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FLOOD VULNERABILITY MAPPING OF KOSOFE LOCAL GOVERNMENT AREA, LAGOS, NIGERIA

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ABSTRACT

The devastating nature of the floods on the environment that causes loss of lives and properties thus necessitates the need for flood vulnerability maps. This research identified and delineated area liable to flood and subsequently generate vulnerability maps that will aid in the efficient management of flood and flood related issues. This study identified heavy rainfall as the major cause of flooding which results in the overflow of the Ogun River. Land cover Analysis was carried out and six major land cover types were identified namely: Bare earth, Built up Area, Water-body Mangrove, Vegetation and Wetland. Results obtained from the analysis performed showed that bare earth decreased by 0.75km^2 (1984 - 2002) and further decreased by 0.4km^2 (2002 - 2013), built up area also showed a marked increase of 25.83km^2 (1984 - 2002) to 1.35km^2 (2002 - 2013). Mangrove had significantly decreased was as a result of rejuvenation 6.05km^2 to 0.64km^2 while vegetation and wetland decreased marginally from 15.87km^2 to 9.18km^2 and from 11.58km^2 to 6.47km^2 both between 1984 and 2013 respectively. The area occupied by water-body increased slightly within the period of this study which implies that the wetlands were lost due to human encroachment and urbanization i.e. reclaimed and used or transformed into built-up area which explains the increases in the settlements in Kosofe LGA. Some of the environmental consequences of this land cover change and alteration of coastal habitats are known to include erosion, flooding, pollution, threats to groundwater, effects of climate change and rising sea levels (UNEP, 2002; Okude and Ademiluyi, 2006; Brody et. al, 2007). Two methods are used in this research to identify flood, generate vulnerability maps and identify infrastructures at risk. The first method is

'bath-tub' method, a zero dimensional approach method using the Arc-GIS 9.3 environment to produce maximum flood extent for different flood scenarios. The second one is CAESAR model, a two dimensional flow and sediment transport model than can simulate morphological changes in river catchments or reaches, on a flood by flood basis, over periods up to several thousands of years. The model results show flood extent spread at different flow regimes with infrastructures at risk in the area and the method results show flood vulnerability maps at normal, medium and worst flood scenarios.

KEYWORDS: Bath-tub, Flooding, Rejuvenation, Scenario, Urbanization.

1.1 BACKGROUND OF THE STUDY

Flood is among the most devastating natural hazards in the world claiming lives and properties more than any other natural phenomena (Ologunorisa, 2004). It happens in varying locations and at varying magnitudes giving them markedly different effects on the environment. Flood hazard comprises many aspects which include structural and erosion damage, contamination of food and water, disruption of socio economic activity including transport and communication, as well as loss of life and property (Hewitt and Burton, 1971).

Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide. Etuonovbe (2011), opine that floods cause about one third of all deaths, one third of all injuries and one third of all damage from natural disasters. Flooding has been identified as one of the major factors that prevents Africa's growing population of city dwellers from escaping poverty and stands in the way of United Nations 2020 goal of achieving significant improvement in the lives of urban slum dwellers (Action Aid, 2006).

In Nigeria, the pattern is similar with the rest of the world. Flooding in various parts of Nigeria has forced millions of people from their homes, destroyed businesses, polluted water resources and increased the risk of diseases (Nwaubani, 1991; Edward-Adebiyi, 1997). In addition, Record shows that more than two hundred people have lost their lives to flooding while hundreds of thousands have been rendered homeless and properties worth billions of Naira have been destroyed as a result of devastating floods across the country.

Etuenovbe (2011), reports that for residents of Lagos and most Nigerian towns and villages, the rainy season is undoubtedly not the best time of the year. This period comes with the perennial problems of flooding which leaves many homes swamped with the resultant loss of property and sometimes human lives. Properties estimated at several millions of Naira were destroyed in many communities in the Ikorodu axis in 2010. It was gathered that the persistent overflow of River Ogun caused the disaster in the State. Also, the exceptional rainfall witnessed globally in 2012 made the Atlantic Ocean level to rise, and this in turn forced Lagos Lagoon water to rise and spread into the flood prone areas of River Ogun.

Causes of flood tend to vary from one locality to another depending on the available protection and management process. Urbanization and or the concentration of settlements have continued to raise the flood damage, as settlements continue to encroach on the flood prone areas. Also, over reliance on safety provided by flood control infrastructure such as levies, dykes, reservoirs, dam can also result in flood disaster. For example dyke though a flood protective structure can collapse, thereby resulting into immense water destruction. Human action also causes flooding; there is the tendency to encroach on flood plains which attract development due to their flatness, soil fertility and proximity to water.

Other causes of increasing flood risk include increase in the proportion of impervious area; deforestation and channel interference e.g. channel suffocation by solid waste. Nigeria in recent time had also experienced many flood occurrences with several consequences especially in Lagos and Ibadan. In Lagos State, Kosofe has experienced highest number of flood in recent time. These occur after a heavy and prolong downpour of rain and consequently the damage is usually enormous. In addition, thousands of people are displaced, buildings, farmlands, social infrastructure are destroyed and economic activities disrupted.

Flood disaster management just as other disasters management can be grouped into;

1. The preparedness phase where activities such as prediction and risk zone identification or vulnerable mapping are taken up long before the event occurs;
2. 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
3. The response and mitigation phase where activities are undertaken just after the disaster and it includes damage assessment and relief management (Van-Westen and Hofstee, 2001).

However, Blong (2003), Olusegun (2004) and Barroca (2006) felt that flood vulnerability mapping can offer more in terms of security against floods.

On the other hand a vulnerability map gives the precise location of sites where people, the natural environment or property are at risk due to a potentially catastrophic event that could result in death, injury, pollution or other destruction. Such maps are made in conjunction with information about different types of risks. A vulnerability map can show the housing areas that are vulnerable to a chemical spill at a nearly factory. But it just as likely, could delineate the commercial, tourist, and residential zones that would be damaged in case of a 100 year flood or, more devastation, a tsunami.

In this case, the vulnerability map would show by means of delineation areas susceptible or prone to flood or flooding induced by flash floods, impervious surfaces, and sudden release of water from dams as recorded in 2011 at Ibadan, 2012 at Adamawa and 2012 at Lokoja, just to mention a few. Flood vulnerability has its origins in various dimensions that are sometimes hard to capture and to describe precisely and even harder to measure and to evaluate. A prerequisite for effective and efficient flood and vulnerability mapping is the in-depth knowledge of the prevailing hazards and risks throughout a river basin and areas of coastal flood risk.

This includes information about the type of floods (river, coastal, lake and groundwater), the probability of a particular flood event, the flood magnitude expressed as flood extent, water depth or flow velocity, and finally, the probable magnitude of damage (life, property economic activity). Flood maps are indispensable tools to show information about hazards, vulnerabilities and risks in a particular area. There are several methods for flood mapping based primarily on hydrologic, meteorologic and geomorphologic approaches.

Particularly, in developing countries where hydro-meteorological data are commonly insufficient and inaccurate and restricted to generate flood models, the geomorphologic method demonstrated its effectiveness and appropriateness (Lastra et al., 2008) because this method applies satellite datasets such as Quick-bird & Ikonos interpretation and field investigation of flood evidences to study geomorphologic characteristics in relationship with historical flood events (Kingma, 2003).

A geomorphologic map can help to study the extent of inundation area, direction of flood flows, and changes in river channel through remaining flood evidences, relief features and sediment deposits formed by repeated flood, hence understanding the nature of former flood and probable characteristics of flood occurring in the future (Oya, 2002). Approaches to limit disruption and damage from flooding have changed significantly in recent years. Globally, there has been a significant move from a strategy of flood defence to one of flood risk management.

This change in approach reflects the future uncertainties in flood prediction, arising from climate change, urban sprawl and recognition that continuing to strengthen defences against flooding is no longer tenable. Flood risk management includes defence, where appropriate, but also that society learns to live with floods and develops resilience to their impact.

The success of this approach requires integration of enhanced defence and warning systems with improved understanding of the causes of flooding linked to better governance, emergency planning and disaster management (Pender, 2006). Urbanization restricts where floodwaters can go by covering large parts of the ground with roofs, roads and pavements, thus obstructing natural channels, and by building drains that ensure that water moves to rivers more rapidly than it did under natural conditions. Large-scale urbanization and population increases have led to large numbers of people, especially the poor, settling and living in floodplains in and around urban areas (Douglas et al, 2008).

Erege (2011) identified part of the problems attributed to urbanization were highlighted. The research work mentioned ‘Acute flooding and soil erosion are amongst the numerous problems plaguing our natural environment at the present time, as a result of high surface runoff’. At least 20 per cent of the population is at risk from one form of flooding or another (Etuonovbe, 2011). Flooding in various parts of Nigeria have forced millions of people from their homes, destroyed businesses, polluted water resources and increased the risk of diseases (Nwaubani, 1991; Edward-Adebiyi, 1997).

In addition to this is the loss of the home which is seen as a form of security from the outside world. The home is often conceived as an emotional sanctuary providing refuge from the outside world (Sibley, 1995). Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide (Smith, 1996). Floods are natural phenomena, but damage and losses from floods are the consequences of human action (Douglas et al, 2008). Climate change appears to be altering the pattern of flooding in Africa. Modelling shows that the pattern of rare large floods is going to change much more than long-term average river flows.

An example is the work done by Ayila et al. (2012) using CAESAR model, the flood analysis and overlay operation, a large number of settlements in the Adamawa State floodplain were seen to be at risk. Prolonged heavy rains may increase in volume and occurrence (Mason et al, 1997). To get information on most of these, and identify areas that are vulnerable to flooding, reliable techniques of collecting and analyzing geospatial information are required. In this regard, an integrated approach of Remote Sensing (RS) and Geographic Information System (GIS) has proved to be the most effective (Jayasselan, 2006), and perhaps the only option to flood hazard preparedness and to reduce potential risk. This will be part of a larger, long term effort to gain a better understanding of community vulnerability on the floodplains and low elevated areas to flood hazard.

1.2 Statement of the Problem

Flood are among the most damaging of natural hazards, and are likely to become more frequent, more prevalent and most serious in the future due to the effects of climate change and urbanization. The nature of occurrence of flood is governed by diverse factors, including rainfall characteristics, properties of drainage catchment and land water use and management in the catchment. These occurrences reflect reality for urban poor who are faced with little option other than to illegally occupy public land or purchase affordable land in vulnerable zones (Montoya, 2006). The study area suffers incessantly from unmitigated flooding, often resulting in: disruption of communication, structural damages to buildings and loss of lives and properties. The high rate of urbanization in the area also means a high rate of housing construction and encroachment on open spaces and wetlands.

The generally low lying terrain, coastal influences on its micro-climate, heavy precipitation, blockage of drainage and occasional release of water from the Oyan dam, all coalesce to exacerbate flood problems in Kosofe LGA. This contributes immensely to the flood situation in the area as water level rise and is further sustained in the Ogun River catchment areas (Oyinloye et al, 2013). It is also possible to relate the physical causes of floods to other environmental hazard. Necessary information for flood water motions in the Kosofe floodplain is not available for floodplain management, planning and sustainability of the environment. There is therefore, no reliable terrain management information that could be used to check inundation by floods if there are heavy rains and accompany flash floods.

1.3 Aim and Objectives of the Study

The aim of this study is to simulate flood along the Ogun River channel and identify vulnerable areas liable to flood at different scenarios. The following specific objectives were used to achieve the exercise;

1. To ascertain and generate land cover/ land use (LC/LU) information of the study area using remote sensing and GIS techniques.
2. To delineate and map-out flood plains in Kosofe LGA using the CAESER Model and Bath tub method.
3. To ascertain and produce vulnerability maps for different flood scenarios, evaluate and assess the vulnerability of settlements in Kosofe LGA.
4. To investigate the Socio-Economic effects of flooding in Kosofe LGA.

1.4 Research Questions

1. What are the extents of different LC/LU classes in the study area for the three epochs used?
2. How can flood plains in Kosofe LGA be delineated and extracted?
3. How can flood vulnerability maps of Kosofe LGA be produced for the three epochs under review?
4. What are the propose mitigation measures for identified negative impacts and enhancement measures for positive ones?

1.5 The Study Area

Kosofe is one of the twenty (20) Local Government Areas (LGAs) in Lagos state. It was created on the 27th of November, 1980. It is located at the northern part of the state; it is bounded by 3 local governments namely: Ikeja, Ikorodu and Shomolu. It also shares a boundary with Ogun state. Its area of jurisdiction comprises of ten wards and encompasses an area of 81.4sq/km with its headquarters at Ogudu. The major water body in the local government is the Ogun River. Ogun River Catchment is bordered by latitudes 6^o 26' N and 9^o 10'N and longitudes 2^o 28'E and 4^o 8'E. It takes its source from the Igaran hills at an elevation of about 530m above mean sea level and flows directly southwards over a distance of about 480km before it discharges into the Lagos Lagoon (Figure 1) below.

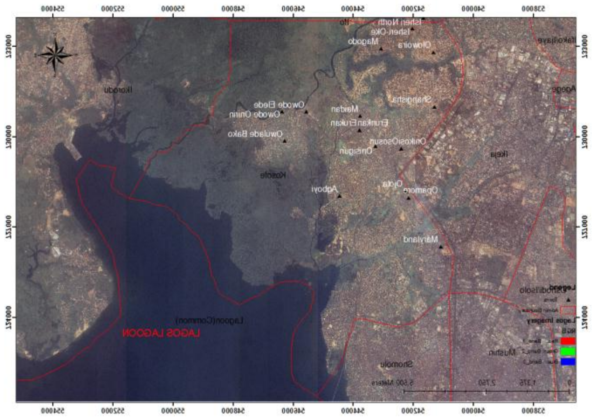


Figure 1: Satellite Imagery of Lagos showing Kosofe LGA and the communities within and environments.

The major tributaries of the Ogun River are the Ofiki and Opeki rivers. About 9km upstream of Abeokuta town there is a sharp change in land gradient, changing the river morphology from fast flowing to slow moving and leading to the formation of alluvial deposits overlying the sedimentary formation of Ewekoro, Ilaro and Coastal plain sands in sequence towards the Lagos lagoon south of Kosofe Local Government Area.

The vegetation of Kosofe is the swamp forest which had been encroached by construction of houses, market and other infrastructure. There are over 35 communities in Kosofe LGA and these include: Oworonsoki., Ifako, Sholuyi, Anthony village, Ajao estate, Ogudu, Ojota; Alapere, Orisigun, Kosofe, Ajelogo and Akanimodo; Ikosi, Ketu, Mile 12, Ayedere, Maiden; Isheri, Olowora, Shangisha, Magodo phase 1 & 2; Agboyi-1; Agboyi-2; Owode-Onirin, Ajegunle and Odo-Ogun among others. For the purpose of this research areas mostly affected by flood will be considered, these include: Mile 12, Maiden, Agboyi-1, Agboyi-2, Owode-Onirin, Ajegunle and Odo-Ogun.

2.0 Concept of Flood

River valleys and flood plain has been the cradle of civilization since ancient times and still they happen to be one of the most populated parts of the world. It is the immense density of population in close proximity to rivers that makes flood one of the most common natural disasters and affecting more people across the globe than all other natural or technological disasters and also the most costly in term of human hardship and economic loss (Huang et al., 2008). Wang (1999) also stated that flood(s) seriously affects people, lives and properties while Farah et al. (2000), stated that flood is a major hazard that affects many countries in the world. It is an inevitable natural phenomenon occurring from time to time along most rivers and natural drainage systems. It causes damage to lives, natural resources and environment as well as loss of economy and health.

Flood disasters account for about a third of all natural disasters by number and economic losses (Nwilo et al., 2012). In a time period of 6 years (1989 – 1994), 80% of federal declared disasters in the United States of America (USA) were related to flooding; flood themselves around the world average four billion dollars annually in property damage alone (Wadsworth, 1999). The frequency with which they occur is on the increase in many regions of the world (Drogue et al., 2004).

Implications of Urbanization and Urban Expansion for Local Environments and the Flood Hazard

Urban centres concentrate people, enterprises, infrastructures and public institutions, while at the same time relying for food, freshwater and other resources from areas outside of their boundaries (Satterthwaite, 2011). Furthermore, urban areas are often located in hazard-prone locations such as low-elevation coastal zones, which are at risk from sea-level rise, or in other areas at risk from flooding and extreme weather events (OECD, 2009; WDR, 2010).

Urbanization is accompanied by increasingly larger-scale urban spatial expansion as cities and towns swell and grow outwards in order to accommodate population increases. Urban expansion alters the natural landscape, land uses and land cover, for example by changing water flows and increasing impermeable areas, thereby adding to the flood hazard problem (Satterthwaite, 2011).

High levels of urbanization in river flood plains and other areas of catchments might also change the frequency of occurrence of flooding. In the mid-1970s, when urbanization was just starting to accelerate, a study by Hollis (1975) showed that the of small floods might increase up to 10 times with rapid urbanization, whilst more severe floods, with return periods 100 years or over, might double in size if 30 percent of roads were paved. The changes in land use associated with urbanization affect soil conditions and the nature of run-off in an area. Increased development of impermeable surfaces leads to enhanced overland flow and reduced infiltration.

It also affects the natural storage of water and causes modification of run–off streams (Wheater and Evans, 2009). Urban centers also change the local environment by reducing rainfall and increasing night-time temperatures. Urban micro-climates, especially urban heat islands caused by lack of vegetation, can modify the hydrology of an area. Heat islands create higher temperatures over cities: for example, during the summer heat wave of 2003 in the UK, differences of up to 10°C between city and rural temperatures were measured in the London area.

2.1 Forms of Floods in Nigeria

Jeyaseelan, (1999) stated that floods are of different forms while Adeoye et al. (2009) and Etuonovbe (2011) have also mentioned that these forms of floods occur throughout Nigeria. They include the following: River Floods, Coastal Floods, Urban Floods and Flash Floods.

3.0 Methodology

This study integrates remote sensing data with geographic information system whereby information on floods, erosion, pollution, desertification, earthquakes, landslides, vulnerability and other natural hazards can be acquired. Figure 1 below gives the procedure used in carrying out the project. It also seeks to determine the environmental impact of flooding on the social, economic and physical status of the study area. To achieve these, data were collected using structured questionnaire which were administered on political ward basis in the study area as shown in Table 3.2 below: however the following operations and their components were carried out in achieving the set goal.

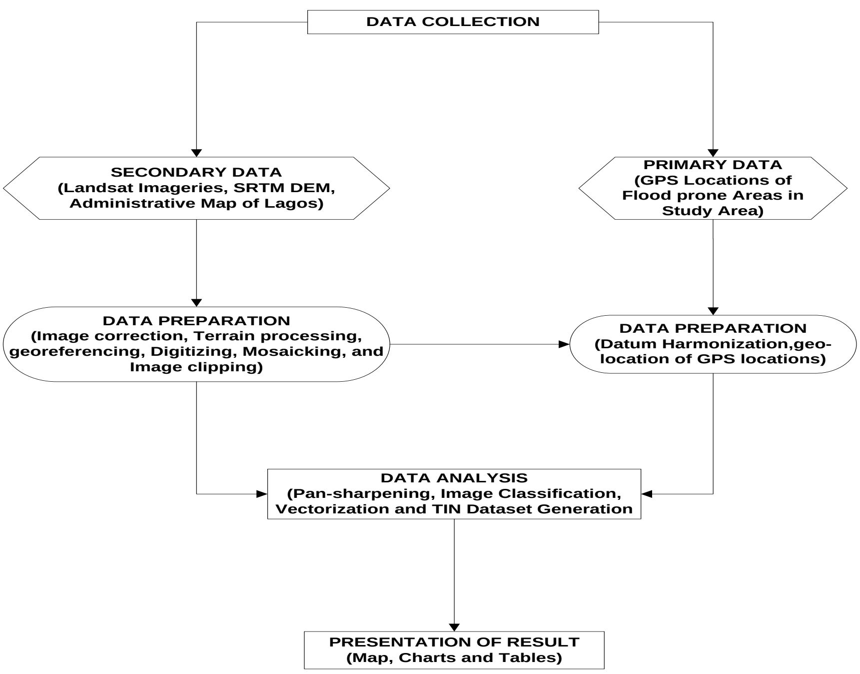


Figure 1: Methodology Framework for LCLU Analysis.

3.1 Reconnaissance

A process that includes selection survey for dataset, processing of software and appropriate technique was used in achieving an expected level of accuracy. It included the following:

1. Site visitation to Kosofe LGA in a bid to locate the flood prone areas especially during a recent rainfall, land cover samples were also collected from the field for the purpose of training the computer to recognize the pixels relating to each class when processing for Land cover of the area.
2. Questionnaire survey and Consultations were carried out to ascertain the causes of flooding in the study area. The questionnaire was administered on household heads and it addressed flood damage to property, causes, benefits and effects among many others.
3. The relevant datasets for processing and analysis were identified and captured.
4. The choice of the appropriate software applications were taken into consideration based on the data availability and requirements.
5. Data preparation which involves terrain processing, datum harmonization, geo referencing etc.

3.2 Data Acquisition

The dataset used for this project was sourced from different areas. The dataset and their sources are given in Table 1 below:

Table 1: Datasets, acquisition dates and sources.

S/N	Data	Scale	Date	Source
1	Lagos Admin map	25000	2009	GCLME Lab, Unilag
2	Landsat datasets	60m 30m	1984, 2002 & 2013	http://glovis.usgs.gov
3	Ikonos Imagery	2.5m	2005	GCLME Lab, Unilag
4	SRTM DEM	90m	2000	http://srtm.csi.cgiar.org
5	Field coordinates	-	2013	Field work
6	Questionnaire Survey	-	2013	Field work

3.3 Software Requirement

A number of software was put to use in order to achieve the set objectives of this project and they include the following:

1. ENVI 4.5: Remote sensing software employed for the classification and extraction of features in the satellite imageries used in the study.
2. ARCGIS: GIS software used for analysis, map production, TIN generation.
3. Arc Hydro Tool: Used for terrain processing.
4. DEM Editor: A very simple utility for clipping DEMs saved in the arc ASCII format.

5. CAESAR: A two dimensional flow and sediment transport model. It can simulate morphological changes in river catchments or reaches, on a flood by flood basis, over periods up to several thousands of years
6. Raster Edit: A great utility for editing individual cells within a raster DEM saved in the ASCII format from Arc GIS. Also allows smoothing and interpolation between points. Great for editing valley floor DEMs for CAESAR
7. Spatial package for social sciences (SPSS): Used for analysis of data gotten from questionnaire.
8. MS-Excel and MS-Word: Used for charts and numerical data manipulation and report presentation.

3.4 Data Processing and Procedures

This involved a stepwise arrangement and organization of acquired data in a manner that was appropriate for analysis. Based on the objectives of this study, procedures of the research are discussed.

3.4.1 Landsat Datasets

The processing of satellite imageries was carried-out using Environment for Visualizing Image (ENVI) software. ENVI is known primarily as a remote sensing software system, it also offers a full suite of image processing capabilities. Image processing software allows one to take raw remotely sensed imagery (such as LANDSAT or SPOT satellite imagery) and convert it into interpreted map data according to various classification procedures. Multi-temporal subsets of Landsat TM, ETM^+ and OLI were used to effectively identify the various Land cover of the study area. The imageries were acquired through the USGS Earth resource Observation System Data Centre, which has corrected the radiometric and geometrical distortions of the images to a quality level of 1G before delivery. They were downloaded from the website link (http://glovis.usgs.gov/) through the satellite pass of paths and rows specific to the area of study (Path 191, Row 55).

The scenes were clipped and a subset of the Landsat imageries that defined the area of study was subsequently generated as follows; subset of Landsat TM acquired on December 1984; subset of Landsat ETM^+ acquired on December 2002 and a subset of Landsat 8 acquired on January 2013 respectively. In the Land Cover classification, a band sequence of (543) for TM and ETM^+ and a sequence of (654) for OLI respectively was used to produce a composite multispectral imagery which was used to classify the imagery. An unsupervised classification of the imagery using the K-means method was carried out for six classes. The classes are Bare surface, Built-up, Mangrove, Vegetation, Water body and Wetland. These features were subsequently classified to vector and exported to ARCGIS environment for statistical analysis and production of Land cover maps.

3.4.2 Change Detection and Area Calculation

Changes in land cover were detected by identifying areas with changes in the various features. The features for Landsat 4 TM was subtracted from that of Landsat 7 ETM^+ 2002 and that of 2002 from 2013 and the percentage change of the features was calculated from the areas of the three change categories.

3.4.3 Ogun River Settlement Extraction

Settlements within and around the entire stretch of the Ogun river within kosofe LGA, was identified and subsequently digitized from the Ikonos Imagery.

3.5 Dem Processing Operation

Shuttle Radar Topographic Mission (SRTM) DEM data of the study area was derived from USGS/NASA SRTM data and was in decimal degrees and datum WGS84. The data was downloaded from the CIAT-CSI SRTM website (http://srtm.csi.cgiar.org) as cited in Jarvis et al, (2008). It was projected to the UTM coordinate system and clipped to the extent of the study area.

3.5.1 Filling of sinks

In order to carry out hydrology analysis on DEM, all depressions have to be filled. Such depressions are called sinks (ESRI, 2009a). The SRTM 90m DEM sinks were filled using the ‘Fill’ tool in ArcGIS.

3.5.2 Generation of the TIN

This is created from elevation information extracted from the DEM which subsequently is used to produce a relief map of the area. An advantage of using a TIN over a Raster DEM in mapping analysis is that the points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to these non-stationary surfaces accurately and efficiently, one must use a method an accurate representation of the terrain.

3.5.3 Change in surface elevation manipulation

The profile graph tools on the 3D Analyst interactive toolbar are used to derive a graphic representation of one or many profiles. Profiles can be generated from any 3D line feature drawn over a surface. The steps include the following:

- In ArcMap, click the layer drop-down arrow on the 3D Analyst toolbar and click the surface that you want to profile
- Click the interpolate line button
- Click the surface and digitize a line you want to profile. When you are finished adding vertices to the line, double click to stop digitizing.
- Click the create profile graph button
- Optionally, you can change the layout of the profile graph. Right click the title bar of the profile graph and click properties. Change the basic layout options and click OK, or click advanced options to make more complex changes to the layout.

3.6 The 'Bath-Tub' Method

The 'bath-tub' method is called a zero-dimensional approach. It is not based on physical and hydraulic principles like other models. It is a simple and quick method in ArcGIS 9.3 environment to predict maximum flood extent (floodplain) in Kosofe LGA for extreme water levels. It approximates the flood wave as a plane or series of plane (corresponding to extreme water levels) that are intersected with DEM to identify flood extent and possibly flood depths (Bates et al., 2005). Figure 2 shows the flowchart for the bath-tub approach.

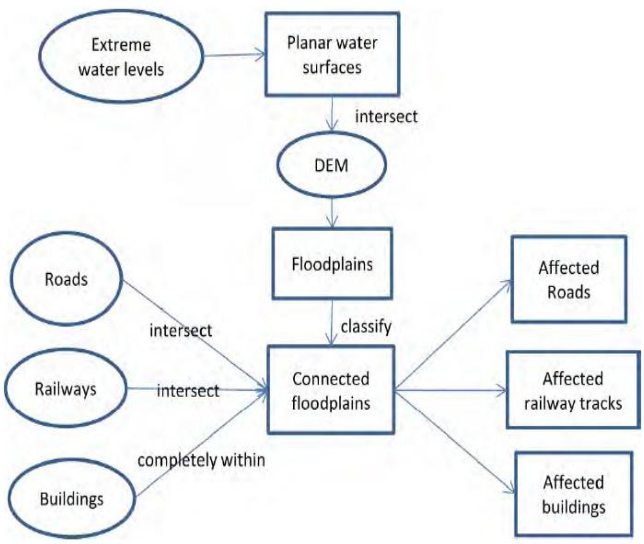


Figure 2: Flowchart of the Bath-tub Method.

4.3 Mapping Land Cover Changes

Analysis of the Land use progress carried out for each of the land cover classes of interest in this study (Built-up, Bare surface, Mangrove, Vegetation and Wetland) and database created for the Landsat TM/ETM+ data of 1984, 2002 and 2013 respectively are presented below. Results obtained from the analysis performed in

Table **2: Land cover analysis of features.**

Features	**1984**	**2002**	**2013**	**Change (1984-2002)**	**Change (2002-2013)**
	km2	**km2**	**km2**	**km2**	**km2**
Bare Surface	3.91	3.16	2.76	-0.75	-0.40
Built up	8.34	34.17	35.52	25.83	1.35
Mangrove	15.87	9.82	9.18	-6.05	-0.64
Vegetation	30.19	15.64	14.86	-14.55	-0.78
Water body	10.87	11.04	11.97	0.17	0.93
Wetland	11.58	6.93	6.47	-4.65	-0.46

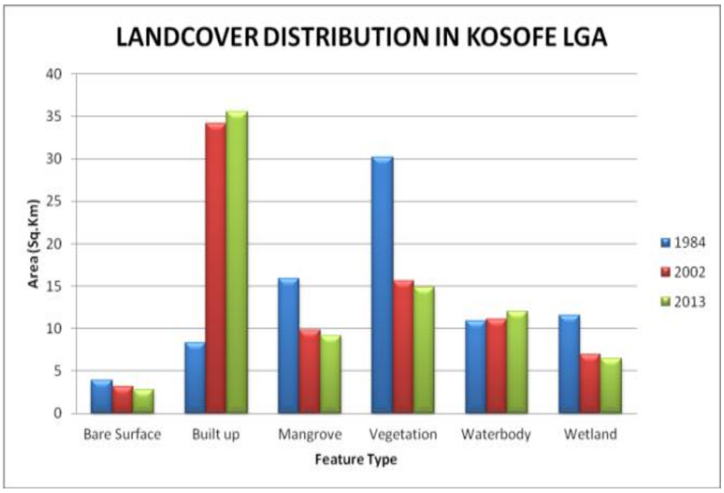


Figure 3: Land cover distribution for the three epochs.

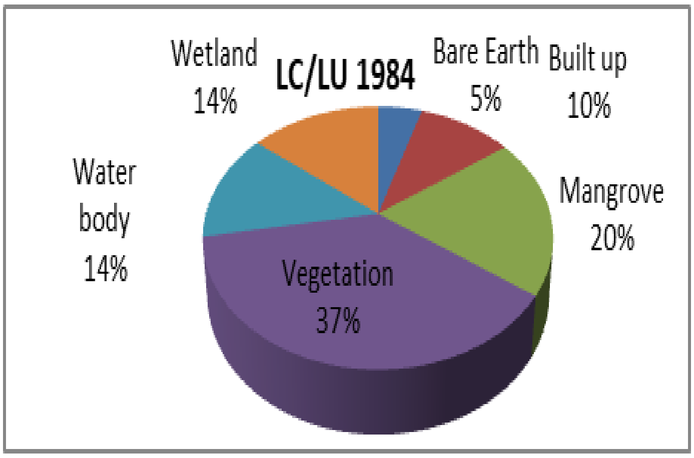


Figure 4: Land cover distribution for 1984

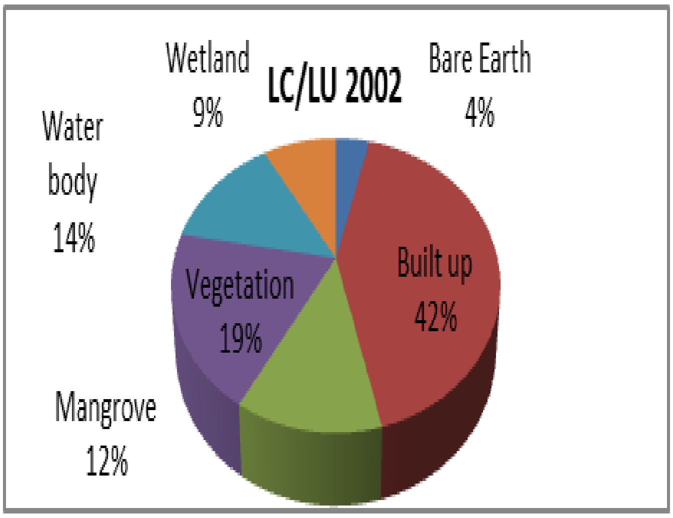


Figure 5: Land cover distribution for 2002

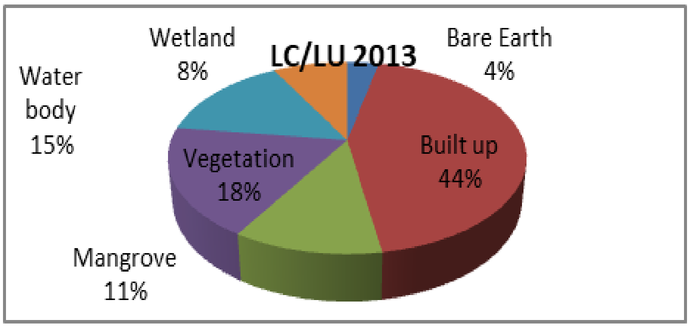


Figure 6: Land cover distribution for 2013.

Table 3: Land cover analysis for 1984 and 2002.

Feature	1984		2002		Change	Inference
	km2	%	km2	%	km2	
Bare Earth	3.91	4.84	3.16	3.91	-0.75	Loss
Built up	8.34	10.33	34.17	42.31	25.83	Gain

Mangrove	15.87	19.65	9.82	12.16	-6.05	Loss
Vegetation	30.19	37.38	15.64	19.37	-14.55	Loss
Water body	10.87	13.46	11.04	13.67	0.17	Gain
Wetland	11.58	14.34	6.93	8.58	-4.65	Loss
Total	80.76	100.00	80.76	100.00	0.00	

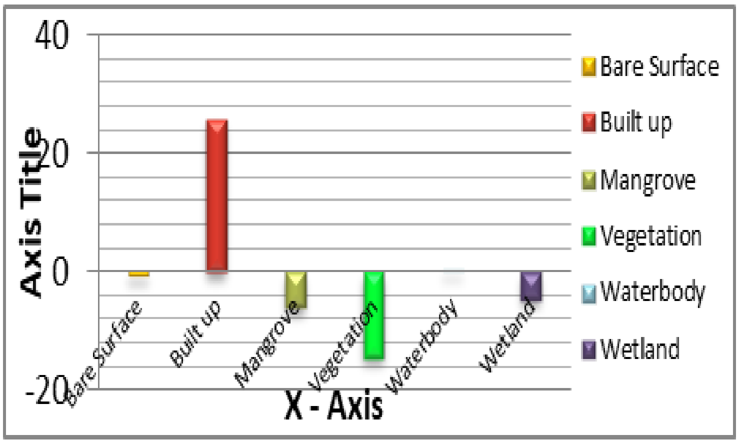


Figure 7: Land cover change between 1984 and 2002.

Table 4: Land cover analysis for 2002 and 2013.

Feature	2002		2013		Change	Inference
	(km2)	(%)	(km2)	%	(km2)	
Bare Earth	3.16	3.91	2.76	3.42	**-0.40**	Loss
Built up	34.17	42.31	35.52	43.98	**1.35**	Gain
Mangrove	9.82	12.16	9.18	11.37	**-0.64**	Loss
Vegetation	15.64	19.37	14.86	18.40	**-0.78**	Loss
Water body	11.04	13.67	11.97	14.82	**0.93**	Gain
Wetland	6.93	8.58	6.47	8.01	**-0.46**	Loss
Total	80.76	100.00	80.76	100.00	**0.00**	

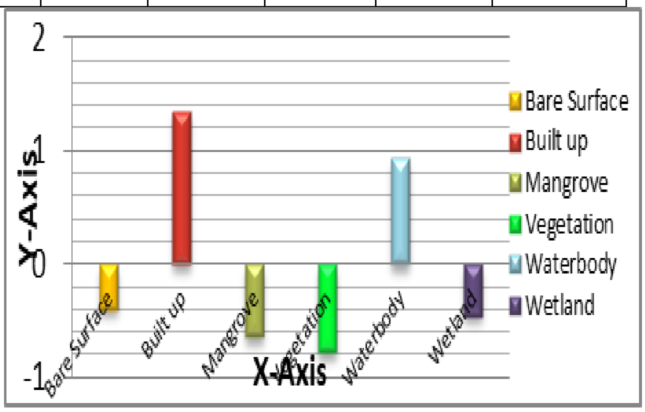


Figure 8: Land cover change between 2002 – 2013.

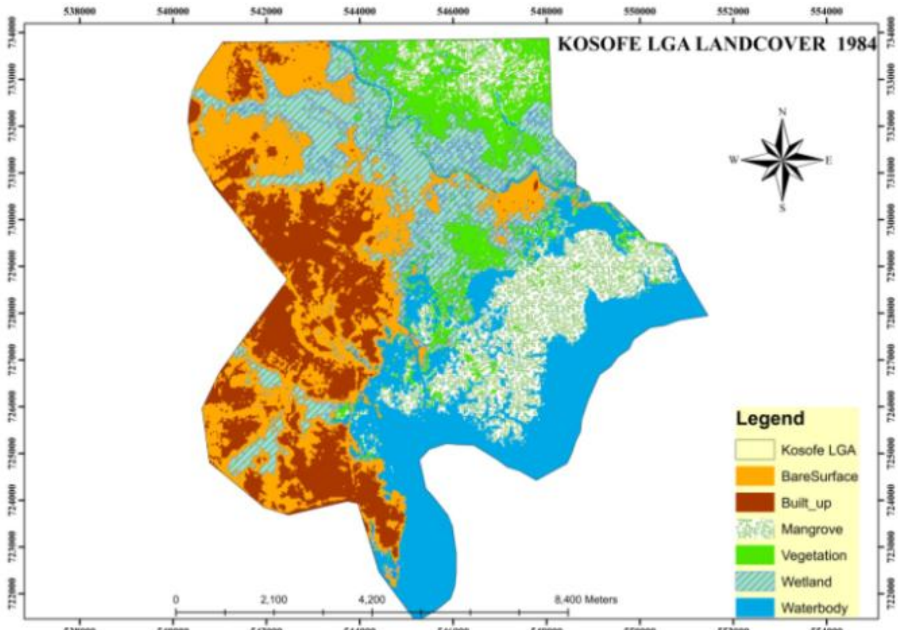


Figure 9: Land cover map of Kosofe LGA in 1984.

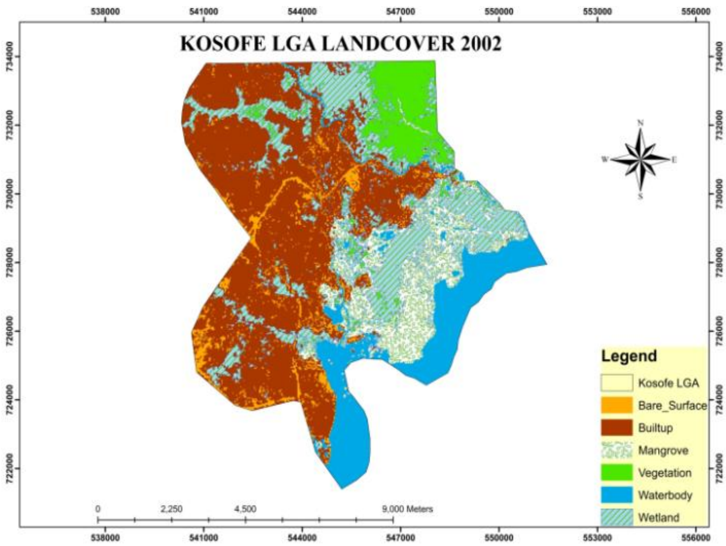


Figure 10: Land cover map of Kosofe LGA in 2002.

below shows that bare surface decreased by 0.75km^2 (1984 to 2002) and further decreased by 0.4km^2 (2002 to 2013), built up area also showed a marked increase of 25.83km^2 (1984 to 2002) to 1.35km^2 (2002 to 2013). Similarly Mangrove decreased relatively from 1984 to 2013, vegetation and wetland decreased marginally from 15.87km^2 to 9.18km^2 and from 11.58km^2 to 6.47km^2 both between 1984 and 2013 respectively. The area occupied by water body increased slightly within this period as shown in Figure 3 – Figure 8 **Error! Reference source not found.**. The implication is that the wetlands are lost due to human encroachment and urbanization, thus they are used or transformed into built-up area which explains the increases in the settlements in Kosofe LGA.

The consequences of this land cover change and alteration of coastal habitats are known to include threats to groundwater, erosion, flooding, pollution, effects of climate change and rising sea levels (Okude et al, 2006; Brody et al. 2007; UNEP, 2002). Studies have argued that as mangroves and coastal wetlands provide protection for coastal areas (UNEP, 2002), their depletion and replacement with impervious surfaces would increase flooding, disrupt associated marine processes, food web and biodiversity among others. Perhaps, the perennial flooding in the Lagos coastal area (Okude et al, 2006) may have been exacerbated by the land cover changes and large scale conversion of mangroves and wetlands observed here and in similar studies. Land cover maps for the area depicting the change over time have been generated for visualization in Figure 9 – Figure 11 **Error! Reference source not found.**below.

Table 2: Land cover analysis of features.

Features	**1984**	**2002**	**2013**	**Change (1984-2002)**	**Change (2002-2013)**
	km^2	**km^2**	**km^2**	**km^2**	**km^2**
Bare Surface	3.91	3.16	2.76	-0.75	-0.40
Built up	8.34	34.17	35.52	25.83	1.35
Mangrove	15.87	9.82	9.18	-6.05	-0.64
Vegetation	30.19	15.64	14.86	-14.55	-0.78
Water body	10.87	11.04	11.97	0.17	0.93
Wetland	11.58	6.93	6.47	-4.65	-0.46

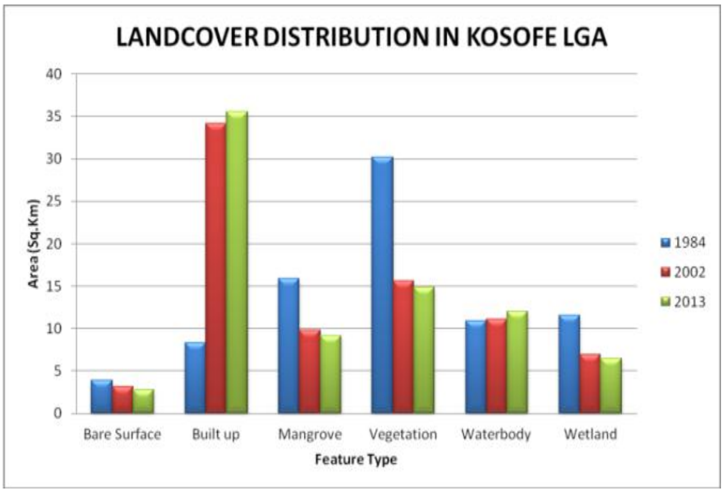


Figure 3: Land cover distribution for the three epochs.

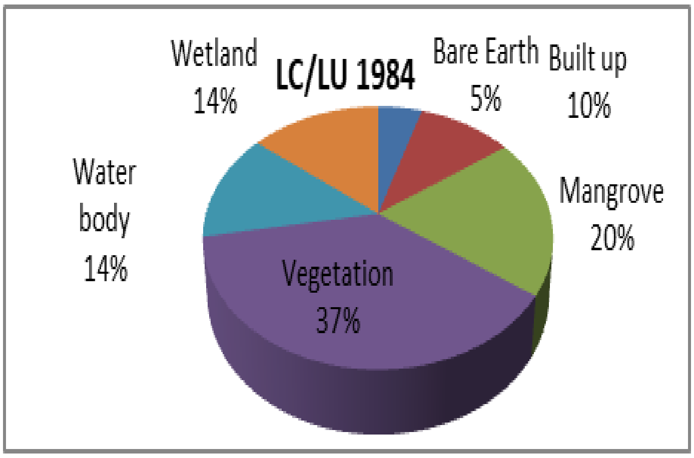


Figure 4: Land cover distribution for 1984

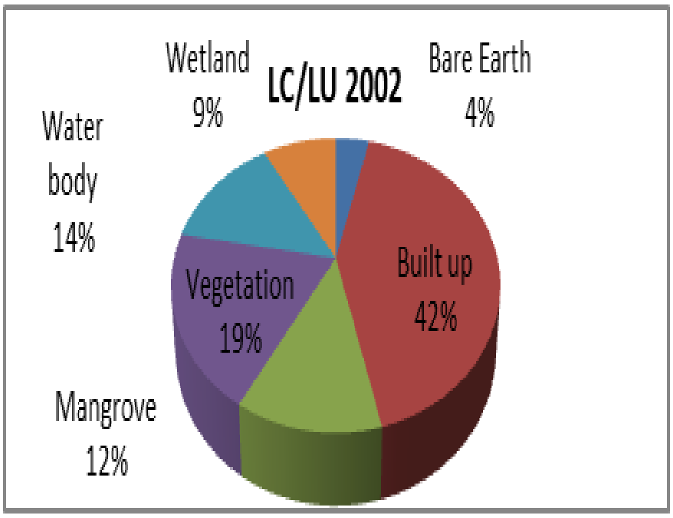


Figure 5: Land cover distribution for 2002

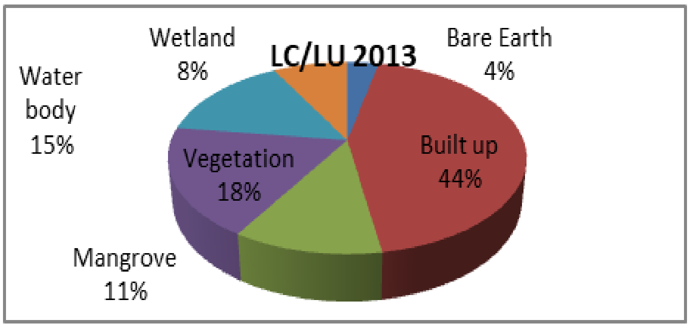


Figure 6: Land cover distribution for 2013.

Table 3: Land cover analysis for 1984 and 2002.

Feature	1984		2002		Change	Inference
	km^2	%	km^2	%	km^2	
Bare Earth	3.91	4.84	3.16	3.91	-0.75	Loss
Built up	8.34	10.33	34.17	42.31	25.83	Gain

Mangrove	15.87	19.65	9.82	12.16	-6.05	Loss
Vegetation	30.19	37.38	15.64	19.37	-14.55	Loss
Water body	10.87	13.46	11.04	13.67	0.17	Gain
Wetland	11.58	14.34	6.93	8.58	-4.65	Loss
Total	80.76	100.00	80.76	100.00	0.00	

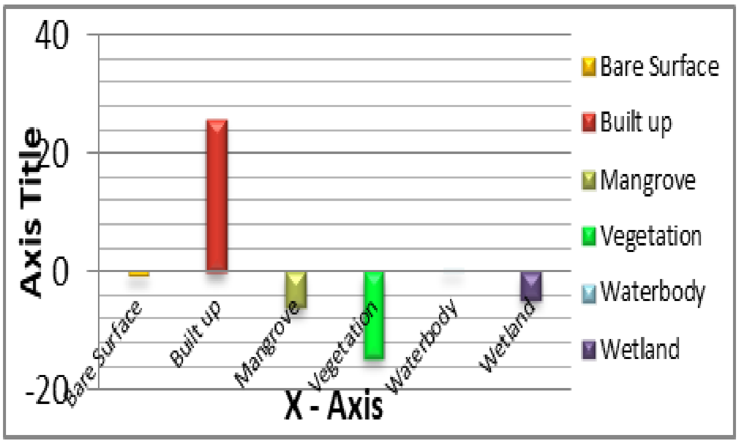


Figure 7: Land cover change between 1984 and 2002.

Table 4: Land cover analysis for 2002 and 2013.

Feature	2002		2013		Change	Inference
	(km^2)	(%)	(km^2)	%	(km^2)	
Bare Earth	3.16	3.91	2.76	3.42	**-0.40**	Loss
Built up	34.17	42.31	35.52	43.98	**1.35**	Gain
Mangrove	9.82	12.16	9.18	11.37	**-0.64**	Loss
Vegetation	15.64	19.37	14.86	18.40	**-0.78**	Loss
Water body	11.04	13.67	11.97	14.82	**0.93**	Gain
Wetland	6.93	8.58	6.47	8.01	**-0.46**	Loss
Total	80.76	100.00	80.76	100.00	**0.00**	

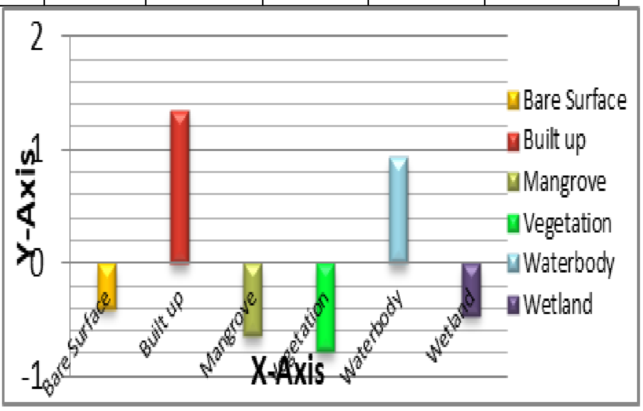


Figure 8: Land cover change between 2002 – 2013.

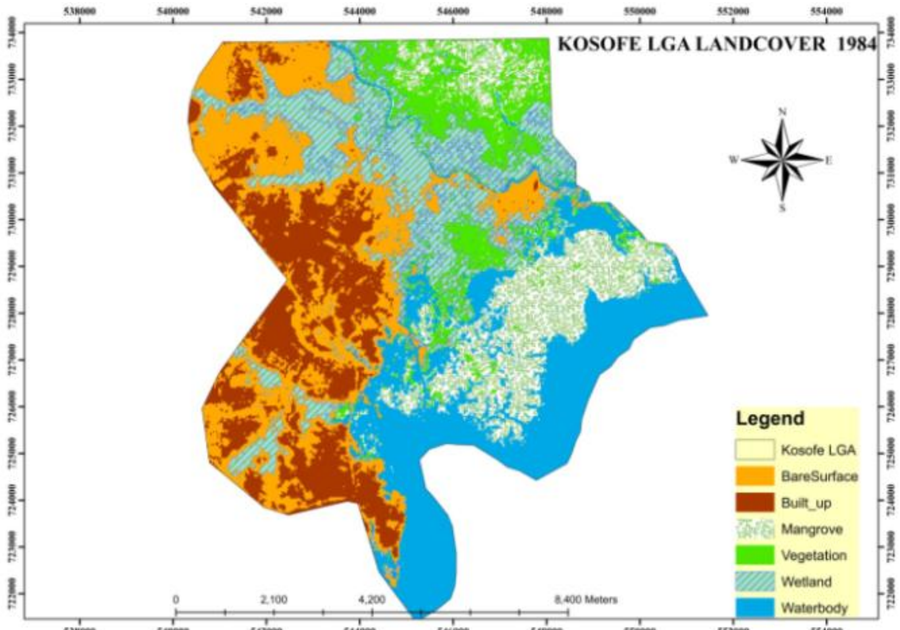


Figure 9: Land cover map of Kosofe LGA in 1984.

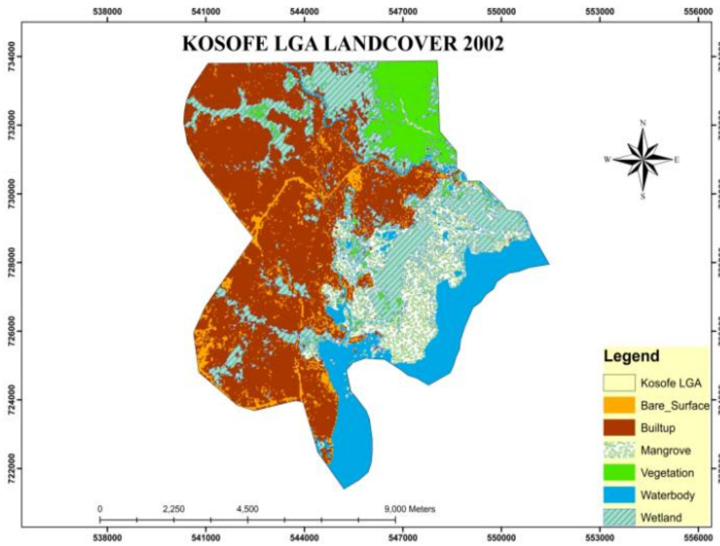


Figure 10: Land cover map of Kosofe LGA in 2002.

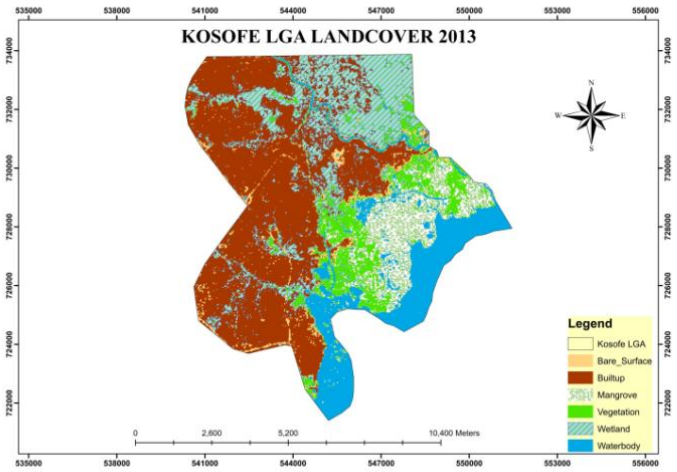


Figure 11: Land cover Map of Kosofe LGA in 2013.

4.4 Longitudinal and Cross Sections

Profiles for the surface were generated to show the change in elevation of the surface. Figure 12 shows the longitudinal section of Kosofe LGA, it extended from the north end of the study area down towards the Lagos Lagoon. Figure 13 shows the cross sectional profiles from the western end of the study area towards Ogun river, likewise the profile from the eastern end of the study area towards Ogun river is also shown in Figure 13 and Figure 14. The profiles were generated from 3D line features such as triangulated irregular network (TIN), or terrain dataset surface drawn over the surface. The surface is rather irregular which depicts that water would collect on the surface rather than flowing, this explains why issues of flooding arise here.

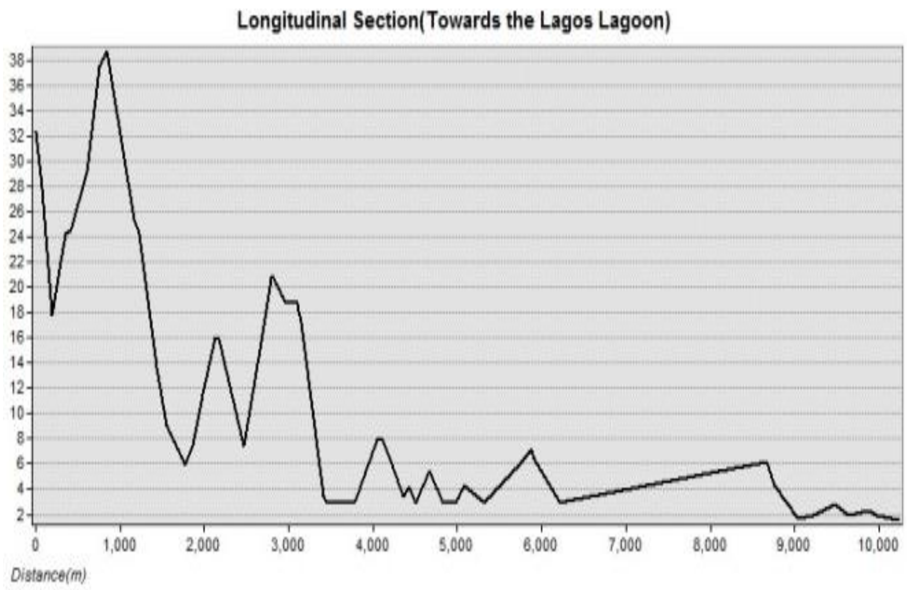


Figure 12: Longitudinal Sections.

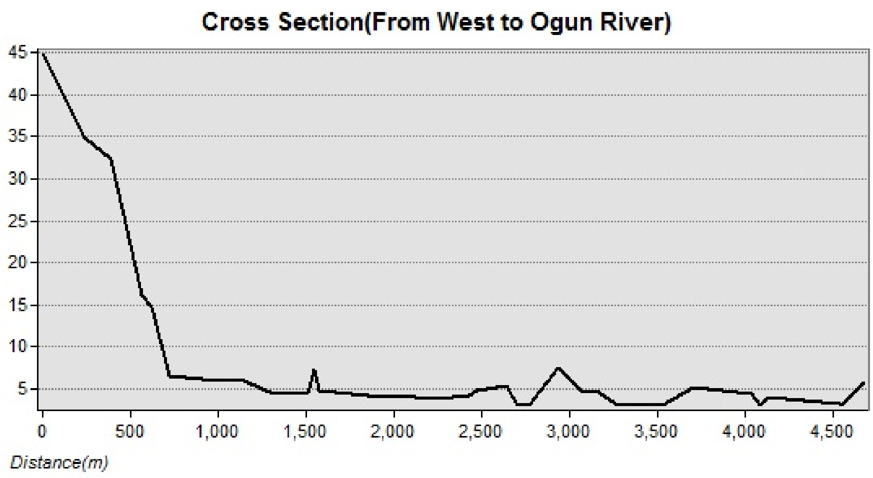


Figure 13: Cross section BB.

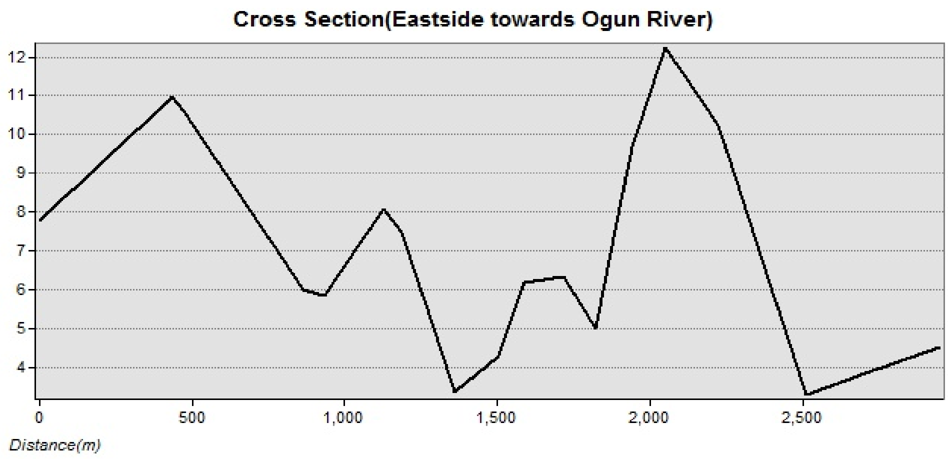


Figure 14: Cross section CC.

4.4 Vulnerability Assessment and Mapping

A vulnerability map gives the precise location of sites where people, the natural environment or property are at risk due to a potentially catastrophic event that could result in death, injury, pollution or other destruction. Figure 15 - Figure 17 below shows the vulnerability map of the study area for different scenarios, which depicts the water level due to rainfall.

The map shows areas like Magodo, Olowora, Shangisha, Opamore, Onikosi as less vulnerable or safe zones to flooding within Kosofe LGA for normal rainfall scenario but vulnerable when the rainfall becomes continuous thus leading to a worst case scenario and ultimately a flood disaster.

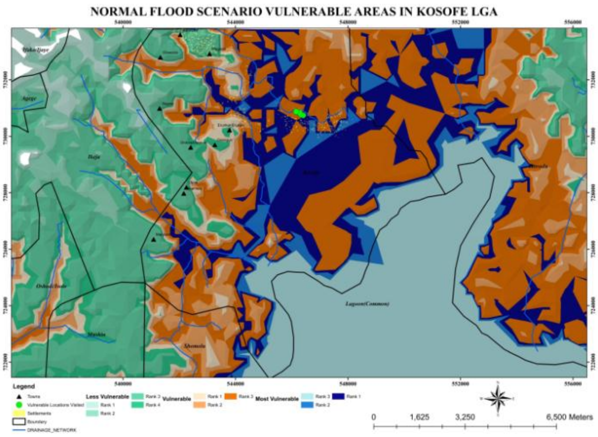


Figure 15: Vulnerability Map for Normal Flood Scenario.

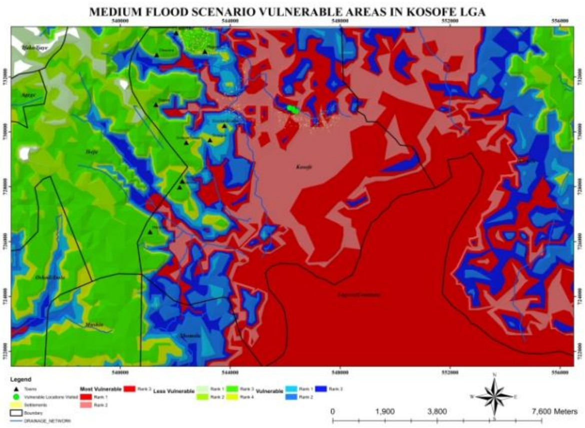


Figure 16: Vulnerability Map for Medium Flood Scenario.

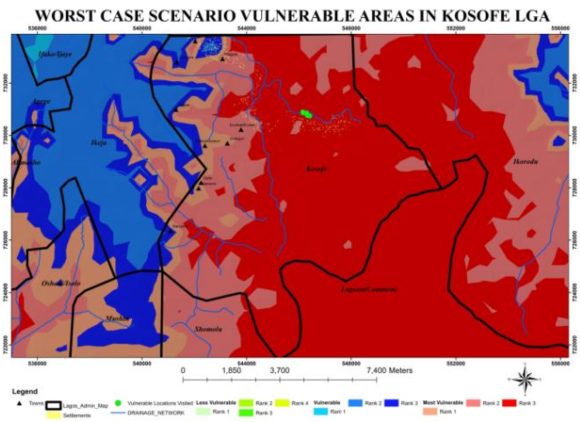


Figure 17: Vulnerability Map of Worst Flood Scenario.

The implication of the maps produced is that any location identified or categorized can be acted upon by the necessary government agencies in a bid to mitigate the flood hazard and adequate precautionary measures taken to guarantee effective response, quick recovery and effective prevention (See figure 18 below for chart statistics).

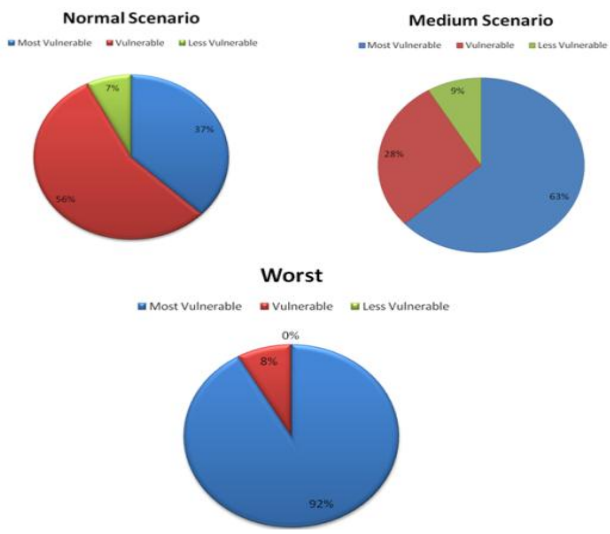


Figure 18: Percentage of the three flood scenarios.

Table 5 below gives a summary of the area covered by the vulnerability scales for the different flood scenarios identified in the study area. Figure 18 also depicts the percentage spread of these scenarios. It implies that naturally Kosofe LGA is vulnerable to flood which could largely be as a result of the presence of the Ogun river that flows across it and the terrain of the area which is irregular, thus any little increase in the water level of the river makes it very vulnerable to flood disasters as seen in the percentage spread shown below. However, we could still identify some safe areas where we have normal and medium flood scenarios, areas like Magodo, Olowora, Shangisha, Opamore, Onikosi, Maryland, Ojota, Ojodu Berger and a few other communities.

Table 5: Area covered by the vulnerability scales.

Scenarios	Most Vulnerable (km^2)	Vulnerable (km^2)	Less Vulnerable (km^2)
Normal	18.6366	27.8390	3.7340
Medium	31.7958	14.1270	4.2868
Worst	46.0966	4.1130	0.0000

From the Table 54 above normal regime had 3.734km^2 for less vulnerable, 27.839km^2 for vulnerable and 18.637km^2 for most vulnerable. Similarly, medium regime had 4.287km^2 for less vulnerable, 14.127km^2 for vulnerable and 31.796km^2 for most vulnerable. Lastly, worst regime has 0.000km^2 for less vulnerable, 4.113km^2 for vulnerable and 46.097km^2 for most vulnerable. The average difference in area covered between normal, medium and worst regime for most vulnerable is approximately 14,000km^2.

4.5 Caesar Flood Analysis

SRTM DEM and Flow/ Discharge are the two major data inputted into the model in a bid to simulate the flood along Ogun River channel. The flow/discharge was a 42 years, hourly water discharge data which was increased accordingly and it resulted in three flow regimes. Figure 19 - Figure 21 shows flood extent maps produced for these three flow regimes represented as high, medium and low flow respectively.

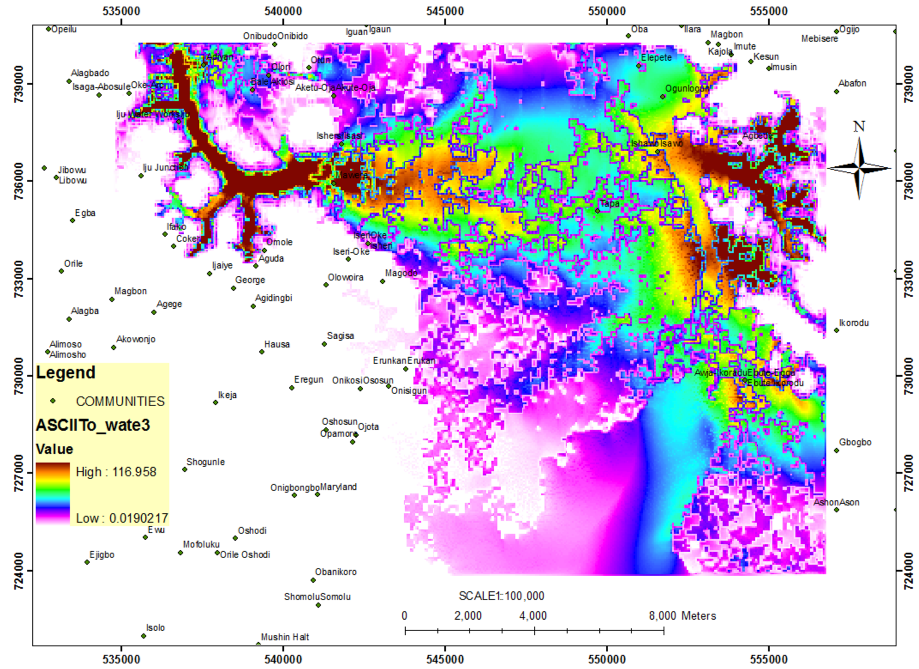


Figure 19: Flood extent map for high flow.

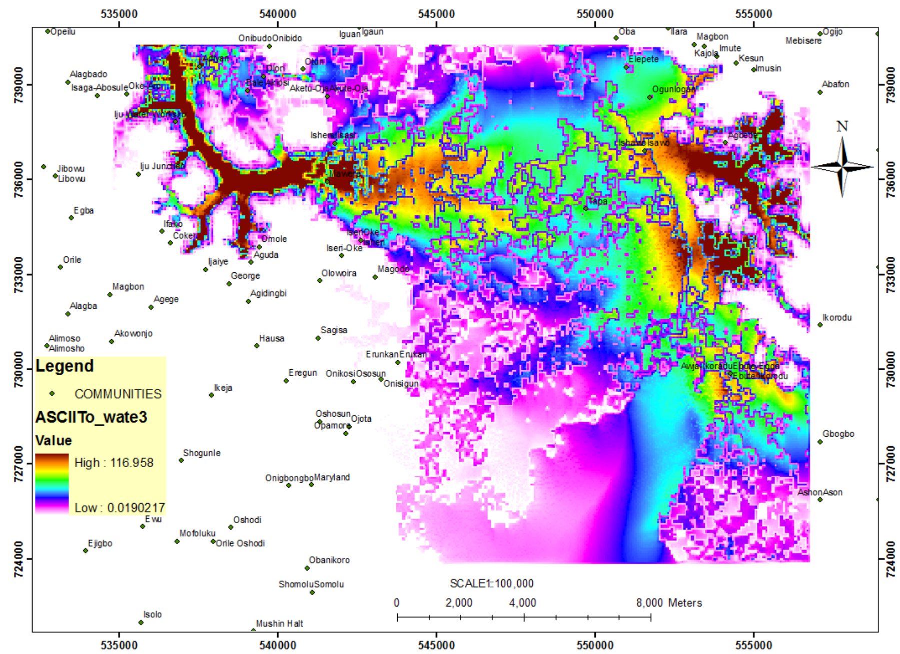


Figure 20: Flood extent map for medium flow

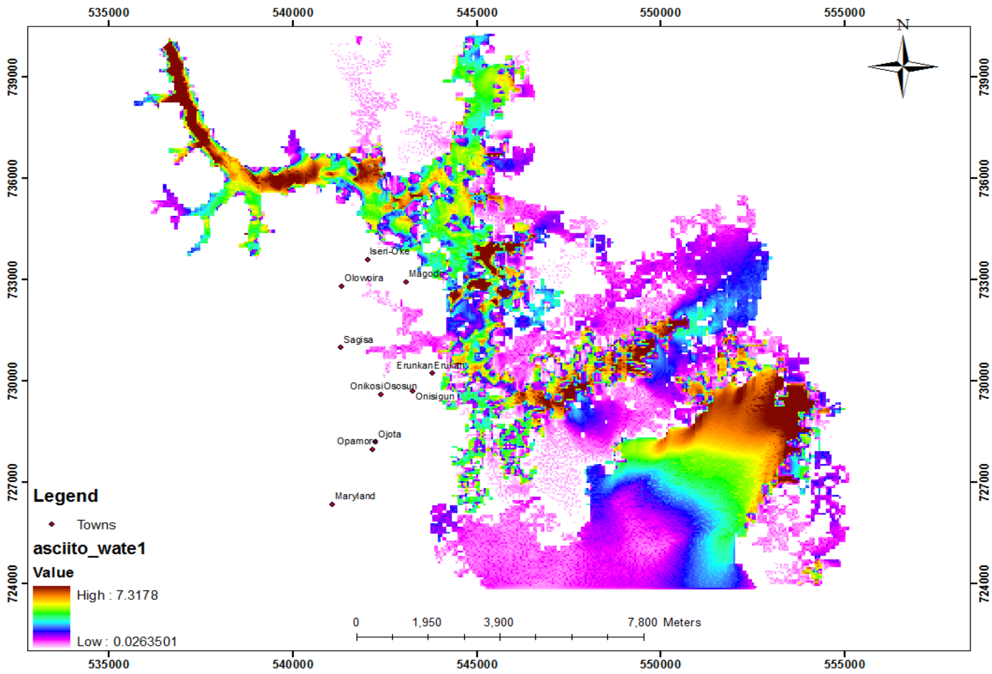


Figure 21: Flood extent map for normal flow

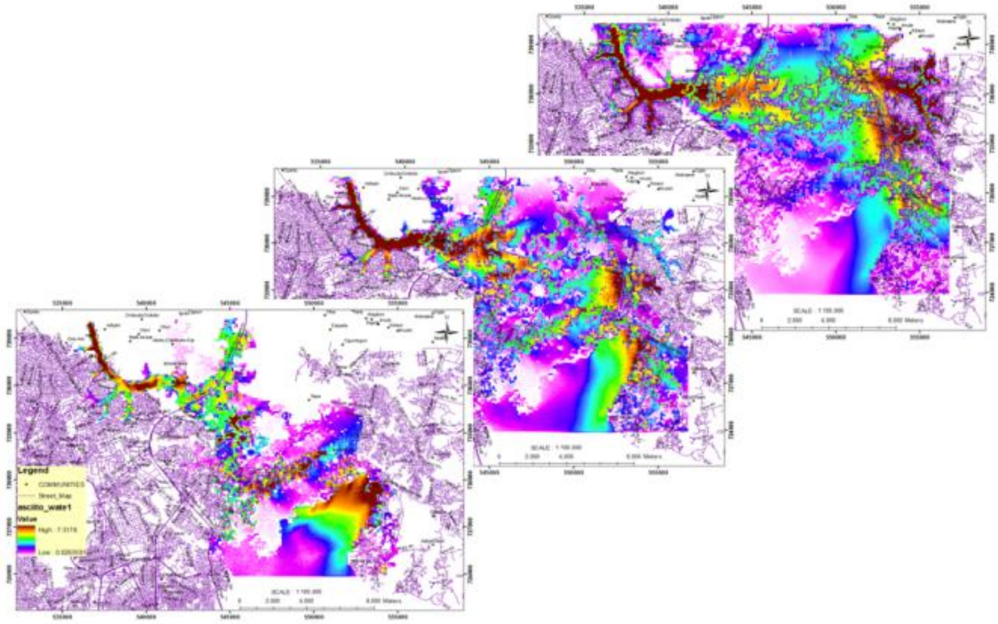


Figure 22: Shows vulnerability map for normal, medium and high flow regimes in ascending order.

4.6 Analysis of Infrastructures at Risk

The analysis of the buildings at risk as shown in Figure 27 - Figure 28 and Table 6 denotes that the higher the flow the greater the buildings at risk and vice versa. Table 5 below shows the street flooded as a result of the flows. Figure 27 - Figure 28 depicts flooding along the major road due to high flow from River Ogun in Kosofe LGA.

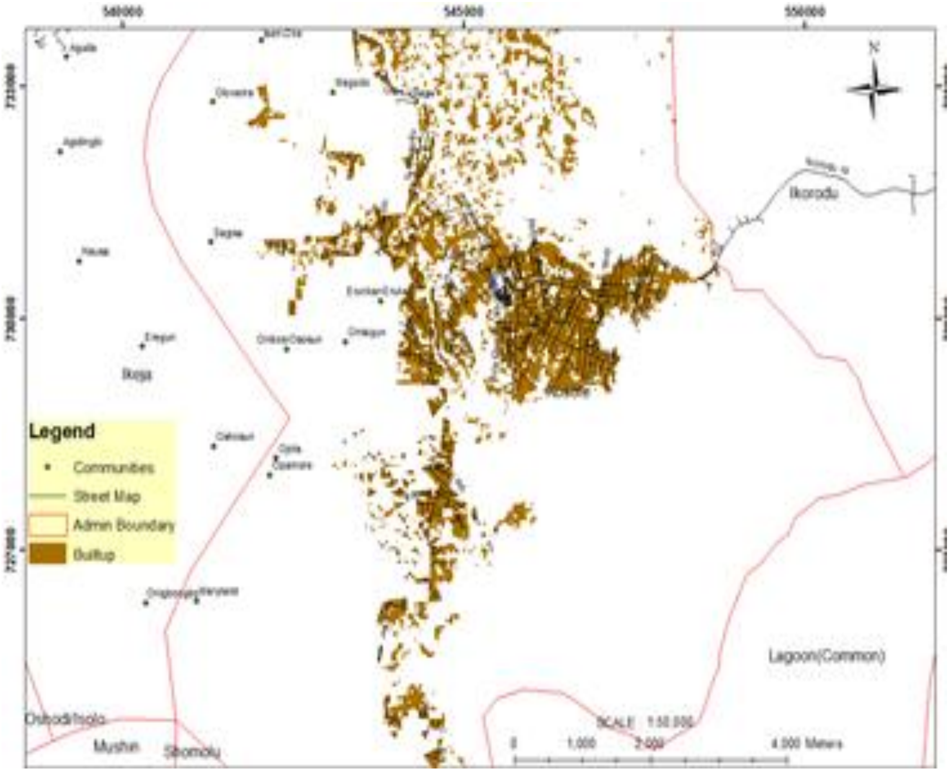


Figure 23: Shows infrastructures at risk during high flow.

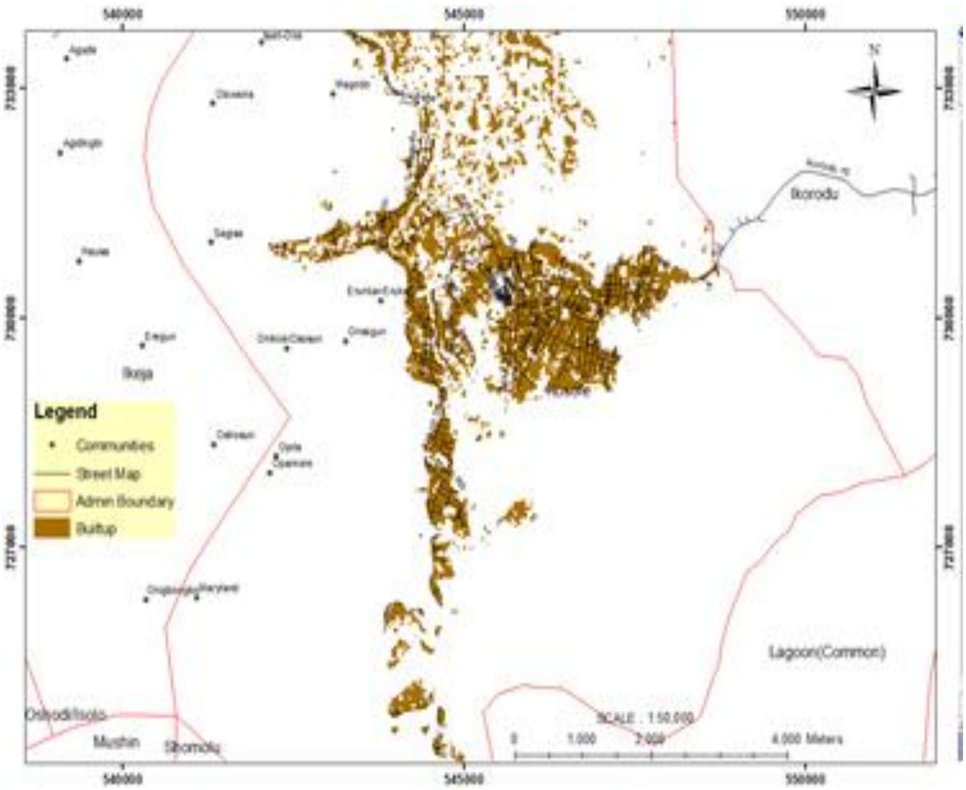


Figure 24: Shows infrastructures at risk during medium flow.

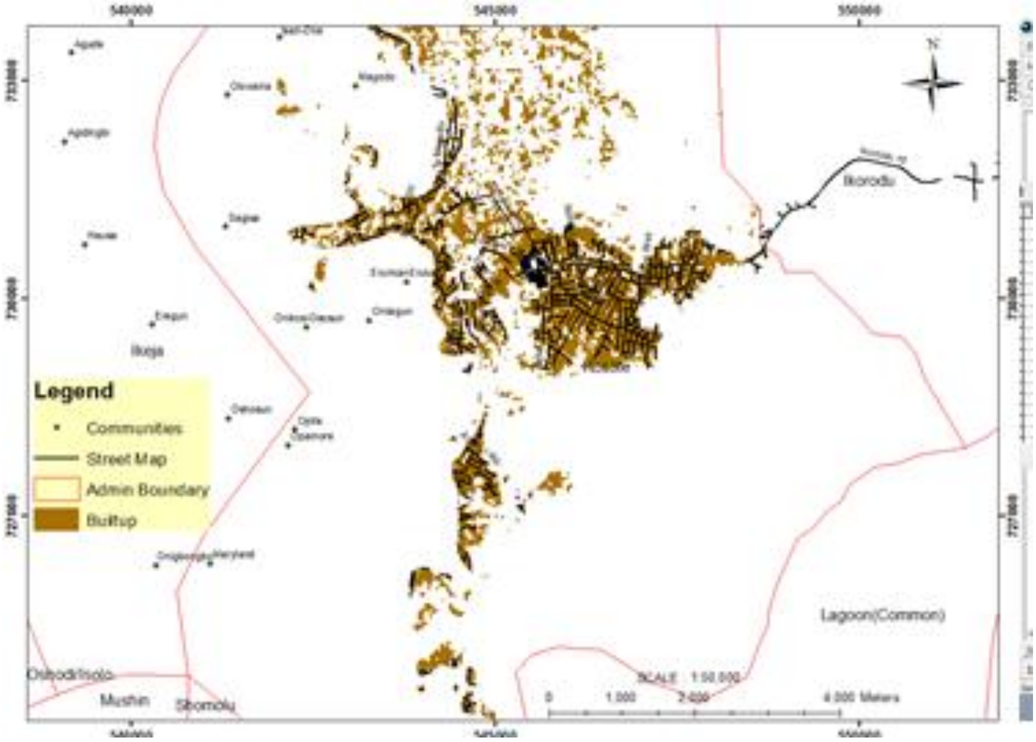
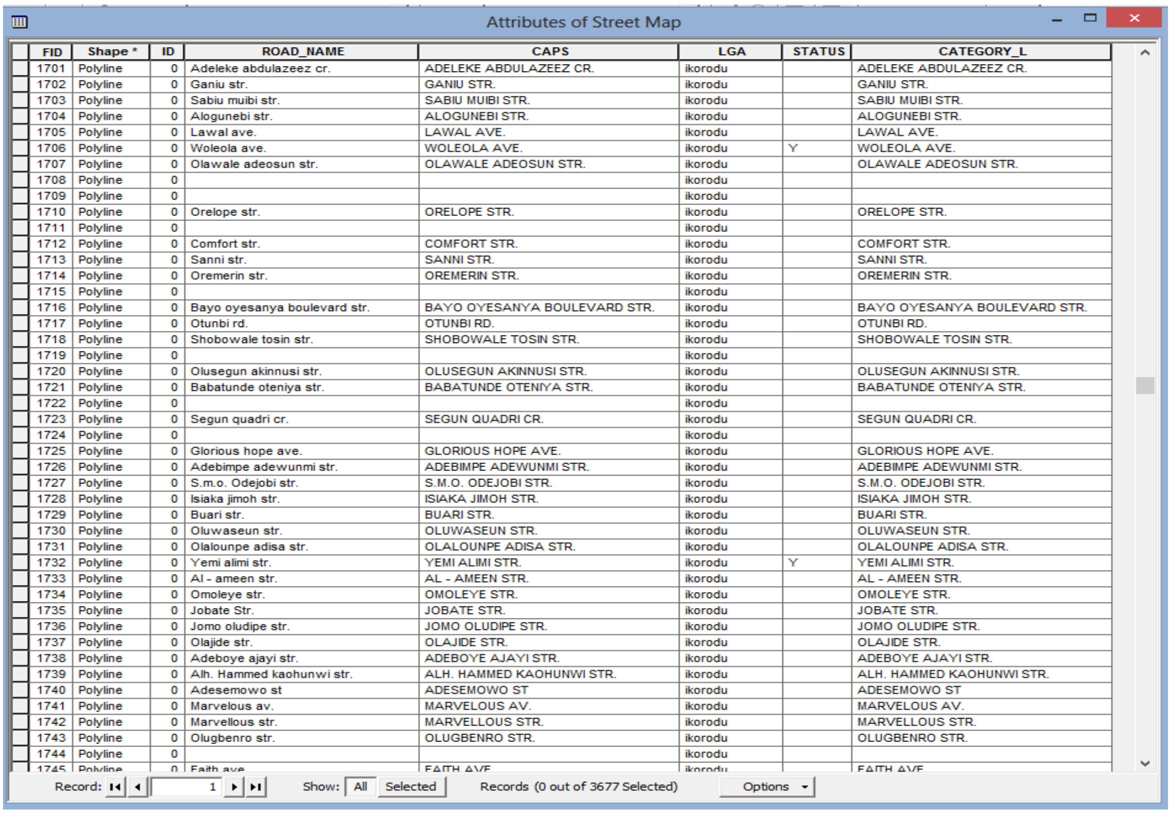


Figure 25: Shows infrastructures at risk during normal flow.

Table 6: Shows infrastructures at risk during different flow regimes.

Flow Regime	Discharge (M^3/Hr)	Built Up Area At Risk (Km^2)
High	100,000	8.95
Medium	10,000	8.21
Low	1,000	7.88

Figure 26: Shows flooding due to high flow in Kosofe LGA.



Attributes of Street Map

FID	Shape *	ID	ROAD_NAME	CAPS	LGA	STATUS	CATEGORY_L
1701	Polyline	0	Adeleke abdulazeez cr.	ADELEKE ABDULAZEEZ CR.	ikorodu		ADELEKE ABDULAZEEZ CR.
1702	Polyline	0	Ganiu str.	GANIU STR.	ikorodu		GANIU STR.
1703	Polyline	0	Sabiu muibi str.	SABIU MUIBI STR.	ikorodu		SABIU MUIBI STR.
1704	Polyline	0	Alogunebi str.	ALOGUNEBI STR.	ikorodu		ALOGUNEBI STR.
1705	Polyline	0	Lawal ave.	LAWAL AVE.	ikorodu		LAWAL AVE.
1706	Polyline	0	Woleola ave.	WOLEOLA AVE.	ikorodu	Y	WOLEOLA AVE.
1707	Polyline	0	Olawale adeosun str.	OLAWALE ADEOSUN STR.	ikorodu		OLAWALE ADEOSUN STR.
1708	Polyline	0			ikorodu		
1709	Polyline	0			ikorodu		
1710	Polyline	0	Orelope str.	ORELOPE STR.	ikorodu		ORELOPE STR.
1711	Polyline	0			ikorodu		
1712	Polyline	0	Comfort str.	COMFORT STR.	ikorodu		COMFORT STR.
1713	Polyline	0	Sanni str.	SANNI STR.	ikorodu		SANNI STR.
1714	Polyline	0	Oremerin str.	OREMERIN STR.	ikorodu		OREMERIN STR.
1715	Polyline	0			ikorodu		
1716	Polyline	0	Bayo oyesanya boulevard str.	BAYO OYESANYA BOULEVARD STR.	ikorodu		BAYO OYESANYA BOULEVARD STR.
1717	Polyline	0	Otunbi rd.	OTUNBI RD.	ikorodu		OTUNBI RD.
1718	Polyline	0	Shobowale tosin str.	SHOBOWALE TOSIN STR.	ikorodu		SHOBOWALE TOSIN STR.
1719	Polyline	0			ikorodu		
1720	Polyline	0	Olusegun akinnusi str.	OLUSEGUN AKINNUSI STR.	ikorodu		OLUSEGUN AKINNUSI STR.
1721	Polyline	0	Babatunde oteniya str.	BABATUNDE OTENIYA STR.	ikorodu		BABATUNDE OTENIYA STR.
1722	Polyline	0			ikorodu		
1723	Polyline	0	Segun quadri cr.	SEGUN QUADRI CR.	ikorodu		SEGUN QUADRI CR.
1724	Polyline	0			ikorodu		
1725	Polyline	0	Glorious hope ave.	GLORIOUS HOPE AVE.	ikorodu		GLORIOUS HOPE AVE.
1726	Polyline	0	Adebimpe adewunmi str.	ADEBIMPE ADEWUNMI STR.	ikorodu		ADEBIMPE ADEWUNMI STR.
1727	Polyline	0	S.m.o. Odejobi str.	S.M.O. ODEJOBI STR.	ikorodu		S.M.O. ODEJOBI STR.
1728	Polyline	0	Isiaka jimoh str.	ISIAKA JIMOH STR.	ikorodu		ISIAKA JIMOH STR.
1729	Polyline	0	Buari str.	BUARI STR.	ikorodu		BUARI STR.
1730	Polyline	0	Oluwaseun str.	OLUWASEUN STR.	ikorodu		OLUWASEUN STR.
1731	Polyline	0	Olalounpe adisa str.	OLALOUNPE ADISA STR.	ikorodu		OLALOUNPE ADISA STR.
1732	Polyline	0	Yemi alimi str.	YEMI ALIMI STR.	ikorodu	Y	YEMI ALIMI STR.
1733	Polyline	0	Al - ameen str.	AL - AMEEN STR.	ikorodu		AL - AMEEN STR.
1734	Polyline	0	Omoleye str.	OMOLEYE STR.	ikorodu		OMOLEYE STR.
1735	Polyline	0	Jobate Str.	JOBATE STR.	ikorodu		JOBATE STR.
1736	Polyline	0	Jomo oludipe str.	JOMO OLUDIPE STR.	ikorodu		JOMO OLUDIPE STR.
1737	Polyline	0	Olajide str.	OLAJIDE STR.	ikorodu		OLAJIDE STR.
1738	Polyline	0	Adeboye ajayi str.	ADEBOYE AJAYI STR.	ikorodu		ADEBOYE AJAYI STR.
1739	Polyline	0	Alh. Hammed kaohunwi str.	ALH. HAMMED KAOHUNWI STR.	ikorodu		ALH. HAMMED KAOHUNWI STR.
1740	Polyline	0	Adesemowo st	ADESEMOWO ST	ikorodu		ADESEMOWO ST
1741	Polyline	0	Marvelous av.	MARVELOUS AV.	ikorodu		MARVELOUS AV.
1742	Polyline	0	Marvellous str.	MARVELLOUS STR.	ikorodu		MARVELLOUS STR.
1743	Polyline	0	Olugbenro str.	OLUGBENRO STR.	ikorodu		OLUGBENRO STR.
1744	Polyline	0			ikorodu		
1745	Polyline	0	Faith ave	FAITH AVE	ikorodu		FAITH AVE

Record: 1 Show: All Selected Records (0 out of 3677 Selected) Options

Figure 27: Shows the database of attribute information infrastructures within the study area.

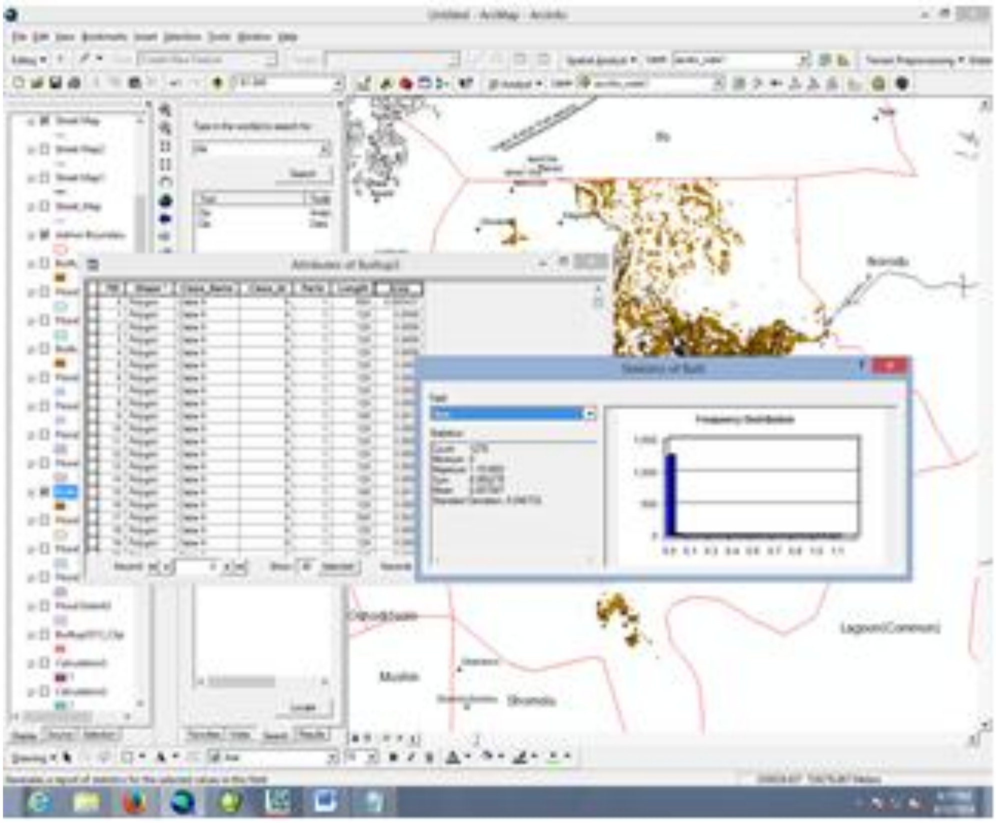


Figure 28: Infrastructures at risk during high flow in Kosofe LGA.

Vulnerability mapping can allow for improved communication about risks and what is threatened. It allows for better visual presentations and understanding of the risks and vulnerabilities so that policy makers can see where resources are needed for protection of these areas. Such maps will allow them to decide on mitigating measures to prevent or reduce loss of life, injury and environmental consequences before a disaster occurs. An important aspect of vulnerability assessment based on risk maps is defining and limiting the area affected by one or more risks. The area to be mapped needs to encompass the entire area where a risk can affect the natural environment to be protected or developed sites whether it be a houses, an apartments, commercial sites, public facilities and city infrastructure. Maps made after a disaster can assist in defining risk areas that were not fully understood or defined prior to the disaster. Historical information is important for determining the extent of the area to be mapped.

5.0 CONCLUSION

Flooding poses a continuous and tremendous threat to residents of Kosofe LGA because of its severity, magnitude of its impact and frequency of occurrence and it calls for a prompt and systematic management of the disaster. From the results of the study a number of findings have been identified which are that:

1. There are land cover changes within the study area, which shows that the estuarine lands are being depleted due to human encroachment and urbanization thus increasing the built up area. However, the environmental consequence of this is increased flooding, disruption in the associated marine processes, food web and biodiversity among others.
2. The CAESAR model, Bath-tub Method and the remote sensing techniques are very useful tools in the identification, delineation and can offer a genuine control of flood of whatever form.
3. Moreso, as long as flood exists in an area; infrastructures remain at high risk, as such the higher the flood flow the greater the number and extent of infrastructures affected.
4. Kosofe LGA is prone to flooding and the major cause of the flood is continuous rainfall which subsequently takes its toll on the major water body (River Ogun) and the adjoining low lying areas.
5. Geo-information technology was of great advantage in the generation of the vulnerability maps because the output from various platforms were embedded into the GIS environment from which all the various flood regimes and vulnerability scenarios were produced.

5.1 Recommendations

The following recommendations are proffered for effective management of flooding in the environment:

1. Relevant agencies should constantly to monitor our waterways so as to prevent people from putting up structures along the waterways especially the flood prone areas and creating reasonable setbacks.
2. Building approval plans should be charted as designed so as to discourage incessant building construction along waterways using the GIS.
3. Drainages should be frequently de-silted and deteriorated ones maintained to enhance free flow of water along the drainages.
4. An effective meteorological centre should be set up such that the acquired datasets could be utilized to provide a realistic early warning system.
5. Research of this nature should be encouraged with regular data collection i.e. regular measurement of tide levels and flow rates in the river systems and lagoon such that the hydraulic models of the whole system can be carried out.
6. River channels should be dredged as often as possible as this would remove debris deposited and create space for more water to flow.
7. Waste management enlightenment programs should be encouraged so as to educate the populace on the side effects of dumping waste in drainages during rainfall.

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