Flood Vulnerability Mapping of Lagos Island and Eti-Osa Local Government Areas Using a Multi-Criteria Decision Making Approach

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ABSTRACT

This study discusses the assessment and analysis of areas vulnerable to flooding in Eti-Osa and Lagos Island Local Government areas of Lagos state, using Geographic Information System (GIS), LIDAR and spatial modelling techniques. These areas require quality assessment of their level of vulnerability to floods, in order to take adequate measures and develop programs that will help prevent the impacts of flooding. A set of indicators influencing flooding, which are elevation, slope, flow accumulation and land use, were identified and used in the study. A vulnerability scale of (1 – 3) was developed, where 1 represents 'low', 2 represents 'moderate' and 3 represents 'high'. The indicators identified were reclassified in the vulnerability scale. The flood vulnerability maps, in three different case scenarios, were created using the weighted overlay of the reclassified indicators identified. The weights used are determined by a Pairwise comparison method (Analytical Hierarchical Approach (AHP)). The mapping method was implemented in ArcGIS environment. The vulnerability mapping results show that for a normal case scenario, 27.15% of the area have high vulnerability, 49.79% have moderate vulnerability and 23.06% have low vulnerability. However, for a worst-case scenario, 60.01% have high vulnerability, 37.71% have moderate vulnerability and 2.28% have low vulnerability. Buildings at risk and the extent of areas at risk were determined and relevant recommendations were made.

Keywords: Flooding, Mapping, Multi-criteria, GIS, Vulnerability assessment.

1.0. Introduction

Flood is one of the most devastating natural hazards that occur in our world. The occurrence of floods has claimed so many lives and has been of great concern to man. Flooding, which is a natural occurring phenomenon, has also led to the destruction of properties in the flood prone parts of the world, leading to major economic damages in such places. Although, flood hazard is natural, human modification and alteration of nature's right of way can accentuate the problem, while the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas (Eludoyin *et al.*, 2010). Over time some causes of flooding in most urban areas have been due to increase in population, blockage of channels as a result of bad waste disposal as well as human activities at flood plains. But in addition to having a knowledge of these causes, a precise location of areas that are vulnerable to flooding as well as their assessments is of great importance in preparing for and managing flood disasters.

Flood vulnerability mapping is considered to be the key component of the preparedness phase of any flood disaster management. It is carried out long before the occurrence of the flood events. This makes it an indispensable activity in the process of managing flood events because the flood vulnerability maps will depict the precise location of areas that are at risk of flood hazards. These areas depicted by the maps could be a natural environment, notable properties or simply a place where people live. With a precise knowledge of the spatial location of areas vulnerable to flood, activities such as early warning, flood forecasting, can be carried out to help prevent its occurrence or minimize its effects after such occurrences. This is now followed by a response and mitigation process that includes the assessment of damages that have occurred after such a flood event. These steps in managing flood disaster makes flood vulnerability mapping and assessment of great need in the preservation of the environment.

Vulnerability mapping can allow for improved communication about risks and what is threatened (Edwards *et al.*, 2007). Hence, Spatial Information on areas vulnerable to flood in Lagos State, especially in the flood prone areas like the study area considered in this research project, (Eti-Osa and Lagos Island Local Government areas), is not adequately available and this information is required for the determination of the potential loss of lives and even physical infrastructures as well as the effect such losses will have on the lives of the people present. The provision of such spatial information in the form of maps is a key measure that should be taken in the reduction and possible prevention of the negative effects of flooding.

In some parts of Nigeria, various attempts and tools have been employed in the mapping of flood vulnerable areas. Ishaya *et al.*, (2009) made use of Remote Sensing and GIS techniques in flood management with the goal of mapping areas vulnerable to flood hazard in Gwagwalada urban area. The data obtained were simply Topographic Map and Landsat TM image of 1991 and 2001 respectively. They were processed, scanned, digitized, interpolated, classified and overlaid using ILWIS GIS software modules to generate classified Land use/land cover map, Digital Terrain Map and Flood vulnerability map of the study area. The results obtained were vulnerability maps of the study area and a vulnerability assessment showing that areas lying along the banks of River Usuma are most vulnerable to flood hazards with the vulnerability decreasing towards the northern part of the town. Much of the area is built up and this gives rise to high vulnerability to flash flood hazard. Streefland (2013), in the course of creating a small island Flood Vulnerability tool for Mauritius, paid close attention to local communities present in the study area. The aim of the research was to provide a tool that is simple and transparent in order to enable its use by third parties, such as decision and policy makers. In the study, a literature survey was conducted on indicators influencing flood vulnerability. These indicators were Slope, elevation, drainage density, land use and soil were identified. A vulnerability scale of 1 to 5 was developed, where 1 = extremely low flood vulnerability and 5 = extremely high flood vulnerability. The identified indicators were reclassified into the vulnerability scale. The flood vulnerability map was created through weighted overlay of the reclassified indicators. The weights were determined through a literature survey and pairwise comparison. The result showed that 52% of Mauritius is moderately vulnerable to floods, 28% of Mauritius has high flood vulnerability, 18% has low flood vulnerability, and both extremely high and extremely low flood vulnerability account for 1%. According to the study, the results provided can be used to assist decision makers on hazard mitigation, and compare different islands on the basis of their flood vulnerability. GIS applications in flood risk mapping range from storing and managing hydrological data to generating flood inundation and hazard maps to assist flood risk management (Evans *et al.*, 2007).

The aim of this work is to map areas in Eti-Osa and Lagos Island Local Government areas of Lagos state that are vulnerable to flood, using GIS, LIDAR technology and advanced spatial analyses of features present in the areas. LIDAR (DEM), GIS and various input data indicators were used in the production and analyses of the level of vulnerability to flooding of features present in the study areas. It involved the use of 'weighted overlay' GIS tool to produce the vulnerability maps. The weights used in the cause of the weighted overlay process were determined using a Pairwise comparison method developed by Saaty (1970, 2008). It covers the production of flood vulnerability maps showing the precise locations of physical infrastructures and features that are at risk. It also involves typical vulnerability analyses that reveal the effect flooding has on the land uses.

1.1. The Study Area

The study area, Eti-Osa and Lagos Island local government areas (shown in Figure 1) are dynamic in nature. They are adjoining Local government areas both sharing boundaries on the North with Lagos Lagoon, which is the largest coastal lagoon in western Africa. Eti-Osa L.G.A. directly shares its boundary on the south with the Atlantic Ocean. Lagos Island Local Government area in Lagos is a densely-populated area in Lagos State. It has a land area of approximately 4.996 square kilometres. It is located within Latitude 6° 26' 34" N and Longitude 3° 24' 30" E on the left and Latitude 6° 27' 38" N and Longitude 3° 22' 42" E on the right. Lagos Island L.G.A. can be described as a place with a variety of land uses. It's a notable commercial area but also has a mixture of residential and institutional land uses.

Figure 1: Map of the study area (Lagos Island – 1, Eti-Osa - 2)

On the other hand, Eti-Osa Local Government area of Lagos state, Nigeria is located within Latitude $6^{\circ} 26' 34''$ N and Longitude $3^{\circ} 24' 30''$ E on the left and Latitude $6^{\circ} 29' 04''$ N and Longitude $3^{\circ} 39' 09''$ E on the right. It covers a land area of approximately 174.066 square kilometres and it is an area that consists of very high commercial activity in Lagos State.

1.2. The Pairwise Comparison Method of Weight Determination

The Analytic Hierarchy Process (AHP), introduced by Saaty (1980), is an effective tool that can be used to deal with making decisions that are complex in nature. It helps the decision maker to set priorities that will help in making the best decisions. Hence, what is required is to reduce the complex decision to a pairwise comparison, synthesize the results and make the best decision out of it. What AHP does is to consider a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. It generates a weight for each evaluation criterion according to the decision maker. This means that the higher the weight, the more important the corresponding criterion. Pairwise comparison on the other hand is a method that is used to compare indicators to one another based on their importance in a particular phenomenon or context of decision making. This makes it an indispensable part of a complete AHP decision making method. Pairwise comparison has been used in various aspects from individual to collective decision making. According to Saaty (2008), in order to make a decision in an organised way to generate priorities we need to decompose the decision into the following steps:

- i. Define the problem and determine the kind of knowledge sought.
- ii. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels.
- iii. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it. In order to measure the relative importance between two criteria, a numerical scale from 1 to 9, suggested by Saaty (2008) should be used. This is represented in Table 1.
- iv. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority.
- v. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level is obtained.

But in this work, since we are more interested in determining the vector of weights for the various criteria, Kunz (2010) in his presentation on Analytic Hierarchy process provided the following steps to carry out the determination of weights, as follows:

- i. Develop a single pairwise comparison matrix for the criteria
- ii. Multiply the values in each row to get the product
- iii. Normalize the aforementioned product to get the appropriate 'nth' weight; r and
- iv. Calculate and check for the Consistency ratio (CR)

Table 1: The Fundamental Scale of Absolute Numbers (*Source: Saaty, 2008*)

Intensity of Importance	Definition	Definition Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance Moderate importance	Experience and Judgement slightly favour one activity over another
3	Moderate plus importance	Experience and judgement strongly favour one activity over another
4	Strong importance	
5	Strong plus importance	An activity is favoured very strongly over another; it's dominance demonstrated in practice
6	Very strong or demonstrated importance	
7	Very, very strong importance	The evidence favouring one activity over another is of the highest possible order of affirmation
8	Extreme importance	

The procedure above provides the same results (weights) as that provided by Saaty (1980). As a matter of fact, Kunz (2010) presentation made reference to Saaty's work. The consistency ratio CR is used to tell how consistent the pairwise comparison is. If $CR < 0.1$, the consistency ratio (CR) is tolerable, and a reliable result may be expected. RI is the Random Index, i.e. the consistency index when the entries of P are completely random. The values of RI for small problems ($n \leq 10$) are given in Table 2.

Table 2: Values of the Random Index RI for Small Problems

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

2.0. Materials and Methods

2.1. Data Acquisition

The data acquisition process covered all the methods applied in acquiring data for the project and their sources, it involved all the various methods used in obtaining the raw data used for the mapping process and the subsequent analyses to be carried out. The data acquired and their sources for the study are as follows:

- LIDAR data (DEM) acquired in the year 2008, in classified text file format, covering a total of 241 tiles (a tile is 1 square kilometre) from the Office of the Surveyor General of Lagos State.
- Shapefile (Vector Data) of buildings (general infrastructure) covering most part of the study area for the year 2009 was obtained from the office of the Surveyor General of Lagos State.
- Landuse map covering the entire study area for the year 2002 from the ministry of Physical Planning, Lagos State.
- Landuse map covering the western part (Banana Island inclusive) of the study area, for the year 2011.
- Global Positioning System (GPS) coordinates of flood prone locations (a total of 62 locations) in the study area.

2.2. Data Processing

The data processing involved the following:

- The GPS positions for all locations prone to flooding were acquired from the field and a database was created for them.
- LIDAR data processing was carried out using Surfer 10 and a further processing mosaicking of the LIDAR tiles was carried out using ArcGIS 10.1 software package. A LIDAR DEM of 5m resolution was generated.
- The land use map acquired was vectorised using AutoCAD 2012 software and a composite land use map of the study area was produced using ArcGIS 10.1

- iv. A criteria selection process was carried out and they were selected based on their relevance to the study. These criteria are considered to be indicators or factors that influence flooding. Four factors or indicators were considered in this study and they are given as follows:
 - a) Elevation
 - b) Slope
 - c) Flow accumulation
 - d) Land use
- v. Thematic raster maps were produced for each of the indicators using the Reclassification method as provided in the ArcGIS environment.
- vi. Weights were determined for the indicators using a pairwise comparison method as provided by the Analytical Hierarchical Processing (AHP). A detailed process of this is given as follows.

2.3. Determination of Weights for the Indicators Influencing Flooding

2.3.1. Developing a Single Pairwise Comparison Matrix for the Criteria

In order to develop the pairwise comparison matrix, each of the indicators were compared to each other and a particular intensity of importance (a scale of 1 to 9, as shown in Table 1), was given each comparison. When comparing an indicator with itself, the scale attached is one (1). Hence all values in the diagonal are given as 1. But in the cause of making comparisons in this study, the elevation data is considered to be the most important and the land use the least important. This is due to the availability and correctness of the data acquired. Vertical indicators are compared to the horizontal indicators. A higher mark indicates the indicators importance compared to the other indicator. Hence, the comparison matrix [which is a four by four (4 x 4) matrix] is as given in Table 3.

Table 3: Pairwise Comparison Matrix

	Flow Accumulation	Slope	Elevation	Land Use
Flow Accumulation	1	1/2	1/4	3
Slope	2	1	1/4	3
Elevation	4	4	1	5
Land use	1/3	1/3	1/5	1

From the matrix in Table 3, we see the amount of importance attached to each row and column of the matrix of indicators. Taking a look at the comparison of the slope with the flow accumulation, a flow accumulation is dependent on the slope of the terrain, hence slope is twice more preferred or important compared to flow accumulation. That is why in row 2 columns 1, the comparison value given is '2' and in row 1 column 2 the value is '1/2'. This same process was applied in attaching the intensity of importance value to each comparison and adjustments were made until an acceptable consistency ratio was obtained. The matrix translates into Table 4 (with the values in decimals).

Table 4: Pairwise Comparison Matrix (In Decimals)

	Flow Accumulation	Slope	Elevation	Land Use
Flow Accumulation	1.000	0.500	0.250	3.000
Slope	2.000	1.000	0.250	3.000
Elevation	4.000	4.000	1.000	5.000
Landuse	0.333	0.333	0.200	1.000

2.3.2 Multiplying the Values in Each Row Together and Calculating the 'Nth Root' of Same Product

The values on the row are multiplied together and the nth root of their product is determined. In this case n = 4. The tabulated calculation is given in Table 5.

Table 5: Determination of the 4th Root for Matrix Values

	Flow Accumulation	Slope	Elevation	Land Use	(Multiplication of The Row)	4th Root of Product
Flow Accumulation	1.000	0.500	0.250	3.000	0.375	0.783
Slope	2.000	1.000	0.250	3.000	1.500	1.107
Elevation	4.000	4.000	1.000	5.000	80.000	2.991
Landuse	0.333	0.333	0.200	1.000	0.022	0.386
					Total:	5.266

From Table 5, the values of the 4th root were calculated and the summation of these values is given to be 5.266. Hence, in order to obtain the weights or priority vector, nth root obtained has to be normalized.

2.3.3. Normalizing the '4th' Root of Products to get the Appropriate Weight

In order to normalize the 4th root, each value of the 4th root obtained, is divided by the summation of the values obtained for the 4th root product (5.266). The normalization results obtained gives us the criteria weights for each indicator. The summation of the obtained criteria weights must be equal to 1. The criteria weights are shown Table 6.

Table 6: Obtaining the Criteria weights

Indicator/Factor	4th Root of Product	Criteria Weight (Priority Vector)
Flow Accumulation	0.783	0.149
Slope	1.107	0.210
Elevation	2.991	0.568
Landuse	0.386	0.073
Total	5.266	1.000

2.3.4. Calculating and Checking for the Consistency Ratio (CR)

Since the consistency ratio serves as a way of checking how consistent our pairwise comparison was, its calculation is compulsory. Hence, in order to calculate for it, the following steps were followed;

- The pairwise comparison values in each column were added together and each added value was multiplied by the respective weight.
- Next the results from the multiplication were then added together (see Tables 7 and 8).

Table 7: Summation of Pairwise Comparison Values

Indicator	Criteria weight (w)	SUM PW	(SUM PW) X (w)
Flow Accumulation	0.149	7.333	1.090
Slope	0.210	5.833	1.226
Elevation	0.568	1.700	0.966
Landuse	0.073	12.000	0.879
Total	5.266	1.000	x = 4.161

Table 8: Multiplying Criteria Weights (W) by Summation of Pairwise Comparison Values (SUM PW)

	Flow Accumulation	Slope	Elevation	Land Use	4th Root of Product	Criteria weight (Priority vector)
Flow Accumulation	1.000	0.500	0.250	3.000	0.783	0.149
Slope	2.000	1.000	0.250	3.000	1.107	0.210
Elevation	4.000	4.000	1.000	5.000	2.991	0.568
Land use	0.333	0.333	0.200	1.000	0.386	0.073
SUM PW	7.333	5.833	1.700	12.000		1.000

After this the Consistency Index (CI), which is required for the direct determination of the consistency ratio, was calculated using the Equation given by Saaty (1990) and Kunz (2010):

$$CI = \frac{(x - n)}{n - 1} \quad (1)$$

(Where n = 4 (number of criteria) and value of x = 4.161)

$$CI = \frac{(4.161 - 4.000)}{4.000 - 1}$$

$$CI = \frac{(0.161)}{3.000} = 0.054$$

The value of CI is given as 0.054 and as earlier presented, a perfectly consistent decision maker should always obtain CI=0, but small values of inconsistency may be tolerated.

Hence, the consistency ratio CR, which is used to tell how consistent the pairwise comparisons are, is given by (Saaty, 1990; Kunz, 2010) as:

$$CR = \frac{CI}{RI} \quad (2)$$

The values of Random Index (RI) for small problems ($n \leq 10$) are shown in Table 2. For this particular problem, RI is 0.9. Hence, the consistency ratio is given as follows:

$$CR = \frac{0.054}{0.9} = 0.059$$

The consistency ratio (CR) obtained is given as 0.059, and this value is less than 0.1. This shows that our pairwise comparisons carried out and criteria weights obtained are consistent and accurate respectively, for the decision-making process of producing a flood vulnerability map. Converting the weights to percentage values, we have the percentage influence of each indicator. This is presented in Table 9.

Table 9: Determining Percentage Influence for Each Indicator

Factor (Flood Indicator)	Criteria Weight	Percentage Influence (%)
Flow Accumulation	0.149	14.9
Slope	0.210	21.0
Elevation	0.568	56.8
Landuse	0.073	7.3
Total	1.000	100

Approximating the percentage values (which is required for the weighted overlay process in ArcGIS 10.1), we have the final percentage influence for each indicator in Table 10.

Table 10: Percentage influence as attached to each indicator in this project

Factors (Flood Indicator)	Percentage Influence (%)
Flow Accumulation	15
Slope	21
Elevation	57
Landuse	7
Total	100

After the determination of the weights, the weighted overlay tool in ArcGIS was used to produce a final flood vulnerability raster maps which were then converted to polygonal features for analyses purposes. The flood vulnerability map was created in three different scenarios. The difference in the scenarios was the alteration of the elevation ranges in each of the scenarios. The elevation ranges used are given in Table 11.

Table 11: Elevation Ranges Differentiation for all three case scenarios

Normal Scenario (Elevation Range)	Moderate Scenario (Elevation Range)	Worst Scenario (Elevation Range)	Description	Scale
4.116 – 15.820	5.116 – 15.820	6.116 – 15.820	Low	1
1.797 – 4.116	2.797 – 5.116	3.797 – 6.116	Moderate	2
-9.907 – 1.797	-9.907 – 2.797	-9.907 – 3.797	High	3

3.0. Results and Discussion

3.1. Results

Flood vulnerability maps were produced after executing the GIS based tool (model). These maps were created in three case scenarios. They are represented in Figures 2, 3 and 4.

Figure 2: Flood Vulnerability Map (Normal Case Scenario)

Figure 3: Flood Vulnerability Map (Moderate Case Scenario)

Figure 4: Flood Vulnerability Map (Worst Case Scenario)

3.2. Analysis of Flood Vulnerability Maps

Typical analyses were carried out on the flood vulnerability maps for the three case scenarios. The area covered by the various flood vulnerability classes, which are the low vulnerability, moderate vulnerability and high vulnerability for the three scenarios were calculated using the calculate geometry in the ArcGIS 10.1 environment. The results are presented in Tables 12, 13 and 14. Histograms of the flood vulnerability using the three case scenarios are presented in Figures 5, 6 and 7.

Table 12: Flood Vulnerability Analyses (Normal Case Scenario)

Vulnerability Level	Area (Sq. Km)	Percentage Coverage (%)
Low	41.545	23.061%
Moderate	89.700	49.792%
High	48.904	27.146%

Table 13: Flood Vulnerability Analyses (Moderate Case Scenario)

Vulnerability Level	Area (Sq. Km)	Percentage Coverage (%)
Low	14.003	7.773%
Moderate	76.027	42.202%
High	90.117	50.024%

Table 14: Flood Vulnerability Analyses (Worst Case Scenario)

Vulnerability Level	Area (Sq. Km)	Percentage Coverage (%)
Low	4.099	2.275%
Moderate	67.938	37.712%
High	108.110	60.012%

Figure 5: Flood Vulnerability Analyses (Normal Case Scenario)

Figure 6: Flood Vulnerability Analyses (Moderate Case Scenario)

Figure 7: Flood Vulnerability Analyses (Worst Case Scenario)

From Figures 5, 6 and 7, we can see that there is an increase in the percentage of coverage of the high vulnerable areas. This poses a threat to the features present in the study area. With a percentage of 60.012% of the study area being vulnerable to flooding in the worst-case scenario, this poses a high threat to the people and lives present in the study area should a severe flooding situation occur. This will lead to a high physical and environmental impact on the infrastructure and people present in the environment.

3.3. Flood Vulnerability Assessment on the Building

Flood vulnerability assessments were carried out on the building features (structures provided), and this was to ascertain their level of vulnerability. Selections were made based on their locations on the flood vulnerable map, using the 'Select by Location tool'. This provided a selection of all buildings that were vulnerable and their level of vulnerability were analysed based on the building use. The results provided are for the normal case scenario and they are presented in Tables 15, 16 and 17.

Table 15: Buildings with low flood vulnerability (Area in square meters)

Building Use	Area (Sq. Meters)	Percentage Coverage (%)
Business and Commerce	385611.464	6.199
Industrial	148321.923	2.385
Institutional	426519.431	6.857
Other Uses	1768.240	0.028
Recreational	100.065	0.002
Residential/Commercial	5257854.766	84.529

Table 16: Buildings with moderate flood vulnerability (Area in square meters)

Building Use	Area (Sq. Metres)	Percentage Coverage (%)
Business and Commerce	802891.3659	6.373
Industrial	50032.06801	0.397
Institutional	1421837.22	11.287
Other Uses	17858.86543	0.142
Recreational	39193.76022	0.311
Residential/Commercial	10265656.61	81.490

Table 17: Buildings with high flood vulnerability (Area in square meters)

Building Use	Area (Sq. Meters)	Percentage Coverage (%)
Business and Commerce	802891.366	6.373
Industrial	50032.068	0.397
Institutional	1421837.220	11.287
Other Uses	17858.865	0.142
Recreational	39193.760	0.311
Residential/Commercial	10265656.610	81.490

Table 15, Table 16 and Table 17 show that the residential/commercial buildings are the highest in vulnerability for all levels. This is due partly to the nature of the study area and the classification of the buildings based on the land use maps produced in this study. However, the results show that residential and commercial areas are mostly affected by flood. The vulnerability level to flood, for the institutional areas had an increase in percentage from the low to the moderate level of vulnerability.

4.0. Conclusions and Recommendations

4.1. Conclusion

The results and information generated from this study using LIDAR data, remote sensing techniques and GIS analyses have demonstrated that it is possible to effectively produce flood vulnerability maps at various levels (low, moderate and high vulnerability levels) as well make predictions as regards flooding in the study area. Desired analyses and inferences may also be carried out at whatever time they are required. After the production of the vulnerability maps and GIS analyses, the results provided serve to show the level of risk of flooding and the extents to which these areas and the people present in it are vulnerable. Major areas such as Dolphin Estate, Sura as well as Idumagbo, which are areas in Lagos Island, are highly at risk.

In conclusion, the use of remotely sensed data, flood modelling as well as Geospatial information system (GIS), has effectively demonstrated and initiated the aim of mapping areas that are vulnerable to flooding. These tools have been able to reveal areas at risk to flooding that need critical attention,

like the major areas in Lagos Island local government areas earlier mentioned, as well as other relevant information that will aid in a better monitoring and management of the study areas as regards to flooding, now and in the future. It is therefore compulsory that care must be taken though to ensure that the data gathered for such studies are accurate, so as to produce precise results, from which effective policies, laws and other regulations will be implemented.

4.2. Recommendations

The following recommendations are made:

- i. The quality of data, maps produced as well as the modelling process carried out will be of great importance in the proper handling and management of flooding in Eti-Osa and Lagos Island.
- ii. This project may be adopted and used as a source for planning and management in the study area and indeed in other administrative capacities.
- iii. The development of good policy and proper planning with the results obtained from this study will go a long way in reducing flooding occurrences as well as help in the control and management of such occurrences in the study area.
- iv. Proper data provision, updating and management for such studies should be carried out. This will ease the execution of such studies more frequently, thereby providing up to date information at various times.
- v. Proper flood warning systems should be put in place for the study area for flood monitoring processes.

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