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Flood vulnerability mapping of Ogbese, Nigeria

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ABSTRACT:*Flood is a continuous yearly menace in Nigeria which causes loss of human lives and, damage to properties and infrastructures. Flood mitigation would play a major role in tackling flood, developing policies and mitigation strategies. This study aims at generating a flood vulnerability map using Remote Sensing and GIS techniques coupled with fuzzy multicriteria analysis. Five factor criteria was used to delineate the flood vulnerability; Slope, Distance to Drainage, Drainage Density, Landuse and Geomorphology. The various criteria factor were assigned fuzzy membership based on the effect they have in causing flood. The fuzzy members were overlaid using fuzzy overlay function. The resulting flood vulnerability map indicates that 92.46% of the study area lies in low flood vulnerability zone, 5.91% of the study area lies in medium flood vulnerability zone and 1.62% of the study area lies in high flood vulnerability zone. The information provided by the study serves as a decision support system for government, stakeholders and policy makers for flood disaster management. The study findings are useful and can be replicated for drainage system planning in many communities affected by flooding in Nigeria.*

KEYWORDS: *GIS, Land use and Land cover, Flood vulnerability, Multicriteria Analysis and Disaster Management*

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I. INTRODUCTION

Flooding is a common hazard in the world with devastating impact on human lives, properties and infrastructures. Flood is an overflow of large expanse of water that submerges land area. Flood disaster causes tremendous loss and social disruption across the world yearly (Kabiretal., 2013). Flooding is a common environmental problem in Nigeria and has become increasingly severe in recent years (Agbonkheseet al., 2014). The effects are more in the urban parts of the country as a result of population explosion and poor urban planning. Flood disaster in Nigeria dates back to 1963 in Ibadan City when River Ogunpa over-flowed and caused loss of lives and properties (Adetunji and Oyeleye, 2018; Adegbola and Jolayemi, 2012). Since then there has been wide spread flood disaster across the country (Mohammed, 2018). In recent times, flooding was recorded in Sokoto (2010), Ibadan (2011), Lagos (2011), Jimeta (2012), River Niger and Benue Flood (2012) which affected 13 states; Niger, Delta, Benue, kogi, Edo, Ondo, Anambra, Imo, Bayelsa, Rivers, Ebonyi, and Makurdi (2017) (Innocent and Steve, 2015; Ojigi, 2012; Bello et al., 2014). The flood catastrophe has been witnessed in various part of the country is attributed to heavy rainfall and release of water from dams. Flood does not discriminate, but marginalizes whosoever refuses to prepare for its occurrence (Angela, 2011). Flood does not only affect the social and economic factors, it also has health effects when water resources are polluted thereby increasing risk of diseases (Baiye, 1988; Akinyemi, 1990; Nwaubani, 1991; Edward-Adebiyi, 1997; Prekeyi et al., 2015). This study aims at mapping flood vulnerability in Ogbese using Remote Sensing and Geographic Information System (GIS) techniques. Remote Sensing provides the dataset and GIS spatial analysis are useful for delineating the flood vulnerability over a spatial extent.

II. METHODOLOGY

2.1 Study area

Ogbese is a town inAkure North Local Government ofOndo State and lies between Longitude 5^{o}21' E to 5^{o}25' E and Latitude 7^{o}15' N to 7^{o}17' N. The Koppen classification of Ogbese is within the AF climate type. There are two climate seasons in Ogbese; the dry and wet season. Average temperature is 25^{o}C. Ogbese lies in the tropical rainforest zone. Figure 1 shows the study area Ogbese.

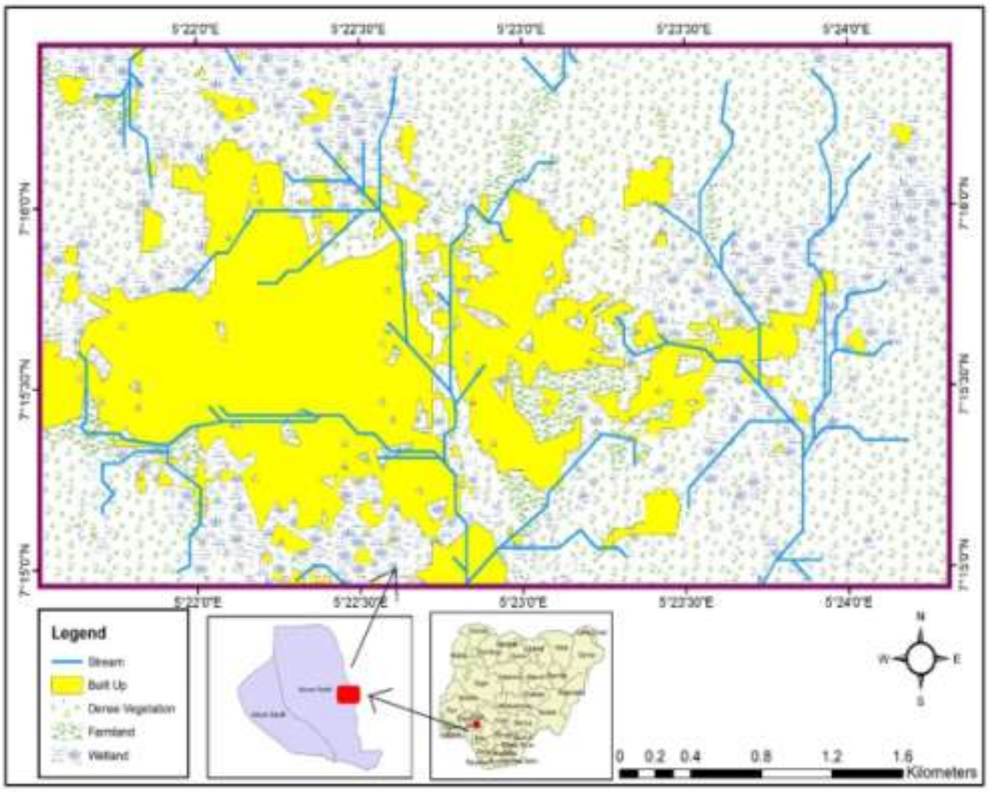

Figure1: Study Area Map

2.2 Data collection

Landsat 8 (OLI) imagery covering Ogbese was acquired from the United States Geological Survey (USGS) website. The date of acquisition was 4th January, 2017. Shuttle Radar Topography Mission (SRTM) imagery for Ogbese was also acquired from USGS website to model the Digital Elevation Model (DEM) and drainage in the area. Soil data was extracted from Harmonised World Soil Database (HWSD). Scanned geological map of Ogbese was acquired from the office of the Nigerian Geological Survey Agency (NGSA).

2.3 Method

Scanned geology map and soil data were georeferenced and digitized. The digitized files were rasterised and reclassified using spatial analyst tools in ArcGIS software. Supervised classification was performed on the landsat 8 imagery using maximum likelihood method (Eastman, 1995). Various landuse and land cover classes were identified using this method. The landuse and land cover map was reclassified. Digital Elevation Model (DEM) was performed on the SRTM imagery using surface analysis tools in ArcGIS to produce a slope map. Hydrology analysis was performed on the SRTM to delinate the drainage network in Ogbese. The criteria generated from the data include; slope, distance to drainage, drainage density, geology, soil and landuse. The criteria were put into a fuzzy membership class based on their impact of causing flood using fuzzy membership tool in ArcGIS. All criteria fuzzy members were overlaid using fuzzy overlay function tool in ArcGIS to generate the final flood vulnerability map.

III. RESULT AND DISCUSSION

3.1 Slope

Figure 5 shows the slope map of Ogbese. The slope distribution within the study area ranges from 0^{o} to 14.3^{o}. Water from rainfall tends to flow from region of steep slope as runoff to flat regions where the water gathers to become flood. The slope factor was ranked based on it's impact in causing flood. Areas with lower slope values i.e. flat or almost flat areas support flood by allowing water to gather in them. Areas with gentle slope have little impact in causing flood. Steep slope do not allow water gather thereby they do not support flooding.

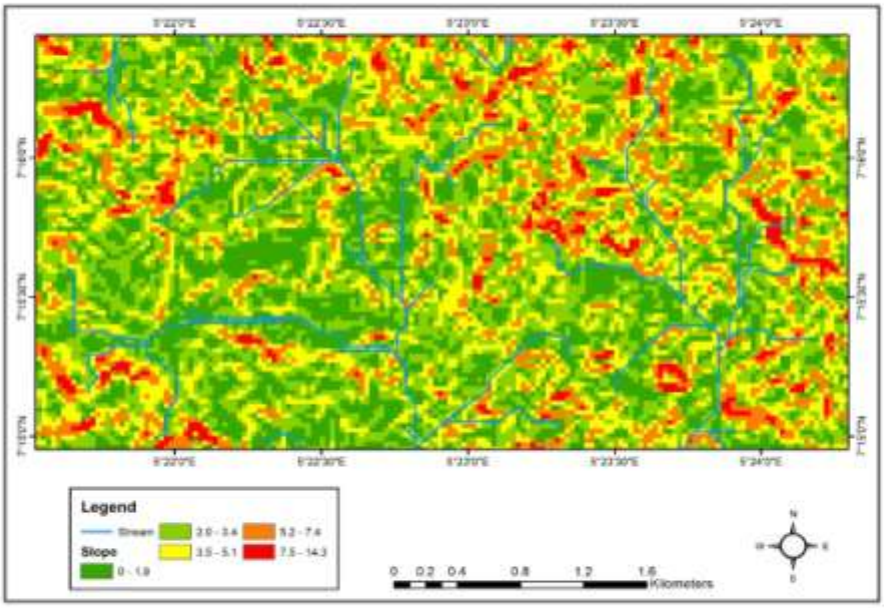

Figure 2: Ogbese slope map

3.2 Distance to Drainage

The drainage pattern within Ogbese was generated from shuttle Radar Toppgraphy Mission (SRTM) Imagery using hydrology analysis tool in ArcGIS. Figure 6 shows the distance to drainage map. The distance to drainage ranges from 0 to 760m. Areas that are closer to drainage systems (0 – 30m) are prone to flooding. This is especially because extreme rainfall causes river water to overflow their banks entering into land with the areas close to the river as been most vulnerable. Distance to drainage was classified based on level of vulnerability to flood. The 30m is the limit set by the Nigerian government through the Town and Regional Planning (Building Plan) regulation, 1986.

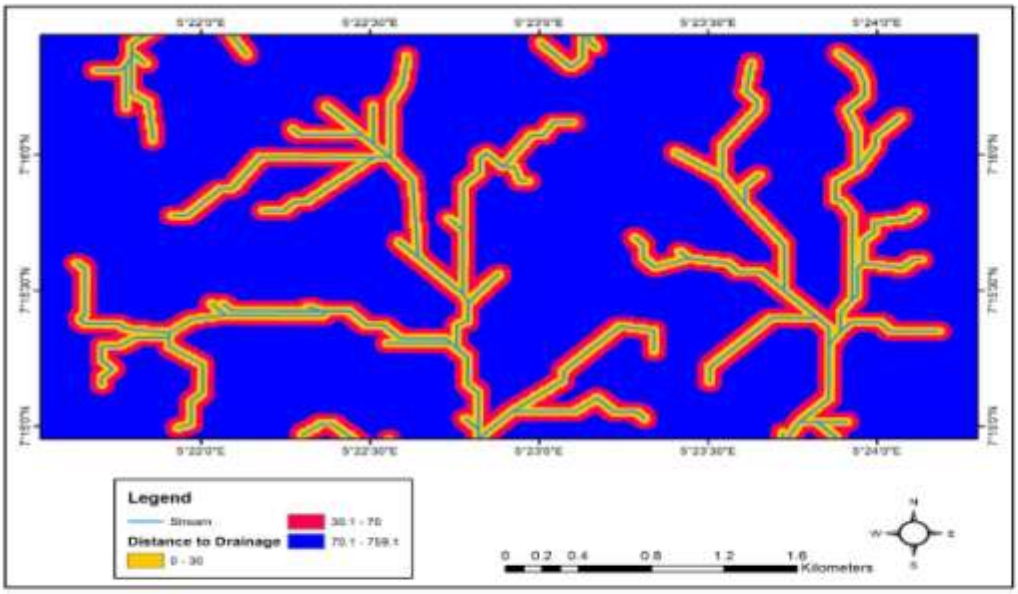

Figure 3: Distance to drainage map

3.3 Drainage Density

Drainage density for the study area was generated from the drainage network using the density function in ArcGIS software. Water tends to gather in areas of high drainage density which makes it to overflow it's bank into dry land thereby causing flood. Figure 7 shows the map of drainage density of Ogbese town. The drainage density was classified into three; low, medium and high density. Places with high drainage density indicates high flood vulnerability, medium drainage density indicates a moderate level of flood vulnerability and low drainage density indicates low flood vulnerability.

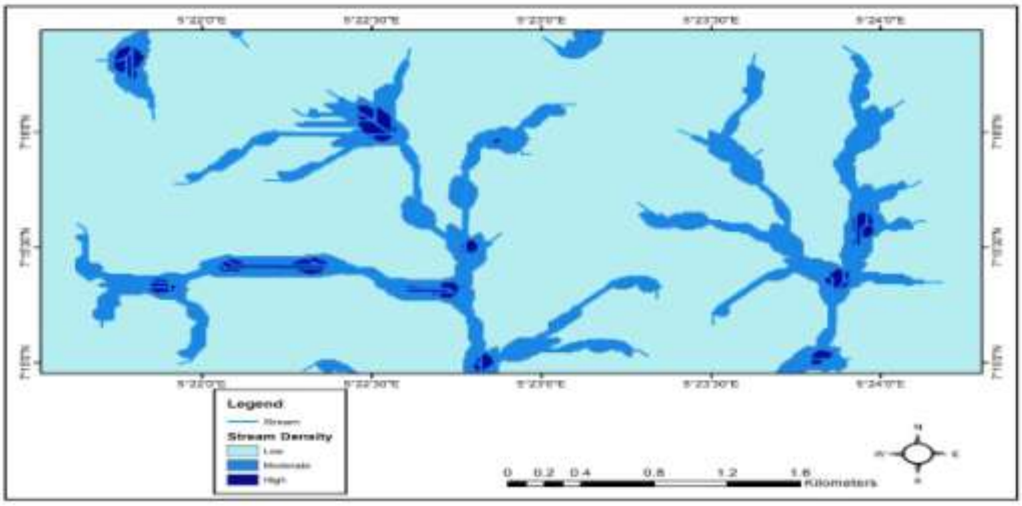

Figure 4: Drainage Density map

3.4 Landuse and land cover

Figure 8 shows landuse and land cover (LU and LC) map of Ogbese. Five LU and LC types are presented within the study area; Built Up, Farmland, Dense Vegetation and Wetland. Figure 9 shows the LU and LC reclassification map. Built up and Wetland areas was ranked the highest i.e. 4 because wetland areas are where water collects to create a waterlogged zone. Farmland and dense vegetation was ranked next i.e. 2 because farm lands and dense vegetation could also be affected by floods with a lesser collateral damage.

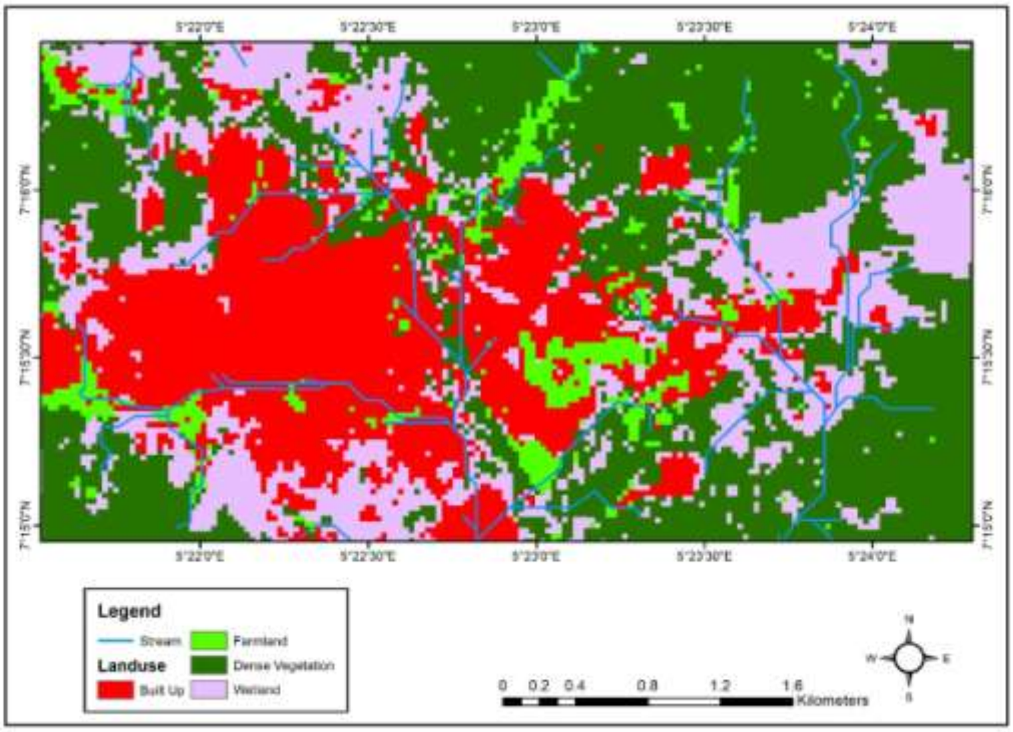

Figure 5: Landuse and land cover map

3.5 Geomorphology

The geographical landforms and formation in the study area include floodplain which are the most susceptible to flooding, low lying land which are moderately susceptible to flooding and undulating land which are less susceptible to flooding. Figure 9 shows the geomorphological map of Ogbese town.

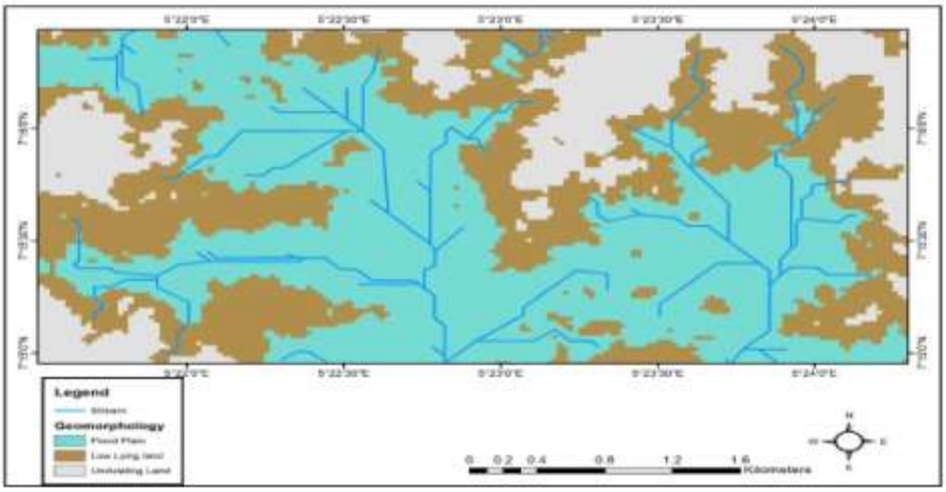

Figure 6: Geomorphology Map

3.6 Flood Vulnerability

The various criteria were ranked according to their impact in causing flood. The criteria were fit into fuzzy membership. The criteria fuzzy members were overlaid to generate the flood vulnerability map. Table 1 shows the membership class of all criteria. The flood vulnerability in Ogbese was classified into three; low, medium and high. Figure 10 shows the flood vulnerability map in Ogbese. The low flood vulnerability zone covers an area of 14.23km^2 which is 92.46% of the total area, medium flood vulnerability zone covers an area of 0.91km^2 which is 5.91% of the total area and high flood vulnerability zone covers an area of 0.25km^2 which is 1.62% of the total area. Figure 11 shows the flood vulnerability overlaid on the LU and LC map. The flood vulnerability for each LU and LC was calculated in area and percentage for Ogbese. For built up, low vulnerabillity covers 3.71km^2 which is 90.5% of the built up, medium vulnerability covers 0.21km^2 which is 5.1% of the built up and high vulnerability covers 0.18km^2 which is 4.4% of the built up. For farmland, low vulnerability covers 0.68km^2 which is 51.1 of the farmland, medium vulnerability covers 0.06km^2 which is 4.5% of the farmland and high vulnerability covers 0.05km^2 which is 0.1% of the farmland. For dense vegetation, low vulnerability 6.78km^2 which is 95.8% of the dense vegetation, medium vulnerability covers 0.29km^2 which is 4.1% of the dense vegetation and high vulnerability covers 0.01km^2 which is 0.1% of the dense vegetation. For wetland, low vulnerability covers 3.07km^2 which is 89.5% of the wetland, medium vulnerability covers 0.35km2 which is 10.2% of the wetland and high vulnerability covers 0.01km^2 which is 0.3% of the wetland.

Table 1: Criteria fuzzy membership

CRITERIA	VALUE	FUZZY MEMEBERSHIP
Slope	0 – 1.9 2.0 – 3.4 3.5 – 5.1 5.2 – 7.4 7.5 – 14.3	Fuzzy MS Small
Distance to Drainage	0 – 30 30.1 – 70 70.1 – 759.1	Fuzzy MS Small
Drainage Density	Low Medium High	Fuzzy Large
Landuse and land cover	Built Up - 4 Farmland - 2 Dense Vegetation - 2 Wetland – 4	Fuzzy large
Geomorphology	Flood Plain – 4 Low Lying Land – 2 Undulating Land – 0	Fuzzy Large

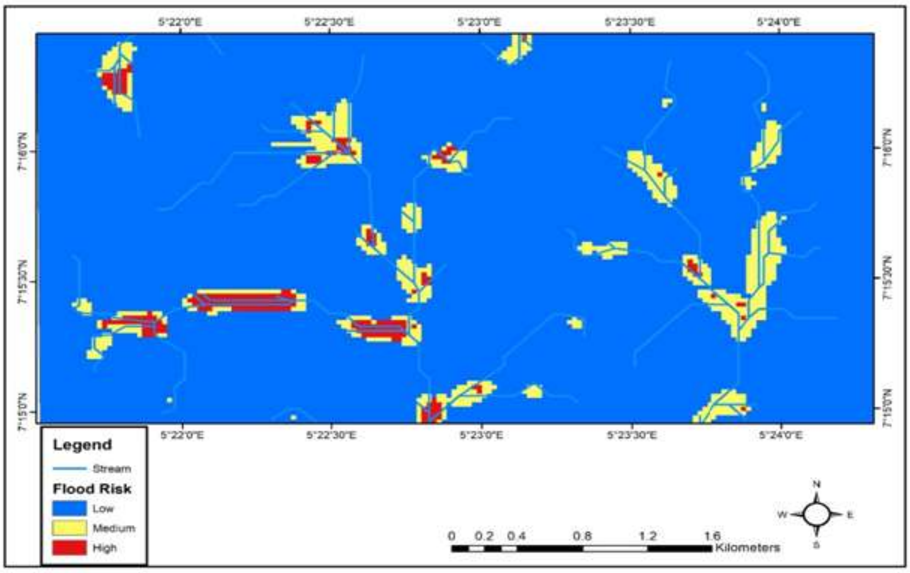

Figure 7: Flood vulnerability Map

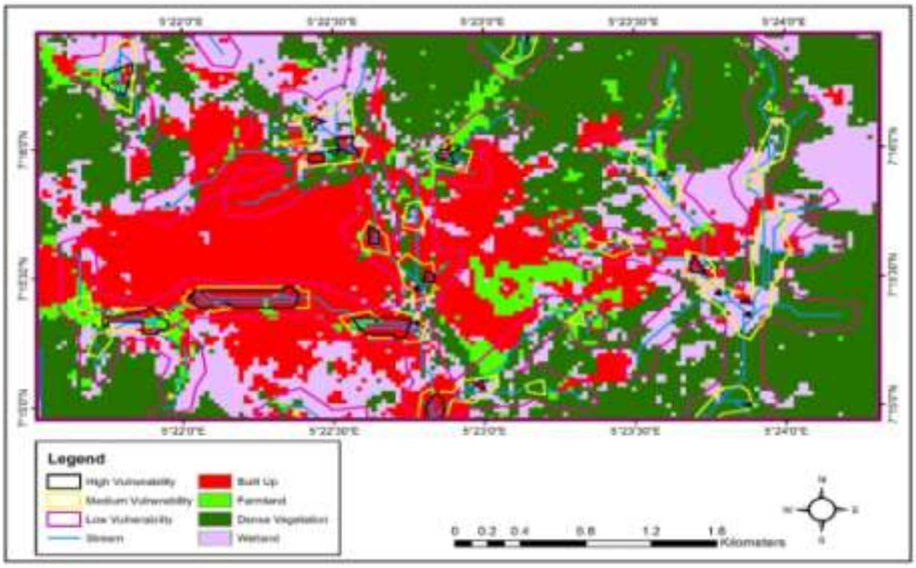

Figure 8: Flood vulnerability for Landuse in Ogbese

Table 2: Flood Vulnerability of Landuse in Ogbese

LANDUSE	LOW		MEDIUM		HIGH	
	Km2	%	Km2	%	Km2	%
Built Up	3.71	90.5	0.21	5.1	0.18	4.4
Farmland	0.68	51.1	0.06	4.5	0.05	3.8
Dense Vegetation	6.78	95.8	0.29	4.1	0.01	0.1
Wetland	3.07	89.5	0.35	10.2	0.01	0.3

IV. CONCLUSION

Flooding hazard has a worldwide effect and are highly destructive. Flood causes damage to the economy, society and environment. Increase in the frequency of flood has made it become a major concern for stakeholders and the government. There is, therefore, a need for proper flood mitigation strategies and policies. This study ultilizes GIS and Remote Sensing capabilities to determine the magnitude and extent of flood vulnerability in Ogbese. Five criteria were taken into consideration which includes slope, distance to drainage, drainage distance, landuse and geomorphology. The flood vulnerability map indicates that 92.46% of the study area lies in low flood vulnerability zone, 5.91% of the study area lies in medium flood vulnerability zone and 1.62% of the study area lies in high flood vulnerability zone. The application of GIS and Remote Sensing serves as a decision support system for flood hazard preparedness, mitigation, response and recovery. The study result serves as guide for stakeholders and government for effective flood management.

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