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Flood Risk Mapping Around Oguta Lake, Using Remote Sensing and Global Positioning System

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Abstract:
This study involved a hydrodynamic flood risk mapping around Oguta Lake using remote sensing and Global Positioning System (GPS).The aim was achieved through the following objectives, production of change detection maps, determination of coefficient of rainfall variability, hydrodynamics modelling and production of flood risk map. Analysis of Landuse change performed using Landsat images of the environment shows that settlement area appreciated by1.507kmsq from 1985 to 2000 and 1.711kmsq from 2000 to 2015 with a great decrease in forest/vegetation cover across board from 2.997kmsq between 1985 and 2000 to 0.925between 2000 to 2015. Non-urban land (Bare land/floodplain) declined from about 1.494kmsq to 0.976kmsq from 1985-2000 to 2000 -2015 respectively. The implication is that the wetlands are destroyed due to human encroachment and urbanization. This is believed to be the reason why there is much flood impact on Oguta population during heavy rainfall. By extension also, the result 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 remained unchanged. Again, from 2000 to 2015, 3.32% of river remained 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 remained unchanged. This is significant as the results obtained in this study will serve as a decision support tool for flood monitoring and management.

Keywords: Flood, Global Positioning System, Remote Sensing, Risk mapping

I. INTRODUCTION

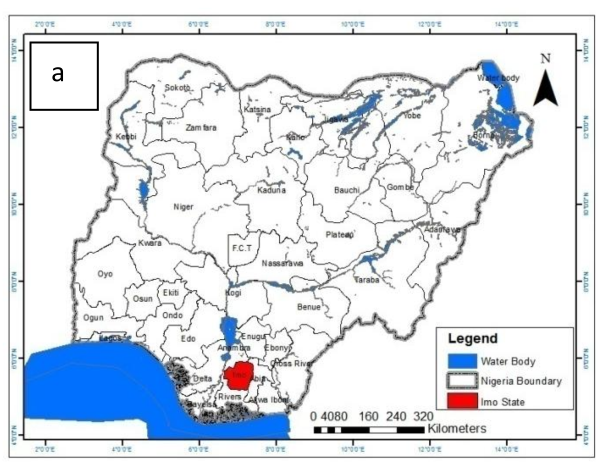
Flooding has become a perennial event. Flooding in urban areas is not just related to heavy rainfall, it is also related to change in built up areas (land use), (Etuonovbe, 2011). Urbanization aggravates flooding by restricting where water can go as a result of the changes in land cover, where large parts of urban environment is covered with roofs, road, and pavements thereby obstructing section of the natural channel. Flooding is a common occurrence in many parts of Imo State especially Oguta town in Oguta Local Government Area. It mostly during the rainy season or at tidal. Rapid rate of land use and population growth around Oguta Lake over the years now has led to uncontrolled and uncoordinated development of the suburbs, swamps, flood plain and natural drainage channels thereby aggravating the risk of flood hazard in the area. Flood hazards are bound to increase in the future with increasing land use, therefore the need to demarcate flood prone areas for effective flood mitigation is imperative.

Reduction of the risk of flooding will depend largely on the amount of information on the flood that is available and the knowledge of the areas that are likely to be affected during a flood event. Therefore, it is necessary to uses modern day technique in developing measures that will help relevant authorities and relief agencies in the identification of flood prone (risk) areas and in planning against flooding event in the future.

Determining the flood prone area is important for effective flood mitigations. For this study, remote sensing techniques, global positioning system (GPS) and digital elevation model (DEM) will be used to demarcate flood areas in the study area. So therefore this study is aimed at mapping flood risk areas around Oguta lake using remote sensing and GPS and set to be achieved through the following objectives, production of change detection maps, determination of coefficient of rainfall variability, hydrodynamics modelling and production of flood risk map.

1.1 STUDY AREA

Oguta lake area of Imo State is located between latitudes 5' 42' 24''N and 5' 50' 33''N and longitudes 6'47' 33''E and 6' 59' 25''E. Oguta Lake area 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. See fig 1



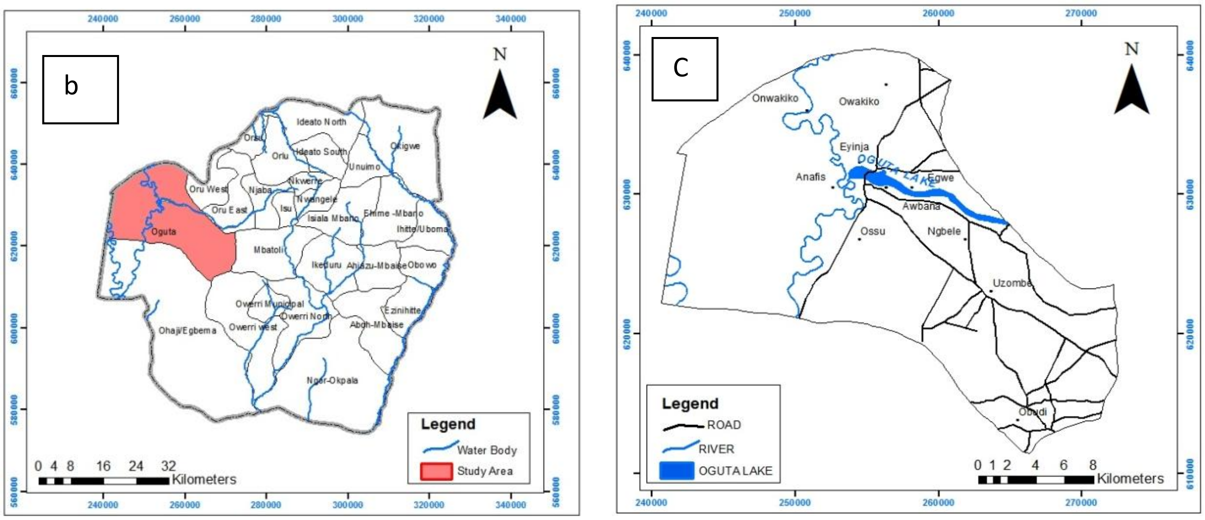


Fig 1 (a) Map of Nigeria, (b) Map of Imo State, (c) Map of Oguta Lake

II. MATERIALS & METHODS

The method used in this paper involves supervised maximum likelihood classification algorithm by (Onojeghuo and Onojeghuo, 2006). This technique was used to produce landcover maps of the study area. A post classification image technique was also employed to determine the changes that have occurred in the time period between 1985 and 2015.

Coefficient of Variation is the percentage variation in mean, standard deviation being considered as the total variation in the mean. Coefficient of variation was calculated for rainfall variability using the formula below

$$\text{CRV(Coefficient of Rainfall Variability)} = \frac{\text{Standard Deviation}}{\text{Mean}} \quad \text{...eq 1}$$

Also an artificial neutral network model was used for the derivation of the weightage of the various thematic layers used for flood vulnerability analysis. Before running the artificial neutral network program, the training site was selected. So, the flood-susceptible (prone) area and the flood-non-susceptible area were selected as training sites computed by logistic regression model. Cells from each of the two classes were randomly selected as training cells. The results from logistic regression models were selected as training sites in artificial neutral network modelling. The back-propagation algorithm was then applied to calculate the weights between the input layer and the hidden layer and between the hidden layer and the output layer, by modifying the number of hidden node and the learning rate. Three-layered feed-forward network was implemented using the MATLAB software package. Here, "feed-forward" denotes that the interconnections between the layers propagate forward to the next layer. The number of hidden layers and the number of nodes in a hidden layer required for a particular classification problem are not easy to deduce. In this study, a 9 (input layer) x 20 (hidden layers) x 2 (output layer) structure was selected for the network, with input data normalized in the range 0.1 - 0.9. The nominal and interval class group data were converted to continuous values ranging between 0.1 and 0.9. Therefore, the continuous values were not ordinal data, but nominal data, and the numbers denote the classification of the input data. The learning rate was set to 0.01, and the initial weights were randomly selected to values between 0.1 and 0.3. The weights calculated were compared to determine whether the variation in the final weights was dependent on the selection of the initial weights. The back-propagation algorithm was used to minimize the error between the predicted output values and the calculated output values. The algorithm propagated the error backwards, and iteratively adjusted the weights. The number of epochs was set to 2,000, and the root mean square error (RMSE) value used for the stopping criterion was set to 0.01. Most of the training data sets met the 0.01 RMSE goal. However, if the RMSE value was not achieved, then the maximum number of iterations was terminated at 2,000 epochs. When the latter case occurred, then the maximum RMSE value was 0.051. The final weights between layers acquired during training of the neural network and the contribution or importance of each of the 9 factors are shown in Table 2.0. For easy interpretation, the average values were calculated, and these values were divided by the average of the weights of the some factor that had a minimum value. The DEM value was the minimum value, 0.011, and the precipitation value was the maximum value, 0.982.

Table 2.0 Weights of each factor derived by data manning model

S/N	Thematic layers	Weights	Normalized weight
1	Slope	0.032	0.020
2	DEM	0.011	0.000
3	Curvature	0.013	0.000
4	Flow direction	0.063	0.050
5	Flow accumulation	0.431	0.430
6	Distance from drainage	0.274	0.270
7	Soil	0.316	0.310
8	Land use/ cover	0.328	0.330
9	Precipitation	0.982	1.000

III. RESULTS

The objectives of this paper forms the basis of all analysis carried out. This section takes a detailed look at the outcome of the data obtained with the view of presenting the results in form of user-interactive figures and maps.

3.1 PRESENTATION OF RESULTS

3.1.1 OGUTA LAKE LANDCOVER FROM 1985 TO 2015

The image classification results show that Oguta 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% in 1985, in 2000 it 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% and in 2015 it 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%.

3.1.2 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 class change information. The land cover changes of Oguta catchment area were computed between 1985 and 2000 and between 2000 and 2015.

From 1985 to 2000, 3.40% of the Lake remains 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 remains unchanged.

Table 3.1 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	

Then from 2000 to 2015 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.

Table 3.2 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	

3.1.3 LANDUSE CHANGE ANALYSIS OF OGUTA ENVIRONS.

Analysis of Landuse change performed using shows that settlement area appreciated by 1.507kmsq from 1985 to 2000 and 1.711kmsq from 2000 to 2015 with a great decrease in forest/vegetation cover across board 2.997kmsq between 1985 and 2000 to 0.925kms between 2000 and 2015. Non-urban land (Bare land/floodplain) declined from about 1.494kmsq to 0.976kmsq from 1985 to 2000 and from 2000 to 2015 respectively.

Table 3.3 : Area of Land Use/Change Category at Different Years - 1985, 2000, 2015

LANDUSE/ CHANGE CATEGORY	YEAR 1985 Area(sqm)	%	YEAR 2000 Area(sqm)	%	YEAR 2015 Area(sqm)	%
Built-up Environment	7257590.797	12.73	8764924.8	15.37	10475928.89	18.41
Agricultural land	9429438.42	16.54	9434772.42	16.54	8464990.88	14.87
Forest	20831638.42	36.54	17834972.4	31.27	16910190.8	29.71
Water body	11329805.08	19.87	14334139.1	25.13	15372530.2	27.01
BareLand/Dry Land	8162527.305	14.32	6668861.31	11.69	5693300.99	10
TOTAL	57011000.02	100	57037670.02	100	56916941.77	100

3.1.4 COEFFICIENT OF RAINFALL VARIABILITY (C.R.V)

The total mean annual rainfall in Imo State from 1984 to 2013 is about 2464.06 mm while the average monthly rainfall is 205.22mm. The rainfall variability coefficient from 1984 to 2013 (30 years) is estimated about 14 %, this means that the variation in yearly rainfall amounts over the period is very low. Fig. 3.1 shows the graph of yearly total rainfall for the period of 30 years. There is stability of rainfall quantity in Imo State over 30 years. The highest Rainfall occurred in 2006 with total annual rainfall of 3209.1mm with 267mm average monthly rainfall. The lowest rainfall occurred in 1998 with 1640.1 mm total mean annual rainfall and 136.7mm average monthly rainfall.

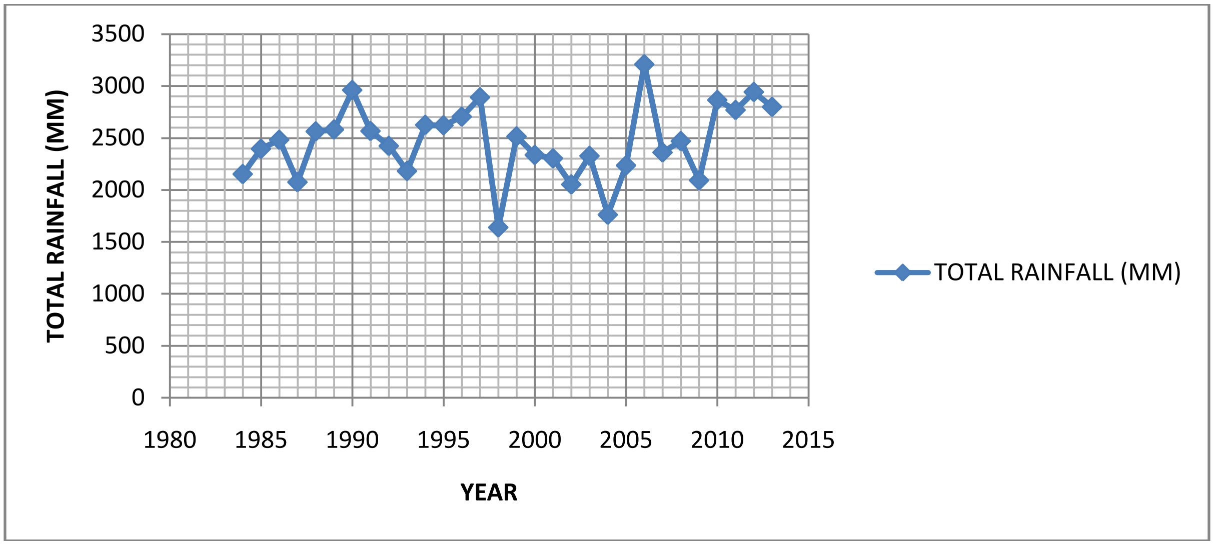


Figure 3.1: Graph of Total Rainfall amount of Imo state from 1984 till 2013

3.1.5 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 the dry area. Figure 3.2 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. 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.

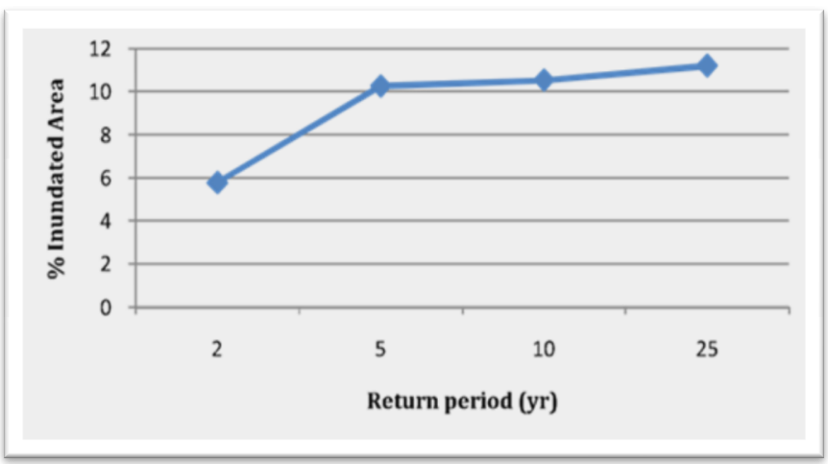


Fig. 3.2 The inundated area increases as the flood magnitude increases

3.1.6 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 were 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 3.3).

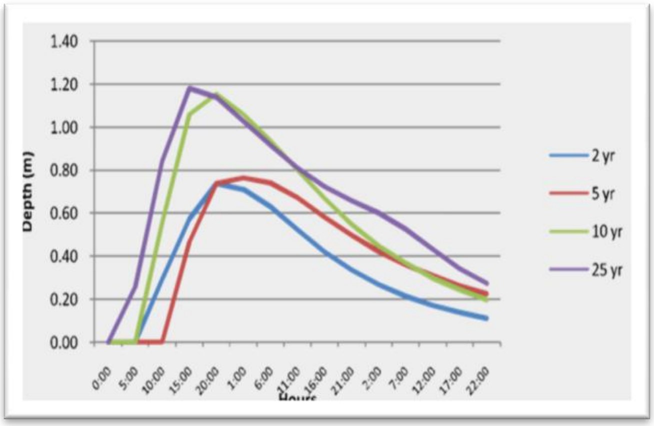


Fig. 3.3 Graph showing modeled flood depth for 2yr, 5yr, 10yr, and 25yr flood

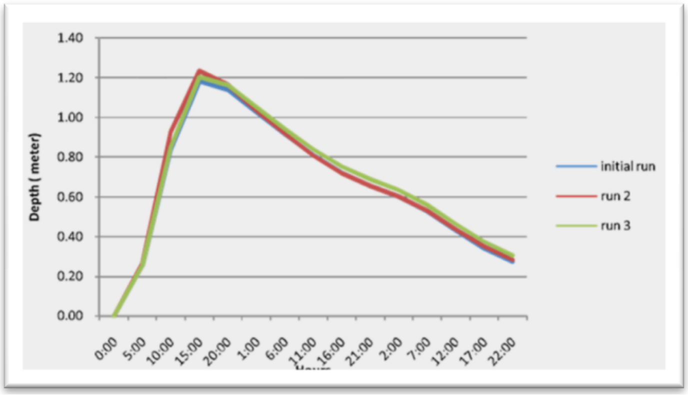


Fig 3.4 Comparison of the flood depth as a result of the flood models using different channel roughness and surface roughness

As indicated in figure 3.4 for the flood depth, there was very small change in the flood behavior. 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.

3.1.7 HYDRODYNAMIC FLOOD RISK MODELS

From the models below fig 3.5, it can be deduced that there is a progressive increase in inundation. The area with patch colors shows the extent of inundation. That is higher return period of flood cause larger spatial distribution. The largest inundated area was caused by 25 year return period of flood. By projection therefore, 25 year return period of flood is equivalent to year 2027.

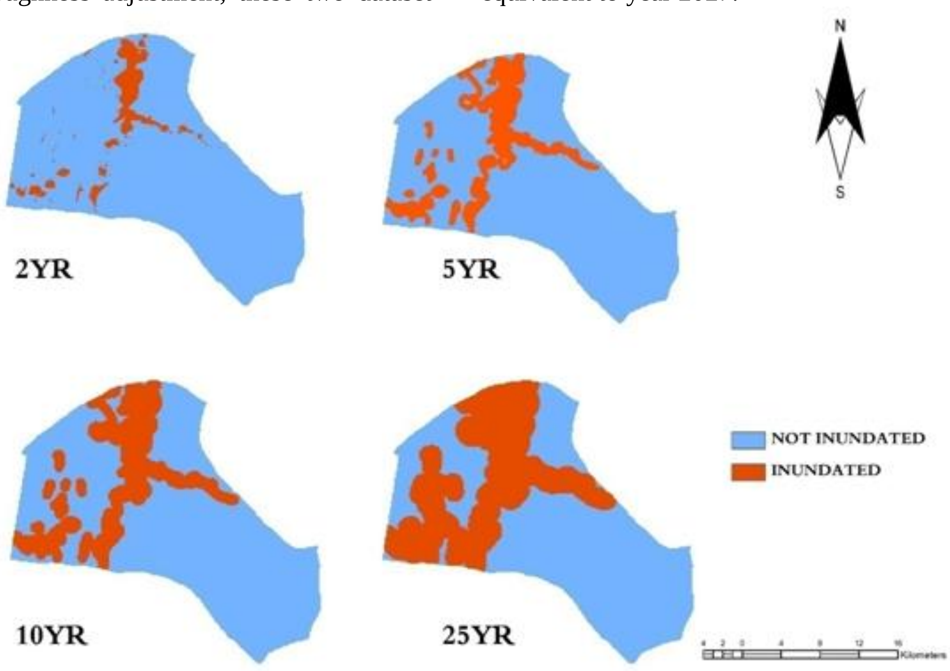


Fig. 3.5 Modeled flood extent for 2yr, 5yr, 10yr and 25yr return periods

3.1.8 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, moderate 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 for the study area created to show vulnerable areas. It is also necessary that the high risk areas indicated on the map 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. See Fig. 3.6

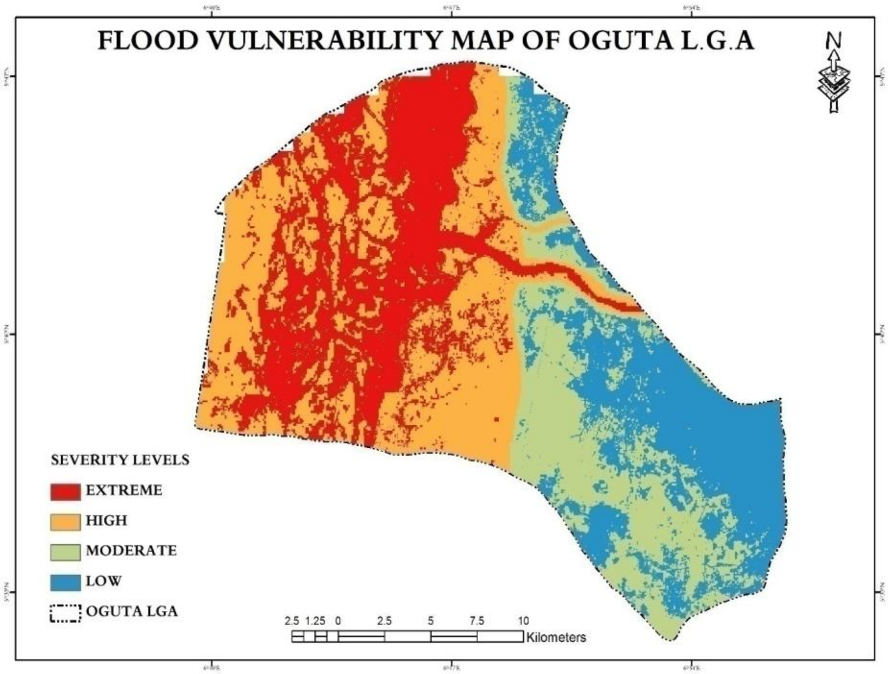


Fig. 3.6 Flood vulnerability map of the study area

IV. CONCLUSION

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 the hydrodynamic 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. 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 paper.

Analysis of Landuse change performed using Landsat images of the environment shows that settlement area appreciated by 1.507kmsq from 1985 to 2000 and 1.711kmsq from 2000 to 2015 with a great decrease in forest/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 from 1985-2000 and 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 Landuse 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 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 remains 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.

Flood vulnerability was classified into four, the extremely vulnerable, highly vulnerable, the moderately vulnerable, low vulnerable and the no vulnerable communities. It was revealed that, out of the 7 communities captured around the study area, two (2) were found to be extremely vulnerable to flooding. That is Oguta 1 and Oguta II with percentage area of 18.97% located on the extreme vulnerable areas, Nkwesi and Egwe were identified as moderately vulnerable with percentage area of 29.41 while community like Orsu Obodo (representing 7.32%) was found to be located within the highly vulnerable areas. And the remaining two (2) communities Ejemekwuru (10.21%) and Izombe (34.08%) were located on the no vulnerable and low vulnerable areas respectively. The two (2) communities (Oguta I and Oguta II) that were found to be extremely vulnerable to flooding 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, moderately or lowly vulnerable to floods. However, it is recommended that Since the forest/vegetation land cover has been noted to be fast disappearing to other land uses, adequate measures such as flood monitoring and management should be encouraged and funded by the Imo State Government and Oguta local Government Authority to mitigate this ugly trend.

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