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(Research Article)

Application of geospatial techniques in mapping urban flooding in parts of Victoria island

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Abstract

This study aimed at application of geospatial techniques in mapping of urban flooding in parts of Victoria Island. Its objectives were to delineate different risk levels of flooding in the study area, to determine the effect or impact of flooding on different land cover types and to produce flood risk map of the study area. The methodology involves data acquisition, data processing and reclassification and overlay analysis. This study has been able display the usefulness of Remote sensing and GIS technologies in classifying and in identifying areas with high, moderate, low risk of flooding within the study area. The classification achieved an overall Classification Accuracy of 84.99% and kappa statistics of 0.8792. The image classification results indicate that built up area accounted for the largest land cover/use of about 50.41% with an area of 856hectares while water body had the second largest with 23.32% and an area of 396 hectares, open space had 14.72% with an area of 250 hectares and vegetation had 11.54% with an area of 196hectares. The flood risk mapping results also that high-risk zone occupied 34.68% of the entire study area, covering an area of 589 hectares, while moderate risk zone occupied 47.05%, covered an area of 799 hectares. low risk zone occupied 18.25% covering 310 hectares. It was recommended that the results achieved in this research should be used as a base to help identify areas at risk of being flooded in the study area

Keywords: Lagos; Landcover/Landuse; Flood Risk; SRTM; Victoria Island

1. Introduction

Flooding is getting more frequently reported in the mass media both the minor events that will be forgotten soon and major events that will be remembered for many years such as massive flooding in Pakistan recently that killed 1,200 people and more than 14 million people affected (UN-OCHA, 2010). The global flood risk has been increasing as the world's population is rapidly growing. The consequences of rapid population growth are the increasing demand for settlement, food resources, etc.

Nwafor (2006), defined flood as a natural hazard which occurs as an extreme hydrological (run off) event. Flooding can also occur as a result of failure of man-made water containment system such as dams, reservoirs and pumping systems. Floods are considered one of the hazards making the most impact on human beings (Blaikie et al).

Smith (2001), also stated that floods claim 20,000 lives and adversely affects around 75 million People worldwide annually, excess water in and of itself may not be a problem, rather the impacts of floods are felt when it interacts with natural and human made environments in a negative sense causing loss of lives or injury, property, damage, social and economic disruption. Floods are also caused by anthropogenic activities and by human interventions in natural processes, such as urbanization, population growth, uncontrolled and uncoordinated development of the suburb, flood

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plains, swamps and natural drainage channels, leading to alterations in the natural drainages, deforestation and climate change (European commission,2007).

Floods have been a dominant natural disaster in terms of event for recent years around the world especially in South East Asia, Africa and South America. Floods have affected over 9 million people in Bangladesh, about 30 million in India and have devastated millions of people in Malaysia, Indonesia, Pakistan and the Philippines (ADB,2007). In January, 2004, 84 people died in Brazil as result of flood related event (Tucci, 2005).

Many African cities have experienced extreme flooding in recent years. Prominent examples are floods due to heavy rain and cyclone that hit Mozambique in February and March 2000 and it led to the worst flood in 50years in that Country and brought widespread devastation to the capital city, Maputo. Upwards of million people were directly affected (Action Aid 2006). In 2002, heavy rains cause by unusually high temperatures over the India ocean killed over 112 people in East Africa. Floods and mudslide forced Tens of Thousands to leave their homes in Rwanda, Kenya, Burundi, Tanzania and Uganda.

Rwanda suffered the heaviest toll, with more than 50 people dead in 10 days (Action Aid, 2006). In August 2006, in Addis Ababa, floods killed more than 100 people and destroyed homes in Eastern Ethiopia after heavy rains caused a River to overflow. The overflowing Dechatu River hit Dire Dawa town at night drowning 129 people and wiping out 220 homes.

Flood is the most common environmental hazard in Nigeria (Etuonovbe, 2011). Flood is not a recent phenomenon in the country, and its destructive tendencies are sometime enormous. Nigeria recorded its first flood in Ibadan, the Oyo State capital in 1948. Since then, the menace has spread like a wild fire to other states of the federation.

Reports have it that serious flood disasters have occurred in Ibadan (1985, 1987, 1990 and 2011), Oshogbo (1992, 1996 and 2000), Yobe (2000), Akure (1996, 2000, 2002, 2004 and 2006), Kano (2006), Taraba (2005) and the coastal cities of Lagos, Port Harcourt, Calabar, Uyo and Warri among others have severally experienced many incidences that have claimed many lives and properties worth millions of naira (Adeoye et al, 2009). The 2012 notable flooding in Nigeria, Urban areas are more exposed to flooding.

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 (Action aid, 2006).

Flooding is a common occurrence in many parts of Victoria Island mostly during the rainy season or at tidal. Rapid rate of land use and population growth over the years now has led to uncontrolled and uncoordinated development of the suburbs, 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 risk (risk) areas and in planning against flooding event in the future.

Determining the flood vulnerable area is important for effective flood mitigations. For this study, geospatial technique will be used to demarcate flood risk in the study area.

Seasonally, coastal communities like Victoria Island are flooded to the extent that damages are caused to human lives and other properties, whenever it rained heavily. In 2018 for example, certain portion of areas in Victoria island was flooded after torrential rains (or intense rainfall). Properties worth millions of Naira were destroyed, it was described as very disastrous. This brought a lot of difficulties and untold hardships on the affected victims in the town; This situation calls for an effective management of flooding in the area. Thus, the integrated use of remote sensing and GIS served as a valuable tool in identifying and monitoring flood risk zones in Victoria Island.

2. Materials and Methods

2.1. Study Area

The study area, Victoria Island is an affluent area that encompasses a former island of the same name neighbouring Lagos Island, Ikoyi and the Lekki Peninsula by the Lagos Lagoon. It is the main business and financial centre of Lagos in Lagos State, Nigeria. Victoria Island is one of the most exclusive and expensive areas to reside in Lagos. The town and island lie within the boundaries of the Eti-Osa Local Government Area (LGA).

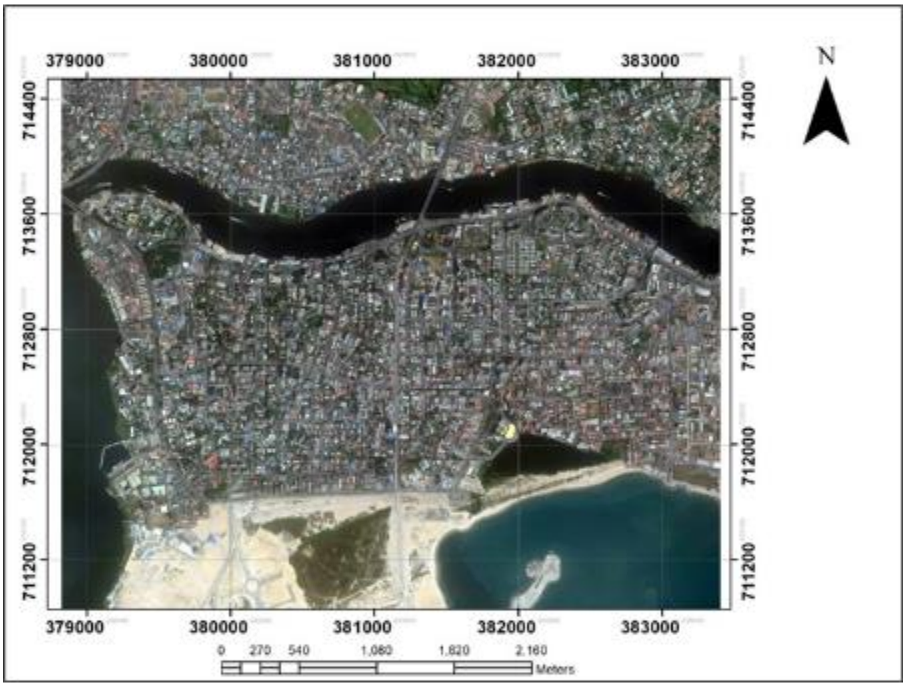

Figure 1 Victoria Island

2.2. Methodology

The Data that was required for this research includes: Sentinel imagery covering the study area, Shuttle radar topographic mission (SRTM) covering the study area and Shape file of the boundary extent of Victoria Island.

The processing techniques involve the following:

2.2.1. Image Sub-Mapping

This process was carried out in order to cut out the area of interest from the satellite image and SRTM using the shape file of Victoria Island extracted from the administrative boundary of Nigeria local government area. This was achieved using the ArcGIS 10.6 software.

2.2.2. Definition of class categories

This was done to identify and define various class features on the scene before following a familiarization visit to the site. Thus, the following class features in Victoria Island were identified and defined according to level 1 classification scheme, this scheme was adopted because of the resolution of the image sets and to ensure that the features are discriminated adequately.

- Built up Area
- Water Body
- Vegetation
- Open Space

2.2.3. Ground Truthing

This exercise was carried out after definition of class categories in order to identify the features on the ground and collect sample points for accuracy assessment.

2.2.4. Image Classification

Digital image classification uses spectral information represented by the digital numbers in one or more spectral bands and attempts to classify each individual pixel based on its spectral information. In this study, the images were classified using the supervised classification method.

2.2.5. SRTM Processing

SRTM is a topographical model with elevation records of cells in certain size. However, there is still potential of existence off sunken areas because of data error or landform Karst Topography. Data error is mainly caused by the resolution limitation of DEM on both vertical and horizontal direction and system error during the generation of DEM. Due to existence of these sinks, unreasonable flow direction may be generated during the calculation. If these sinks are not filled by technical process, then the generated drainage network will not be continuous.

The process of filing sink is called elevation smoothing or filling depressions. The main purpose of elevation smoothing is to reduce the number of artificial depressions generated by data collection system. The most used procedure of sink fill, taken as the official algorithm in the most wide-used GIS software ArcGIS.

The SRTM was processed to fill the sinks present in the elevation dataset; this was done with spatial analyst tool in Arc Toolbox. Since water flows from higher to lower elevations and slope influences the amount of surface runoff and infiltration, and also Flat areas in low elevation may flood quicker than areas in higher elevation with a steeper slope.

Areas of concentrated surface water, river overflows are crucial for the initiation of a flood event. Often the inundation emanates from riverbeds and expands in the surroundings. Flow accumulation is the most important parameter in defining flood hazard. Accumulated flow sums the water flowing down slope into cells of the output raster. High values of accumulated flow will indicate areas of concentrated flow and consequently higher flood hazard.

With this, the classified elevation, slope gradient, flow accumulation, drainage networks were created. This was done in preparation for the weighted layers needed for analytical hierarchy process analysis.

2.2.6. Overlay Analysis

This analysis was used to create flood hazard zones by assigning weight of importance to the layers created. The weighted layers are then overlaid, and a Comparism intersect matrix is performed to produce flood risk zones for the study area. The final calculation is done in ArcGIS raster calculator.

3. Results and discussion

3.1. Land cover Land use Mapping

3.1.1. Land cover Land use Distribution of Victoria Island

In mapping landcover/land use, four different classes were identified to include Built up areas, vegetation, open space and water bodies. The classified image of Victoria Island is shown in figure 2.

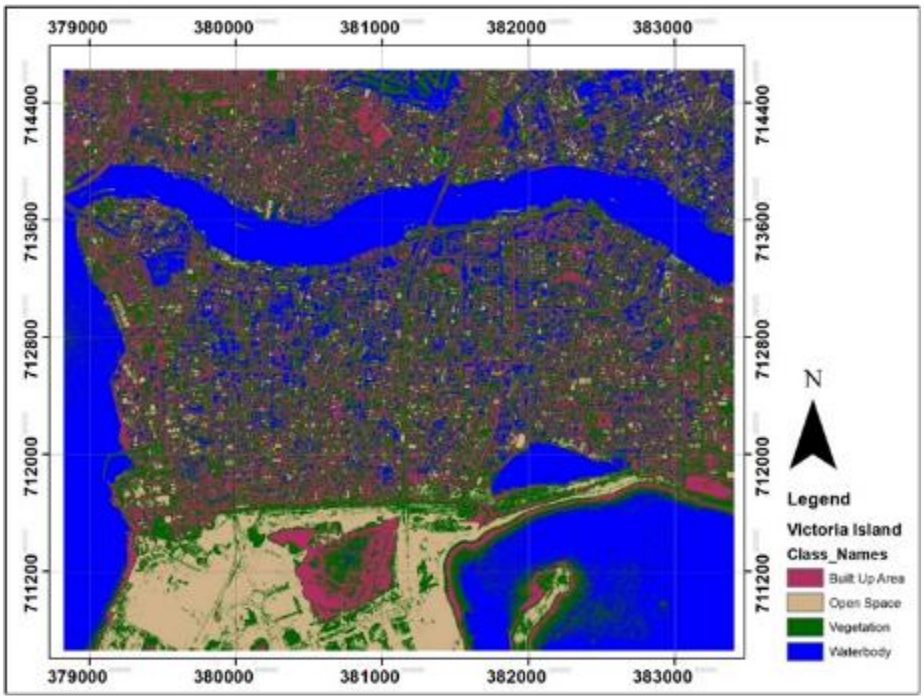

Figure 2 Landcover Landuse map of Victoria Island

Figure 2 shows the results of the land cover/land use classification of Victoria Island, the results indicate that built up area accounted for the largest land cover/use of about 50.41 % with an area of 856hectares while water Body had the second largest with 23.32 % and an area of 396 hectares, open space had 14.72 % with an area of 250 hectares and vegetation had 11.54 % with an area of 196hectares. The landcover landuse distribution is shown in figure 3.

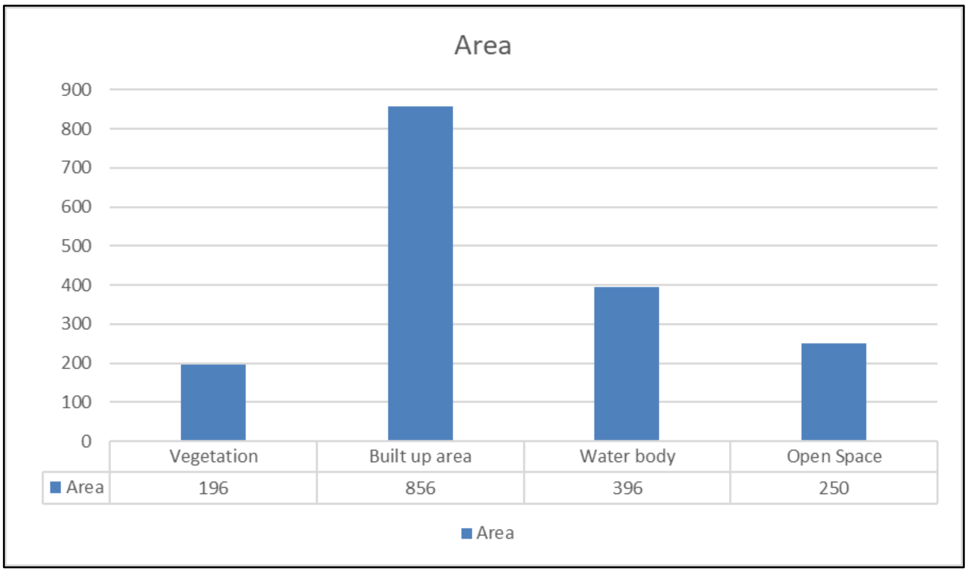

Figure 3 Histogram of landcover landuse distribution of Victoria Island

3.1.2. Accuracy Assessment and Kappa Statistics

In remote sensing-land cover mapping study, classification accuracy is most important aspect to assess the reliability of the final output maps. The main purpose of assessment is to assure classification quality and user confidence on the product.

Kappa statistics was done to measure the level of agreement of the classification of the class categories, kappa is always less than or equal to 1. A value of 1 implies perfect agreement and values less than 1 implies less than perfect agreement.

- Interpretations of kappa
- Poor agreement = Less than 0.20
- Fair agreement = 0.20 to 0.40
- Moderate agreement = 0.40 to 0.60
- Good agreement = 0.60 to 0.80
- Very good agreement = 0.80 t0 1.00

From the results gotten from the Classification Accuracy Assessment Reports and Kappa (K^) statistics for the image, it shows a very good accuracy and also a very good agreement on the Kappa statistics. The result of the classification accuracy assessment report and kappa statistics for the classified image of Victoria Island is shown in table 1.

Table 1 Accuracy Assessment Reports and Kappa (K^) Statistics for Victoria Island Classification

Accuracy totals			**Kappa (k^) statistics**
Class Name	Producers Accuracy	Users Accuracy	Kappa
Vegetation	91.66%	94.45%	0.9305
Built up area	88.67%	85.38%	0.8702
Water body	97.00%	86.00%	0.9300
Open space	97.00%	86.44%	0.9072
Totals			Overall K^
Overall Classification Accuracy = 84.99%			0.8792

3.2. SRTM Processing

3.2.1. Filling Sinks

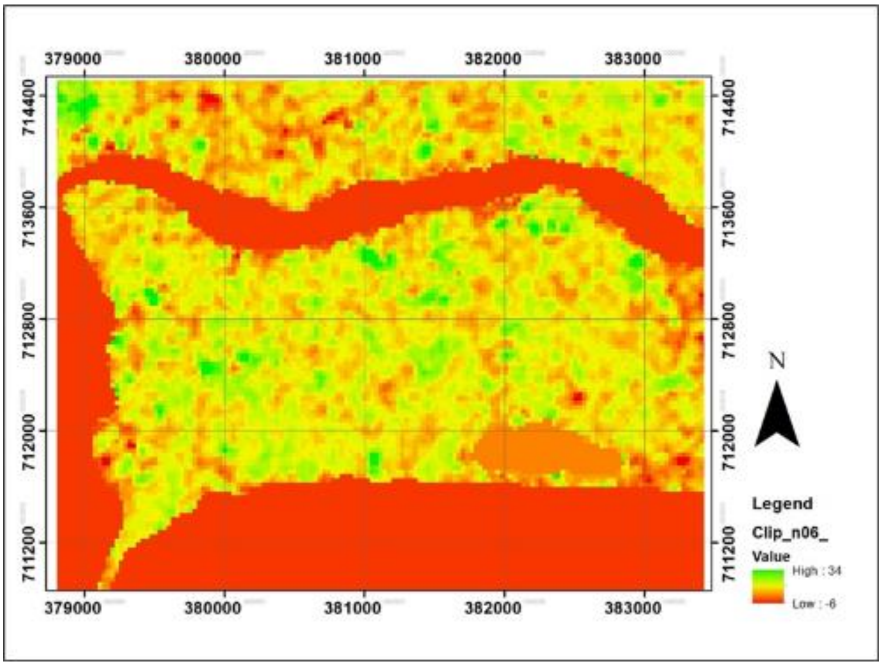

Figure 4 Filled SRTM

SRTM is a topographical model with elevation records of cells in certain size. However, there is still potential of existence off sunken areas because of data error. Data error is mainly caused by the resolution limitation on both vertical and horizontal direction and system error during the generation of DEM. Due to existence of these sinks, unreasonable flow direction may be generated during the calculation. If these sinks are not filled by technical process, then the generated drainage network will not be continuous. The main purpose of elevation smoothing is to reduce the number of artificial depressions generated by data collection system. The results achieved by filling the sinks in the SRTM using ArcGIS hydrology tool, see figure 4.

3.2.2. DEM and slope Reclassification

After the SRTM was filled, Dem was reclassified into the following elevation class as follows:

- 2-6m (High Risk)
- 6m-10m (moderate Risk)
- 10m-34m (low Risk)

These categories of risk were created based on the elevation and ground information obtained within the catchment.

The SRTM was also used to create the slope gradient of the study area. The slope gradient obtained from the SRTM was reclassified using the following five classes based on Food and Agricultural Organization (FAO) classification of slopes:

- 0-4% = Flat (High Risk)
- 4-12% = Undulating (moderate Risk)
- 12 -32 % = Rolling (low Risk)

3.2.3. Flow Accumulation

Flow accumulation is a process that assigns every cell with a value equal to number of cells flow into it. To be specific, the process of flow accumulation is based on the data of flow direction and rules below are followed.

- Starting from the first cell, tracks cells along the flow direction until a stop point (lowest elevation in 3*3 matrix) of flow or edge of DEM.
- Cells along the tracking route gain 1 accumulated value;
- When cross with tracking routes, the accumulated value of the other tracking route is added to current tracking route.
- Calculation stops when each cell in flow direction data matrix is calculated.

Catchment area was calculated by multiplying value in accumulated flow matrix with the area of a single cell. Since areas of concentrated surface water, river over-flows are crucial for the initiation of a flood event and often the inundation emanates from riverbeds and expands in the surroundings. Flow accumulation is the most important parameter in defining flood hazard. Accumulated flow sums the water flowing down slope into cells of the output raster. High values of accumulated flow will indicate areas of concentrated flow and consequently higher flood hazard.

3.2.4. Distance from Drainage Networks

The drainage channels are defined as cells with accumulated flow exceeding a user-defined threshold. Apart from areas of concentrated surface water, river-overflows are crucial for the initiation of a flood event. Often the inundation emanates from riverbeds and expands in the surroundings. The role of riverbed decreases as the distance increases. That explains why “distance from the drainage network” has been assigned a high weight in the methodology. It appears that areas near the river network < 200 m are highly flood hazard, whereas the effect of this parameter decreases in distances > 2000 m. therefore a Boolean distance buffer was created for 200, 500, 800 and 1000 representing high risk, moderate risk, low risk and no risk areas.

3.2.5. Overlay analysis

An overlay analysis was conducted by overlaying all reclassified factors against each other. The resulting layer indicated the intersection between the various risk classes. This intersection defined the risk in the study area.

3.3. Flood Risk Zones

The results of the overlay analysis produced a layer showing three hazard zones; namely high risk, moderate risk and low risk in the study area.

The results indicated that high-risk zone occupied 34.68% of the entire study area, covering an area of 589 hectares, while moderate risk zone occupied 47.05%, covered an area of 799 hectares. low risk zone occupied 18.25% covering 310 hectares. This is distribution is also represented in figure 5.

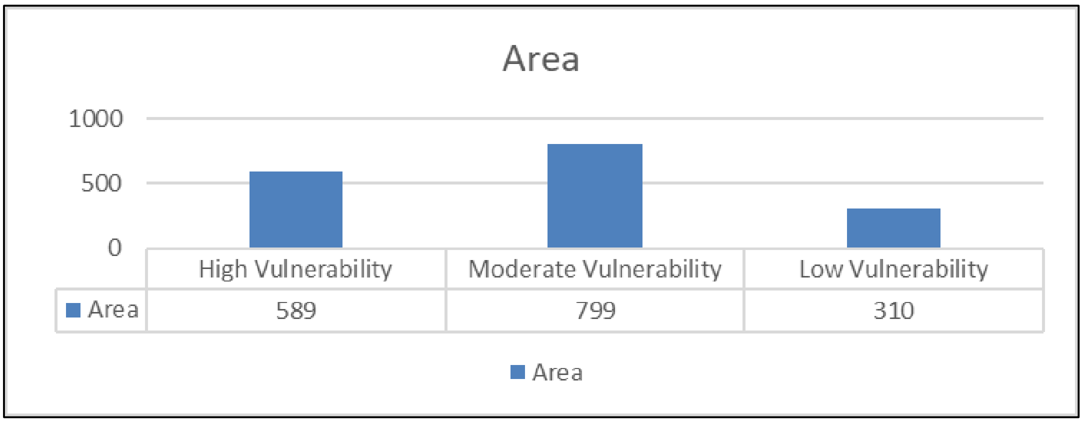

Figure 5 Flood Risk Zones within the Study Area

3.3.1. Feature class at risk of Flooding

Feature at high-risk flooding

An overlay analysis was done, overlaying the flood hazard layer with the landcover/landuse layer to determine areas at risk. The results in shown in figure 6 and table 2.

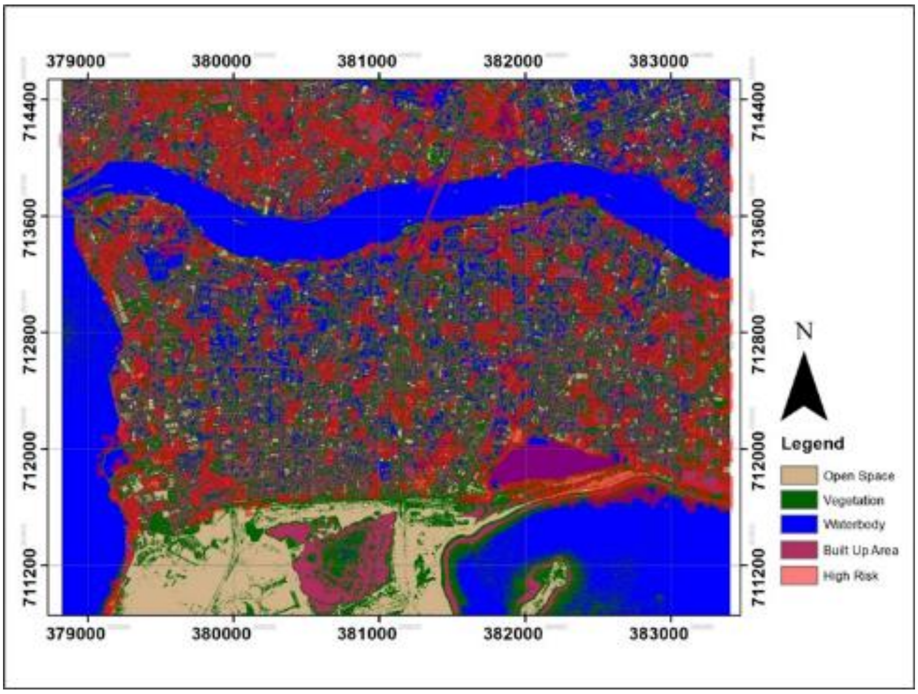

Figure 6 Feature class at high-risk flooding

The results showed that built up area occupied the largest area in high-risk flood zone with an area of 459 hectares, followed by waterbody covering an area of 75 hectares. While water vegetation occupied 55 hectares. The distribution of class within the very high-risk flood zone is shown in table 2.

Table 2 Distribution of feature class at high-risk flooding

Landcover/Landuse Class at Risk Flooding		
Class Name	**Area (km2)**	**Percentage (%)**
Vegetation	55	9.33
Built up area	459	77.92
Water body	75	12.73
`Total	589	100

Features at risk of Moderate flooding

The overlay results showing feature class at Moderate risk is shown in table 3 and figure 7.

Table 3 Distribution of feature class at risk of Moderate risk flooding

Landcover/Landuse Class at moderate Risk Flooding		
Class Name	**Area (Hectares)**	**Percentage (%)**
Vegetation	141	17.64
Built up area	397	49.68
Water body	111	13.89
Open space	150	18.77
`Total	799	100

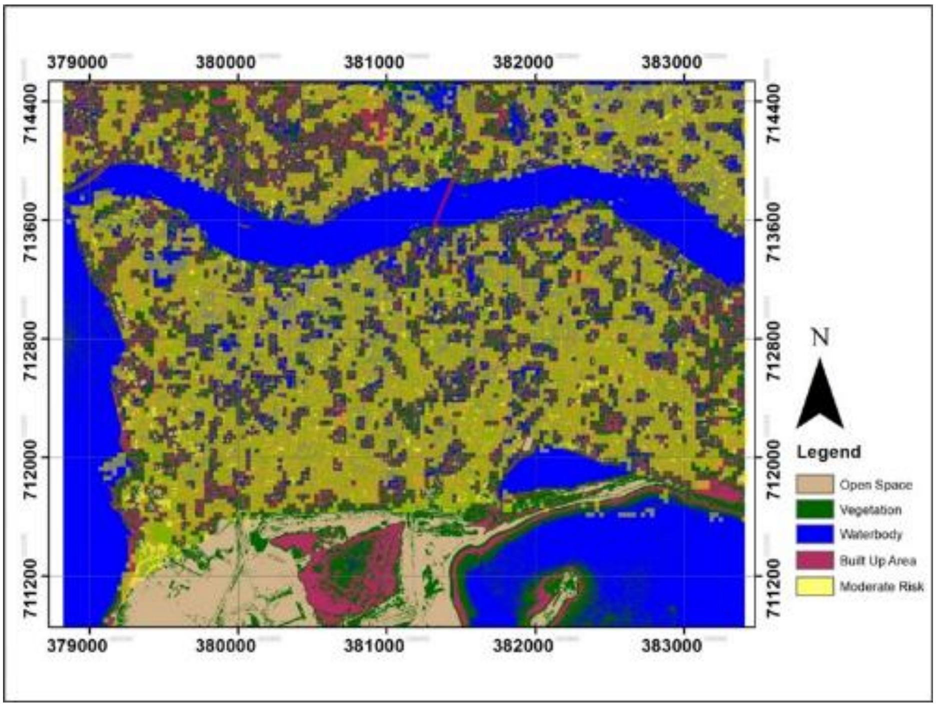

Figure 7 Feature class at moderate risk flooding

The results in figure 7 indicates that built up area occupied the largest area in moderate risk flood zone with an area of 397 hectares, followed by open space covering an area of 150 hectares. While water body and vegetation occupied 111 and 141 hectares respectively.

Features at low-risk flooding

The results for feature class at low-risk flooding indicate that built up area occupied the largest area in low-risk flood zone with an area of 140 hectares, followed by open space covering an area of 70 hectares. While water body and vegetation occupied 60 and 40 hectares respectively. The distribution of class within the low-risk flood zone is shown in table 4 and figure 8.

Table 4 Distribution of feature class at moderate risk flooding

Landcover/Landuse Class at risk of low-Risk Flooding		
Class Name	**Area (Hectares)**	**Percentage (%)**
Vegetation	40	12.90
Built up area	140	45.16
Water body	60	19.35
Open space	70	22.58
`Total	310	100

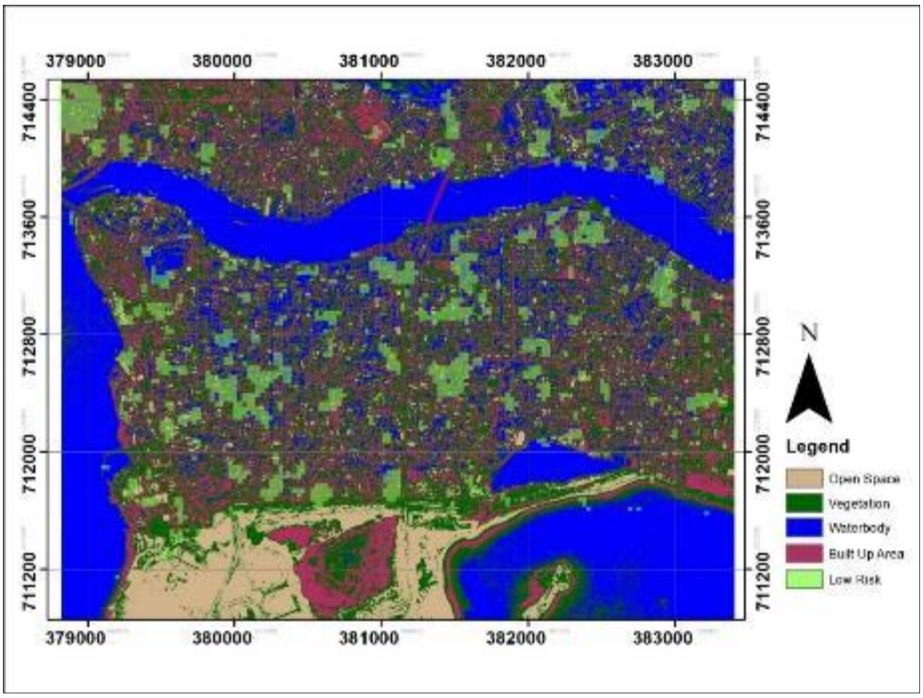

Figure 8 Feature class at low-risk flooding

4. Conclusion and Recommendation

This study aimed at performing an assessment of flood risk in parts of Victoria Island using flood Remote sensing and GIS. Its objectives were to delineate different risk levels of flooding in the study area, to determine the effect or impact of flooding on different land cover types and to produce flood risk map of the study area. The methodology involves data acquisition, data processing and reclassification and overlay analysis. This study has been able display the usefulness of Remote sensing and GIS technologies in classifying and in identifying areas with high, moderate, low risk of flooding within the study area. The classification achieved an overall Classification Accuracy of 84.99% and kappa statistics of 0.8792. The image classification results indicate that built up area accounted for the largest land cover/use of about 50.41% with an area of 856hectares while water body had the second largest with 23.32% and an area of 396 hectares, open space had 14.72% with an area of 250 hectares and vegetation had 11.54% with an area of 196hectares. The flood risk mapping results also that high-risk zone occupied 34.68% of the entire study area, covering an area of

589 hectares, while moderate risk zone occupied 47.05%, covered an area of 799 hectares. low risk zone occupied 18.25% covering 310 hectares.

Based on the results and analysis obtained, the following recommendations were made:

- The risk maps produced in this research are beneficial and are recommended that they be used in encouraging risk zone residents to prepare for the occurrence of flooding.
- It is recommended that the results achieved in this research can be used as a base to help identify areas at risk of being flooded in the study area.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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