A Study of Contributory Factors to Flood Hazards in Ifelodun Local Government Area, Osun State, Nigeria

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Floods are water induced disasters that lead to temporary inundation of dry land and cause serious damages in the affected location such as loss of lives and properties and destruction of infrastructures. Records show that thousands of people have lost their lives to flooding while hundreds of thousands have been rendered homeless and properties worth of millions of Naira have been destroyed by devastating floods across the country. This research therefore focuses on Flood Hazard Zoning in Ifelodun Local Government Area Using Spatial Multi-criteria Decision Analysis by the integration of Remote Sensing data such as Landsat 8, SRTM DEM, SPOT 5, other ancillary data like the administrative map and geophysical investigation involving Vertical Electrical Sounding (VES) techniques using Schlumberger configuration. Factors such as rainfall, drainage, slope, soil, vegetation and land use/land cover and nature of the subsurface were multi-criteria decision making. The ranking of the spatial data was based on their influence on flooding using Analytic Hierarchy Process (AHP). The AHP ranked rainfall as the highest factor to flooding while the land use/land cover was ranked as the lowest factor to flooding. The flood hazard zone map was generated based on the influence of the factors enumerated above in a GIS framework showing zones of very high, high, moderate, low and very low hazard areas. The flood zone map was overlaid on SPOT 5 image of the study area for visualization of areas that could be affected by flooding. The use of high resolution DEM and rainfall data to improve the accuracy of modelling and generation of flood inundation map is therefore recommended for better accuracy and visualization.

Keywords: Flood, GIS, Multi-Criteria Decision Analysis, VES, Ifelodun LGA

Introduction

Natural disasters, like floods, earthquakes, hurricanes, volcanic eruptions, and landslides have always been a major problem in many developing and developed countries. The natural hazards kill thousands of people and destroy property worth billions of dollars yearly. The rapid growth of the world's population has increased both the frequency and severity of natural disasters due to the movement of people into the flood plain areas. Flood disaster has a special place among natural hazards (Agbaje *et al*. 2009; Adeoye *et el*. 2009 and Aderoju *et el*. 2012). According to European Commission (2007), a flood can be defined as "a natural phenomenon that results in the temporary submerging with water of a land that does not occur under normal conditions". Flood can also be defined as a flow of water above the carrying capacity of a channel (National Oceanic and Atmospheric Administration-NOAA, 1998). Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (runoff) event. Of all natural disasters, the most recurring, widespread, disastrous and frequent in the world is flood (Kelvin, 2012)). Long term data on natural disasters suggest that floods and wind storms have been by far the most common causes of natural disaster worldwide over the past 100 years (Few et al. 2004). Flood is one of the costliest types of natural hazard in the world and constitutes 31% of the economic losses resulting from natural catastrophes (Olajuyigbe *et al*., 2012). It is widely distributed leading to significant economic and social damages than any other natural disaster (Disaster Management Support Group, 2001). They are the naturally occurring event and hence cannot be prevented and they can have serious consequences such as displacement of people and damage to the environment, (International Federation of Red Cross Societies (IFRCS), 2001; Adeoye *et al*., 2009; Olajuyigbe *et al.*, 2012). Floods can also be caused by anthropogenic activities and human interventions in the natural processes such as increase in settlement areas, population growth and economic assets over low lying plains prone to flooding leading to alterations in the natural drainage and river basin patterns, deforestation and climate change European Commission 2007; Balabanova, 2008;,Lawal,2012). Floods cause about one third of all deaths, one third of all injuries and one third of all damage from natural disasters (Orimoogunje, 2009)).

Adeoye *et al*. (2009) reported that floods have caused over 10,000 deaths in the United States since 1900. According to Asian Development Bank (ADB 207), floods have affected over 9 million people in Bangladesh and about 30 million people in India. In Nepal, more than 22,000 people have been temporarily displaced by floods, 46,000 houses damaged and more than 130,000 hectares of useful agricultural land have been submerged by floods (ADB, 2007). Floods have claimed over 500 lives in Thailand since July 2011 (BBC Mobile, 2011b). The report stated that these floods were caused by heavy rains that lasted for three months (BBC Mobile, 2011b). African nations too have been badly affected by floods. Media and aid organizations have reported a lot of flooding incidences in Sub-Saharan Africa which resulted from several days of rainfall (Paeth *et al*., 2010). In Benin, floods have severely affected lives of over 600,000 people and rendered hundreds of thousands of people homeless (ADB, 2007). The cost of losses resulting from floods in Mozambique has been of the order of millions of United States dollars and the country has been affected by flooding almost yearly since it gained its independence from Portugal in 1975(ADB, 2007). The average number of emergencies in Africa per year has almost tripled since the mid-1980s to about 25million people in 2005 (IFRCS 2008).

Nigeria has recorded some of the highest death toll in the West African region. In the northern parts of the country, entire villages and huge sparse of agricultural land have been destroyed by flooding (ARB, 2010). In recent times, floods have destroyed property worth millions of naira in the different areas of Nigeria. Flooding in urban areas is seriously becoming an ecological menace in Nigeria as several coastal areas along the Atlantic Ocean, surrounding cities and river valleys are affected by flooding on a yearly basis (Jeb and Aggarwal, 2008). Floods have caused land degradation in some other parts of the country (Abbas, 2008). The obvious reason for flooding especially in municipalities and coastal areas in Nigeria lies in the wide distribution of low-lying coastal areas and river floodplains, and because these areas have fast become a long standing attractions for human settlement (Ologunorisa and Abawua, 2005).

Geographic Information Systems (GIS) are widely used to analyze natural hazards such as landslides, flooding, among others. GIS is extremely useful for integrating various geographic data, and for numerical analysis of such data. A geophysical investigation of the earth's interior involves taking measurements at or near the earth's surface that are influenced by internal distribution of its properties whose measurements can reveal how the physical properties of the earth's interior vary vertically in the sub-surface The electrical resistivity method is used for Engineering site investigation, determination of depth to bedrock, structural mapping, environmental studies, determination of nature of superficial deposits and others (Early and Dyer, 1994; Lucius and Bisdorf, 1995; Bisdorf, 1996).

The aim of this study is to use spatial multi-criteria decision and geophysics analysis in zoning flood hazard in the study area

Objectives

i. Geophysical investigation
ii. Assessment of rainfall distribution pattern
iii. Integration other environmental factors (soil ,drainage, and NDVI) GIS framework in order to analyze and propose floodplain zoning
iv. Determination of the LU/LC
v. Cross overlay of flood inundation map over land use/cover map to analyze potential impact of the flood inundation.

Materials and Method

Study Area

Ifelodun is a Local Government Area in Osun State, Nigeria (Figure 1**).** The headquarters is at Ikirun, which is about 10 minutes' drive to the north of Osogbo, the state capital and it is located between longitude 7°55'Nand latitude 4°40'E with a total land mass of 114 km² and a population of 96,748 at the 2006 census. Towns within the local government are Ikirun, Iba, Eko-Ende, Eko-Ajala, Obaagun, Dagbolu, Seke, Fidibomi, and Oluode. There are twelve wards in the local government of which most of them are agrarian. The local government is widely known for large scale production of kolanut, palm oil, root crops and fruits. The geologic formation of the study area falls within the basement complex of the South-Western Nigeria which consists of the amphibolites, migmatite gneisses, granite and pegmatites.

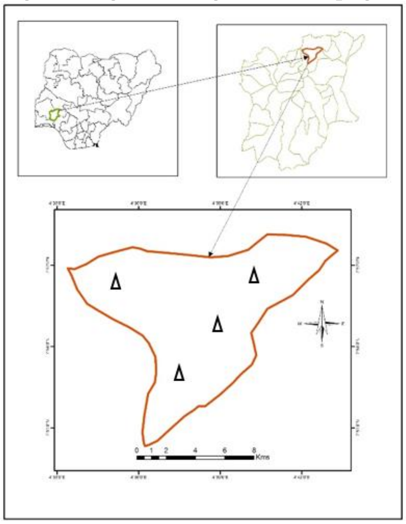


Fig. 1: Map Showing the Study Area

Data Used

Table below shows the summary of the datasets used in carrying out this study in order to achieve the set objectives.

Table 1: List of data used for this study.

	Data Used	Data Source
1	Rainfall data	NASA/POWER Agro-climatology Daily Averaged Data
2	Digital Elevation Model (DEM)	GLCF Website
3	Soil map	Federal Department of Agricultural Land Resources (FDALR)
4	Geology map	Geological Survey of Nigeria
5	Landsat 8	GLCF Website
6	SPOT 5	FUTA Remote Sensing & GIS Dept.
6	Drainage Map	FUTA Remote Sensing & GIS Dept.
7	Vertical Electrical Sounding data	FIELD by FUTA Applied Geophysics Dept.

Data Source and Data Acquisition

The average daily Rainfall data between 2000 and 2013 was obtained from NASA/POWER Agro-climatology for the study area. The digital elevation model (DEM) was acquired from Global Land

Cover Facility (GLCF) website. The soil map and the geology map were obtained from the department of Remote Sensing and GIS FUTA. Landsat 8 image was obtained from the Global Land Cover Facility (GLCF) website. The SPOT 5 image was obtained from the department of Remote Sensing and GIS FUTA. The geophysical investigation involved carrying out Vertical Electrical Sounding (VES) techniques applying Schlumberger configuration on the locations. Data collected were analysed and interpretation to produce the geoelectric sections.

Data Processing

The area of interest was clipped out from the images using the clip tool from the data management tool in ArcGIS 10.2 software. The datasets were projected to WGS 1884, Universal Traverse Mercator (UTM), and zone 32°N, Minna Datum, Nigeria. The soil and geology map were as georeferenced using ArcGIS 10.2 software. The digitizing process was done in ArcMap. Digitizing is the process of converting geographical features from analogue to vector format. The vector soil and geology map was then converted to raster format.

Rainfall Data

Rainfall is one of the major factors that could contribute to the flooding in Ifelodun Local Government Area. Rainfall of the study is relatively uniform in behavior and it ranges from 1366.5300mm/year to 1624.8900mm/year with its peak in July causing an increase in the water level of the river in the study area. The rainfall product used for the analysis is of very coarse resolution but was used because of the non-availability of better data.

Slope Map

The length and the steepness of the topographic slope affect the flow and inundation of the particular area. For example, low and flat topography decreases the runoff, causing high infiltration within the area thereby resulting in water logging condition. Also, the low-lying area with low slope angle will be inundated first as compared to the high slope area during flooding. Those areas with steep slope show high peak discharge as compared to the low-lying area and causes the depletion of the storage in the upstream areas. The sink-filled Shuttle Radar Topography Mission (SRTM) digital elevation model was used for the generation of the slope map.

Creation of Soil Map

The soil map was generated through on-screen digitizing in ArcGIS software and was later converted to raster and reclassified for the sake of the analysis.

Creation of Geology Map

The geology map was generated through on-screen digitizing in ArcGIS software and was later converted to raster and then reclassified for the sake of the analysis. The data shows the distribution of the rock types present in the area are granite-gneiss, porphyritic granite, pegmatite, schist and epidorite complex, gneiss and migmatite undifferentiated.

Creation of NDVI

The Normalized Difference Vegetation Index was created from the Landsat 8 image in order to know areas that are well vegetated and areas that are less vegetated because vegetation reduce run-off. The near infrared and the red band is usually used for this NDVI. It is obtained by finding the ratio of band 5 – band 4 to that of band 5 + band 4 (of Landsat 8). In zoning of flood risk, NDVI has been evaluated as one of the crucial parameters.

Creation of Land use/land cover

Supervised Classification using maximum likelihood classifier (MLC) was carried out for Landsat-8 OLI/TIRS image for the year 2015. MLC classifies the image based on the information contained in the samples collected. The layer assigned with name "Land use Landcover". The available LULC include six different categories namely: farm land, dense forests, light forest, bare surface, water bodies and built ups.

Creation of Drainage Density

The drainage density was computed and then reclassified using the spatial analyst tool of ArcGIS for the purpose of analysis.

The Analytical Hierarchy Process (AHP)

Multi Criteria Decision Analysis (MCDA) or often called Multi-Criteria Decision Making (MCDM) (Linkov *et al*., 2004) is a technique that contains regulated set of methods that helps decision makers to decide or to make critical decision on the basis of several criteria orbiting that decision. Analytic Hierarchy Process (AHP) is the most recommended and most suited MCDM method that was developed by Saaty (1977, 1980, 1988, and 1995). Thomas Saaty (University of Pittsburgh) has developed the AHP based on three principles: decomposition, comparative judgment and synthesis of priorities.

Flooding Hazard Zoning

The flood hazard zone map was generated from the integration of the various layers highlighted above using the weighted overlay tool in ArcGIS based on their corresponding weightage value in AHP.

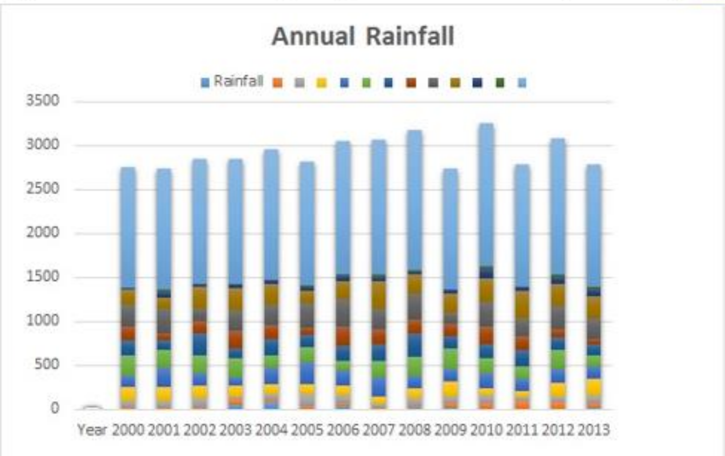
Results and Discussion

The Geoelectric results (Figure 1-7) indicate that the terrain is a waterlogged area which is evident in occurrence of the fresh rocks at shallow depth near the surface thereby preventing percolation of surface watering thus enhances flooding. This non percolation brought about flooding which have drastic effects on the foundation bed and engineering structure in the area. (Table 2) The nature of the slope also enhances the flooding activities in the study area. Also it is evident from the result of LU/LC in the study area that Osogbo Metropolis is exposed to flood hazards as a result of many factors such as: high rainfall pattern and distribution (Figure 2), geoelecric nature (Table 2, Figures 3-7), nature of the slope (Figure 8) and high rate of urbanization when Osun State was created.

Table 2: Vertical Electrical Sounding (VES) Results

VES No	Resistivity (Ω-m) $\rho_1/\rho_2/\rho_3.........\rho_n$	Thickness (m) $d_1/d_2/d_3/...d_n$	Curve Type
1	30/ 9/ 828	0.5/ 4.4	H
2	12/ 7/ 369	0.7/2.6	KH
3	10/ 5/ 346	0.7/ 2.7	KH
4	8/ 5/ 271	0.7/ 0.4	KH
5	19/ 7/ 1150	0.5/ 0.4	KH

Fig. 2: Annual Rainfall of the Study Area (Source: NASA/POWER Agro climatology Daily



Averaged Data)

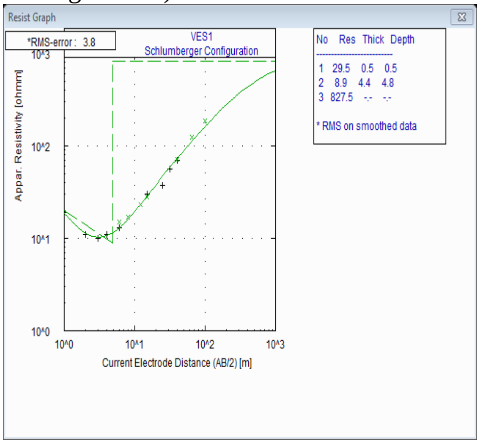


Figure 3: Resistivity curve for VES 1

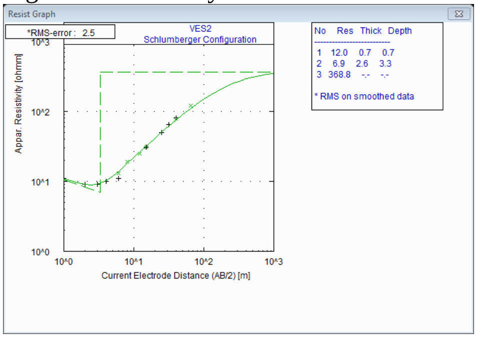


Figure 4: Resistivity curve for VES 2

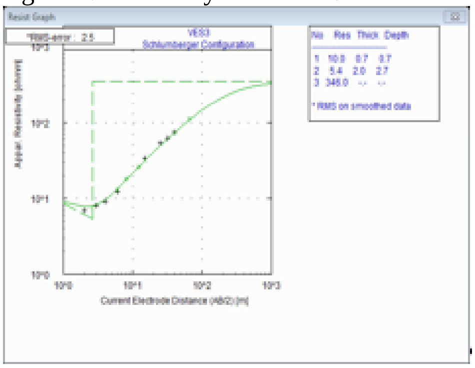


Figure 5. Resistivity curve for VES 3¶

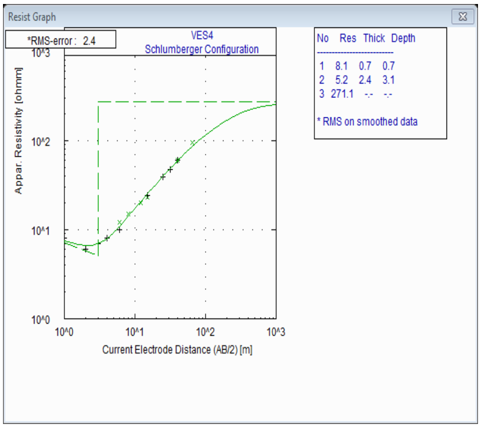


Figure 6: Resistivity curve for VES 4

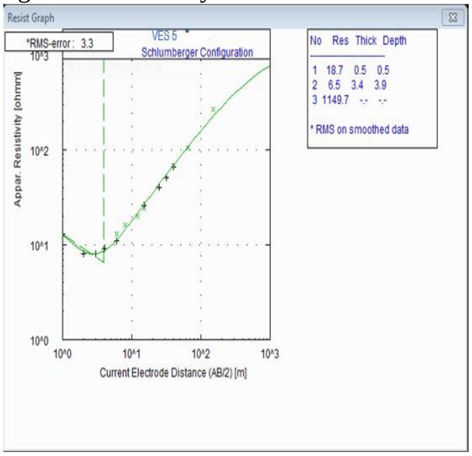


Figure 7: Resistivity curve for VES 5

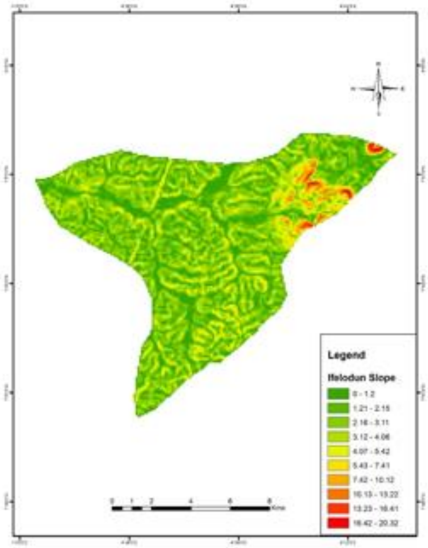


Fig. 8: Slope Map of the Study Area

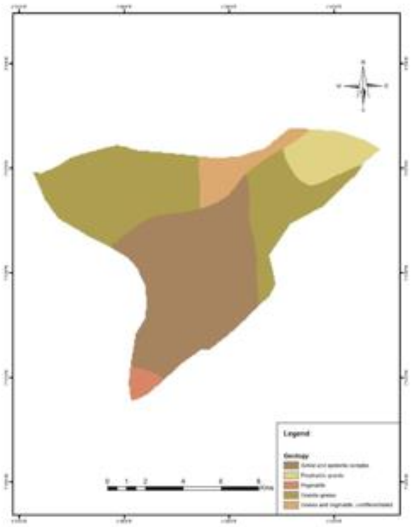


Fig. 9: Geology Map of the Study Area

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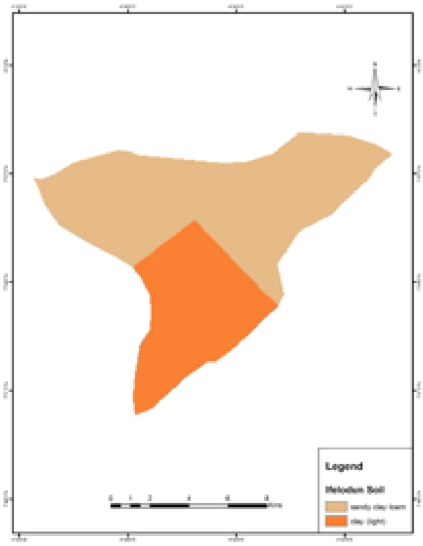

Fig. 10: Soil Map of the Study Area

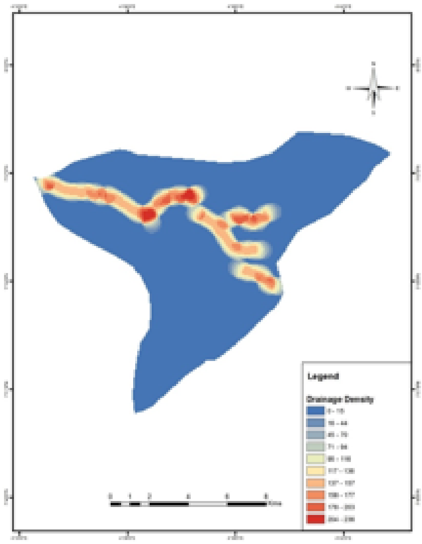

Fig. 11: Drainage Density Map of the Study

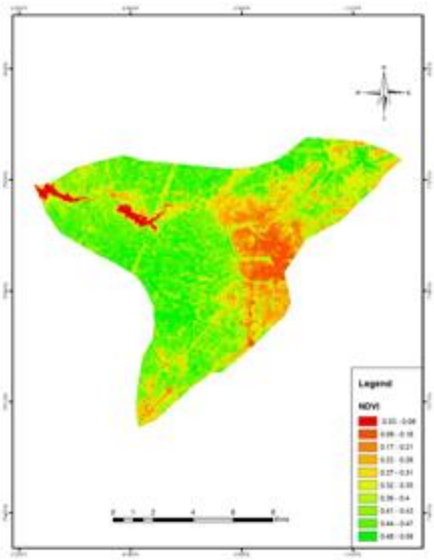

Fig. 12: NDVI Map of the Study Area

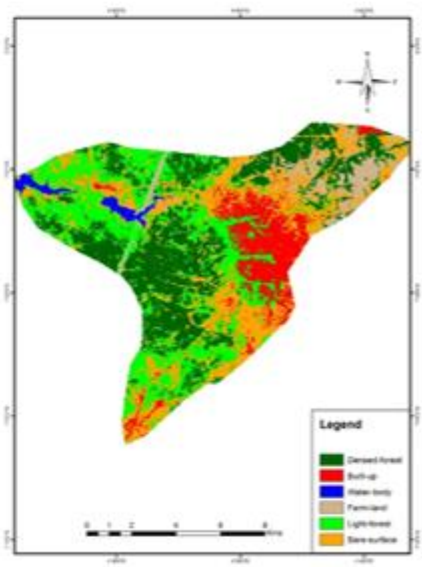

Fig. 13: LULC Map of the Study Area

Table 3: Description of the Land use/land cover identified in the study area

Land use/Land cover Categories	Area (Ha^2)
LU/LC Classes	Description
Built up	Areas covered with residential, industrial, commercial and industrial complexes.
Dense forest	An area covered with mainly thick forest/vegetation
Light forest	An area covered with lesser concentration of vegetation
Bare surface	A plain areas
Farm land	Areas covered with agricultural crops and cultivated during the growing season.
Water body	Areas covered with water such as rivers, dams and swamps.

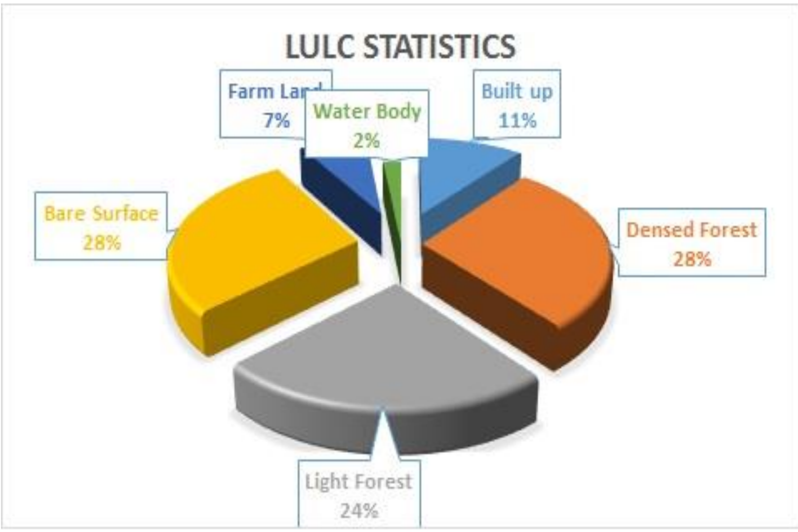

Fig. 14: LULC Statistics of the Study Area

The result proves to be consistent with the results other research work e.g morphometric and LU/LC analysis of Oshogbo and Ilesa (Akinwumiju, 2015), flood vulnerability in the Southwestern part of Nigeria (Orimoogunje *et al* 2009). Nostratic *et al*. (2000) investigated the parameters effective in flooding, and concluded that due to less time focusing and high slope and low permeability of surface layer of the earth and less vegetation, an area would have great potential of flooding. This is evident in some part of the study area like Ikirun and Eko-Ende as they fall in high hazard zone due to their less vegetation cover, slope and presence of river around the areas.

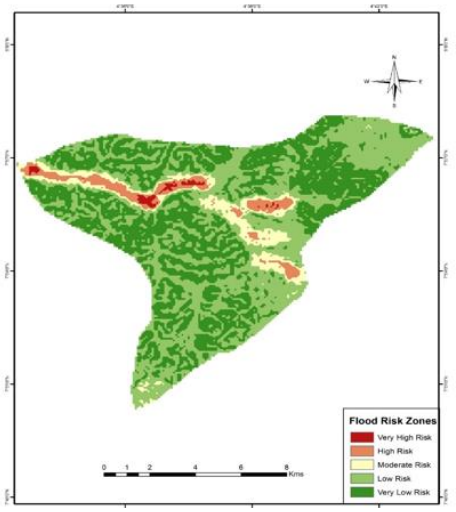

Fig. 15 : Map Showing Flood Hazard Zones the Study Area

Conclusion

Five zones were specified: very high, high, moderate, low and very low zones. It has been concluded that the approach used in this research is useful in mapping flood zones in the study area. Some of the important conclusion drawn are as follow:

i. The Flood hazard zone map has been generated from the public domain data with the use of satellite imagery in a cost effective way. The approach followed can be applied in many of the flood prone area where availability of the data is poor and resources are limited

ii. The use of spatial–AHP has been used in the flood hazard zoning and it has been further elaborated with other datasets to generate flood hazard map with.

iii. The flood zone map is based on the integrated effect of different parameters. Hence it is not only the hydrological phenomenon but integrated condition of the environment.

iv. The fresh rocks occur at shallow depth near the surface thereby preventing percolation of surface water leading to flooding.

v. The approach followed can be applied at any scale depending on the availability of the data. The basic merit of the map lies on the user friendliness, the cost effectiveness and the easy availability of the maps.

vi. The use of high resolution DEM and rainfall data to improve the accuracy of modelling and generation of flood inundation map is therefore recommended for better accuracy and visualization.

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