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Geospatial Assessment and Hydrodynamic Modelling of Flood Risk in the Oguta Lake Catchment, Imo State, Nigeria.

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Abstract

Flooding has become one of the most destructive environmental hazards affecting human settlements, infrastructure, and ecosystems worldwide, with increasing frequency due to rapid urbanization, land-use changes, and climate variability. This study assessed the temporal dynamics of land use/land cover, flood hazard and community vulnerability within the Oguta Lake catchment of Imo State, Nigeria, using an integrated remote-sensing, Geographic Information System (GIS), Global Positioning System (GPS) and hydrodynamic-modelling framework. The study specifically evaluated land-use/land-cover changes between 2000 and 2015; examined the influence of terrain, rainfall, drainage and land-use characteristics on flood susceptibility; simulated flood extent, depth and velocity under different return-period events; and delineated communities and areas exposed to varying levels of flood hazard and vulnerability. Multi-temporal Landsat imagery, Shuttle Radar Topography Mission (SRTM) elevation data, rainfall information, soil and administrative datasets, field observations and GPS coordinates were integrated for the analysis. Importantly, the satellite sensors corresponding to the three observation years are Landsat 5 Thematic Mapper (TM) for 1985, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2000, and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for 2015; the original description of all three datasets as ETM+ should therefore be corrected. Landsat imagery was processed using radiometric enhancement, band combinations, band ratios, density slicing, supervised classification and post-classification change detection, while SRTM-derived elevation, slope, aspect, curvature and flow-direction information were integrated within GIS. Rainfall frequency analysis and Snyder's Synthetic Unit Hydrograph were used to derive design flood hydrographs for 2-, 5-, 10- and 25-year return periods, which were subsequently simulated using SOBEK hydrodynamic modelling. The results demonstrated substantial landscape transformation during the study period. Built-up land increased by approximately 1.507 km² between 1985 and 2000 and by a further 1.020 km² between 2000 and 2015, while forest/vegetation cover decreased markedly, with reported reductions of approximately 2.997 km² and 0.925 km² across the corresponding periods. Non-urban land, including bare land and floodplain areas, also declined. Water-body change detection showed that 2.84% of water-body area was converted to land between 1985 and 2000, compared with 0.72% between 2000 and 2015, while 0.18% and 0.35%, respectively, underwent conversion from land to water. Hydrodynamic simulations showed increasing inundation with increasing flood magnitude. Design rainfall increased from 133 mm for the 2-year event to 251 mm for the 25-year event, with corresponding peak discharges increasing from 128.92 to 313.26 m³/s. Simulated flood depth increased approximately from 0.70 m to 1.30 m, while maximum

flood velocity increased from 2.44 m/s for the 2-year event to 2.77 m/s for the 25-year event. The 25-year event generated the greatest inundation extent, although comparison with observed flood information indicated a substantial model–observation difference of approximately 43.07 km². Vulnerability analysis identified Orsuobodo, Oguta I and Oguta II among the communities within the extreme flood-risk category, collectively accounting for approximately 18.97% of the assessed area, while Nkwesi occurred within the high-vulnerability category. The principal implication is that flood risk within the Oguta Lake catchment cannot be attributed to rainfall alone. The progressive conversion of vegetation, wetlands, floodplain and water-associated land into built-up surfaces has reduced natural flood-storage capacity and altered runoff and drainage behaviour, while the low-lying terrain surrounding Oguta Lake and the Orashi River increases exposure to overbank inundation. The study therefore demonstrates the value of combining multi-temporal Earth observation, terrain analysis, GIS and hydrodynamic simulation for spatially explicit flood-risk assessment in data-constrained environments. It concludes that continued encroachment into floodplains and wetlands, together with increasing settlement exposure, is likely to sustain or intensify flood impacts in the Oguta catchment unless development control, floodplain protection, targeted early-warning measures and evidence-based spatial planning are strengthened.

Keywords: Flood risk, Mapping, Geographic Information System (GIS), Remote Sensing, Global Positioning System (GPS), Hydrological Modelling, Landsat ETM+, Digital Elevation Model, Change Detection, Flood Vulnerability, Oguta Lake, and Rainfall Variability.

1. INTRODUCTION

Flooding is one of the most widespread and damaging environmental hazards, affecting human settlements, infrastructure, agricultural systems, ecosystems and local economies. Flood impacts arise not simply from the occurrence of excess water but from the interaction between hydrological extremes and the exposure and vulnerability of people and assets occupying flood-prone environments. Consequently, an area with relatively moderate physical flood hazard can experience severe losses when settlement expansion, inadequate drainage, weak land-use control and high population exposure coincide. Flooding ranks among the most destructive natural hazards globally, recurring frequently in riverine and coastal floodplains and affecting millions of people each year. Smith and Ward (1998) conceptualised flood risk as the probability that a severe hazardous event will occur unexpectedly and inflict adverse consequences on human populations and their livelihoods. The increasing frequency of flood events reported in mass media (ranging from minor, quickly forgotten incidents to catastrophic episodes that linger in collective memory) reflects a growing global exposure. A stark example is the massive flooding that struck Pakistan in 2010, which claimed approximately 1,200 lives and affected over 14 million people (UN-OCHA, 2010). Globally, flood risk continues to intensify in tandem with rapid population growth, which drives escalating demand for settlement space and food resources in vulnerable areas.

Several scholars have offered definitions that underscore the physical and societal dimensions of flooding. Ceylon (2004) described a flood as a natural event with profound consequences for people and the environment, involving the overflow of a large volume of water onto normally dry land due to heavy rainfall or the exceedance of a water body's capacity. Nwafor (2006) defined it as a natural hazard arising from an extreme hydrological (runoff) event, while Abam (2006) characterised a flood as a volume of water that enters and occupies a stream channel and its floodplain so rapidly that it prevents timely mitigation of damage to economic activities, infrastructure, and homes. Flooding may also result from the failure of engineered water-containment structures such as dams, reservoirs, and pumping systems. Across the hazard literature, floods are consistently regarded as one of the natural phenomena that exact the heaviest toll on human societies (Blaikie et al., 1994; Ward, 1978). According to Smith (2001), floods claim approximately 20,000 lives and adversely affect around 75 million people worldwide each year. The mere presence of excess water is not the core problem; rather, the impacts of flooding manifest when floodwaters interact negatively with natural and human-made environments, causing loss of life, injury, property damage, and social and economic disruption.

Floods are also increasingly triggered or exacerbated by anthropogenic activities and human interventions in natural processes. Key drivers include urbanisation, population growth, uncontrolled and uncoordinated suburban development, encroachment on floodplains, swamps, and natural drainage channels, deforestation, and climate change (Balabanova & Vassilev, 2010; Kwale & Kondoh, 2008; European Commission, 2007). Over recent decades, floods have consistently been the dominant natural disaster type in terms of frequency, especially in South East Asia, Africa, and South America. Notable events include floods that affected over 9 million people in Bangladesh, about 30 million in India, and millions more in Malaysia, Indonesia, Pakistan, and the Philippines (ADB, 2007). In January 2004, 84 people died in Brazil as a result of flood-related events (Tucci, 2005).

African cities have experienced a series of extreme flood disasters. In February and March 2000, heavy rainfall and a cyclone caused the worst floods in Mozambique in 50 years, devastating the capital Maputo and directly affecting upwards of one million people (Action Aid, 2006). In 2002, unusually warm Indian Ocean temperatures generated heavy rains that killed over 112 people in East Africa; floods and mudslides displaced tens of thousands in Rwanda, Kenya, Burundi, Tanzania, and Uganda, with Rwanda suffering the highest death toll (Action Aid, 2006). In August 2006, the overflowing Dechatu River struck Dire Dawa town in eastern Ethiopia at night, drowning 129 people and destroying 220 homes (Demessie, 2007).

Flooding is a recurrent environmental hazard in Nigeria, affecting both rural and urban environments. Nigerian flood impacts have been associated with intense rainfall, river overflow, inadequate drainage, settlement expansion, environmental degradation and occupation of flood-prone locations. A recent review of flooding in Nigeria identified remote sensing and GIS as among the most commonly used approaches for flood mapping and modelling, while also highlighting continuing challenges associated with data availability and modelling practice (Umar & Gray, 2023). In Nigeria, flooding represents the most prevalent environmental hazard (Etuonovbe, 2011). The country's first major recorded flood occurred in Ibadan in 1948, and the menace has since spread across numerous states. Severe flood disasters have been documented in Ibadan (1985, 1987, 1990, 2011), Oshogbo (1992, 1996, 2000), Yobe (2000), Akure (1996, 2000, 2002, 2004, 2006), Kano (2006), Taraba (2005), and the coastal cities of Lagos, Port Harcourt, Calabar, Uyo, and Warri, among others, with cumulative losses of lives and properties worth millions of naira (Adeoye et al., 2009). Urban centres are particularly susceptible to recurrent flooding, not solely because of heavy rainfall but also because of extensive changes in land cover that accompany urban growth (Etuonovbe, 2011). Urbanisation exacerbates flooding by limiting infiltration and obstructing natural drainage; large portions of the urban environment are covered with roofs, roads, and pavements that reduce permeable surfaces and constrict channels (Action Aid, 2006).

Within Imo State, flooding is a recurrent phenomenon in many localities, most notably in Oguta town in Oguta Local Government Area, where it occurs predominantly during the rainy season or at high tide. Flooding in Oguta is associated with the rainy season and the hydrological behaviour of the lake and connected drainage system. The study identifies rapid land-use transformation and population growth around Oguta Lake, together with development within swamps, floodplains and natural drainage corridors, as factors that increase flood hazard.

The physical setting is particularly important because low-lying areas surrounding Oguta Lake and the Orashi River are susceptible to water accumulation and overbank inundation. The hydrodynamic analysis in the study indicates that flood depth is strongly influenced by elevation and flood magnitude and that the areas surrounding Oguta Lake and the Orashi River experience inundation exceeding 1 m under some simulated conditions. Rapid land-use transformation and population growth around Oguta Lake have fuelled unregulated and uncoordinated development of suburbs, swamps, floodplains, and natural drainage corridors, thereby heightening the area's flood hazard. Given that flood risks are projected to intensify with further land-use change, there is an urgent need to delineate flood-prone zones to support effective mitigation. Reducing flood risk will depend heavily on the availability of detailed flood information and a clear understanding of areas likely to be affected during flood events. Consequently, modern geospatial techniques must be employed to develop tools that assist relevant authorities and relief agencies in identifying flood-prone areas and planning for future flood occurrences. This study employs remote sensing, Global Positioning System (GPS), and a digital elevation model (DEM) to demarcate flood-vulnerable zones around Oguta Lake. Key contributing factors, including elevation and land use, are explicitly considered in the analysis. The overarching aim of this research is to integrated geospatial and hydrodynamic assessment of flood risk, land-use change and vulnerability in the oguta lake catchment using remote sensing, gis, gps, and hydrological modelling.

1.1. Study Area

Oguta lake area of Imo State was chosen for the study. The study area lies between latitudes 5° 42′ 24″ N and 5° 50′ 33″ N and longitudes 6° 47′ 33″ E and 6° 59′ 25″ E. Oguta Lake is located in Oguta town, the administrative seat of Oguta L.G.A. of Imo State. Oguta Lake is the largest natural lake in the Imo state, Nigeria, within the equatorial rain forest region. It is important to the people of Oguta, Ezi-orsu, Nkwesi, Egwe, Egbuoma, Orsuobodo and Nnebukwu, as a source of water. 'Uhamiri' is the goddess of Oguta Lake. Oguta Lake served as a Biafran Army marine base during the Nigerian civil war. The maximum depth of the Lake is 8meters. See fig. 1.1 (a), 1.1(b) and 1.1(c). for study area.

Fig 1 MAP OF STUDY AREA SHOWING OGUTA LAKE ,

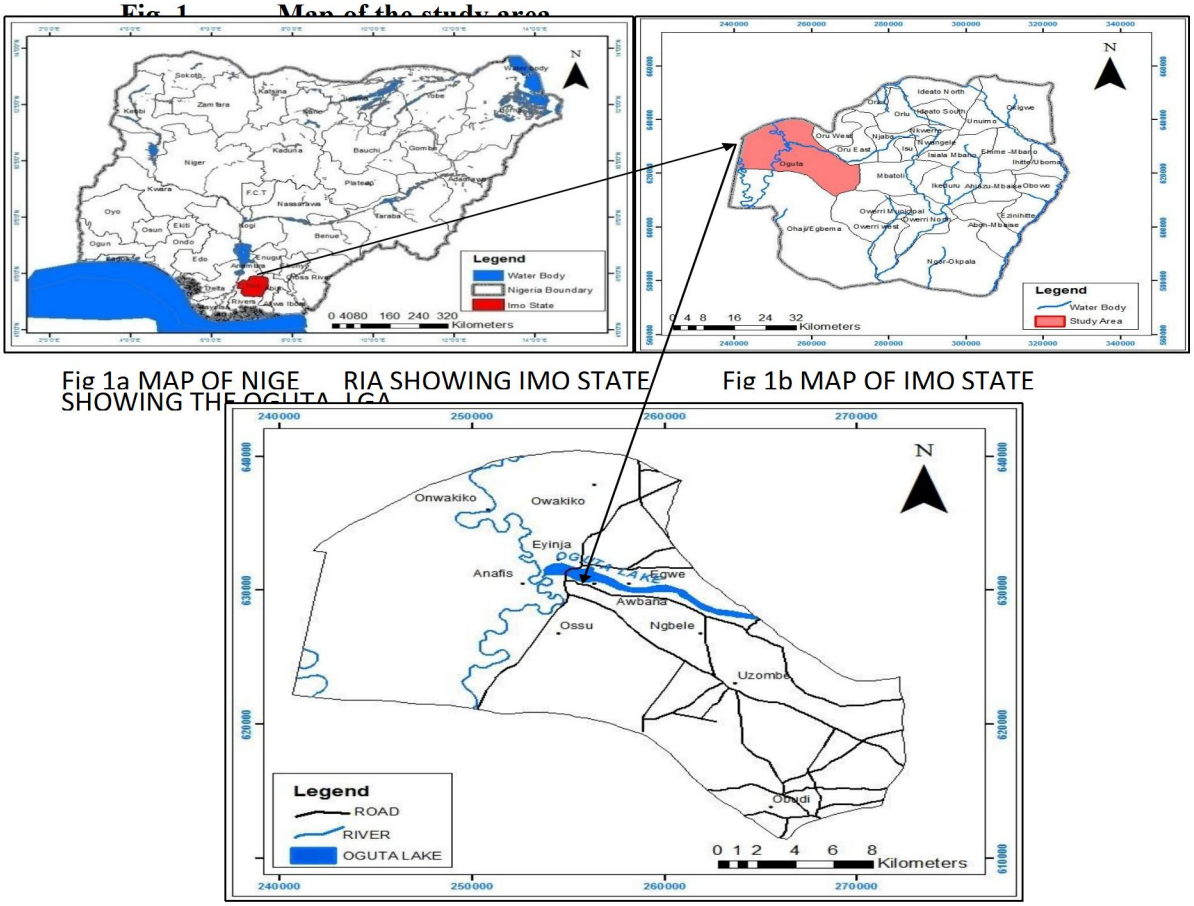


Fig 1a MAP OF NIGE RIA SHOWING IMO STATE SHOWING THE OGUTA LGA

Fig 1b MAP OF IMO STATE

2. LITERATURE REVIEW

2.1 Flood

A flood is defined by the Oxford English Dictionary as an overflowing or irruption of a great body of water over land in a built up area not usually submerged. Floods are natural phenomena, but they become a cause for serious concern when they exceed the coping capacities of affected communities, damaging lives and property. Globally floods are the most frequently occurring destructive natural event affecting both rural and urban settlements (Jha et al., 2012).

Flood risk Mapping

Area at risk of flooding can be dynamic in nature. With a changing level of development the nature and degree of risk also changes (Jha et al., 2012). Jha, et al., (2012) explained that flood risk increases mainly because of an increased level of exposure of the elements under threat. For example, there are occasions when infrastructure or other building are constructed in area already at risk, thereby automatically falling within a risk zone. There are also instances, when at the

time of construction, the assets and infrastructures are thought to be outside the risk region, but there are newer affects arising from changing land uses as urban development proceeds. These can include increased rates of runoff, lack of drainage system, lack of storage system, overwhelming amount of rain fall leading to over flow, and the channelization of rivers which may reduce the amount of discharge they can accommodate (Jeb et al., 2012). All these factors can increase the number of elements at risk of flooding in an area continuous updating and monitoring of risk maps is therefore, most important for proper flood risk management. Decision – makers need up to date information in order to allocate resources appropriately. It has been argued that, even without an increase in flood hazard over time, the impact of flooding has risen (and will continue to rise) because of the increase exposure of primary and secondary receptors (Jha et al., 2012).

2.2. Management and Control of Floods in Nigeria

The government of Nigeria are the primary initiators of measures for the management of flooding in Nigeria. Various institutions, policies and regulations have been set up by government to address issues relating to floods and activities that promote/influence flooding in Nigeria (Oladipo, 2010). They include;

2.3. National Erosion and Flood Control Policy (NEFCP), 2005

"The goal of the National erosion and flood control policy (NEFCP) of 2005 is to protect the environment from degradation loss of productive land and negative impacts of flood. Ensure coordinated and systematic measures in the management and control of the hazards of erosion and floods to reduce their impacts on the people and the environment" (Oladipo, 2010).

2.4. National Emergency Management Agency (NEMA)

A federal government agency that is responsible for co-ordinating, managing and controlling disaster related activities in the country (NEMA, 2011).

Since the inception of these various agencies, polices and regulations, the country's responses to flood risk management has still been mainly that of relief management after a flooding incident, even then, coordination of rescue operation have always been slow exacerbating the damage and loss in the aftermath of the event (NEMA, 2011; Job and Aggarwal, 2008). Part of this problem may be due to lack of technical expertise for handling environment issues and insufficient information on flood vulnerability of different parts of the country, hence, the need for introducing proven strategies for combating this menace.

2.5. Remote Sensing, GPS and GIS in Flood Risk Mapping and Management

Remote sensing is the technology that is used in gathering of these spatial information used for identifying, classifying, mapping, monitoring, planning, mitigation and management of natural disasters (Ishaya and Ifatimehin, 2009, Jeyaseelan, 1999). This technology has been used extensively in Asian and developing countries for agricultural, aviation, and environmental purposes (Ishaya and Ifatimehin, 2009).

For an effective flood risk management plan, it is becoming very important to provide flood risk maps that show different vulnerable areas and the potential adverse consequences of different flood risk map, information on important criteria for flood risk analysis including elevation, slope orientation, closeness of built up areas to drainages, drainage network and density, presence of buffers, extent of inundation, land cover / land use information, rainfall data, cultural practices as well as attitudes and perceptions are needed for mapping studies (Ishaya et al., 2009; Tanavud et al., 2004).

Remote sensing and GIS provide the tool for assessing these information (Auggel et al., 2003) and have proved to be an effective and perhaps suitable choice in flood hazard preparedness and reduction of potential risk. These digital maps must take into recognition the environmental factors leading to floods (Forte et al., 2006). The different data sets gotten from remote sensing can be integrated into Geographic Information System (GIS) to create map that shows vulnerability of a location to natural disaster such as flooding (Ishaya and Ifatimehin, 2009; Dewan et al., 2006).

3. METHODOLOGY

3.1. Data Acquisition Modeling and Processing

The following materials and data were acquired for this study: Digital Elevation Dataset from Shuttle Radar Topographical Mission (SRTM) downloaded from USGS explorer, remote sensing satellite imageries captured by moderate resolution imaging spectroradiometer (MODIS) on NASAS terra satellite. Imageries of 1985, 2000 and 2015 were captured. The spatial locations of some flooded communities were also acquired by the use of Garmin 72 GPS, administrative map from where political boundaries and soil map were digitized. Field work with GPS and notebook were also used to acquire and record the coordinates of the communities respectively. Others datasets are population data from Nigerian population commission information gathered from NIMET, NEMA, NIWA, ASFDCC publications and through social survey.

3.2. SRTM Data.

The *Shuttle Radar Topography Mission(*SRTM) of 90m resolution of the study area was extracted from Global land Cover Facility (GLCF). Figure 3.2 below shows the GLCF web site : http://glcf.umd.edu/data/srtm/

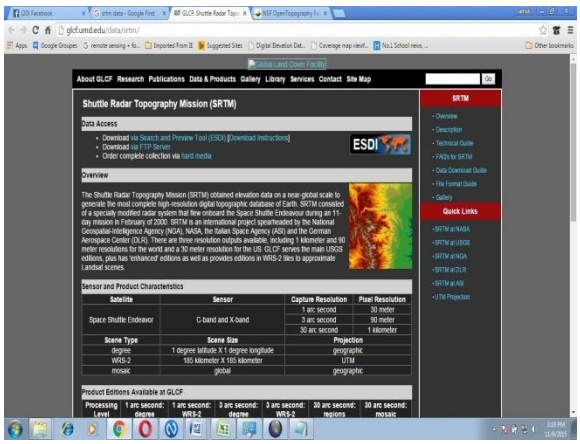


Figure 2: Global Land Cover Site (GLCF)

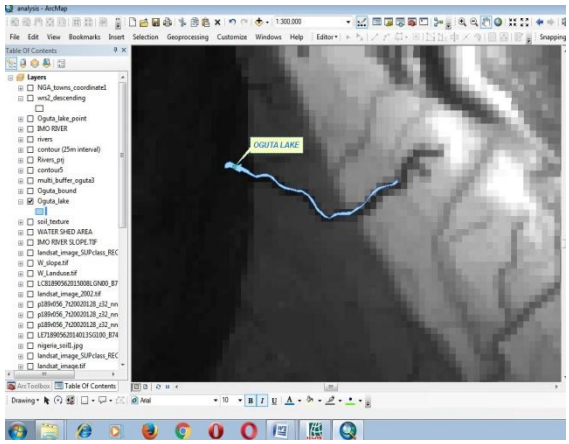
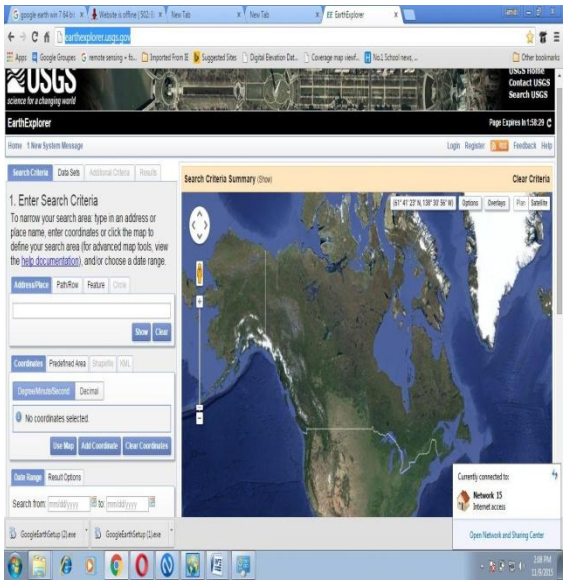


Figure 3: Display of SRTM data

The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA), NASA, the Italian Space Agency (ASI) and the German Aerospace Center (DLR). There are three resolution outputs available, including 1 kilometer and 90 meter resolutions for the world and a 30 meter resolution for the US.

3.3. Landsat Enhanced Thematic Mapper Plus (ETM+)

The multi-temporal Landsat imageries of the study area path 189 row 56 of 1985, 2000 and 2015 with 30 meters resolution were downloaded from USGS (United State Geological Survey) web site:http://earthexplorer.usgs.gov/See figure 4 below



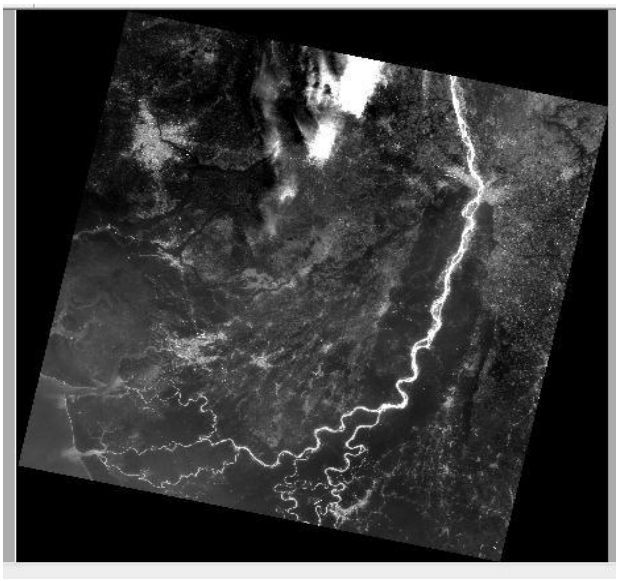


Fig. 4: web site of Landsat 7 ETM+ satellite imagery data acquisition Fig. 5: Landsat 7 ETM+ of scene of satellite imagery of the study area.

Landsat Enhanced Thematic Mapper Plus (ETM+) images consist of eight spectral bands with a spatial resolution of 30 meters for Bands 1 to 7. The resolution for Band 8 (panchromatic) is 15 meters. All bands can collect one of two gain settings (high or low) for increased radiometric sensitivity and dynamic range, while Band 6 collects both high and low gain for all scenes. Approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi)

Table 1 . Spectral resolution of Landsat ETM+ (Source: United State Geological Survey)

Enhanced Thematic Mapper Plus (ETM+)	**Landsat 7**	**Wavelength (mm)**	**Resolution(meters)**
	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.77-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	60 * (30)
	Band 7	2.09-2.35	30
	Band 8	.52-.90	15

4. DISCUSSION

4.1 Data Processing

In the execution of the work, a well analyzed input and output formats, and appropriate data structured models were carried out, using relevant data, software and hardware. Since, maps are produced by the combined efforts of many professions using a variety of technologies (Lo and Yeung, 2002). Typically the research process involves the following phases of work: image ratio, determination of radiometric threshold, image slicing, and cross tabulation using Ilwis academic software. Therefore, the input and output specifics used in the work are as explained below.

4.1.1 Selection of a single band in which water can be differentiated

This method can be applied when individual bands are selected in which water has a specific reflectance that does not spectrally overlap with other cover classes. Three different bands were used for each year. The landsat band 7, band 2 and band 4 were imported in ilwis academic software; the bands were radiometrically enhanced using linear Stretching method. the Digital Number of each feature class was carefully analyzed and recorded (See table below) . this method is to have a better knowledge of the band where the river have a high reflectance.

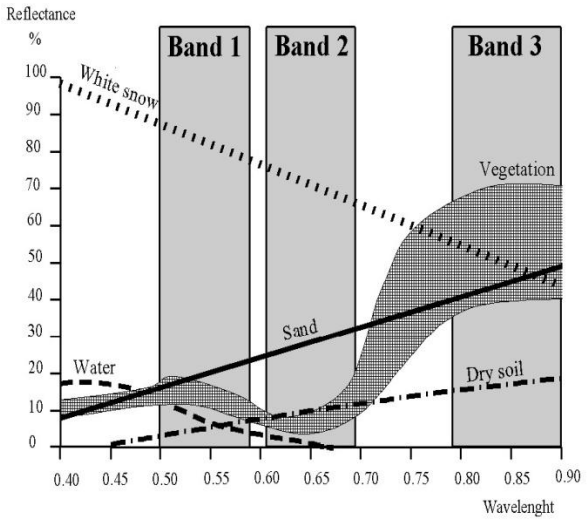


Fig. 6: Reflectance curves and spectral resolution

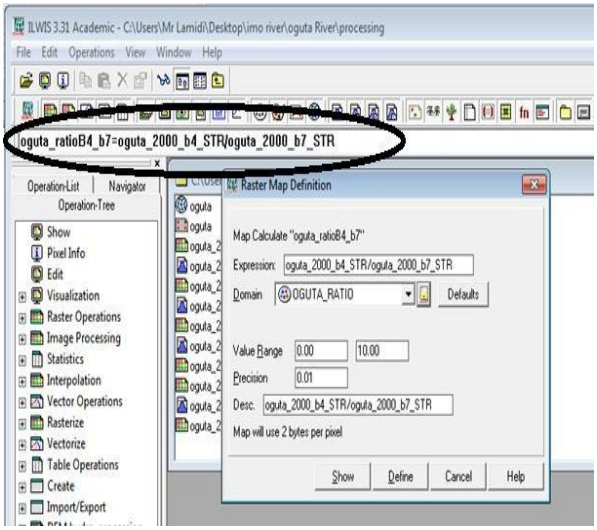


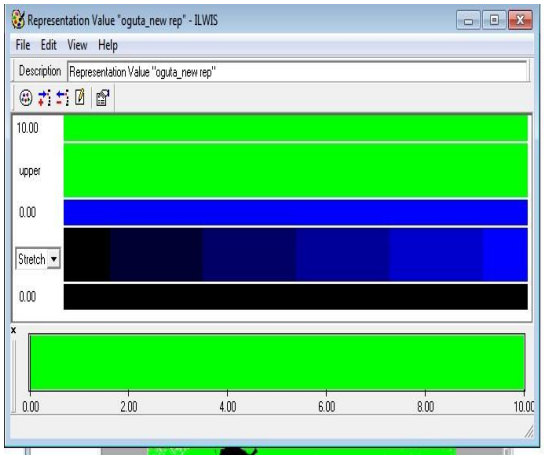
Fig. 7: band ratio parameter of Oguta Lake

a. Band ratio's

The preselected bands were combined to enhanced the radiometric resolution of Oguta Lake, the band ratio method was used to combine two bands among the preselected bands. The band ratios, are combinations of the individual bands. This method has the advantage that if spectral reflectances of cover types in one band are similar, the ratio of two bands can be used to differentiate them. Before the band ratios are made, it is important to get a good idea of the individual images. in this analysis band4 and band 7 were mostly used. The band ratio formula was wrote on ilwis command line: Output Band = Band4/band7 (see figure below)**.** the domain parameter was created to set the output display value within 0 to 10 at 0.01 precision.

b. Band slicing

Single-band density slicing and the multispectral maximum likelihood algorithm were used to classify the satellite data. The density slicing attempted to quantify the accuracy of a simple technique using a single band to map water bodies. The more advanced multispectral classification was completed to give a benchmark result using all reflective bands for comparison with the density slicing results. The out band ratio was used to apply the density slicing. The Two classes defined including Land and water, only the Oguta lake and other water tributary were Classified as water while other land cover type were classify as Land .To find out the limiting value for differentiating land and water, a representation file were created to defined two colors (blue and green). All pixels with values below the limit will be displayed in blue (water), and those with higher values in green (land). When you change the limit, the display changes as well, and you can Evaluate if all the water pixels are classified as water. This way you can interactively find out the best value for differentiating land and water.



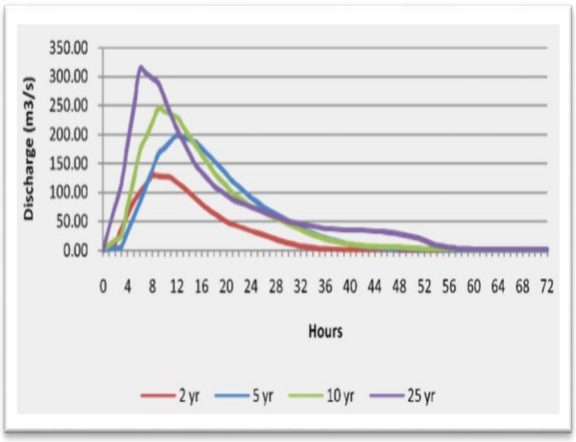


Figure 8 : Two color classify water and land. Fig.9:- Extrapolated flood discharge of Oguta lake

4.1.2 Coefficient of Rainfall Variability CRV

Coefficient of Variation is the percentage variation in mean, standard deviation being considered as the total variation in the mean.

$$\text{CRV(Coefficient of Rainfall Variability)} = \frac{\text{Standard Deviation}}{\text{Mean}}$$

In other words coefficient of variation is defined ratio of the Standard Deviation to the Mean.

The value of CV is calculated only for non-zero mean.

4.2 GLOBAL POSITION SYSTEM (GPS) DATA

The GPS data were acquired from field observation done around oguta lake catchment areas. The GPS data set was typed in a Excel spread sheet and subsequently exported to arcGIS environment along side with the SRTM data. This is to enable ground truthing.

Thematic Layer Preparations

The SRTM (DEM) was used to generate the slope angle, slope aspect, and slope curvature. Areas with negative curvatures represent concave, zero curvature represent flat and positive curvatures represents convex respectively. It is important to note that the DEM was preprocessed before being used for the various analysis. The curvature map was generated in the ArcMap environment. The soil map delineating three soil types was extracted from the soil map of Imo state. Land cover data was classified using Landsat image employing an supervised classification method in the arcGIS environment. The land use/cover map was classified into six classes namely; Thick forest, Light forest, Built environment, Agricultural Land, Bare land and Water body. Finally, precipitation data which was obtained from World Climate data Centre were compiled using precipitation records from 1950 to 2000 (Hijmans et al., 2005) thus it is expected that they are representatives of the rainfall regimes in the area.

4.3 Flood Hydrograph

For the 1D channel flow model, hydrological condition is required in setting up the upstream boundary condition. SOBEK provides several options such as water level (constant, tabulated function time) and discharge (constant, tabulated function of time, tabulated function of the water level). In this study, a flood hydrograph was selected as the relation of flood discharge and time in the upstream boundary. The rainfall was designed for the different return period through the frequency analysis. The peak discharge was calculated by using Snyder's Synthetic Hydrograph. The duration of the 2012 flood was approximately 72 hours, thus the linear flood hydrograph was then extrapolated.

Table 2. Summary of designed rainfall and peak flow of the study area

	Return Period		
	Years	**Rainfall (mm)**	**Peak flow (m^3/s)**
Oguta LGA	2	133	128.92
	5	175	198.39
	10	200	244.53
	25	251	313.26

4.3.1 Cross Sections

An essential element of flood modeling in SOBEK is river cross section. A cross section represents the shape and size of the river which is perpendicular to the river. The field data of the cross section showed the relation between the distances (Y), interpreted as width of the cross section in SOBEK, and the vertical(Z). The Y-Z profile is opened cross section since the width of the surface level is larger than 10 mm. Figure 10 illustrates the Y-Z profile in Oguta Lake. The cross section was placed in every calculation point and the bed level was interpolated.

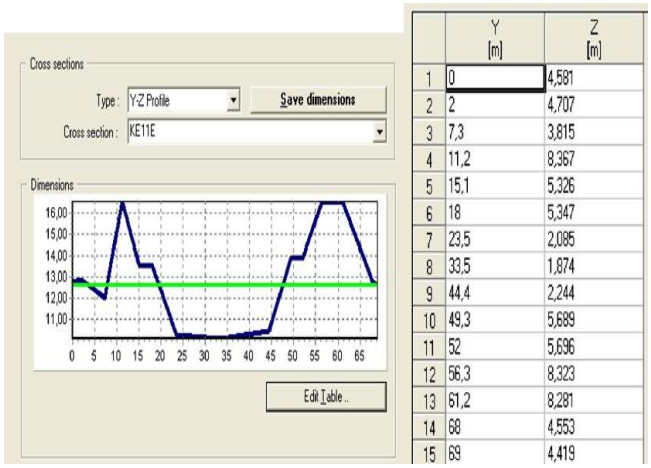


Fig. 10: Y-Z profile used in 1D flow model study area

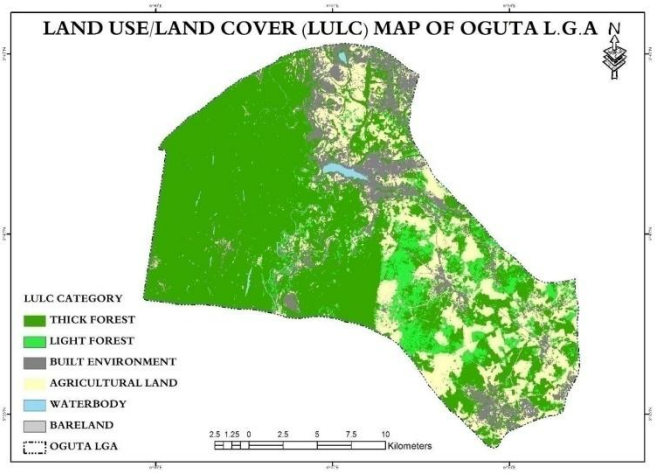


Fig. 11:- Land use/cover map of the

4.3.2 Surface Roughness

Manning's n represents the resistance of the channel or floodplain to the flood flow. Surface roughness contributes to the flood model and is normally used to do the Calibration. The surface roughness determines how the flood behaves either in the Channel or on the flood plain. The type of the channel and the land use type of flood plain have a considerable contribution in the flood modeling. Land use type have been related to the flow behavior and translated into Manning's value (Manning's n). Surface roughness by using Manning's n has been implemented for medium to large catchment. Every land use/cover type has specific surface structure and embed complex interaction due to the elevation change, surface irregularity, flow depth, vegetation density scale, and obstructions (Kalyanapu, et al., 2009). Hence, Manning's n might be varied dependent on the land use type. The spatial distribution of the land use type is illustrated in Figure 11.

5. PRESENTATION OF RESULTS

Composite map of Oguta lake from 1985, 2000 and 2015

The multi data landsat image of Oguta catchment area from 1985, 2000 and 2015 were acquired for monitoring of the flood disaster in the area. see figure 12 below.

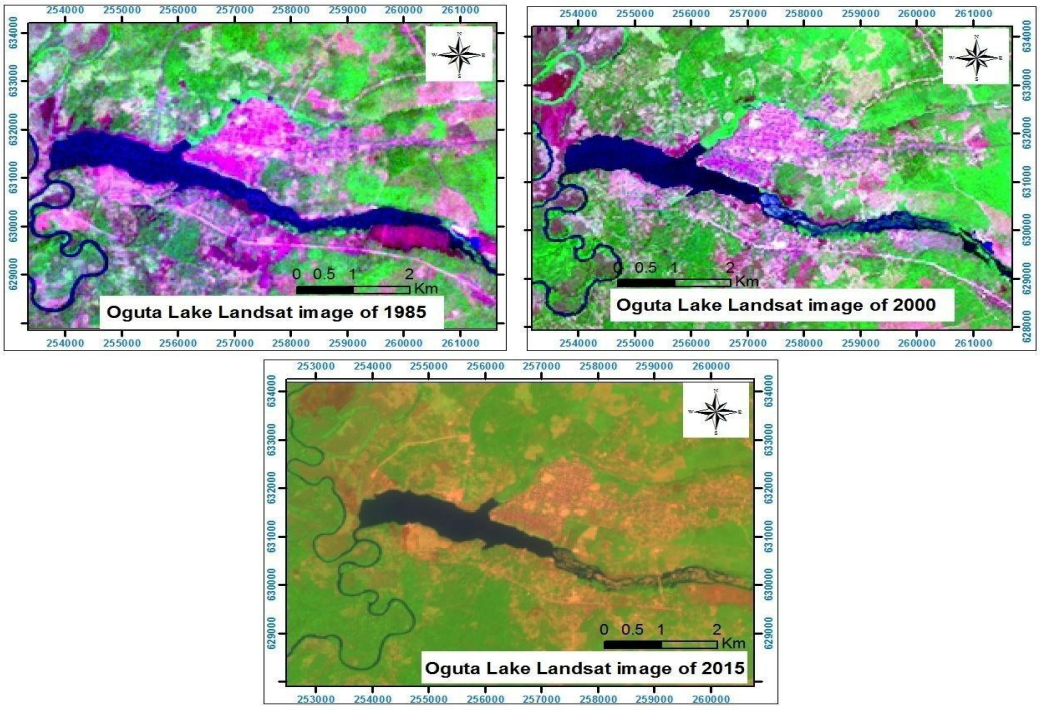


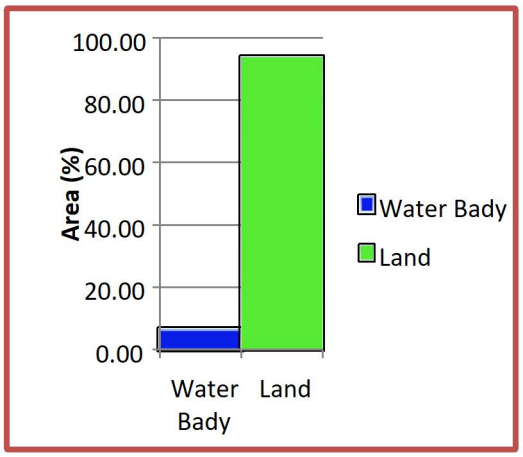
Figure 12: Composite map of Oguta Lake showing temporal change between 1985, 2000 and 2015

5.1 Oguta Lake land cover in 1985

The relative distribution of land use classes of Oguta lake catchment area in 1985 is summarized in table 5.1 below. In 1985, the Lake occupied the total area of 3.909Km^2 about 6.22% while Catchment (Land) area occupied a total area of 58.911 Km^2 about 93.78%: the table and histogram below is the representation of land use classes of the study area in 1985.

Table 3: statistical table of land use classes of ogutalake 1985

S/N	CLASSES	Pixel	Area (km2)	Area (%)
1	Water Body	4343	3.909	6.22
2	Land	65457	58.911	93.78
Total			**62.820**	**100.00**



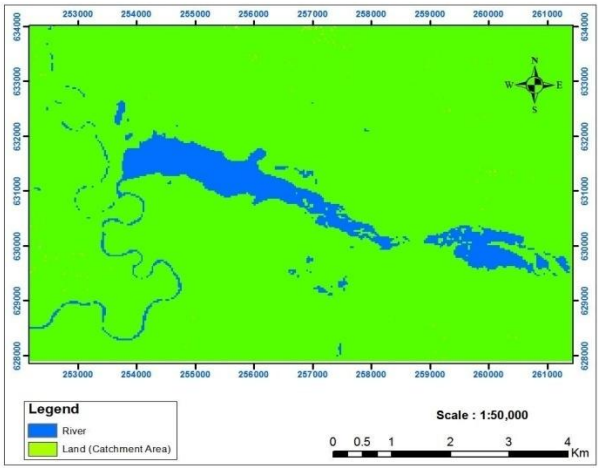


Fig. 13: Land use Histogram of Ogutalake **Fig.: 14** : Map of Oguta Lake & Its Catchment Area

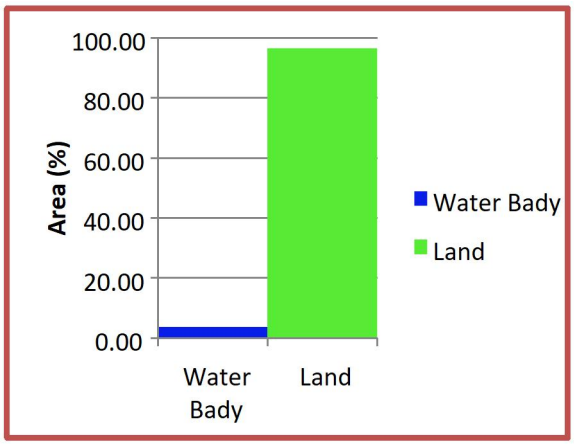
5.1.1 Oguta Lake land cover in 2000

The relative distribution of land use classes of Oguta lake catchment area in 2000 is summarized in table 5.2 below. In 2000 the lake occupied the total area of 2.246Km^2 about 3.59% while Catchment (Land) area occupied a total area of 60.359 Km^2 about 96.41%: the table and histogram below is the representation of land use classes of the study area in 2000.

Table 4: statistical table of land use classes of Oguta lake 2000

S/N	Classes	Pixel Count	Area (km2)	Area (%)

1	Water Body	2496	2.246	3.59
2	Land	67065	60.359	96.41
Total			**62.605**	100.00



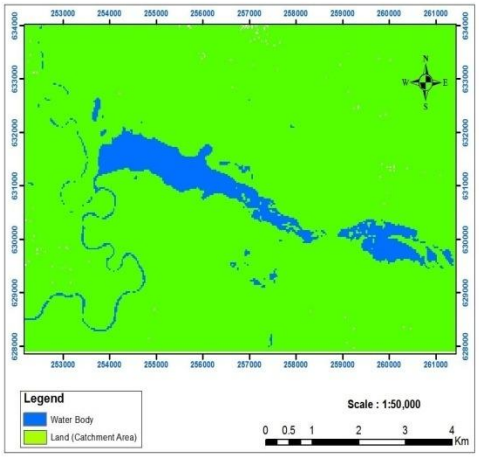


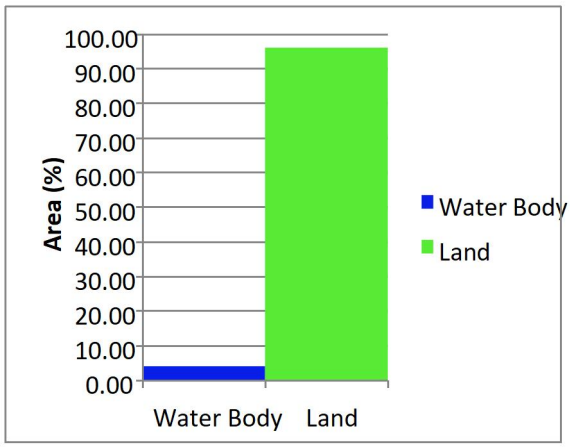
Fig. 15: Oguta-lake land use histogram classes of 2000 Fig. 16: Map of Oguta lake Catchment Area in 2000

5.1.2 Oguta Lake land cover in 2015

The relative distribution of land use classes of oguta lake catchment area in 2015 is summarized in table 5 below. In 2015 the river occupied the total area of 2.474Km^2 about 4.02% while the Catchment (Land) area occupied a total area of 59.063 Km^2 about 95.98%: the table and histogram below is the representation of land use classes of the study area in 2015.

Table 5: statistical table of land use classes of ogutalake 2015

S/N	Classes	Pixel Count	Area (km2)	Area (%)
1	Water Body	2749	2.474	4.02
2	Land	65625	59.063	95.98
Total			**61.537**	100.00



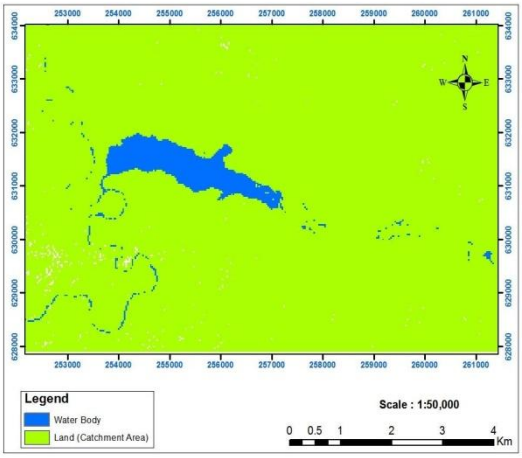


Fig. 17: Oguta lake land use histogram 2015 classes Area in 2015

Fig. 18 Oguta lake Catchment

5.1.3 Change Detection in Oguta Lake Between 1985, 2000 and 2015.

In land use/land Cover mapping, the post comparison technique is the only method that resulted in a change matrix that provided " " from-to " " information. The land cover changes of Oguta catchment area were computed between 1985 to 2000 and between 2000 to 2015.

5.1.4 Change Detection of Oguta lake between 1985 to 2000

The change detection between 1985 to 2000 in Oguta catchment area can be explained by comparing the two table below:

Table 6: Table of Change detection of Oguta catchment area (1985 to 2000)

S/N	Change (1985-2000)	Pixel Count	Area (KM^2)	Area (%)	Changes Detection
1	Land to Land	65142	58.628	93.57	Land Constant
2	Water Body to Land	1978	1.780	2.84	Water Body Decreased
3	Land to Water Body	128	0.115	0.18	Water Body Increased
4	Water Body to Water Body	2370	2.133	3.40	Water Body Constant
Total			**62.656**	**100.00**	

From 1985 to 2000 the 3.40% of the Lake remain unchanged , the change occurred when 0.18% of the catchment area was converted to lake and 2.84% of lake was converted to Land. 93.57%

of the catchment area remain unchanged. The map below shown the spatial change from 1985 to 2000.

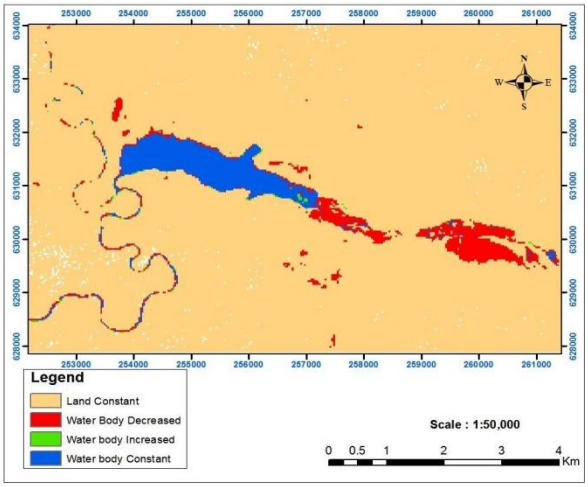


Figure 19: Change detection map of Oguta Lake between 1985 to 2000

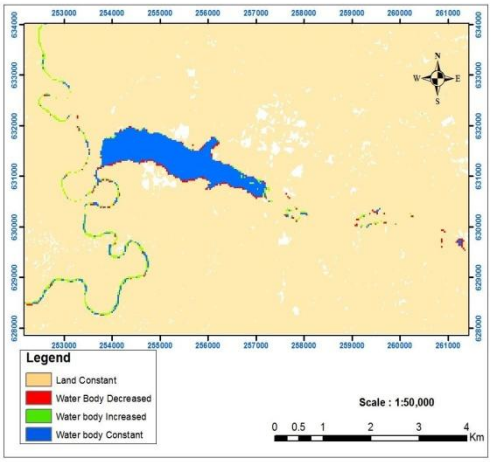
5.1.5 Change detection of Ogutalake between 2000 to 2015

The change detection between 2000 to 2015 in Oguta catchment area can be explained by comparing the two tables below:

Table 7: Table of Change detection of oguta catchment area (2000 to 2015)

S/N	Change (2000-2015)	Pixel Count	Area (KM2)	Area (%)	Changes Detections
1	Land to Land	64989	58.490	95.61	Land Constant
2	Water Body to Land	490	0.441	0.72	Water Body Decreased
3	Land to Water Body	238	0.214	0.35	Water Body Increased
4	Water Body to Water Body	2258	2.032	3.32	Water Body Constant
Total			**61.178**	**100.00**	

From 2000 to 2015 the 3.32% of lake remain unchanged , the change occurred when 0.35% of the catchment area was converted to lake and 0.72% of lake was converted to Land. 95.61% of the catchment areas remain unchanged. The map below shown the spatial change from 1985 to 2000



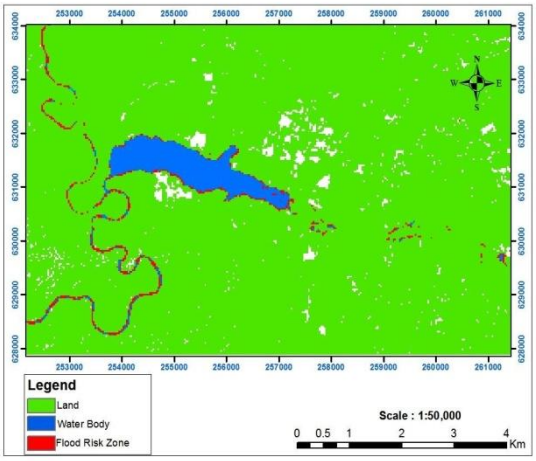
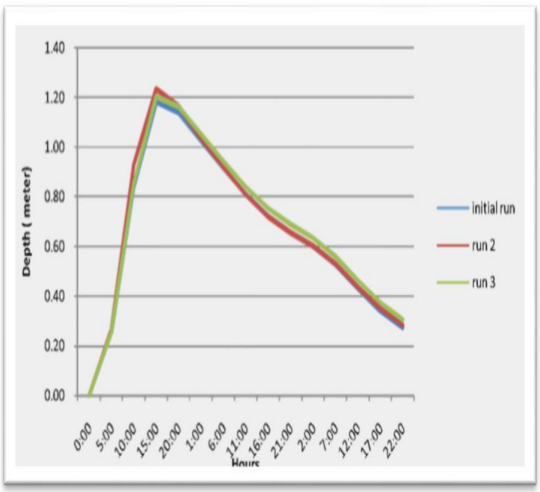


Figure 20: 2000 to 2015 Change detection map of Oguta Lake **Figure 21**: Flood Risk map of Oguta lake Catchment area from 2000 till 2015.

5.2 Flood Extent

The first output of flood modeling is the flood extent. It shows the spatial distribution of the flood in the floodplain. In general, the inundated area is much less than not- inundated area. Figure 5.14 shows that higher return period of flood cause larger spatial distribution. The largest inundated area was caused by 25 year return period flood and it is covered less than 15% of the study area (see figure 5.15). In general, the difference of the flood extent from low magnitude flood to high magnitude flood was not significant. The difference from the lowest magnitude (2yr) and highest magnitude was about 12km (50%) different. The flood extent caused by 5yr and 10yr flood was similar with less 1% different. The low elevation variation in the study area may contribute in the flood spatial distribution.



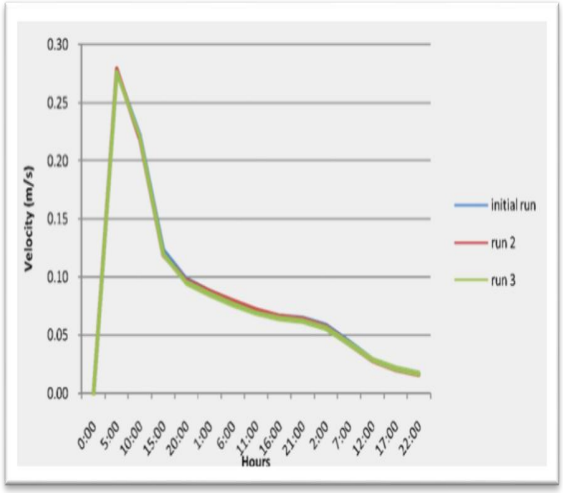
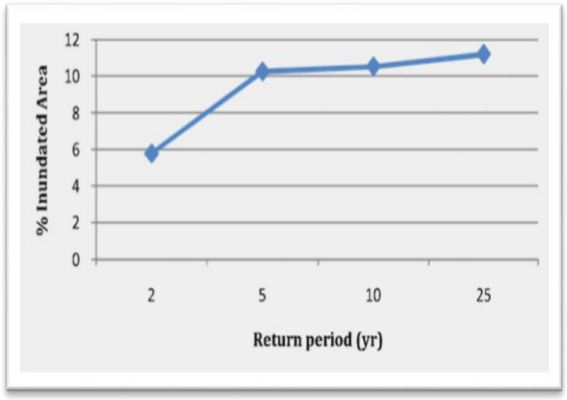


Fig. 22: Comparison of the flood

Fig. 23:- Comparison of the flood velocity



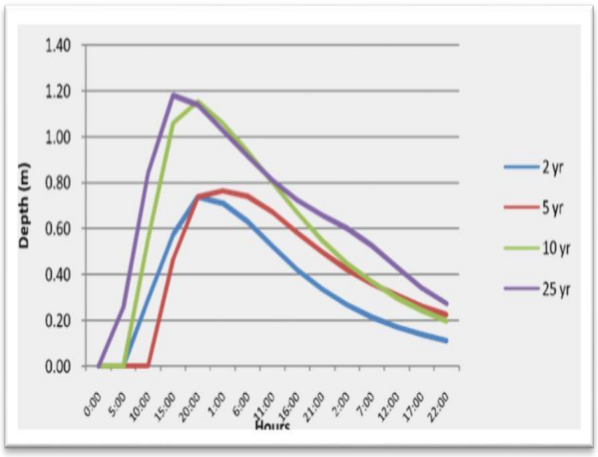
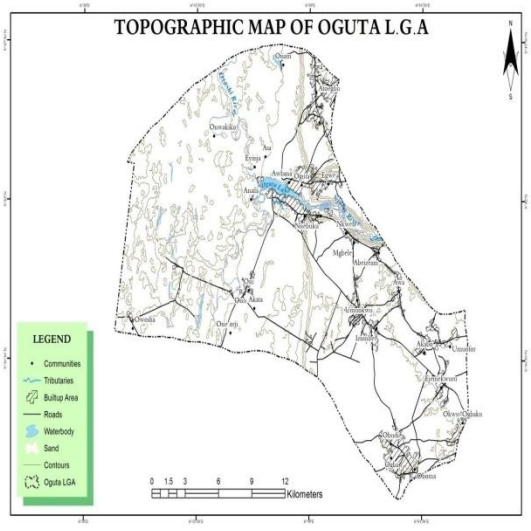


Fig. 24:Inundated area increases with flood magnitude **Fig. 25:-** Modeled flood depth for years flood



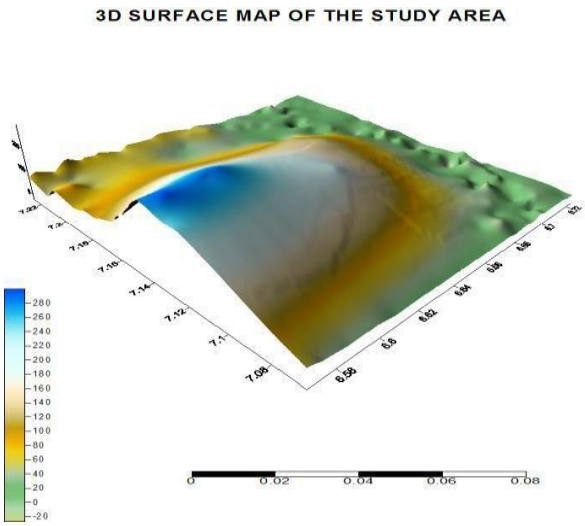


Fig 26 Oguta topographic map of study area **Fig. 27**: 3D Surface Model of the Study Area, Oguta

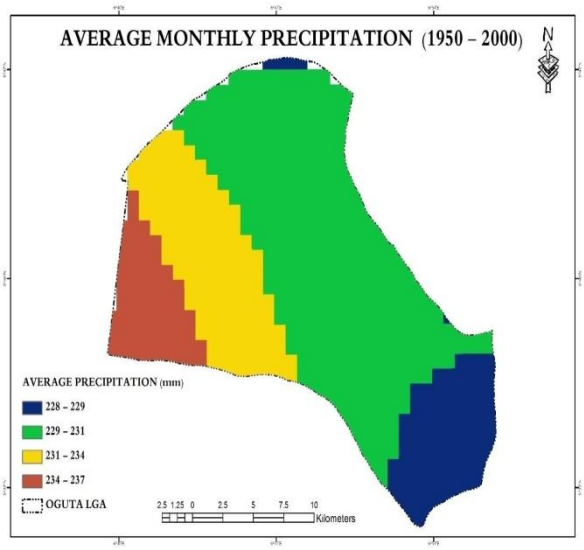


Fig. 28:- Rainfall map of Oguta LGA

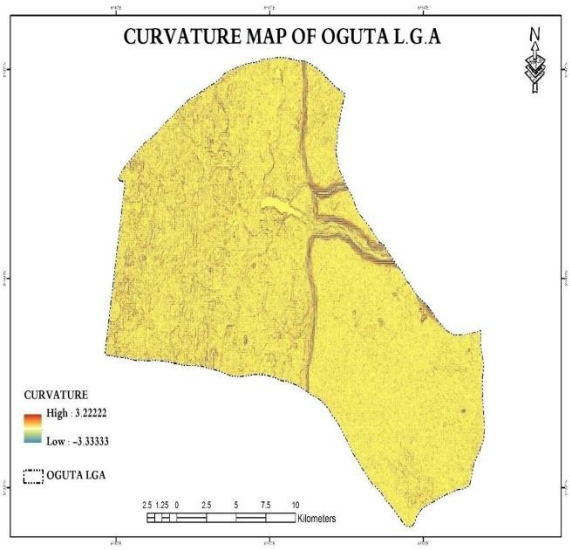


Fig. 29:- Curvature map of Oguta LGA

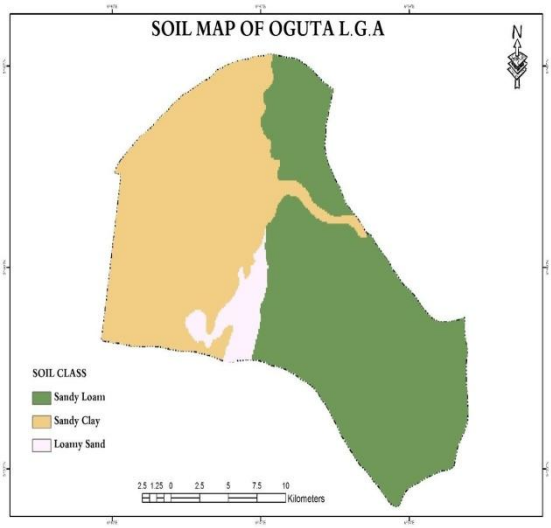


Fig. 30:- Soil map of Oguta LGA

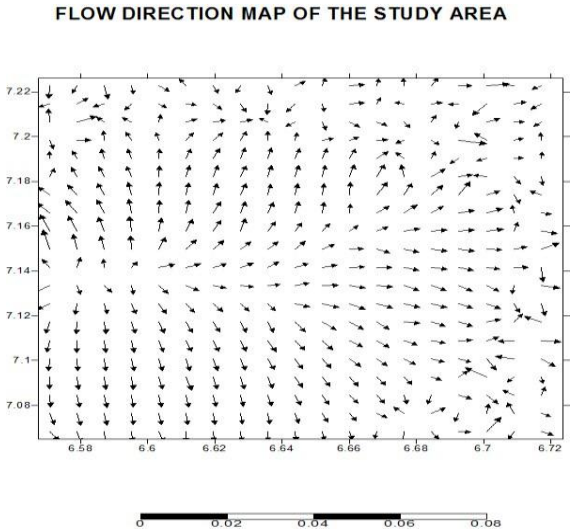


Figure 31 : Flow direction of the study area

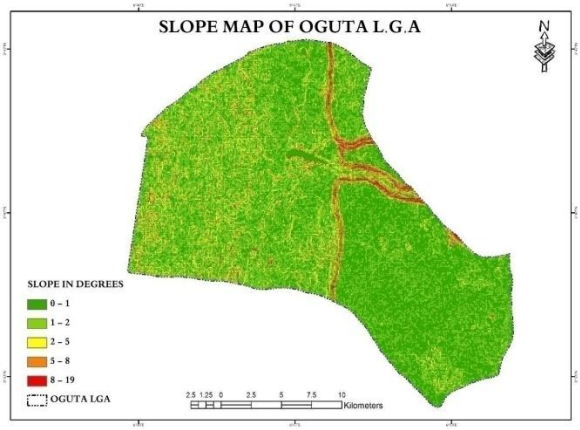


Fig. 32:- Slope map of Oguta LGA

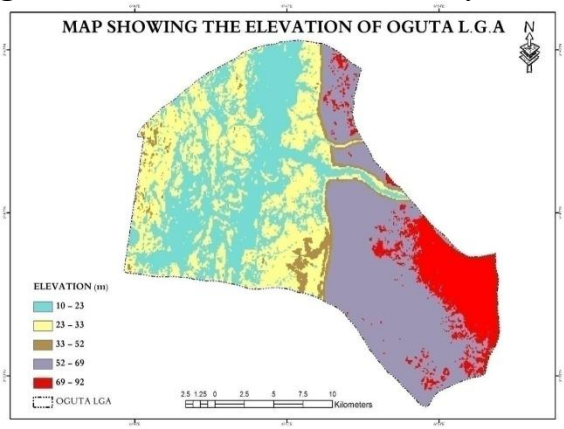


Fig. 33:- Elevation map of Oguta

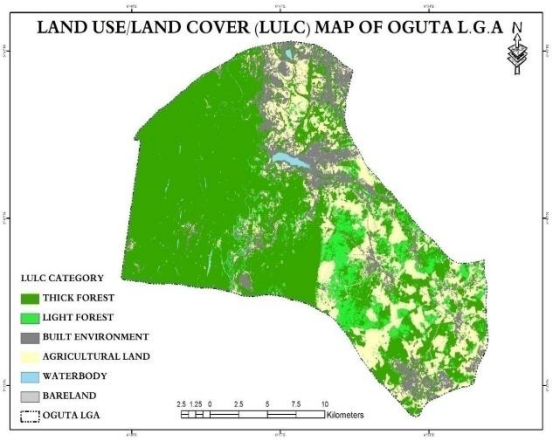


Fig. 34:- Land use map of Oguta LGA

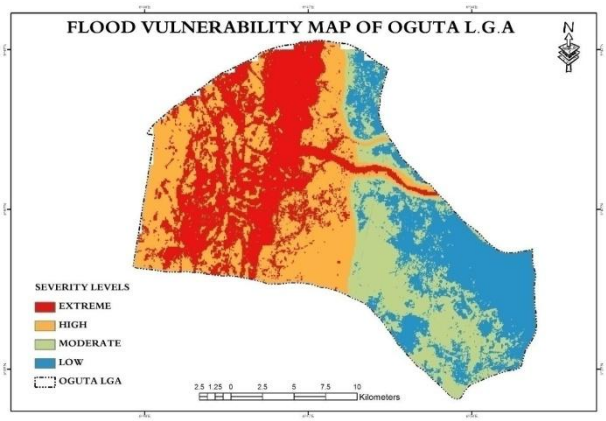


Fig. 35:- Flood vulnerability map of the study area

5.3 Discussion of Results

5.3.1 Mapping Landuse Change

Analysis of Landuse change was carried out for each of the land cover classes of interest in this stud (floodplain, water bodies, vegetation and built–up area) and database created for the Landsat ETM+ of 1985, 2000 and 2015 under consideration. Results obtained from the analysis performed (Table 5 and 6) show that Built-up area appreciated by 1.507kmsq. (1985 to 2000) and 1.020kmsq. (2000 to 2015) with a decrease in foerest/vegetation cover across board (2.997kmsq. between 1985 and 2000 to 0.925kmsq. from 2000 to 2015). Non-urban land (Bare land/floodplain) declined from about 1.494kmsq to 0.976kmsq. The implication is that the wetlands are destroyed due to human encroachment and urbanization (Vegetation/Forest and Floodplain are now used or transformed to built-up areas). This is believed to be the reason why there is much flood impact on Oguta population during heavy rainfalls.

5.3.2 Flood Depth

The flood depth is varied by the elevation and the flood magnitude. The area in around Oguta Lake and Orashi River is a low elevation area thus the water from the two rivers overtops and inundates this area. The depth of the inundation is more than 1 meter. The different flood magnitude may produce variation in the flood depth. The deepest inundation recorded was about 1.2 meter. Significant changes was found when 2 yr flood shifted to 5 yr flood or higher. The flood depth increased from 0.70 meter to 1.3 meters (see figure 36).

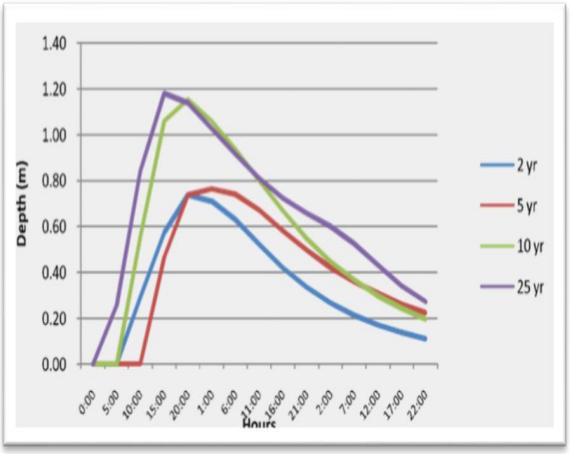


Fig. 36:- Modeled flood depth for 2yr, 5yr, 10yr and 25yr flood

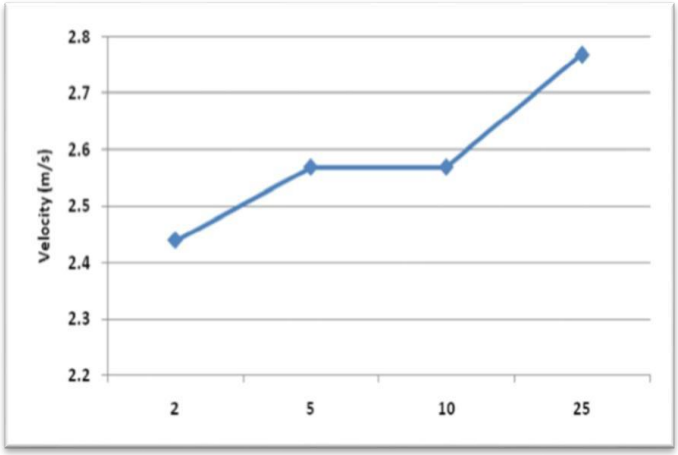


Fig. 37:- The increasing of the flood velocity as the flood magnitude increased

As indicated in figure 36 for the flood depth and figure 37 for the flood velocity, there was very small change in the flood behaviour. The adjustment of built environment by 0.05 $m^{1/2}s^{1}$did not make any significant change. By changing the channel surface into 0.025 and using the adjusted Manning's, the run 2 performs the highest depth and the velocity. The flood depth was 1.20 m and the velocity was 0.25 m/s. Comparison of the flood velocity resulted from flood models using different channel roughness and surface roughness. The available data of the past event flood in 2012 was only flood peak discharge and flood extent map. In addition to surface roughness adjustment, these two dataset were used to validate the flood model. The flood extent was mapped and updated through field survey. The modeled flood extent map was compared to the observed flood extent map. This comparison was also applied for the flood depth. The observed flood depth was derived from the interview with local community. The modeled and the observed flood extent show 43 km^2 differences which are quite significant (see Table 8). The 25 year flood model underestimates the flood extent in some areas. Comparing the spatial distribution of the observed and modeled flood extent, the underestimation is represented by the patchy structures.

Table 8: The comparison of the observed and modeled inundation point

	Inundated (km^2)	Not-inundated (km^2)
Observed	66.44	417.20
Modeled	23.37	460.27
Difference	43.07	43.07
Total area	483.64	483.64

5.3.3 Flood Velocity

To analyze the flood parameter, flood velocity is essential due to the energy in which it is contained. The maximum velocity resulted by this model was ranged from 2.44 m / s for 2 yr

flood to 2.77 m/s for the 25 yr flood. There was no significant change between the 5yr and 10 yr flood. In general, the velocity correlated positively with the flood magnitude i.e. greater flood creates higher velocity (see figure 37). The spatial distribution of the flood velocity was varied by the distance from the river. The high velocity took place in the northern part or the floodplain of Oguta Lake. The built-up area located along the river increased the velocity due to the low friction. To assess the amount of water movement in the floodplain, the flood depth and flood velocity were multiplied. Amount of water movement = flood depth x flood velocity (Alkema & Middelkoop, 2005).

5.4 Flood Hazard

Flood hazard mapping can be done by taking flood depth and flood velocity into account. Flood impulse as the product of multiplication of these two parameters draws the energy of the water movement. Deep inundating water with high velocity is considered as the destructive flood. Deep inundating water with low velocity has less energy to destruct and adversely, shallow inundating water with high velocity may have greater energy to cause damages. The study area was dominated by low and medium flood hazard. The classification was based on the relationship between the average velocity and depth developed by Penning-Rowsell and Tunstall (1996). The flood average flood velocity of 2 m/sec with flood depth 1 m was the threshold for the high hazard. The flood hazard classification was based on Table 1. The low flood velocity and shallow inundating water in the floodplain reduce the impulse level.

Table 9:- Hazard classification based on impulse

Impulse class	Hazard classification
0 - 0.1	Low hazard
0.1 - 1	Medium hazard
> 1	High

5.5 Flood risk analysis

A risk map demarcates the areas under potential consequences, where consequences can be those affecting human life, having economic effects or causing environmental changes for instance. A particular surface area subject to the same hazard can face a variety of consequences, depending on land use/cover types. Flood risk analysis takes into consideration flood susceptibility factors, land use/cover information, settlement data, transportation networks, and social economic data in deriving risk categories: low risk, medium risk, high risk and extreme risk. In the flood vulnerability map, the potential event and its probability of occurrence were combined. The susceptible categories are expressed as probability in qualitative forms (e.g. low, moderate, high and extreme). Therefore, the flood vulnerability map was overlaid on damageable objects maps such as settlement and facility centres. Those high risk areas need to be brought to the notice of

the public so that people can realize the possibility of future floods. This could save their property and life.

6. SUMMARY AND CONCLUSIONS

One of the main technical difficulties which have faced the application of analytical techniques to regional development analysis in many African countries has been the lack of relevant information (Ayeni, O.O, 2009). Oguta like many other regions equally is confronted with similar problems. In determining flood risk mapping of Oguta lake catchment area, Remote Sensing technique was applied using the ILWIS software in image processing and analysis. The Landuse and landcover map of the study area were produced using ArcGIS software. Thus the capability of Geographic Information System, Global positioning system and Remote Sensing techniques for identification and delineation of communities and areas vulnerable to floods has been demonstrated in this research.

Analysis of Landuse change performed using Landsat images of the environment shows that settlement area appreciated by 1.507kmsq. (1985 to 2000) and 1.020kmsq.(2000 to 2015) with a great decrease in foerest/vegetation cover across board (2.997kmsq. between 1985 and 2000 to 0.925kmsq. from 2000 to 2015). Non-urban land (Bare land/floodplain) declined from about 1.494kmsq to 0.976kmsq. (1985-2000) to (2000 to 2015) respectively. The implication is that the wetlands are destroyed due to human encroachment and urbanization (Vegetation/Forest and Floodplain are now used or transformed to built-up areas). This is believed to be the reason why there is much flood impact on Oguta population during heavy rainfalls. Similarly, The Landsat ETM+ of 1985, 2000 and 2015 imageries were resample to one resolution and classified and the various spectral and temporal changes in Landuses and Land cover were obtained and analyzed in ILWIS 3.3 Academic using Map calculation and Map crossing, which showed that from 1985 to 2000 the 3.40% of the Lake remain unchanged , the change occurred when 0.18% of the catchment area was converted to lake and 2.84% of Lake was converted to Land. 93.57% of the catchment area remain unchanged. Again, from 2000 to 2015 the 3.32% of river remain unchanged , the change occurred when 0.35% of the catchment area was converted to lake and 0.72% of Lake was converted to Land. 95.61% of the catchment areas remain unchanged. Vulnerability was classified into four, the highly vulnerable, vulnerable, the marginally vulnerable and the not vulnerable communities. It was revealed that, out of the 7 communities in the study, three (3) were found to be vulnerable to floods. That is, OrsuObodo, Oguta 1 and Oguta

11 with percentage area of 18.97% were found to be located on the extreme vulnerable areas, while community like Nkwesi (representing 7.32%) were found to be located within the high vulnerable areas. And the remaining three (3) communities (38.08%) were located on the low vulnerable areas.

The three (3) communities that were found to be extremely vulnerable were suggested to be urgently relocated to higher grounds to prevent future occurrences while proper early warning and effective town planning measures should be put in place in those communities that are highly vulnerable or lowly vulnerable to floods. GPS data (X,Y,Z) was used for ground truthing with the integration of SRTM data in Mapping Flood risk Zones using arcGIS 10.1. However, it is recommended that Since the forest/vegetation land cover has been noted to be fast disappearing to other land uses, adequate measures should be taken by the Imo State Government and Oguta local Government Authority to mitigate this ugly trend.

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