Application of Geo-Spatial Technology in Identifying Areas Vulnerable to Flooding in Ibadan Metropolis

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Abstract
This study makes use of the integrated approach of Remote Sensing and GIS techniques in flood management with the goal of identifying areas vulnerable to flood hazard in Ibadan Metropolis. Ibadan is the largest indigenous city in the continent of Africa and had experienced a lot of various severities of flood occurrences in the last fifty years. Topographic Map and Landsat TM image of 1993 and 2000 respectively were processed, scanned, digitized, interpolated, classified and overlaid using ILWIS 3.3 academic and ARC GIS 9.2 software modules to generate classified land cover map, Digital Terrain Map (DTM), Triangulated Irregular Network (TIN) and flood vulnerability map of the study area respectively. The results obtained shows that, areas lying along the banks of River Ona and River Ogunpa are most vulnerable to flood hazards with the vulnerability decreasing towards the northern part of the city, much of the area is built up with improper planning and this gives rise to high vulnerability to flash flood hazards. The Odo Ona, Idi Isin, Eleyele, Olopometa and Molete areas are the most vulnerable to flood threat. The incessant violation of land use plan, unchecked population growth, old nature of the structures and poor materials used in the construction of the houses make the areas vulnerable to flood hazard. In reducing the vulnerability of these areas from flood there is need for improved land use planning, removal of structures from River Ona and Ogunpa flood plains around the city, intensify environmental education to the residents and enhance the active participation of government agencies in the continual generation of flood vulnerability maps of urban centres.
Keywords: Flood, Vulnerability, DEM, GIS, Remote Sensing, TIN.

1. Introduction

Flooding is the commonest natural hazard that can happen any time in wide variety of locations within rainy season due to high intensity of rainfall events. The projections of climate change trends indicate increase of the occurrence of the intense rainfall events both in terms of the intensity as well as their frequency (IPCC, 2007). The projected high intensity rainfall events coupled with the changes in the land use patterns are expected to have implications on the intensity of river flooding and local flash flooding in a flood plain region and can significantly alter the spatial extent of future flood risk. A flood is an overflow of expanse of water that submerges the land. Floods are among the most destructive acts of nature. Over the past thirty years, floods have been the most catastrophic natural disaster affecting, on average, about 80 million people per year or half of the total population affected by any natural disaster, causing economic damage worth over US$11 million annually around the world (IFRCRCS,1998). As human activities downstream of rivers increases, it results to increase in greater flood damage, floods are also increasing in size and frequency due to human activities in the upstream section of the river system (Dutta et al., 2006). World-wide, flood damages to agriculture, properties and public utilities amount to billions of dollars each year in addition to the loss of precious human and animal lives. In most cases, flooding is caused by a river over-spilling its banks. This can be due to excessive precipitation, combined with inadequate channel capacity. Over-spilling can also occur due to obstruction in the river bed. Flooding can also occur at confluences of streams when the main river is in high stage and backs up into the tributaries and areas there about.

The role of Geographic Information Systems (GIS) in disasters analysis and management is typically important in critical life saving measures and has been using in developed countries in the last two decades. Advancements in remote sensing (RS) technology and GIS the help in real time monitoring, early warning system and quick damage assessment of flood and drought disasters (Ishaya *et al.,* 2008a. A Geographic Information System is a tool that can assist floodplain managers in identifying flood prone areas in their community. With a GIS, geographical information is stored in a database that can be queried and graphically displayed for analysis. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or stricter floodplain management practices. Remote Sensing can be very effective for flood management in two ways; firstly by detailed mapping that is required for the production of hazard assessment maps, hence for input to various types of hydrological models, and secondly by developing a larger scale view of the general flood situation within a river basin with the aim of identifying areas at greatest risk and in the need of immediate assistance. Remote sensing and GIS technique has successfully established its application in following areas of flood management such as flood inundation mapping, flood plain zoning and river morphological studies.

In the past few decades in Nigeria, thousands of lives and properties worth millions of Naira have been lost directly or indirectly to flood occurrences. In most urban centers of the country most especially in the fast growing cities like Ibadan and Lokoja, human population increases, landscaping in paved areas, streams and channel obstruction due to bad waste disposal habit and other human activities at flood plains were considered to be the major causes of floods. Blong (2003) and Barroca (2006) concluded that flood vulnerability mapping can offer a hundred percent security against floods. Flood disaster management just as other disasters management can be grouped into three. Firstly, the preparedness phase where activities such as prediction and risk zone identification or vulnerable mapping are taken up long before the event occurs; secondly, the prevention phase where activities such as forecasting, early warning, monitoring and preparation of contingency plans are taken up just before or during the event and thirdly, the response and mitigation phase where activities are undertaken just after the disaster and it includes damage assessment and relief management (Mantovani *et al*., 1996).

Ibadan is the largest metropolitan geographical area in Sub-Saharan Africa (Lyold *et al*., 1967 and Onibokun and Faniran, 1995 and Kufoniyi, 1998). It is the third largest metropolitan area by population in Nigeria after Lagos and Kano with a population of over 3 million. Ajayi *et al.*, 2012 presented the population growth from 1856 to 2010, the physical expansion from 1830 to 1988 and flood occurrences with causative rainfall amount from 1951 to 2011 over Ibadan. Ajayi *et al*., 2012 further proved that continuous increase in population of the area in the past few decades has forced the inhabitants to construct buildings on the flood prone areas, incessant violation of land use plan, old nature of the structures and poor materials used in construction contributed to the flood vulnerability of the area. The city of Ibadan has been affected by severe flood crisis in the past sixty-five years which has resulted to loss of properties worth billions of naira. This makes forecasting and detecting areas most vulnerable to flooding a welcome task and will allow other analysis of flooding within the area of study (analysis such as flood vulnerability map, which will include infrastructures, economy and demography data) to be made available.

The main aim of this study is to identify areas most vulnerable to flooding within Ibadan metropolis by utilizing modern technology like remote sensing and GIS in flood disaster management and the objectives are to create Digital Terrain Model (DTM) of the study area using the spatial and the 3D Analysts, produce the land use/cover of the study area, produce the segment map of the study area and finally by comparing/overlaying the segment map with the DTM.

Different researchers and scientists from all over the world had performed detailed analysis of flood risk assessment specifically for human population and to make precautionary measurements before or after the critical condition of disaster occurrence using remote sensing, GIS techniques and satellite images (Farrisier and Givone 1993; Eludoyin, 1999. Ahmad *et al.*, (2013) gave a review of some of these studies. In Nigeria, Ishaya (2008a and 2008b) produced vulnerability map for area near Hadeija-Jama'are river basin using two main Multi-Criteria Evaluation (MCE) approaches in GIS, namely Boolean overlay and weighted linear combination. The study also utilized two other MCE methods, pairwise comparison (Analytical Hierarchy Process-AHP) and Ranking to calculate the weights of each factor considered. Using AHP the weightage derived for the factors; rainfall has 33.9%, drainage network has 25.5%, slope of the river basin has 19.7%, soil type has 15.2% and land cover has 5.7%. A case study of flood vulnerable areas determination in HadejiaJama'are River Basin, Nigeria was then employed to illustrate the different approaches. A map of flood vulnerable areas in the river basin was then generated with a view to assist decision makers on the menace posed by the disaster.

With a view to identify the causative factors responsible for coastal area flooding and hence facilitate data integration that will enable graphic and holistic appreciation of environmental challenges peculiar to the coastal area urbanisation. Kienzle, 1993 and Sarma *et al.*, 2005 used GIS tools. Factors considered are the apparent increase in natural water supply through the swelling ocean, increase in precipitation and expansion of impervious concrete surfaces. About 20% of the city where proper drainage and waste disposal infrastructures are available with well-planned residential structures, minimal or no flooding is experienced. Floodplains were found to be highly liable to flooding, while areas that are poorly planned with no drainage facilities were found to be highly susceptible to flooding. Digital terrain model (DTM) was developed for the study area. An ideal drainage channel/network for sustainable urban development in the city was thus attempted.

Micheal (2007) used multi-temporal remote sensing for mapping and monitoring floods towards validation of the KAFRIBA model over Kafue flats, Zambia. The research uses of high resolution imageries of various products. The natural floods which used to sustain the wetlands of the floodplain have been altered due to construction of dams and water abstraction for various uses. This has led to ecological, social, and economical problems. Hence accurate and current geo-referenced information is needed to understand the hydrological and support wetland and water management in order to restore the ecology of the flats. Due to the dynamic nature of Kafue Flats, its vastness, and poor accessibility, the flooding can only be mapped and monitored reliably with a multi-temporal remote sensing approach. This study therefore explored a multi-temporal remote sensing approach to map and monitor floods of the floodplain. Optical and radar data from the Landsat, Aster, MODIS and the Envisat ASAR sensor were used. The flood maps derived were used to validate the KAFRIBA hydrological model. Multi-temporal flood maps were generated from time series flood maps while the model validation was executed with several statistical methods namely; coefficient of efficiency, reliability diagram, RMSE and the kappa statistic.

2. The Study Area

The study area is Ibadan metropolis of the city of Ibadan in Oyo state, Nigeria. Figure 1 shows map of the study area which is Ibadan metropolis (c) and its relative position to Oyo State (b) and the relative position of Oyo State in Nigeria. The town falls between latitude 3°49`E and 3°57`E and longitude 7°20`N and 7°27`N. The study area has a total landmass of about 111km^2, a population of 1,339,259 persons in the year 2006 census and with the rapid rate of urbanization and developmental processes. Table 1 gives the constituents five local governments that make up the study area with their respective landmass and population. The climate of the study area just like most climate in the tropics have a number of climatic elements in common, most especially the wet and dry season's characteristics. Mean temperature in the area ranges from 21.42°C – 26.42°C yearly with average relative humidity of 74.55% and mean annual rainfall of approximately 1,420mm (Tomori, 2001). Rainfall plays a vital role with respect to flood threat within this area and with most threatening events from June to September, because over 60% of the annual rain falls during these months. The study area is drained by River Ogunpa and Eleyele dam which is an important tributary of River Ona and is the largest.

3. Materials and Methodology

Data used comprises of two categories. These are the satellites imageries and the topography maps. The satellites imageries comprise of 2001 LANDSAT imageries over Ibadan of bands 4, 3 and 2 and serve as the primary data source in producing the land use/cover of the study area while the topography map contains contour that was digitized and raster to interpolate and hence create the Digital Terrain Model (DTM) in both spatial and 3D analyst. ILWIS 3.3 academic software was used in producing the land use /land cover and also the histogram of the study area while ARCGIS 9.2 was used in creating the DTM and the Segment map of the study area. A composite image was generated from the Landsat's Enhanced Thematic Mapper (ETM) image and then classified to extract the different land uses (water, settlement and vegetation) of the study area using the Box classifiers and the supervised classification algorithm provided by the ILWIS 3.3 Academic software. The percentage area covered by each classified features on the land use/cover was gotten from the histogram as provided by the software. The Topographic map (of Ibadan with ratio 1:25000) was scanned and imported into the GIS environment where it was geo-referenced, digitized and later interpolated to raster using Kringing method which generated the digital terrain model (DTM), this is done using the spatial analyst. The Triangulated Irregular Network (TIN) was also got from the topography map using the 3D Analyst. Overlay and comparison was made between the segment map of Ibadan metropolis and the TIN features, also between the land use and the TIN features, with these, one can see and know areas that are vulnerable to flooding.

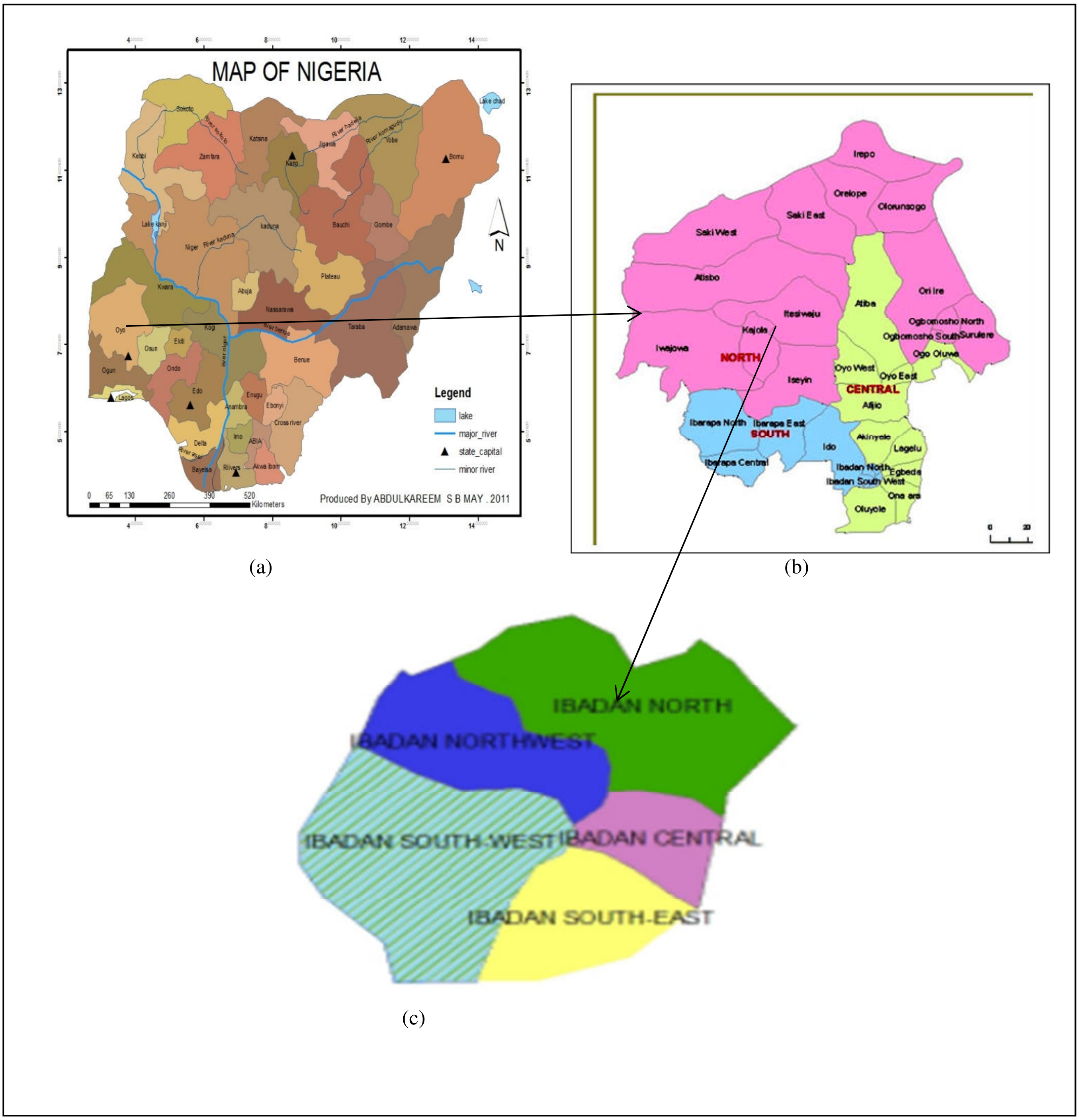

Figure 1: Map of (a) Nigeria, (b) Oyo state and (c) the entire study area comprising the six local government areas.

Table 1: Study area with respective landmass coverage and populations (2006 census)

Study Area	Landmass	Population
Ibadan North	27km^2	306,795
Ibadan Northeast	18km^2	330,399
Ibadan Northwest	26km^2	152,834
Ibadan South east	17km^2	266,646
Ibadan Southwest	40km^2	282,585
Total	**111km^2**	**1,339,259**

4. Results and Discussions

4.1 Analysis of Land Cover Type

The classified satellite imagery of Ibadan metropolis as seen by LANDSAT in 2000 is shown in Figure 2 below. It shows the distribution of three major land cover types which are the vegetation (green), settlement (pink) and water body (blue). The area is mostly covered by settlement and vegetation with very little water body. After digitization, the number of pixels covered by each land cover type is presented in Figure 3 while Table 2 lists the number of pixels, percentage and total area covered (m^2) by each land cover type. While settlement and vegetation respectively covers 54.54% and 44.77%, water body covers only 0.69%.

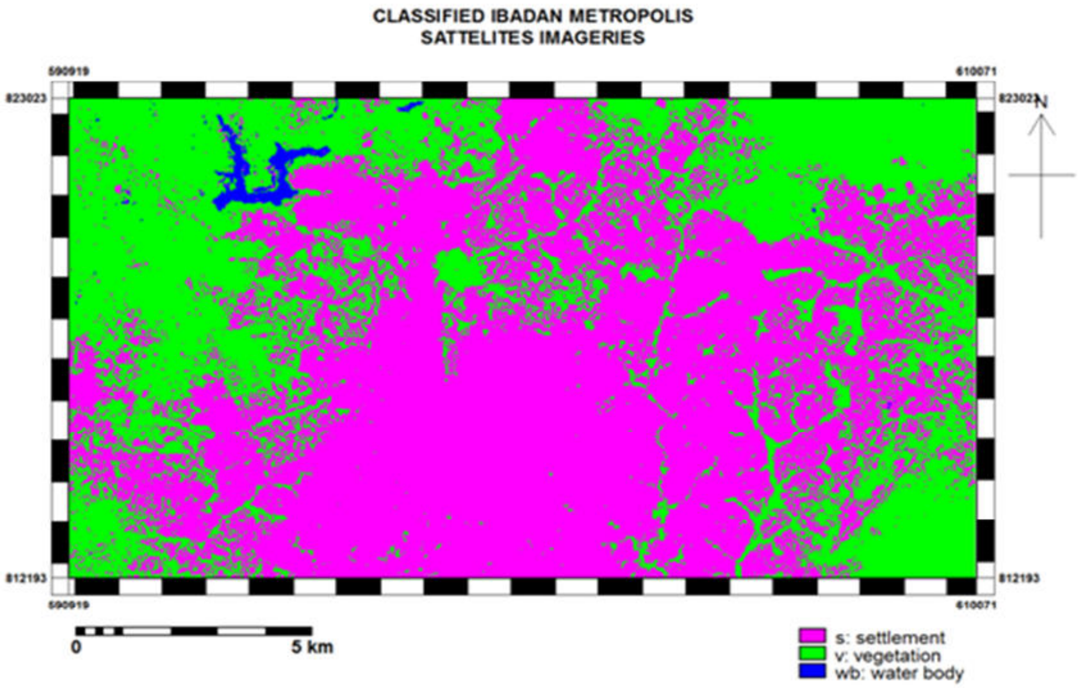

Figure 2: Classified satellite imagery of land cover of Ibadan metropolis (Landsat, 2000)

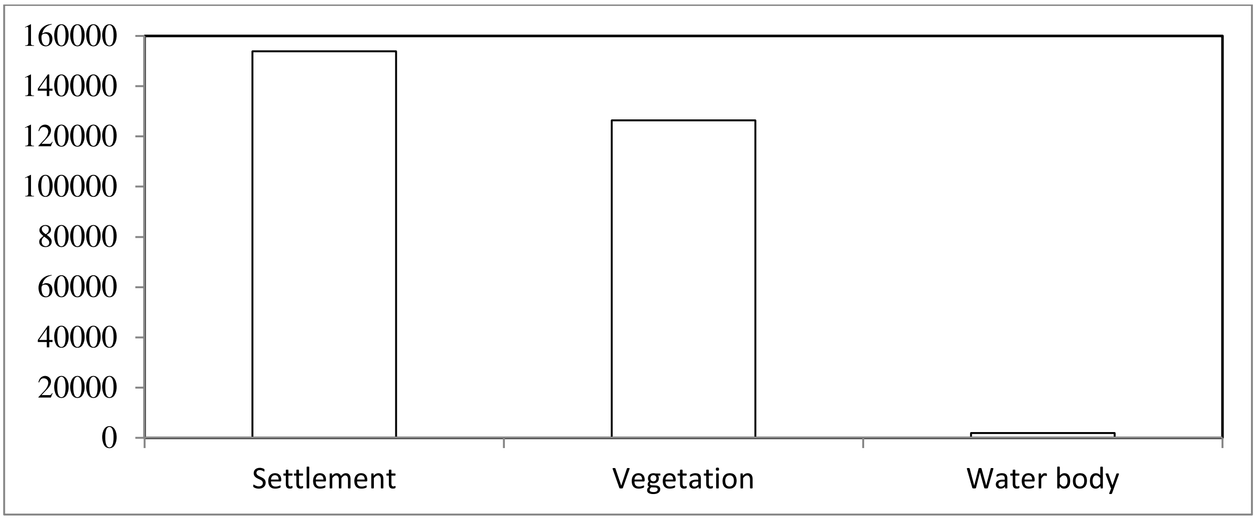

Figure 3: No of pixels covered by each land cover type as digitized from Landsat 2000 imagery.

Table 2: Number of pixels, percentage and area covered by each land use cover.

	No of Pixels	Pixels by %	Area covered (m^2)
Settlement	153941	54.54	125038577.3
Vegetation	126362	44.77	102637534.5
Water body	1937	0.69	1573328.3

4.2 Terrain Analysis

Ibadan metropolis terrain analysis was achieved by first looking at the segment map of the study area. Figure 4 shows the segment map of Ibadan metropolis comprising of the major water bodies which are the two rivers namely the River Ona and River Ogunpa (shown in red) and the Eleyele Lake in western and northern parts of Olopomewa. The three major features display in Figure 4 are the built-up area, major road and water bodies.

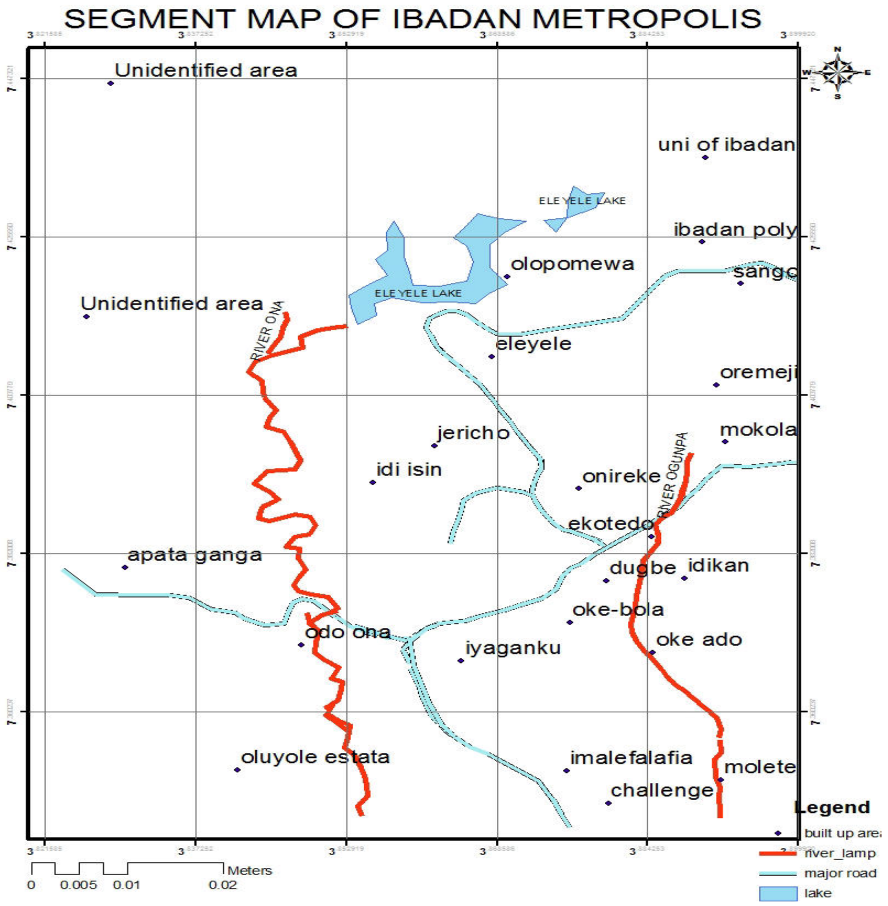

Figure 4: The segment map of Ibadan metropolis showing the rivers, built-up area and major roads.

A Digital Terrain Model (DTM) of Ibadan metropolis in Figure 5 shows the height (in meters) above mean sea level. It can be deduced that from DTM, areas that lie between 105m and 172m are most vulnerable to flooding, area that lie between 172m and 199m are just vulnerable to flooding while area that lie between 212m and 226m are less vulnerable to flooding. This classification is based on the fact that lowland regions are more vulnerable to flooding compare to the high ground regions.

4.3 Triangulated Irregular Network Feature of Ibadan Metropolis

From the topography map and using the 3d Analyst as earlier mentioned, a Triangulated Irregular Network (TIN) of Ibadan metropolis can be created and it is presented in Figure 6, the legend are steps of 25.55mm. The TIN feature reveals that areas that lie between 0m and 153m are most vulnerable to flooding while areas between 153m and 204m are just vulnerable to flooding and areas between 204m-230m are less vulnerable to flooding.

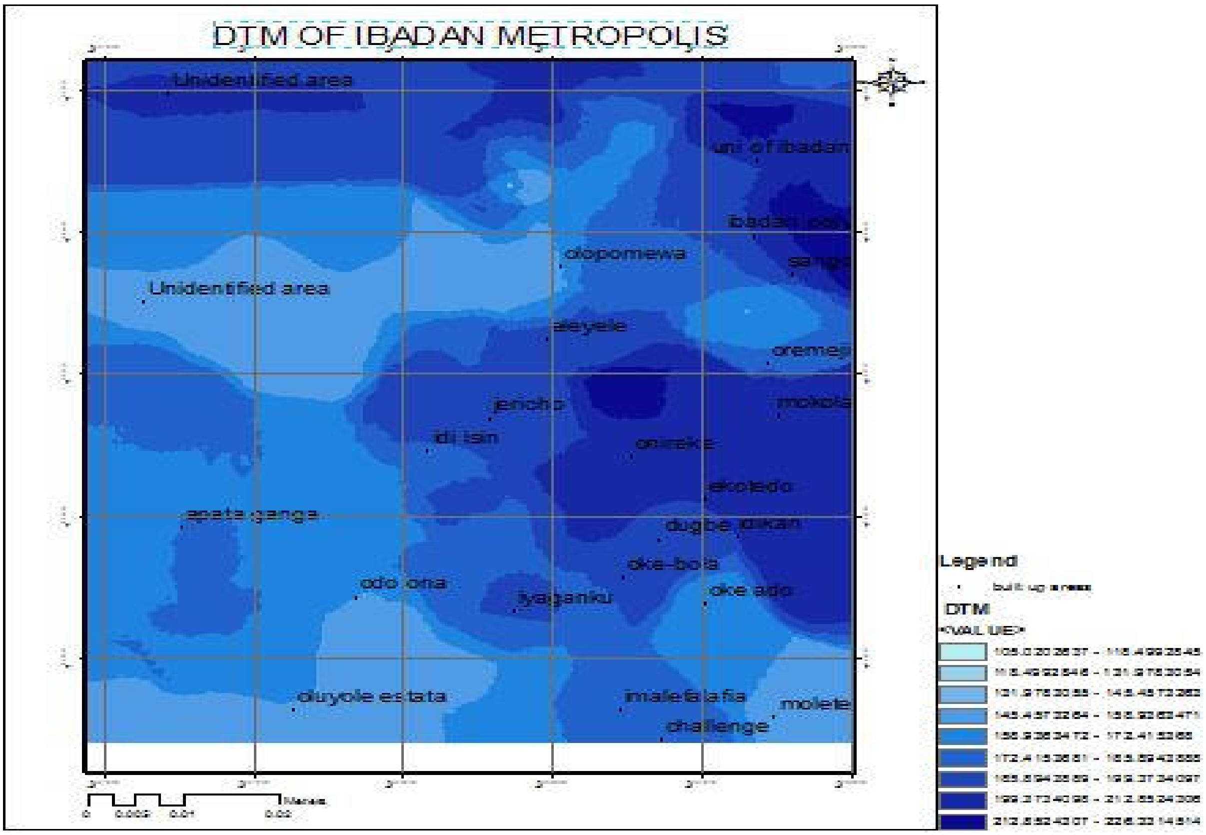

Figure 5: Digital Terrain Model (DTM) of the study area.

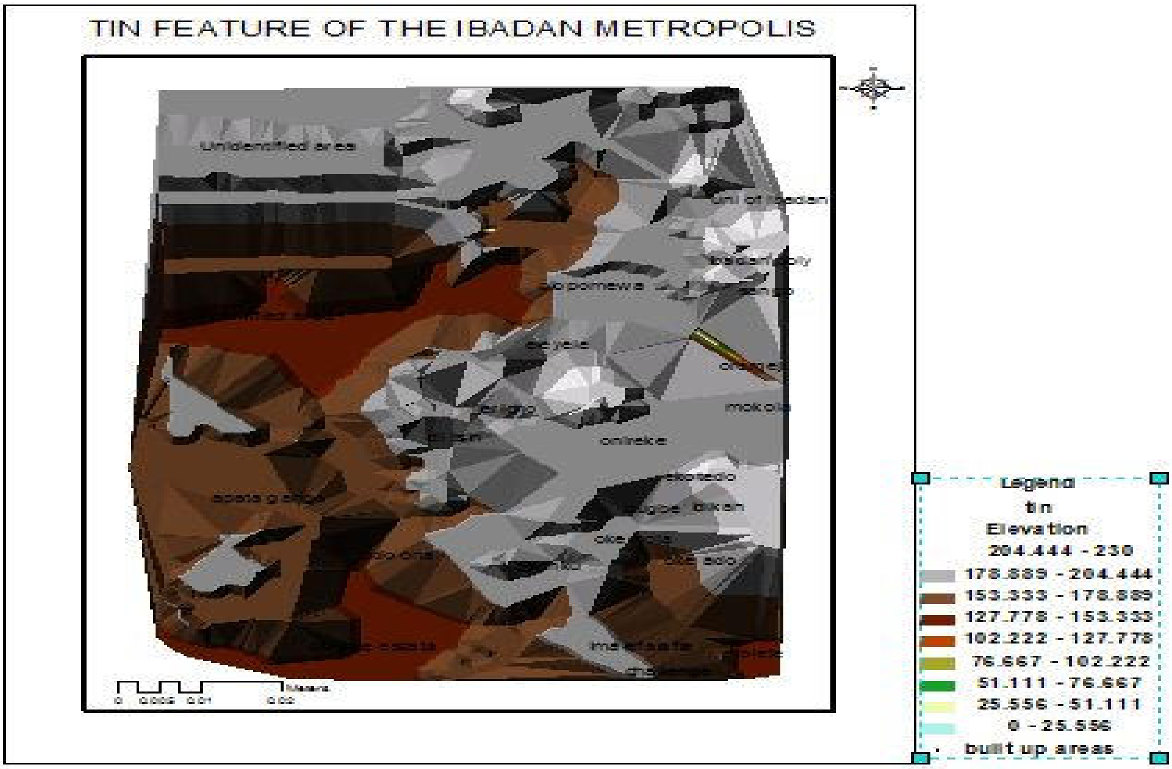

Figure 6: Triangulated Irregular Network (TIN) feature of Ibadan metropolis.

4.4 Overlaid Maps of DTM and Segment

For better and clearer understanding of the area prone to flood occurrences over Ibadan metropolis, superimposition or overlaid maps of DTM and Segment is presented in Figure 7. The DTM clearly shows that the lowest elevation is found around River Ona and River Ogunpa with an elevation of 150m above sea level in the South-western and a few areas in south-eastern part of study area. The elevation of the town increases gradually up towards the northern part of the city with the highest elevation at about 230m above sea level. Considerable area of the Odo-Ona, Apata Ganga, Molete, Idi-Isin and Eleyele with elevation less than 160m above sea level are mapped vulnerable to flood hazard. The vulnerability of these areas to flood hazard is very disastrous this is because of the high degree of the planning violation in the areas, high population concentration, poor nature of materials used in building of the houses, old nature of the houses, solid waste disposal in streams and River Ona and Ogunpa, high level of concentration of houses around the streams and the two rivers draining the town cause serious constriction of the streams exacerbating an unease flow of surface water after a heavy down rainfall event, which usually brings about flash flood. One important finding during the verification study is that clogging of drains which are usually caused by dumping of solid waste in the drainage system is an usual thing in these areas which is actually a major factor contributing to flood vulnerability of an area.

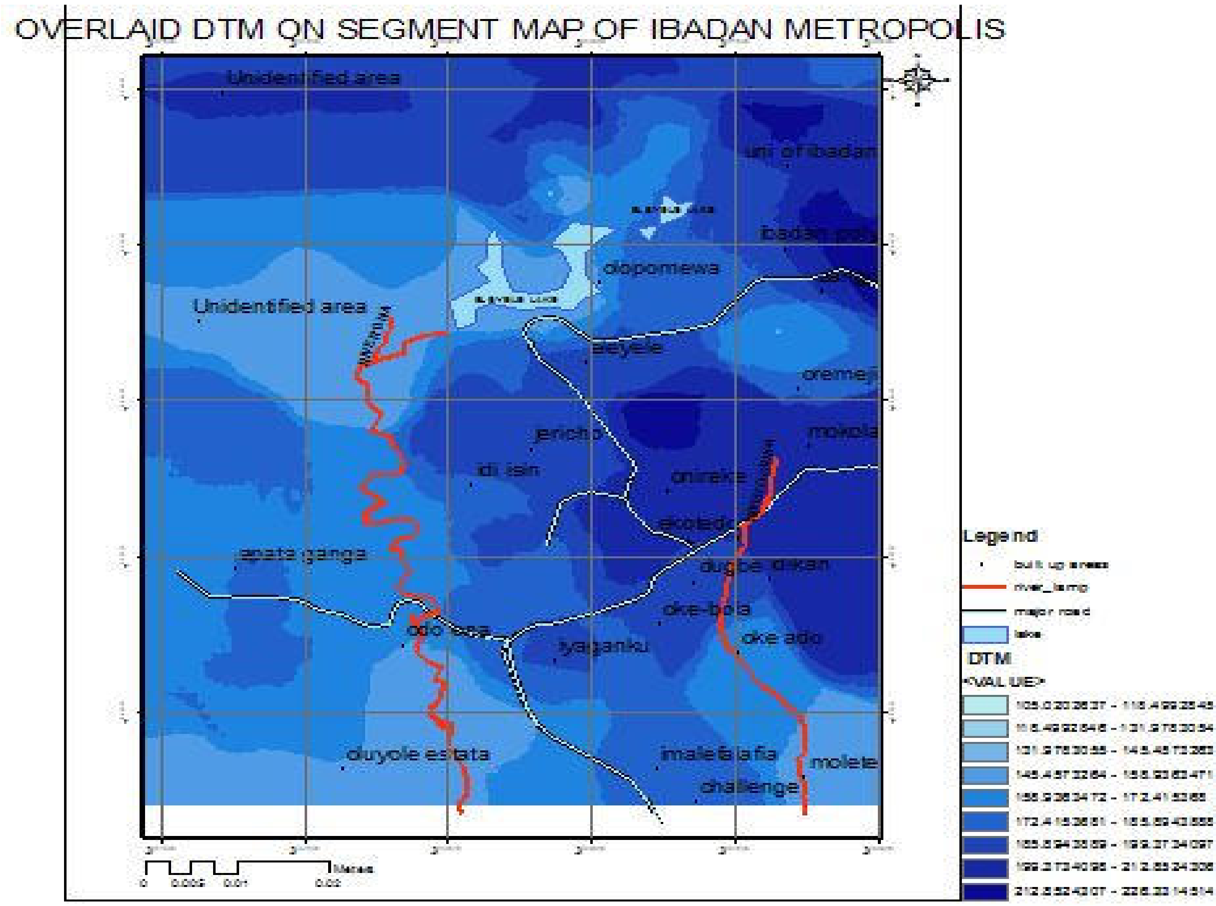

Figure 7: Overlaid DTM on Segment Map of Ibadan Metropolis.

5. Conclusion and Recommendation

5.1 Conclusion

This study main was to use combined tools of RS and GIS techniques in identifying areas that are vulnerable to flooding within Ibadan metropolis. To address this, a methodology was developed involving, pre-processing and classification of Landsat TM (2000) of the study area to show land use/ land cover (LULC) information, digitizing of topographic maps of the area, generation of digital terrain model (DTM) of the area from the produced contour data, segment map was also produced from the topography map as features like built up area, river and major roads are available in the map, integration of the segment map and DTM to generate maps showing areas of different vulnerability to flood hazards within the town. Areas lying along the banks of River Ona and Ogunpa are at locations that are most vulnerable to flood hazards with vulnerability of the town to flood decreasing towards the northern part**.** Much of the area is built up and this gives rise to high vulnerability to flash flood hazards. OdoOna, Apata Ganga, Idi Isin, Eleyele, Molete and Olopomewa are the main areas of the town that are vulnerable to flood hazard. Lack of proper landuse planning, population growth, old nature of the structures and poor materials used in the construction of the houses are other factors responsible for exposing the areas to be more vulnerable to flood hazards.

5.2 Recommendation

The study hereby recommends that there should be an improved land use planning with laws for its enforcement to the area very vulnerable to flood. Frequent awareness campaign should be made to the people while structures within the reach of the rivers and Lake should be removed and better response of National Emergency Management Agency (NEMA) and other related agency in case of flood. As population grows and land use changes, there is need for continuous vulnerability mapping with the combined analysis of RS and GIS and hence development of reliable flood forecasting and hence early warning system.

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