

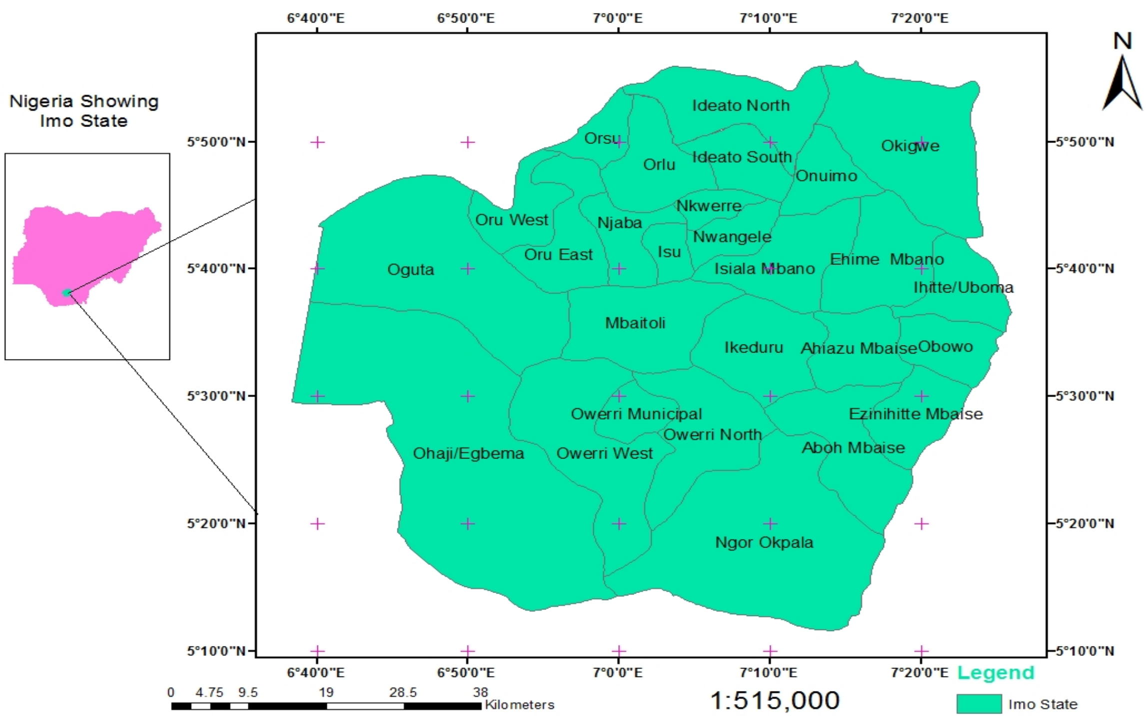


Fig 1. Map of study area (Imo State)

2.2. Data collection

Procured DEM from the regional centre for aerospace survey (RECTAS) was integrated with recently downloaded SRTM from Global mapper software, delineated to the study area (Imo State) and processed in ArcGIS software for elevation, slope and flow accumulation. Landsat imagery of the Imo State downloaded from Global Land Cover Facility, with band 5, 4 and 3, images was composited on ENVI (version 5.0) software where various region of interest (ROI) was created to form the basis for classification. Rainfall (meteorological) data procured at NIMET Office, for various gauging stations within and outside the study area was processed for intensity calculation, interpolated and delineated to the study area using the coordinate of rain gauge stations and study area shapefilein ArcGIS spatial analyst tool.

2.3 Method of Analysis

ArcGIS 10.7 software was used in this study based on its potential in allowing users to create, manipulate and analyze geospatial data. Arc Hydro software which works as extension in ArcGIS software was used to process DEM for flow accumulation. Envi 5.0 was used in classification of thematic landsat imagery of the study area into various region of interests. Input data (flood causative factors) for GIS based analysis integrating analytical hierarchical and weighted linear combination methods of multicriteria analysis were; the precipitation data from the Nigerian meteorological office for rainfall intensity estimation, the population data for population density estimation, the thematic landsat imagery for land use classifications, the digital elevation model (DEM) with ground resolution of 10m for processing of flow accumulations, slope and elevation factors. The input factors were first preprocessed in ArcGISsoftware environment, transformed to projected coordinate system of (UTM_WGS1984_Zone_32N) and converted to raster grid using the spatial analyst tool of the ArcGIS software.

2.3.1 Procedure for Flood Risk/Hazard Mapping

Flood causative factors particularly for this study was identified from field survey and reviewed literature. Thus, proposed flood risk factor assessed include; slope, elevation, land use type, flow accumulation and rainfall intensity. Slope and elevation raster layer were processed from procured recent Digital Elevation Model (DEM) of Imo State using the spatial analyst tool box of ArcGIS software, flow accumulation was generated with the integration of Arc-Hydro Terrain Processing software extension of ArcGIS with its Spatial analyst tool.

Landsat thematic imagery of the state was classified with ENVI 5.0 Remote Sensing software using maximum likelihood method for various regions of interest such as open spaces, built up areas, farmlands, vegetated, wetlands, forested etc. Rainfall data (amount and duration) primarily collected at strategic rain harvesting stations were integrated with secondary rainfall data collected at the Nigerian Metrological Agency Office, Imo Airport for estimation of rainfall intensity. Thus, with the coordinates of rain harvesting stations, rainfall intensity raster data for the State was generated in ArcGIS software environment through interpolation.

The five flood risk factors were processed, converted to raster, classified into sub-groups and ranked with their flood hazard influence (vulnerability to flooding) through Multi-Criteria Analysis (analytical hierarchical process and weighted linear combination) method and weighed in ArcGIS weighted overlay tool to produce flood hazard map for the State.

2.3.2 Determination of Flood Hazard Weighting Value

Flood causative factors influence in contributing to flood hazard was determined by integrating and calculating the mutual interaction ratios for most reviewed flood causative factors. Their mutual interaction was classified into primary and secondary factor effects, with a straight line indicating fundamental (primary) impacts on the other while dotted lines represented secondary effects between two factors (Fig 2). For instance, flow accumulation has a fundamental impact on land use and a secondary effect on slope. Similarly, elevation has a fundamental primary impact on rainfall intensity, landuse and flow accumulation with a secondary effect on slope.

Thus, in order to measure these effects, one (1) point was assigned to primary effect while half (0.5) point was assigned to secondary effect. With these effects, a factor rate is estimated as the sum of impacts on the others (Table 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 (Shaban, Khawile& Abdullah 2006; Selvin &Cigdem, 2015; Eastman, 2015) in flood hazard mapping as summarized in Table 2.

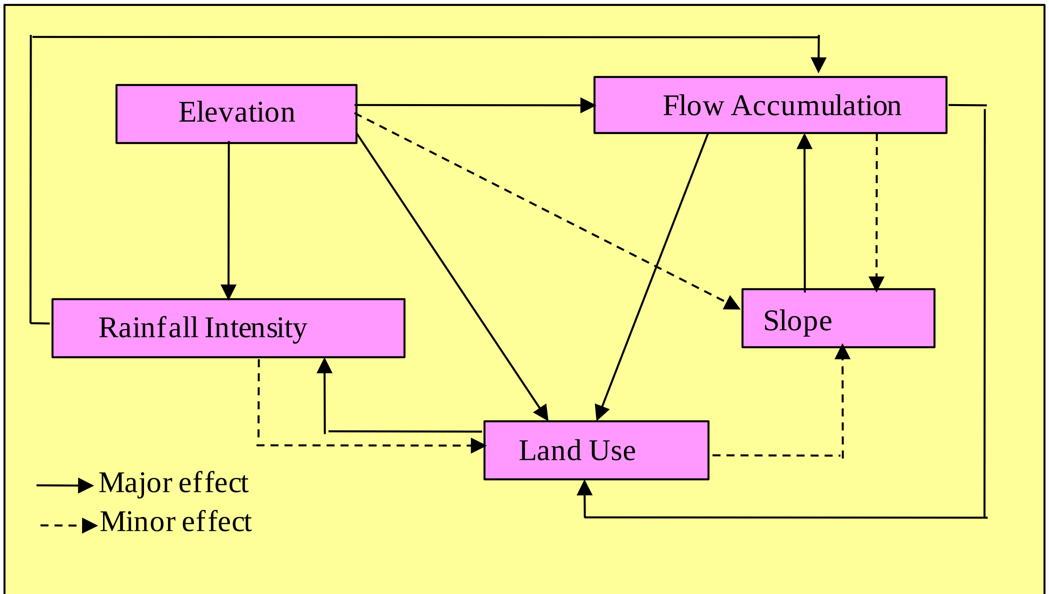


Fig 2. Chart of interaction of flood causative factors (Source; Modified After Selvin and Cigdem, 2015)

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) =	.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

(Source; Author's generated from Fig 2)

2.3.3 Weighted Overlay for Flood Hazard Mapping

Multi-Criteria Analysis was applied in producing and combining spatial data describing causative factors. In the first part, the flood risk factors were produced as a numerically map layer describing the study area. All criteria (flood risk 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.

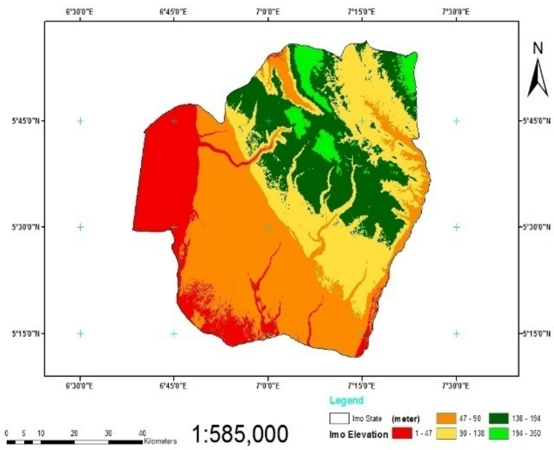
In the second part analytical hierarchical process method was used, where, every criterion under consideration is ranked in the order of universally acceptable flood risk influence. To generate criterion values for each evaluation unit, each factor was weighted accordingly to the estimated significance for causing flooding. With this method, 1 was the least important and 10 was the most important factor (Table 2). The criterion maps in raster grids (Figures 3-7) were mathematical processed and applied to ArcGIS spatial analyst tool and combined by means of a weighted overlay in ArcGIS environment.

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. The ratio of the flood hazard factors according to their weight on hazard formation was based on; Flow accumulation 15%, slope 20%, elevation 35%, rainfall intensity 15%, land use 15% and population density 15% (Table 2).

Table 2. Weighting Factors and their classifications

Factor	Domain	Descriptive level	Proposed weight (a)	Ratio (b)	Weighted ratio (a*b)	Total weight	Percentage (%)
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
Slope	40.5-60.5 25.5-40.5 15.5-25.5 5.5-15.5 0 – 5.5	Lowest Low Moderate High Highest	1 2 5 8 10	2.0	2.0 4 10 16 20	52	20
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
Factor	Domain	Description level	Proposed weight (a)	Ratio (b)	Weighted ratio (a*b)	Total weight	Percentage (%)
Rainfall Intensity	156-167 167-172 172-178 178-189 189-206	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**

(Source: Shaban, Khawile and Abdullah 2006; Selvin and Cigdem, 2015, Eastman, 2015)



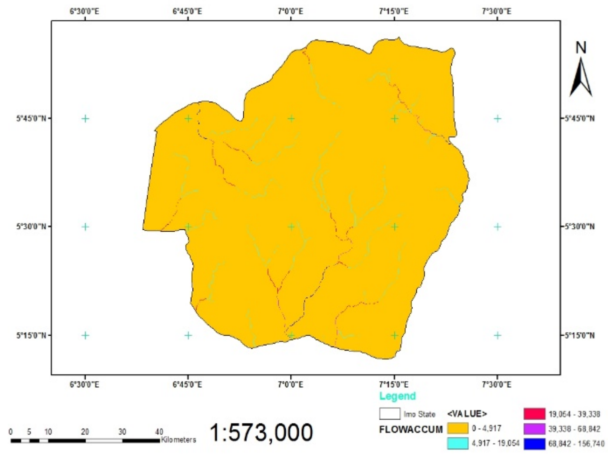
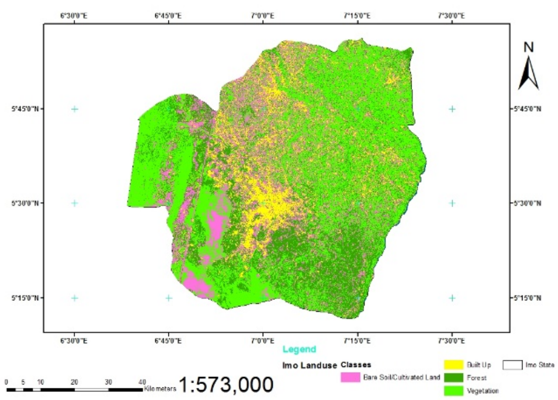


Fig 2; Elevation raster grid Fig 3; Flow accumulation raster grid



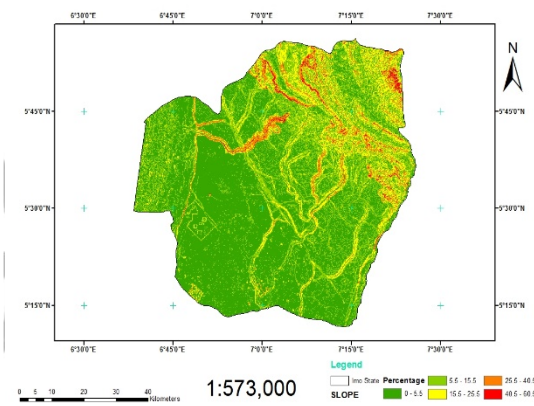


Fig 4; Land use raster grid Fig 5; Slope grid

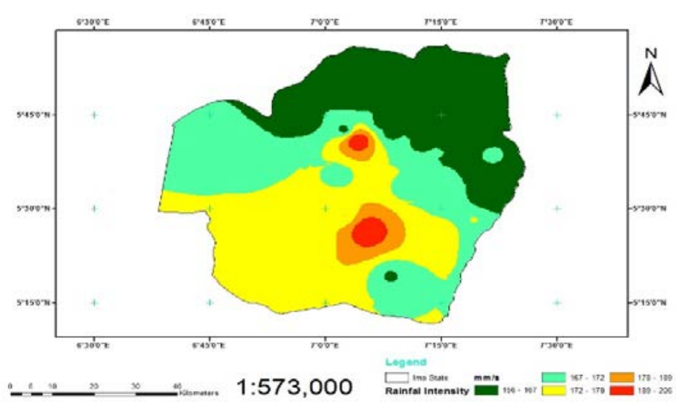


Fig 6;Reclass rainfall intensity grid

2.3.4 Elements at risk

Elements at risk include man and the biophysical component likely to be affected by flood menace. Among the five flood causative factors, land use and population factors contained vulnerable elements at risk covering direct and indirect impacts of flood to man and other biological components of the environment. The two elements at risk are the 2021 projected population raster grid (figure 8) and the classified landsat imagery of Imo State.

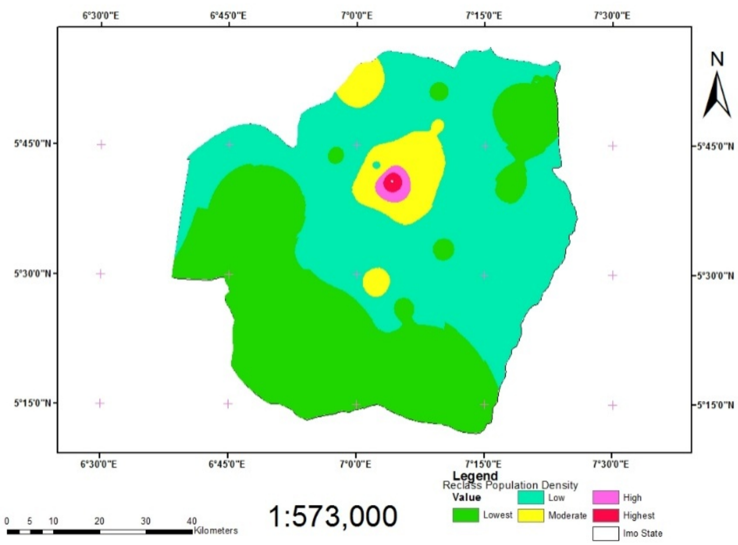


Fig 8; 2021 projected population density grid for Imo State

2.3.5 Flood risk assessment

Flood risk assessment was obtained by combining the product of elements at risk (projected population raster grid and classified landsat imagery) with the degree of flood hazard for the State and characterized as respectively as very high, high, moderate, low, and very low Flood Hazard and Risk Assessment Areas Using GIS and Remote Sensing Technique (Table 3).

With production of flood hazard map, varying degrees of it hazardousness (Very high, High, Medium, Low and Very low) is known; Flood risk assessment was done for Imo State using the flood hazard layer and the two elements at risk, (Population density and land use) at equal vulnerability, assuming to be one (Equ 1 and Table 3). These three factors remained to be equally important in the Weighted Overlay process.

$$Fr = Fh * Pd * Lu \qquad \text{(Eqn1)}$$

where

Fr = Flood risk analysis

Fh = Flood hazard map

Pd = Population density

Lu = Land use

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	1.5	1.5 3 7.5 12 15	39	15
Population density	319-1526 1526-2733 2733-3940 3940-5147 5147-6356	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 Cultivated/bare Built-up waterbody	Lowest Low Moderate High Highest	1 2 5 8 10	1.5	1.5 3 7.5 12 15	39	15
Total						**117**	**45**

(Source:Islam, and Sado, 2000b; Joy and Xi, 2003;Woubet and Dagnachew, 2011)

3.0. Result

Flood causative factors producing erosion hazard map (Fig 9 and Table 4) for Imo State showed that the Southern part is more exposed to very high hazard than the northern part following the subdivisions of the level of hazardousness into five groups (very high hazard, high hazard, moderate hazard, less hazard and very less hazard). The very high hazard area covered an area of 1631.4km^2 occurring in parts of Oguta, Ohaji/Egbema, NgorOkpala, Owerri West and Owerri municipal LGAs with a percentage coverage (31.8%) of total area of study. The high hazard area cuts across major parts of all the southern and central Areas (Oguta, Ohaji/Egbema, Owerri Municipal, Owerri North, AbohMbaise, Owerri West and NgorOkpala) LGAs with a coverage of 1419.8km^2, representing 27.67% of total study area. Moderate hazard area covered 1014.23km^2 and 25.1% occupancy, observed on major parts of the central area of study (Mbaitolu, Ikeduru, AbohMbaise, Onuimo, IhiteUboma, Obowo and Ehime Mbano) LGAs. Low hazard area was found on the northern of Isialla Mbano, Nwangele, Nkwere, Orlu, Ehime Mbano and Southern part of Ideato North, Okigwe and Ideato South LGAs, with an area of 606.6km^2, maintaining 11.8% of study. Very less hazard area was dominant on the northern part of the study covering four LGAs (Ideato North, Ideato South, Okigwe and Orlu) at 191.9km^2 and 3.7% of total study area.

Erosion hazard potential classes maintained a ratio of 1.0:3.2:6.8:7.5:8.6 respectively from very less hazard to very high hazard areas, signifying that for every 27.1km^2 of land found in the study area, has 1km^2 exposed to very less hazard, 6.8km^2 standing risked to moderate flood hazard and 8.6km^2 exposed to very high hazard resulting from mostly flash and urban flood types.

Table 5. Flood hazard classification

Class	Area (SqKm)	Percentage	Cumulative	Ratio
Very Less Hazard	191.9	3.7	3.7	1
Less hazard	606.6	11.8	15.5	3.2
Moderate	1286.3	25.1	40.6	6.8
High Hazard	1419.8	27.6	68.2	7.5
Very High Hazard	1631.5	31.8	100	8.6
Total	5136	100		27.1

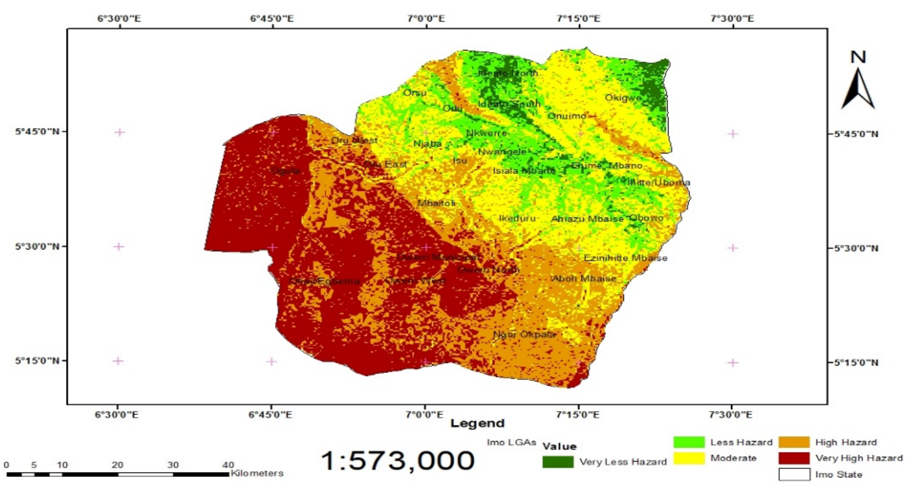


Fig 9; flood hazard map

Flood risk map (Fig 10 and Table 6) obtained by integration of flood hazard layer map with the elements at risk (population and land use), showed that southern part of the study area was more exposed to extreme risk of high flood hazard than the northern counterpart. From the flood risk map (Fig. 10), it was estimated that 35.5%, 17.8%, 38.8%, 2.3% and 5.6% of Imo State were subjected to very high, high, moderate, low, and very low flood hazards respectively.

Table 6 flood risk analysis result

Flood Risk	Area (SqKm)	Percentage	Cumulative
Very Less	286.2	5.6	5.6
Less	114.8	2.3	7.9
Moderate	1988.8	38.8	46.7
High	908.9	17.8	64.5
Very High	1821.9	35.5	100
Total	5136	100	

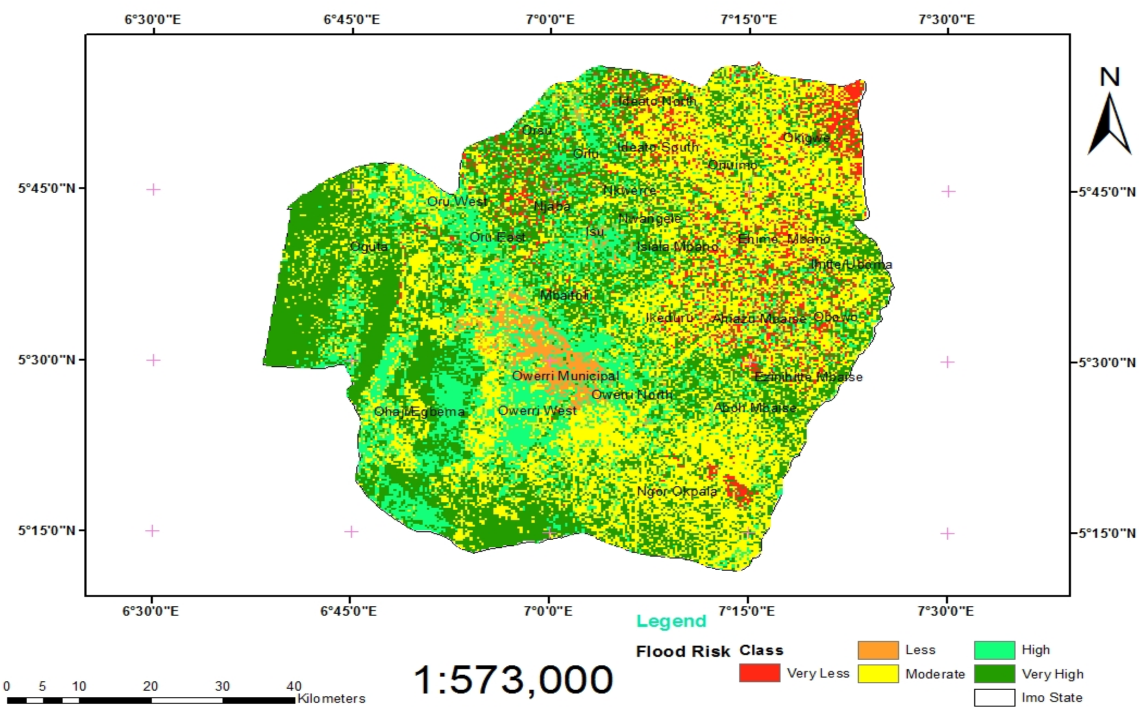


Fig10; flood risk map of Imo State

5.0. Conclusion

Flooding especially by flash flood and unplanned urban setting have been an environmental problem in Imo State, causing loss of lives and destruction of properties worth millions of naira. On assessment of five flood causative factors and risk analysis, flood hazard and risk maps were produced with high hazard potentials respectively dominating southern part of the study. These results revealed that southern part of the study area is more exposed to extreme risk of high flood hazard than the northern part.

This study shows that geographic information system and remote sensing tools are capable of analyzing flood causative factors to produce flood hazard and risk maps through integration of muilt-criteria decision making process. It represents a simple and cost-effective way of obtaining information needed in establishment of flood management organizations with policies aimed at managing and preventing reoccurrence of flood hazards in the state, hence government policies should be aimed at alleviating flood by dealing with all the identified causes.

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