

Flood vulnerability mapping in Ile-Ife, OSUN State, Southwest Nigeria

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ABSTRACT

In recent years, the rapid and uncoordinated urban expansion in the medium-sized city of Ile-Ife has increasingly encroached on environmentally sensitive areas. This uncoordinated exploitation of ecologically sensitive areas for urban development has resulted in urban flooding, posing a serious threat to human lives and property in the city. As a result, this study used geospatial technologies to generate flood hazard models for medium-sized cities in developing countries in general, and Nigeria in particular, with the goal of identifying hotspots and providing flood-prevention measures. The study used Shuttle Radar Topography Mission-Digital Elevation Model (SRTM-DEM), Operational Land Imager 8 (OLI)- 2018 images, and Google Earth map of Ile-Ife. ERDAS IMAGINE 2014 was used to process the satellite imagery and the map embellishment was carried out in ArcGIS 10.2.2. The Digital Elevation Model was processed in ArcGIS 10.2.2 to obtain flood vulnerable areas of the study area. The results revealed that the surface areas covered by settlement, secondary/re-growth forest, shrub/fallow/annual crops, water body, and Bare soil, were 72750 m² representing 78%; 10560 m² representing 11%; 2820 m² which is 3%; 5460 m² representing 6%; 1530 m² representing 2%, respectively, of the coverage area of Ile-Ife in 2018. The most vulnerable areas were built-up areas with a high impervious surface in the basin area, where the flood plain crossed high and moderate vulnerability zones. To reduce flood hazards, the study advocates for the consistent use of dynamic models within GIS for floodplain delineation and management planning.

Keywords: Geospatial, Flood hazard, Digital Elevation Model, GIS

I. INTRODUCTION

Floods are an extreme naturally occurring weather event that results in an overflowing of large amount of surface water over land that is not always inundated, Adeoye et al., (2009). It is

considered to be the worst natural problems and half of damages on facilities around the globe. Floods have cost damages to societies totaling more than 250 billion dollars and the intensity and frequency of floods are increased globally. It is gradually becoming a common phenomenon around the world, caused by increase in global temperature that results in torrential rise in sea level that over flowed their banks and flood surrounding coastal lands (Jeb and Aggarwal, 2008).

The threat to lives and properties by flood is an annual event in urban centres of many countries and Nigeria is not exempted. In Nigeria, aside from droughts, floods caused almost 90 percent of damages resulting from natural hazards (Adeoye et al., 2009). Floods that occur in Nigeria are as a result of extensive rainfall, drainage blockage and dam failure (Jeb and Aggarwal, 2008).

To evaluate the impact of flood in a given area, a flood risk assessment is usually carried out. Flood risk assessment is based on the history of several parameters which include; rainfall, river flow, tidal surge information, topography, flood-control measures, and alterations due to flood plain construction and growth. Among the factors that cause flooding, heavy rainfall invariably precedes them in Nigeria (Ishaya et al., 2008; Adeoye et al., 2009; Ejikeme, J. O, 2015). Other causes of flooding include moderate to serious water winds, uncommon elevated tides, tsunamis caused by undersea earthquakes, dam breaks or failures, levees, retention ponds or lakes, and other water-retaining infrastructure (Adeoye et al., 2009; Etuonovbe, 2011). In towns and outskirts, pavement and rooftops contribute to the inability of the soil to absorb rainfall, thereby leading to flooding in the urban centres (Dor, 2017). The attendant negative effects of floods on man and his environment make it quite important to map out flood risk areas.

Flood disasters have affected the lives of several people more than most natural disasters (Klema, 2015; Komolafeet al., 2015;

Orimoogunjeet *et al.*, 2016). The negative effects of flooding are most times irreversible globally and locally, in which Nigeria, Osun State, and Ile-Ife in particular are not exempted. The impact of flooding repeatedly resulted in damage of lives and properties in Ile-Ife. Several works have been done to identify flood risk, map flood hazard, and assess vulnerability to flooding in Ile-Ife using geospatial technique (Ijaware V. A., 2020; Otokiti *et al.*, 2019; Alfred, 2018; and Ouma and Tateishi, 2014). Unfortunately, the repetitive flooding of Ile-Ife has continued to grow regardless of the existence of literature to curb its occurrence. The problem has been that of non-implementation of existing principles, part of which includes the assessment of vulnerability to flooding, and the implementation of knowledge gained from such assessment. Negative effects of flooding have continued to impact lives and properties in Ile-Ife. This study however, will assess the flood prone areas and flood risk in Ile-Ife, hence contributing to the existing literature on the flood risk areas in Ile-Ife, Osun State, Southwest Nigeria.

II. MATERIALS AND METHODS

2.1 The Study Area

Ife central and Ife East as shown in Figure 1 are two Local Government Areas in Osun State, having their headquarters in the city of Ile-Ife to the

south of the area, which is part of Ife (an ancient Yoruba city in south-western Nigeria). Ife central and Ife East LGAs have a population of 644,373 according to 2006 population census. The LGAs in Ile-Ife approximately lies within Latitudes and Longitudes (7°34', 4°29'), (7°37', 4°32'), (7°32', 4°35'), and (7°28', 4°34'). The climate of Ife Central LGA is characterized after the tropical rainforest of rainy wet and dry seasons. The rainy season lasts between April and October, while the dry season extends from November to March annually. The annual rainfall of Ife-Central is around 1340 mm and the mean annual temperature fluctuates around 26.2°C. The elevation of the study area ranges between 236m - 449m above mean sea level. Ile-Ife is endowed with forestry reserves and agricultural potentials. Its forestry reserves are found in the areas often regarded as Area five (Area-5) which comprises of villages such as Ife Tuntun, Apoje and Omifunfun. The soil is a low base status forest soil derived from coarse-grained gneiss and granite parent rocks and is classified as an ultisol (Harpstead, 1973). Geologically, Ile-Ife is underlain by metamorphic rocks of the basement complex such as schists, migmatite and meta-sediments. Ile-Ife area is drained by some major rivers which include; Sasa, Osun, Awosan, and Opa (Ifabiyi, 2008).

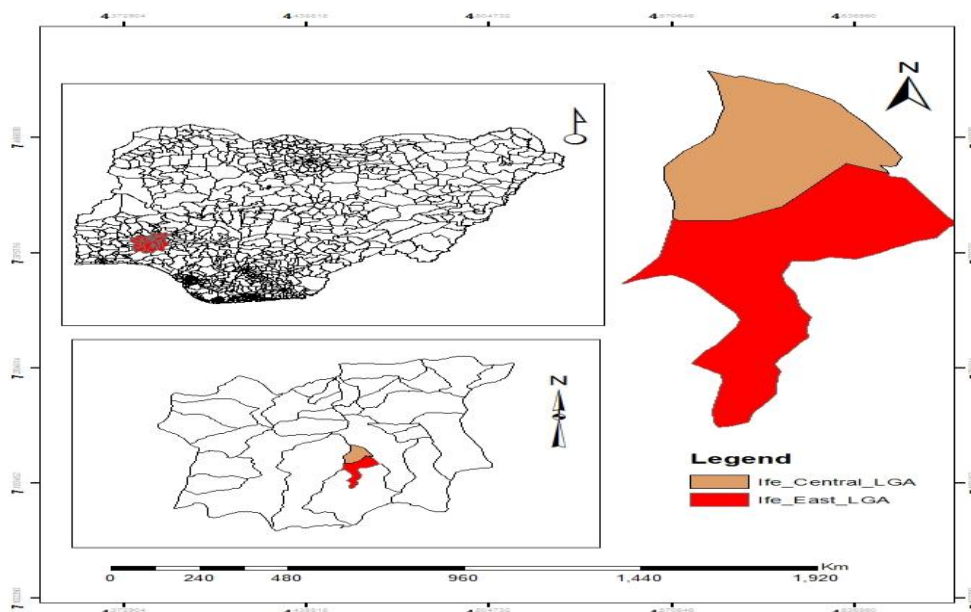


Figure 1: Map showing study area

2.2 METHODS

The coordinates of places with prior history of flooding within the study area was acquired using GARMIN Etrex 20 handheld GNSS

receiver and presented in Table 1. Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data was acquired from the United States Geological Survey (USGS) website; Landsat

8 was acquired from the USGS website for land use/land cover mapping; and the administrative boundary was obtained from the Office of the Surveyor-General of the Federation (OSGOF).

Table 2 shows the type of the data used in this study, their format, scale/resolution, year of acquisition and source.

Table 1: GPS readings of the selected areas in Ile-Ife

S/N	Location	UTM_Northing	UTM_Easting	Elevation (m)	Accuracy (m)
1	OAU Ile-Ife	667818	832741	342	3.2
2	Opa Area Ile-Ife	678192	832778	343	3.5
3	Ede Road Ile-Ife	671364	828441	302	2.8
4	Old NEPA Modakeke	673918	824358	280	3.4
5	Opa Dam OAU Ile-Ife	669150	830534	255	3.0

Table 2: Flood mapping data sources

S/N	Type	Format	Scale/ Resolution	Year	Source
1	Shuttle Radar Topography Mission	Digital	30m	2018	United States Geological Survey (USGS)
2	Landsat OLI/TIRS	Digital	30m	2018	United States Geological Survey (USGS)
3	Digital Elevation Model	Digital	30m	2018	United States Geological Survey (USGS)
4	Administrative Map	Digital	Vector File/ No Resolution	2017	Office Of The Surveyor General Of The Federation (OSGOF)

2.2.1 Data Processing

The DEM image of Ile-Ife was sub-mapped in ERDAS IMAGINE 2014 software from the DEM of Southwest Nigeria, and later exported to ArcGIS version 10.2.2 Environment for further processing. The Landsat 2018 imagery of Southwest Nigeria of bands 432 composite was produced and Ile-Ife was sub-mapped from it. The supervised classification of the image was carried out in ERDAS IMAGINE 2014. Five land use/land cover classes were identified in the classification which are: settlement, secondary/regrowth forest, shrub/fallow/annual crops, water body, and bare soil, Figure 2.

III. RESULTS AND DISCUSSION

3.1 LAND USE/LAND COVER OF ILE-IFE

Land use/land cover of Ile-Ife is classified into five classes namely: settlement, water body, bare soil, secondary/re-growth forest and shrub/fallow/annual crops. Table 3 shows the number of pixels and coverage area (m²) of the land use/land cover features of the study area in 2018. For Landsat 2018 imagery, a pixel is 30 m².

The result of supervised classification of land use/land cover of Ile-Ife as presented in Figure 2, revealed that settlement coverage area is the highest with total number of pixels of 2425 representing 72750 m² surface area, as shown in Table 3, representing 78% of the total area covered by Ile-Ife in 2018, Figure 3. The number of pixels representing the area covered by secondary/re-growth forest is 352 pixels resulting to 10560 m² coverage area, representing 11% of the LULC of Ile-Ife in 2018. The area covered by shrub/fallow/annual crops is 2820 m², obtained from 94 pixels, which is 3% of the total area under study. The coverage area of the water body is obtained to be 5460 m², with 182 pixels, representing 6% of the total area under investigation. Bare soil takes the 2% of coverage area of the study area representing 1530 m² with 51 pixels. The coverage areas of the land use/land cover of Ile-Ife revealed that the settlement coverage area has the highest value, indicating that impervious surfaces are more than areas covered with vegetation and good soil for good infiltration, hence more areas are prone to flood due to less infiltration in the study area.

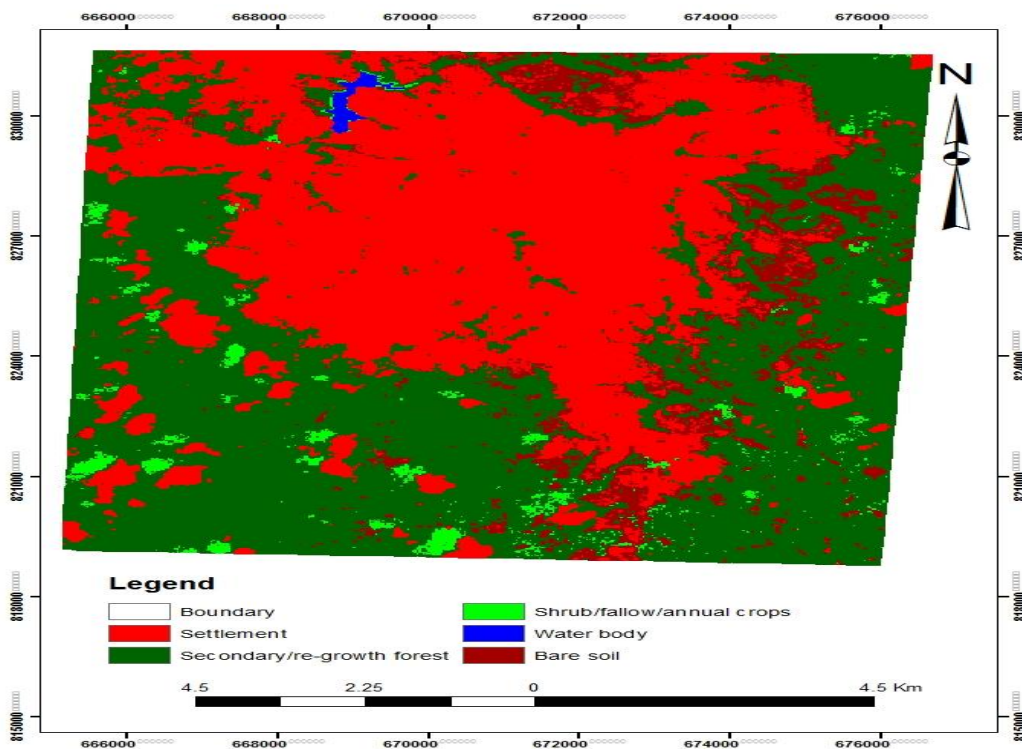


Figure 2: Land use/land cover of Ile-Ife of classified Landsat 2018 imagery

Table 3: Coverage area (m²) of LULC of Ile-Ife in 2018

LULC	Count (Pixel)	Coverage Area (m ²)
Settlement	2425	72750
Secondary/re-growth forest	352	10560
Shrub/fallow/annual crops	94	2820
Water body	182	5460
Bare soil	51	1530

Land use/land cover of Ile-Ife in 2018

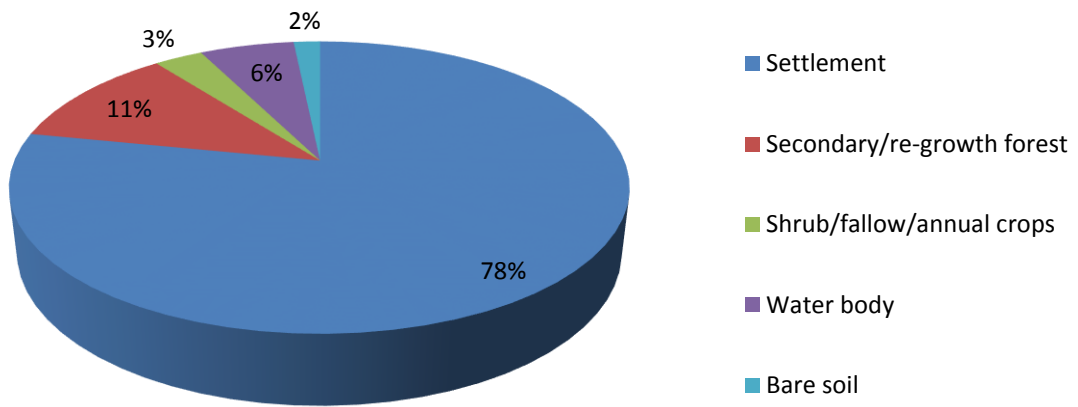


Figure 3: Pie chart showing the percentage of each land use/land cover in Ile-Ife in 2018

3.2 Drainage pattern of Ile-Ife

The drainage patterns can be described either interms of their relation to erosion surface, age of stage of development or geomorphological patterns (patterns formed in relation to surface relief and structure). The drainage patterns exhibited by rivers in Ile-Ife is shown in Figure 4, the patterns can be described as either dendritic pattern or rectangular pattern from the

geomorphological pattern point of view. The rivers in Ile-Ife had exhibited dendritic pattern: tree or root-like pattern, consequent rivers determined by original surface irregularities, common in granitic region. In relation to erosion surface on the other hand, drainage patterns of Ile-Ife can be described as the combination of both subsequent and obsequent streams.

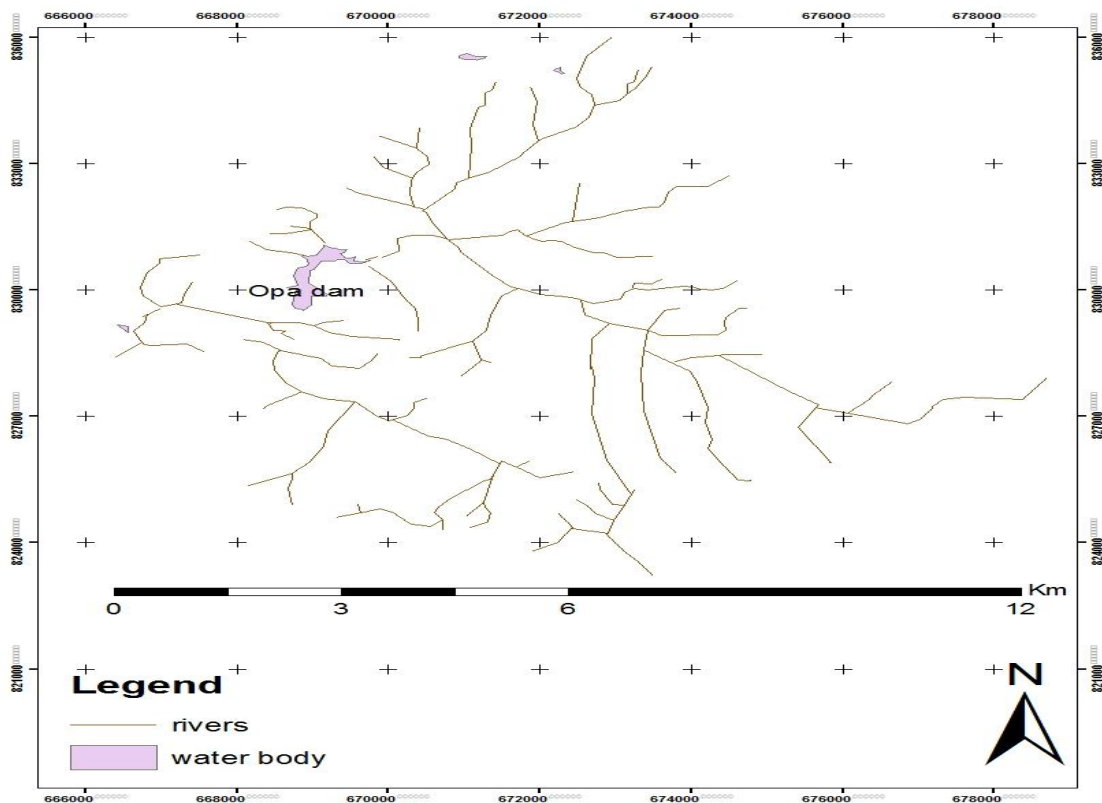


Figure 4: Drainage pattern of Ile-Ife

3.3 Digital Elevation Model of Ile-Ife

The result of processed DEM image of Ile-Ife is shown in Figure 5, the image is classified into 5 classes to group each location. The height of the study area from the sea level ranged from Very High (341 – 445 m), High (302 – 341 m), Moderate (279 – 302 m), Low (260 – 279 m), and Very Low (222 – 260 m) as shown in Figure 5. The low area

and the very low area in Ile-Ife are the area vulnerable to flood disaster. Flat areas are more vulnerable to flood, whereas, high elevated areas are less prone to flood since water moves from high elevation to low elevation. Figure 6 shows the contour map of digital elevation map of Ile-Ife, the map reveals valleys, hills, steepness, or gentleness of the slope of the study area.

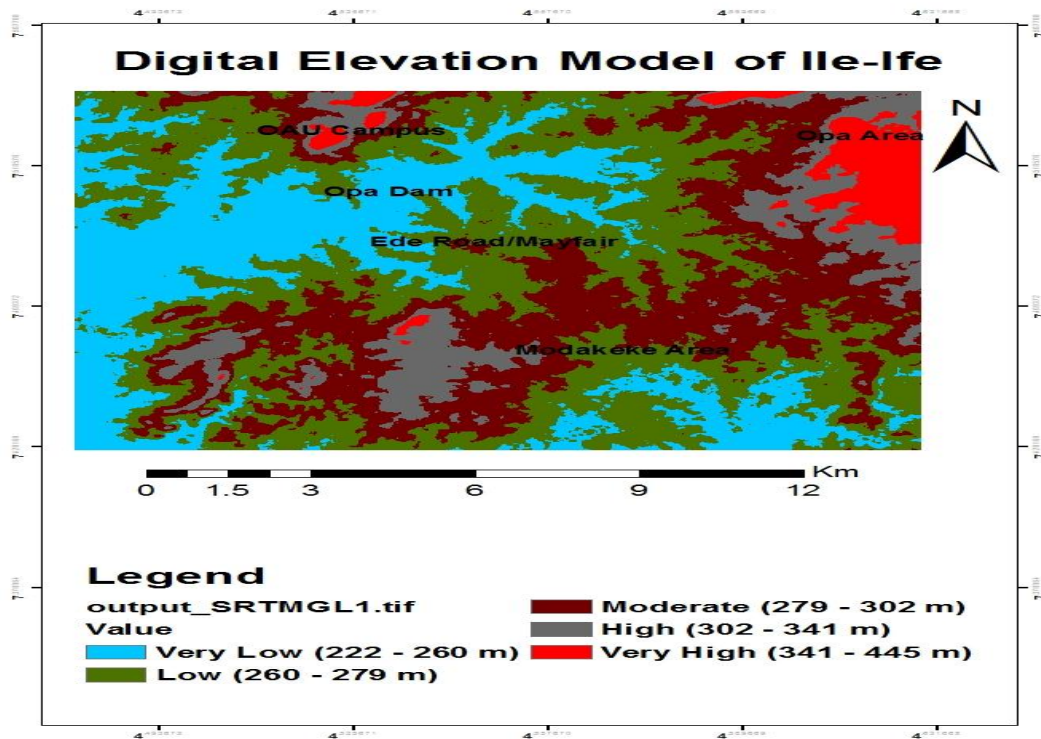


Figure 5: Digital Elevation Model map of Ile-Ife

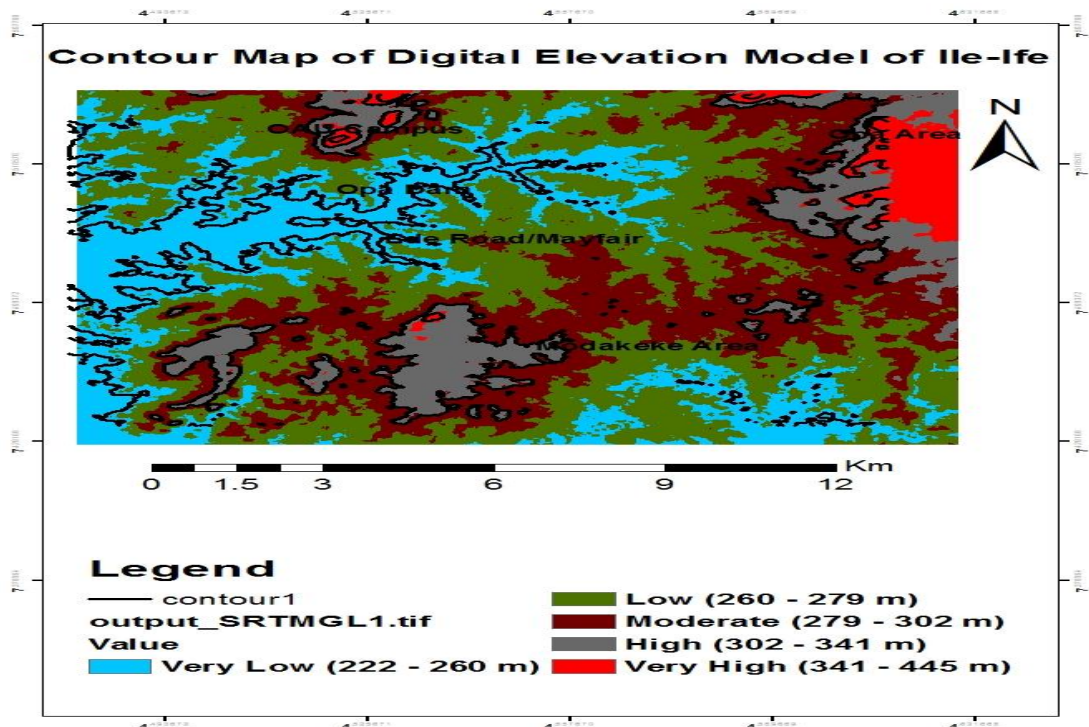


Figure 6: Contour map of Digital Elevation Model map of Ile-Ife

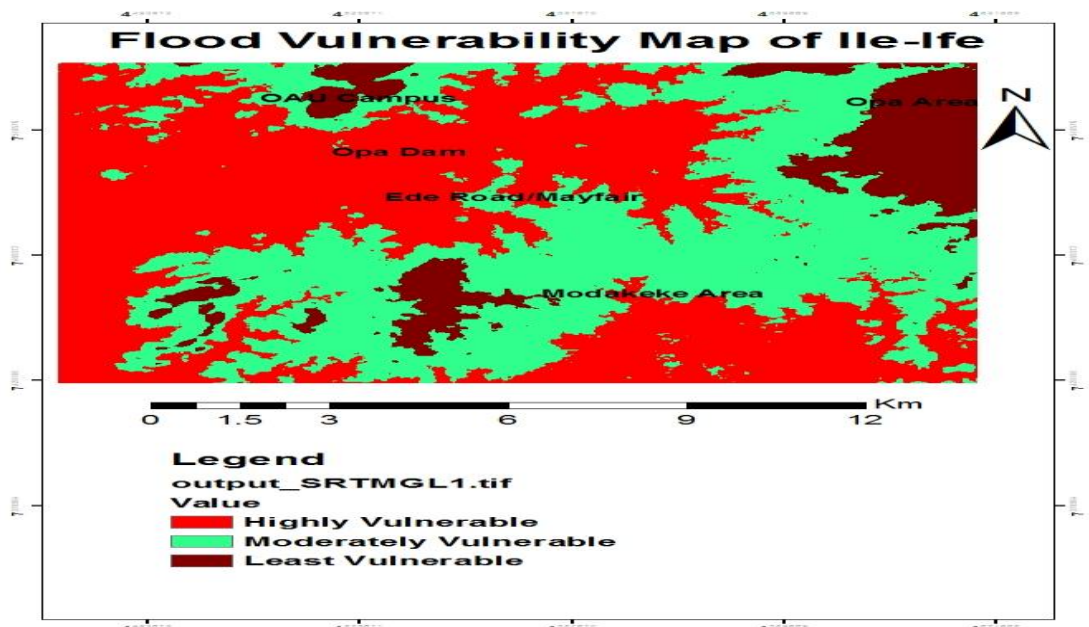


Figure 7: Flood vulnerability map of Ile Ife

3.4 Flood Vulnerability map of Ile-Ife

Figures 7 showed that largest places in extent of vulnerability were moderately and highly vulnerable to flood areas. Most places such as built ups, bare land and grassland close to drainage

system in the study area were extremely vulnerable. This can be used as an add-up estimate of the number of people affected and property worth that was damaged (Orimoogunje et al., 2016) and flood extent. Specifically, approximately 4 km² of

the total area under study was less vulnerable zone while about 100 km² were highly vulnerable to flooding. Places such as Ede road/Mayfair and some parts of Modakeke areas were found to be in the highly vulnerable category while OAU campus and Opa area in Ile-Ife were least vulnerable to flood. The results of the study have been validated by the occurrence of devastating floods precipitated by torrential rain of 2018, which affected areas like Ede road, Parakin, Mayfair areas of Ile-Ife.

IV. CONCLUSION

The knowledge of vulnerability of some areas in Ile-Ife to flooding is important since reliance on such information is ever relevant for decision making on where structures should be constructed to prevent flood disaster. The following conclusion can be drawn from this study: the areas vulnerable to flooding in Ile-Ife includes Ede road, Parakin, MayFair, Old NEPA, Aladanla. The flood disaster in Ile-Ife, Osun is attributed to poor attitude to the environment and lack of enforcement of relevant environmental laws. Dumping of refuse on waterways is one of the major causes of flood disaster in Ile-Ife. Building of structures on waterways also contributed greatly to flood disaster in the area. Unregulated sand dredging activities in the area also contributed to the flood disaster experienced in the area. Ile-Ife and its environment which are surrounded by streams: Esinmirin and Opa streams, and bordered in the Northern side by Shasha and Owena River in the South. Considering the adjoining streams like Agbara, Omi-Okun, and Odo-Okun, there is need for people to be educated about their terrain so as not to build on water plains in areas like, Mayfair, Aladanla and Ede road. Most of the areas affected are flood-prone areas, which are only good for agricultural purposes, rather than residential. Also sand-dredging around Oduduwa, Ajebamidele, Moremi Housing Estate, Kojumole and Oluwatedo had obstructed the water-level and contributed to the flooding in the city. This study therefore recommends that: the unregulated activities of sand and gravel miners should be checked in those areas, there is need for approving building plans before construction to mitigate flooding in the state, there is need for enforcement of building and sanitation laws across the state to enforce compliance, and dumping of refuse on waterways should be strongly discouraged to prevent flood disaster in the area.

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