Development of Flood Prone Area Map for Igbokoda Township using Geospatial Technique

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Abstract

Rapid urbanization has greatly increased the volume of runoff generated in many developed areas and subsequently resulting in flooding. This study evaluated the flood prone area of Igbokoda town in Ondo State and developed a flood risk map to facilitate proper planning and future flood mitigation. Scientific technique of GIS was used to identify flood risk areas within the study area. The Landsat 5 (TM), Landsat 7 (ETM+) and Landsat 8 (LC) images for 1986, 1999 and 2013 coupled with STRM 90 m DEM data of the area were used to identify three categorized risk zones. A total of 339 basins were delineated and stream network on the landscape of this area were carved. Hydrological and vegetation cover analyses were conducted using the satellite imageries obtained from United States Geological Surveys Archive online over the study area for three different epochs 1986, 1999 and 2013. There was a sharp decrease in area of vegetation cover from 1986 (19,630 ha) to 1999 (16,527.36 ha) and in 2013 (12,246.80 ha). The hydrological analysis results revealed that a major part of the residential area within the largest basin delineated was associated with low elevation and high slope angle. The combined stream network and slope of the area were used in developing flood risk zones. Three zones were specified: high, medium, and low flood risk zones. The total area covered by the high risk zone was 28.5615 km^2 while the area of the medium and small risk zones were 15.94759 km^2 and 31.3619 km^2 respectively. It is recommended that an increased awareness on flood risk zone should be created among the populace of Igbokoda to guide them in further development.

Keywords: *Change detection, Drainage basin, DEM, Flooding, GIS, Land use/Land cover, Rainfall, Surface Runoff*

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1. Introduction

Flooding is a critical environmental problem and one of the most common, devastating, and widespread natural disasters of the world. It has major impacts globally, and the risk of flooding is expected to increase substantially over time. Flood has remained the second deadliest of all weather related hazards and has been detrimental to many other societies in most parts of the world because of the large numbers of fatalities and the costly damages to properties and human lives. The management of flood risk is a problem of such importance as to induce a continuous effort of the scientific community in the development of new methods of floodplain mapping [1-7]. Floods are induced by heavy rainfalls, failures of hydraulic structures, and a host of human-induced factors. It occurs in most terrestrial portions of the globe, causing huge annual losses in terms of damage and disruption to economic livelihoods, businesses, infrastructure, services and public health [8]. The main hydrologic-hydraulic factors giving rise to flooding are relief, type and intensity of precipitation, vegetation cover, drainage capacity, geology, river morphology with extension of channel and floodplain, channel-floodplain interaction and roughness [9]. The identification of flood prone areas is a critical issue that is becoming more challenging and pressing for our society [10; 11; 12].

In Nigeria, aside from droughts, floods cause almost 90 percent of damages resulting from natural hazards [13]. Floods that occur in Nigeria are as a result of extensive rainfall, drainage blockages and dam failures [14]. The effect of floods in Nigeria has been on the increase especially in the last three decades. It has become a life threatening concern to the citizenry and the number of deaths and damages caused by this perennial disaster are alarming. Annually, more than 7,700,000 hectares of arable land and built up areas are damaged due to flooding in Nigeria [14]. Nigeria recorded its first flood in 1948 in Ibadan, capital of Oyo State. Since then, the menace has spread like wild fire to other states of the federation. More than half of the thirty-six states in Nigeria have been hit by one form of flood or another that occur along the Rivers Niger and Benue [13; 14].

Lack of baseline data on the urbanization in Nigeria is identified as one of the major factors limiting progress in flood risk management [15]. Baseline data collection in developing flood risk management plan using field survey is tedious, time consuming and expensive process that is gradually being replaced with more timely, less cumbersome and cost effective remotely sensed imagery. Geographic Information Systems (GIS) and remotely sensed imagery can be very effective in identifying the spatial component of flood for management. They are used to measure and monitor the extent of flooded areas, provide a quantifiable estimate of the land area and infrastructure affected by flooding and erosion [16]. GIS have been used in developing flood risk maps that show vulnerability to flooding in different places around the world [17; 18].

GIS and remote sensing techniques were used in evaluating urban growth in Thanjavur city, India [19] and also applied the same technique in estimation of surface run-off for Thanjavur town [20]. Moreover, SCS-CN method and Green-Ampt infiltration model were used to evaluate the urban growth effects on surface runoff [21]. In another study, technique for preparation of flood hazard maps was presented to include development of digital elevation model and simulation of flood flows of different return periods [22]. GIS technique was proven effective in extracting the flood inundation extent in a time

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and cost effective manner for the remotely located hilly basin of Dikrong [23], where conducting conventional surveys were difficult. GIS was able to demarcate the flood hazard prone areas in the Papanasam, Taluk into five zones of varying degrees of flooding [24]. Also, a flood risk map should be able to identify the areas that were the most vulnerable to flooding and estimate the number of people affected by floods in a particular area [25]. An estimation of water volumes that can flow in the river during extreme rains can help to understand the occurrence of floods and provide valuable data sets for further studies like hydraulic modelling [26]. In Nigeria, hazard vulnerability maps for many areas are lacking and the available ones are obsolete. This research is therefore aimed at evaluating the flood prone area of Igbokoda town in Ondo State, Southwestern, Nigeria and developing a holistic flood risk management map to facilitate proper planning and consequently mitigating against future flood occurrence.

2. Research Methodology

2.1. Description of the Study Area

Igbokoda town extends from latitude 6’ 20’’ N to 6’24’’ N and longitude 4’45’’E to 4’48’’E. The town comprises many quarters. It’s about 24 km from the coast of Atlantic Ocean. The existing road network which links the town to the neighboring cities such as Okitipupa, Aboto, Mayin, Igbo Nla, among others, further promotes the town accessibility to regional centers. History has it that the indigenes of Igbokoda are Ilajes who in the course of searching for dry land to promote their economic activities and contact with the people of upland settled in the present Igbokoda town [27]. In addition, Igbokoda is also blessed with agricultural raw materials like fish, poultry products, maize, palm oil, vegetables, timber, raffia palm, okro, cocoyam, banana and cassava. The natural environment of Igbokoda land is particularly suitable for the development of large scale rice plantation and salt industry. Figure 1 shows the map of the study area.

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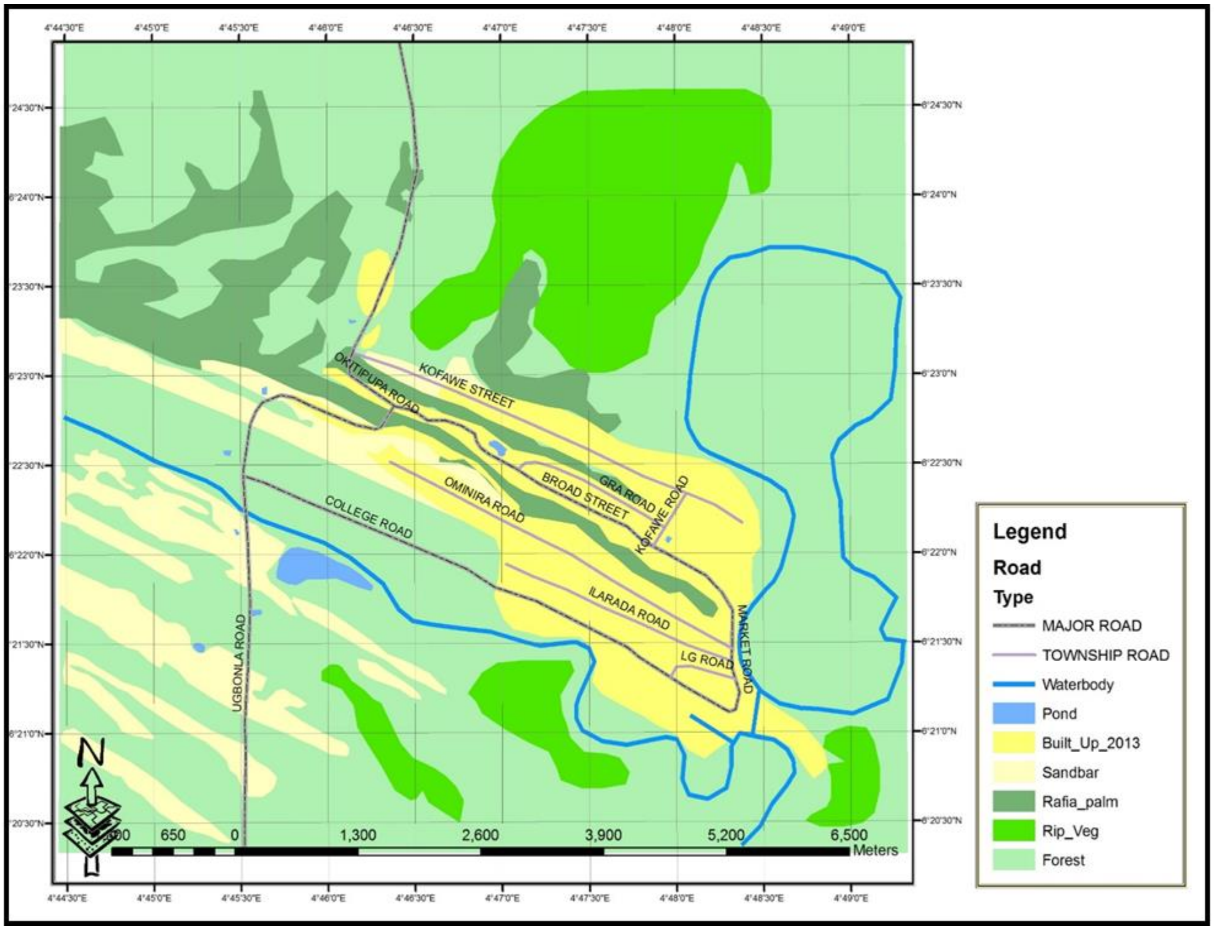

Figure 1. Igbokoda adminstrative map.

2.2. Data Collection and Sources

2.2.1. Digital Elevation Model (DEM)

DEM of the study area (Igbokoda) was derived from United State Geological Survey/National Aeronautics and Space Administration/Shuttle radar topography Mission (USGS/NASA SRTM). The SRTM 90 m data were already in decimal degrees and datum WGS84. The data was downloaded from the CIAT—CSI SRTM website (http://srtm.csi.giar.org). It was projected to the UTM coordinate system and clipped to the extent of the study area.

2.2.2. Satellite Imageries

In this study, Landsat 5 (TM), Landsat 7 (ETM+) and Landsat 8 (LC) imageries were used. The Landsat data were downloaded from United State geological survey online archive. Table 1 shows a list of Landsat images acquired and their dates.

Table 1. Summary of landsat images acquired for the research

S/N	Landsat Satellite	Date	Pathrow
1.	Landsat 5 (TM)	25 April, 1986	190/056
2.	Landsat 7 (ETM+)	13 December, 1999	190/056
3.	Landsat 8 (LC)	12 June, 2013	190/056

2.2.3. High Resolution Imagery-IKONOS Image

Geometrically rectified high resolution imagery (IKONOS image) of resolution of 0.8 m covering the study area was obtained in the year 2014. Road networks and building across the town were digitized. Properties within the flood zones were mapped out considering the buffering zone.

2.2.4. Vector Data

The study area boundary map used to clip out the area of interest from satellite imageries was carved out from the local government boundary map and Nigerian Administrative map on the scale of 1:15,140,906 which was obtained from National Space Research and Development Agency (NASRDA), Abuja, Nigeria.

2.3 Data Re-Processing

The satellite imageries downloaded were verified so that the format was corrected from the manufacturer radiometrically and geometrically to raster image (Geotiff). The image coordinate was in projection coordinate (WGS_84).

2.3.1. Panchromatic Sharpening

Pan-sharpening involved the fusion of the high resolution (1.5 m) panchromatic band/image with the lower resolution bands (30 m) of the same Landsat Image [28; 29; 30]. The three (3) Landsat composite images were pan- sharpened with their respective panchromatic images which enhanced their respective features for the purposes of image recognition while classifying the images.

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2.3.2. Generation of Composite Image and Land Cover Image

Colour composite involved stacking or combination of different bands (band4, band3, and band2) together to produce a false colour composite image purposely for features recognition while classifying. Land Cover (LC) image comprised of vegetation cover types which was a prime indicator of spatial impact extent and flood plain since their population and growth were greatly affected by human anthropogenic activities and prolong accumulation of flooding water. LC image for respective epoch was obtained after classifying the colour composite image using maximum likelihood method of image classification. The classification was done based on the selection of a set of pixels assigned to each of the four classes created (land cover categories) which were bare surface, built-up area, vegetation and water body. Table 2 on land cover categories was obtained after a brief reconnaissance survey had been carried out on the study area.

Table 2. Land covers classification categories

S/N	Classes	Colour
1	Bare Surface	Light Brown
2	Built-up Area	Red
3	Vegetation	Deep Green
4	Water Body	Blue

2.4. Hydrological Analysis

The SRTM 90 m DEM downloaded and clipped to the size of the study area was used for this analysis using the following procedure:

2.4.1. Filling of sinks

DEM was endowed with depressions which caused it difficult to carry out hydrological analysis on them. Therefore, in order to perform hydrology analysis on DEM, all depressions had to be filled. Such depressions were called sinks [31]. The SRTM 90 m DEM sinks were filled using the 'Fill' tool in ArcGIS 9.3.

2.4.2. Delineation of Drainage Basins

The drainage basins in the study area were delineated using the 'basin tool' in ArcGIS 9.3 and further analysis were performed to understand the flow of water on the surface of these basins and the creation of stream channels.

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2.4.3. Determination of Flow Direction

The depressionless DEM was used to generate a flow direction raster. The flow direction showed the possible direction of water run-off on the elevation model. This analysis was performed using the 'flow direction tool' in Arc Toolbox's Spatial Analyst tools of ArcGIS 9.3.

2.4.4. Determination of Flow Accumulation

Flow accumulation analysis was also carried out in ArcGIS 9.3 using 'flow accumulation tool' in Spatial Analyst tool and this always required flow direction as an input. It showed the cells within the study area where water accumulates as it flowed downwards. Thus, settlements around these cells received much water during an event of heavy rainfall or any sudden release of water.

2.4.5. Creation of Stream Network and Buffer Zone

The flow accumulation raster image was used to generate the stream network over the study area, as their paths were revealed on the elevation model in ArcGIS environment. Buffer zones of different scales were created round the stream channels in order to map probable area to be inundated whenever the streams overflows. The scale of 10 m, 50 m, and 100 m were considered for the buffering analysis. The area within the buffering zone of 10 m was classified as the most vulnerable area, area within 50 m from the channel was considered as more vulnerable and that of within 100 m and beyond as less vulnerable.

2.4.6. Generation of Slope and Reclassification

The slope angles of the DEM were generated from SRTM DEM using the Spatial Analyst tool and later reclassified into three (3) categories:

- Areas associated with elevation of 20 m and less (low slope areas);
- Areas associated with elevation of between 30 m – 40 m (Medium slope areas); and
- Areas associated with elevation of 50 m and above (High slope areas).

The total areas occupied by these three (3) categories were also determined.

2.4.7. Overlay of Layers and Production of Flood Risk Maps

After the slope had been determined and the stream buffer zones created, the next major step was to overlay the two resulting layers in the ArcGIS environment consequently to produce a new layer showing the risk zones:

- Areas within the stream buffer zone and in low slope area (High risk zone);
- Areas within the stream buffer zone and in the medium slope area (medium risk zone); and
- Areas within the stream buffer zone and in the high slope area (low risk zone).

This procedure was also repeated for the Swamp layer generated from the IKONOS image. The settlement layer, control points (locations) layer were overlaid with the risk zone layers to create flood

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risk maps A and B that showed characteristics of study areas in different risk zones areas around the stream network and swamp area respectively.

2.4.8. Estimation of Spatial Area Extent at Risk of Flooding

The overlay of built-up area layer on the risk zones delineated with buffering depicted the extent of the spatial area in connection with or in relation to the residential area at risk of flood. The identity tool ArcMap's Toolbox was used to identify names and areas of "point locations" within the layer of the built-up area. The land area cover by each of the buffering zone within the built-up area was calculated in square meter unit using the power option of Spatial Statistical tool "Calculate Area" in ArcGIS Toolbox. The results presented an estimate of the population within each "point location" in the different risk zones.

2.4.9. Creation of Cadastral Map

This was done to delineate the affected residential part of Igbokoda. The major river and residential area were digitized from high resolution satellite imagery (IKONOS Image) and buffering zone was created on either side of the river. Each of the thematic layers (river layer, settlements and boundary map in Shape file format) generated from the IKONOS image were overlaid on each other.

3. Results and Discussion

3.1. Land Cover Distribution

Land Use/Land Cover geo-analysis for Igbokoda was carried out in order to depict not only how the vegetation has changed but also the spatial extent to which anthropogenic activities in the geographical location contributed to flood occurrence [27]. This becomes highly imperative in how vegetation assessment analysis took flood event in any geographical location since vegetation depletion could result in reduction of the surface resistivity to water accumulation and high susceptibility to surface runoff (water flow).

Figure 2 shows the classified Landsat image over the study area for the year 1986, 1999, and 2013. The figure reveals the change in the vegetation cover (the green tone), water bodies (the blue tone) and other features as depicted on their respective legend. A summary from the classified images were listed in Table 3 and illustrated in Figure 3 for easy interpretation.

Figure 3 shows that there exists a change in each of the Land Use/Land Cover categories considered in this study (namely Bare Surface, Built-up Area, Vegetation and Water Body). Vegetation which formed a resistive feature against flood had decreased from 75.04% in 1986 to 46.81% in 2013 which was due to increase in population thus necessitating the construction of infrastructure facilities. The portion within the study area that reflected the influence of human activities (i.e., anthropogenic activities) is denoted as Built-up Area. The Built-up Area covered 1963.21 ha (19.6321 km^2) of the study area which was 7.50% of the whole spatial extent in 1986, but had increased to 14.97% that was 3915.05 ha (39.1505 km^2) in the year 1999 and by the year 2013, 24.52% increment was recorded for Built-up

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Area (Table 3 and Figure 3). Though, most of these Built-ups are situated in the area associated with high elevation and along the road sides that had already been sand filled during road construction activities.

The major bare surface feature in the study area as confirmed via ground truthing was white sands. This development occurred when the water had been drained due to the increase in evaporation rate and sand filling of the area for construction purposes. The major water body in the area of study was from the wetlands which caused the flooding event in this area to be seasonal (meaning only occurred during the rainy seasons whenever there was heavy downpour).

Table 3. Comparison of areas and rates of change of the four land use/land cover classes between 1986 - 1999 and 1999-2013 for Igbokoda

Land Cover Types	**1986 Area (km^2)**	**1999 Area (km^2)**	**2013 Area (km^2)**	**Change between 1986 and 1999 (km^2)**	**Change between 1999 and 2013 (km^2)**
Bare Surface	13.2803	39.6053	50.2400	26.325	10.6347
Built-up Area	19.6321	39.1505	64.1520	19.5184	25.0016
Water Body	32.3844	17.5690	24.7410	-14.8154	7.1720

Note: A decrease carries negative sign while an increase carries positive sign

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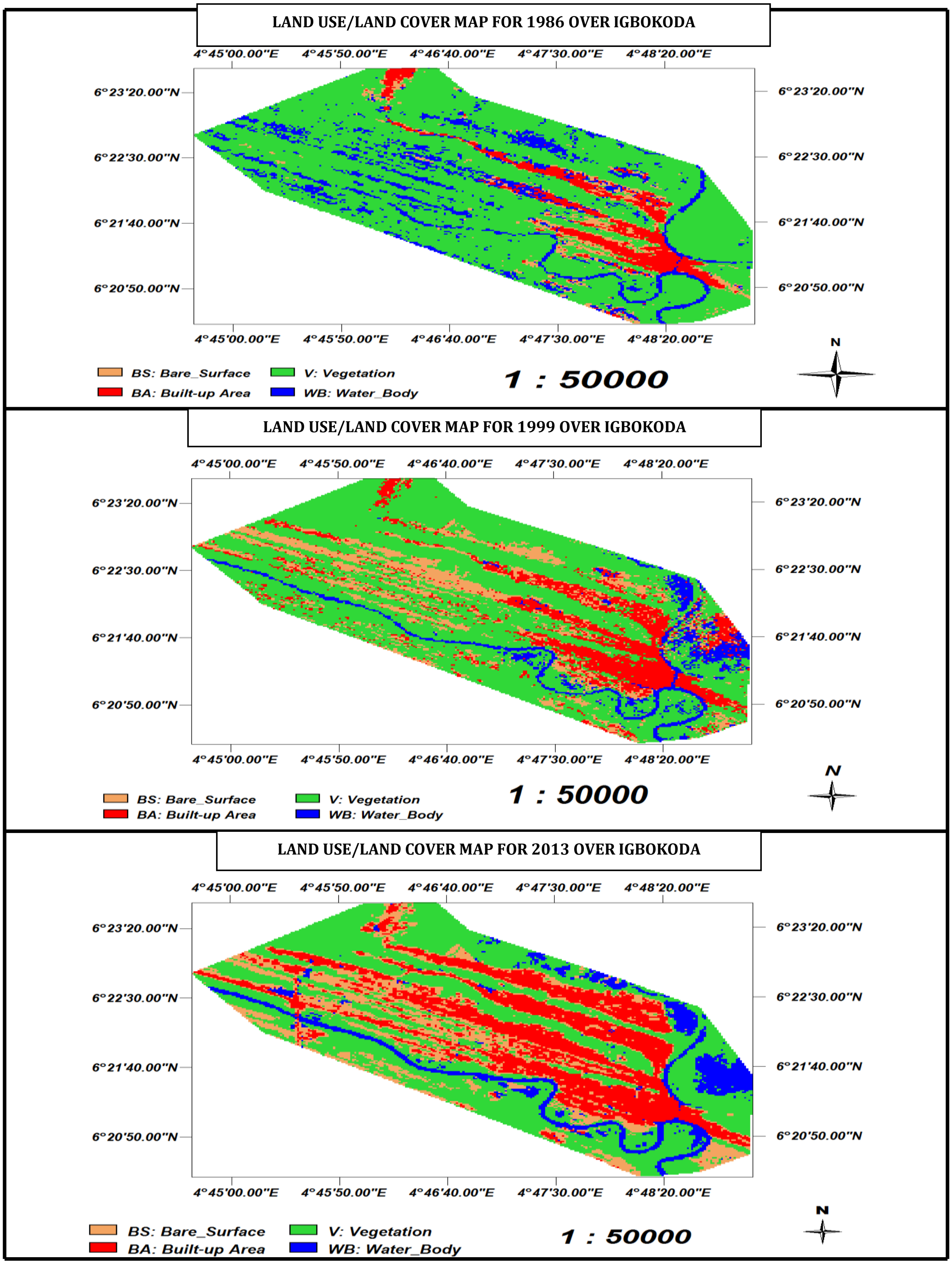

Figure 2. Classified landsat image over study area for the year 1986, 1999, and 2013.

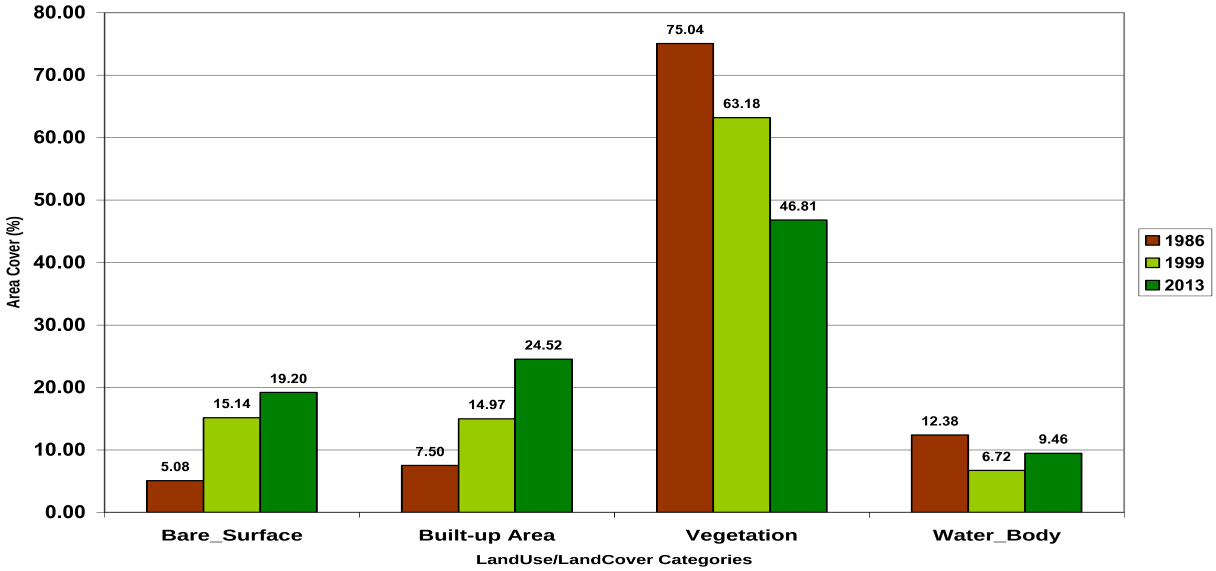

Figure 3. Percentage of the land cover area for three time periods over Igbokoda.

3.2. Hydrological Analysis

3.2.1. Drainage Basins Hydrology in the Study Area

Figure 4 shows the spatial distribution in the drainage basins delineated over the study area. The drainage basins over the study area were subsets of the western lithoral catchment and a total number of 339 were delineated in the study area. The largest of the basin as depicted in Figure 4 had an area of 72.13 km^2; the smallest basin had an area of 0.963097 km^2 while the average size of the drainage basin over that study area was 76.86 km^2. The major spatial extent of the Built-up areas were found to be within the two largest basins over the study area.

The drainage basin size in any geographical location was one the most important morphological features and /or physical characteristics that contributed to the speed of runoff and amount of flooding experienced in that area. Other features included the slope of the basin, basin shape, surface roughness and stream density [32; 33; 34].

Igbokoda township was characterized by low elevation slope angles with its major residential part fell within elevations ranging from 10 m to 20 m and slope angles less than or equaled 7 degrees (Figure 5). Hence, land use planners with the intention of developing infrastructures with this information at their disposal should ensure any future developments are either built on natural or artificially made higher grounds to avoid flooding.

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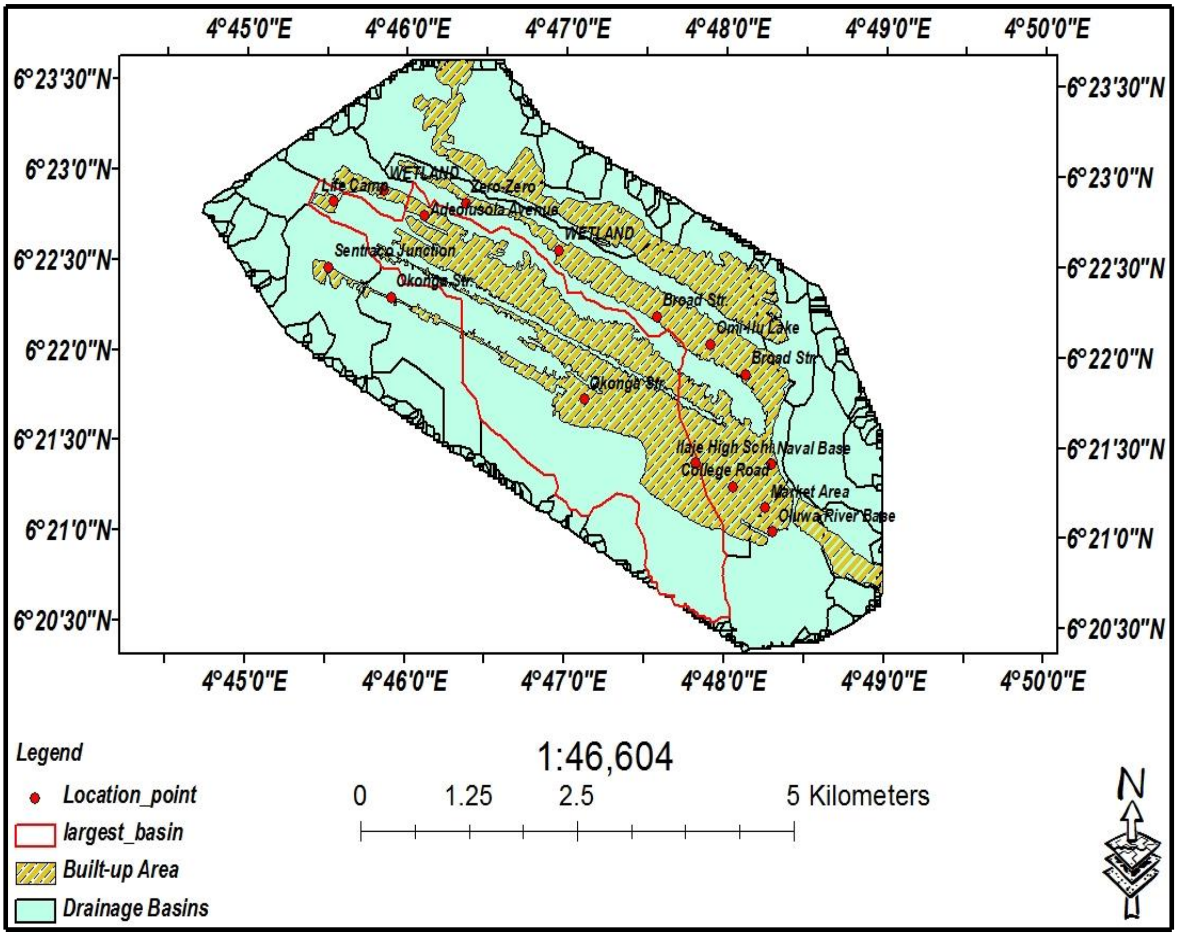

Figure 4. Drainage basins over the study area.

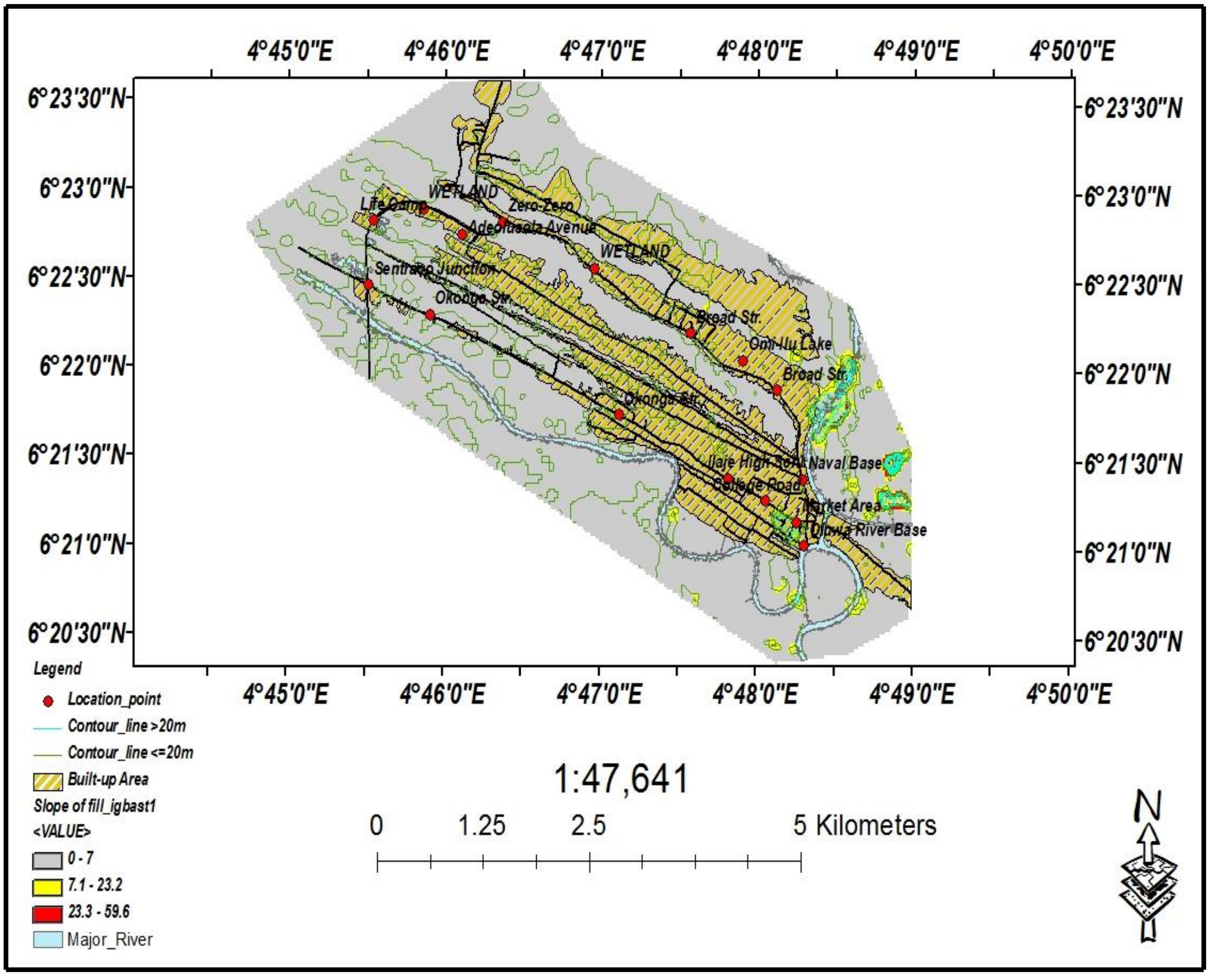

Figure 5. Elevations and slope angles of study area.

Flood plains had been known to be important for agricultural purposes, so government can utilize the potentials of these low lying areas for such purposes like FADAMA Project [35; 36; 37].

The stream network density in any area greatly influenced the runoff potential, and the strength of the stream network density could be determined by the number of channels or tributaries within a drainage basin in an area [32]. The natural stream network of the study area is illustrated in Figure 6. It revealed that few channels existed over the study and this could be accounted for the low draining rate of water which in turn caused accumulation of rain water over the area whenever there was heavy downpour. In this study, the extreme rainfall data available to simulate the flooding area was over the past 27 years. The mean magnitude of rainfall that can create flooding in the study area was 440.9 mm which was in the month of August as shown in Table 4.

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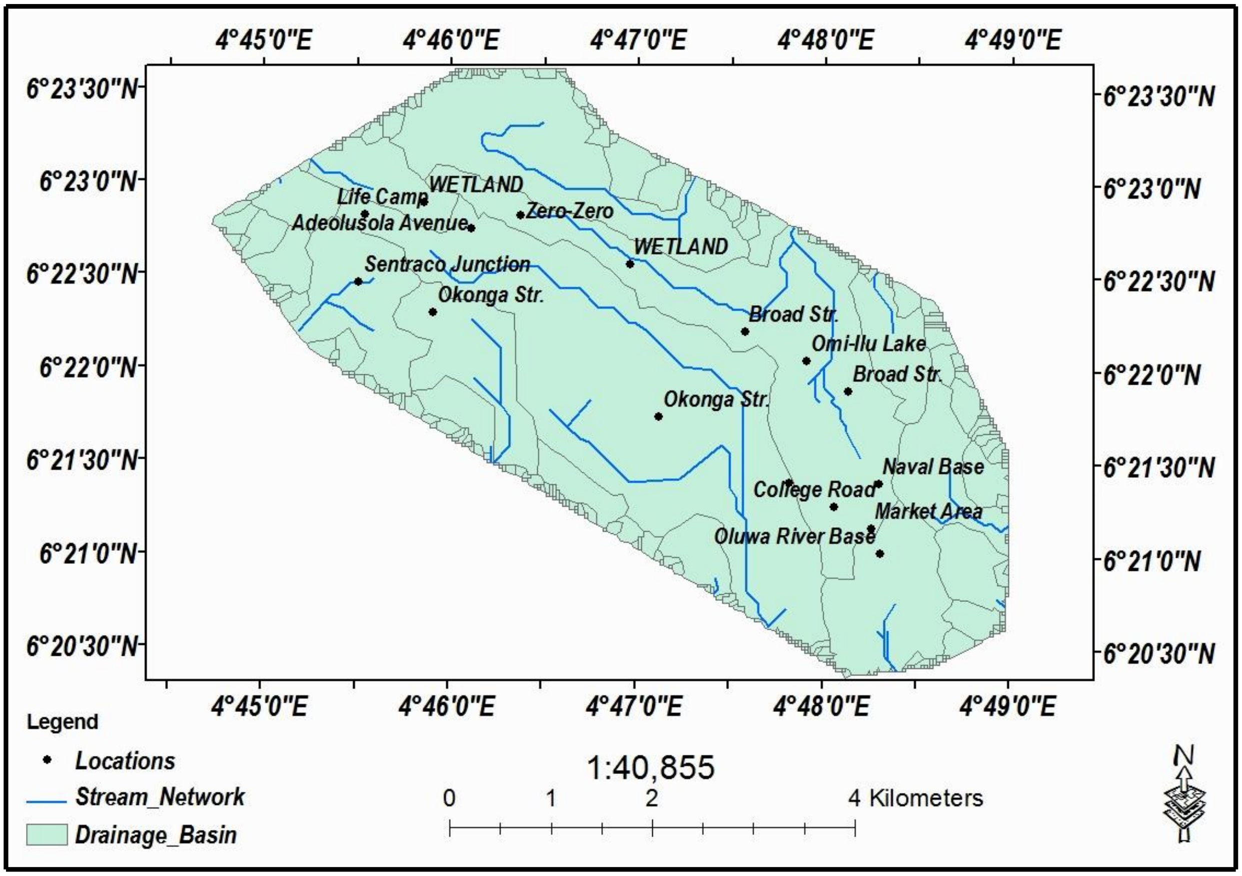

Figure 6. Stream network with the drainage basins over the study area.

Table 4: Mean monthly rainfall derived from a 27–year rainfall data at Okitipupa

Month	Rainfall (mm)	Rainfall (%)
January	19.6	0.82
February	41.1	1.71
March	126.7	5.27
April	205.5	8.56
May	269.0	11.20
June	357.6	14.88
July	440.9	18.35
August	226.6	9.35
September	327.7	13.63
October	283.0	11.78
November	87.1	3.63
December	16.0	0.75
Annual	2402.5	100.00

Source: [38]

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3.2.2 Ground Elevation with Reference to Sea Level

The ground elevations with reference to sea level obtained for the study area are shown in Table 5. The heights above sea level were within the range of 10 m – 20 m. The terrain of the study area was classified as lowland (10–20 m elevation). This further confirmed that the study area was vulnerable to flooding.

Table 5. Ground elevation with reference to sea level

Zone	Elevation
Life Camp	10 m–20 m
Broad Street	10 m
Zero Zero junction	10 m
Raffia palm Swampy Area	10 m–20 m

3.3 Flood Risk Zones

The flood risk maps A and B were generated from the hydrological analysis and digitized layers from IKONOS image over the study area (Fifures 7 and 8). Each of these maps shows the spatial extent within the built-up areas at risk of being flooded whenever there was heavy downpour. Figure 7 depicts the areas around the stream channels within the study area proned to flooding event. The most vulnerable area was within 10 m radius of the stream, and this area was delineated with red polygon. The more vulnerable areas within the distance of 40 m from the red polygon were marked with yellow color; while the higher areas in blue color and beyond were considered to be less vulnerable. A geographical location with high elevation and high slope angle that fell within the vulnerable area might not necessarily get inundated during the flood event but the case of Igbokoda was quite different as the major part of the town was associated with elevation less than 20 m and slope angle between 0 and 8 degrees.

The area of each risk zone within the built-up areas was estimated in ArcGIS using Spatial Statistical tool in unit of square kilometer. The numeric value of the spatial extent of each of the flood risk zones within the built-up areas were depicted in Table 6 in square kilometer. The most vulnerable zone covered a total land area of 28.561561 km^2 and more vulnerable area claimed a spatial area of 15.94759.41 km^2 immediately after the most vulnerable zone (High Risk Zone) while the total land area within the less vulnerable zone was estimated to be 31.36191.79 km^2 all within the built-up area. The built-up area is mainly made up of residential area and other public centers like schools, market place, religious houses and so on. These built-up areas covered a land area of 77.5303049 km^2 of the whole study area.

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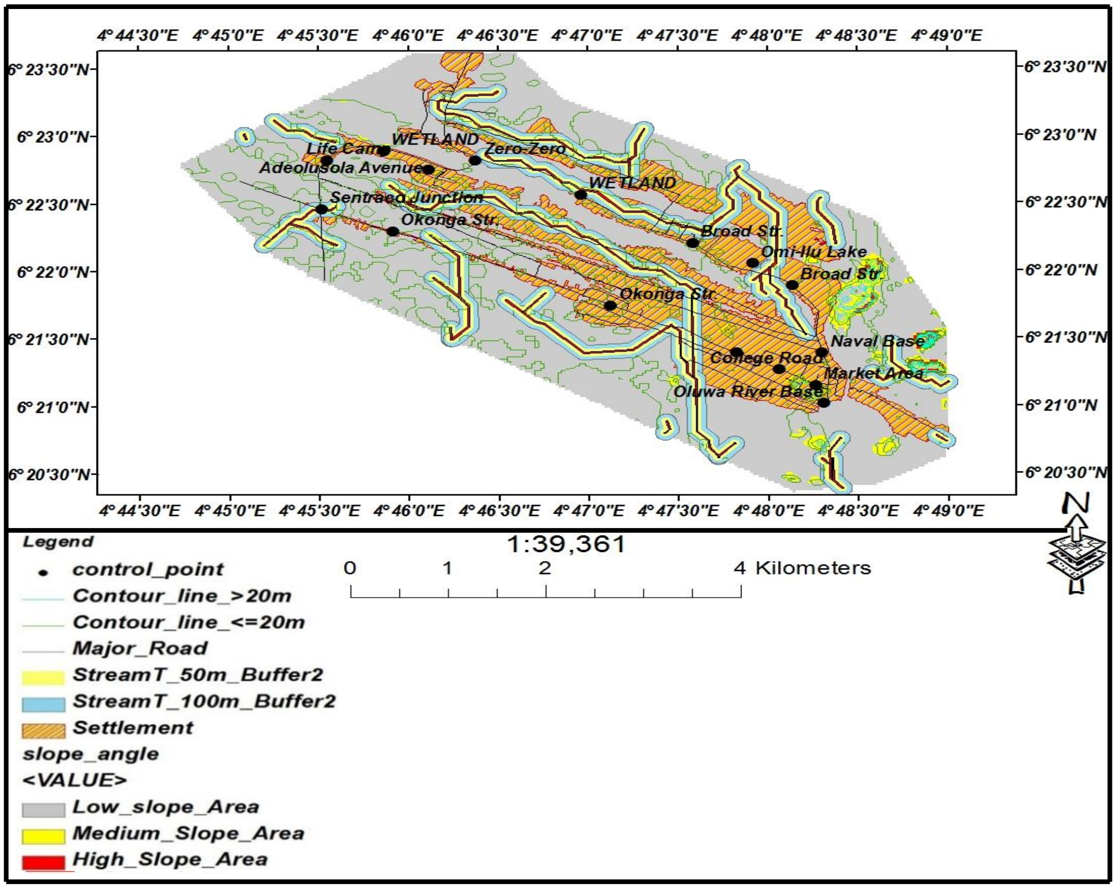

Figure 7. Flood risk Map A.

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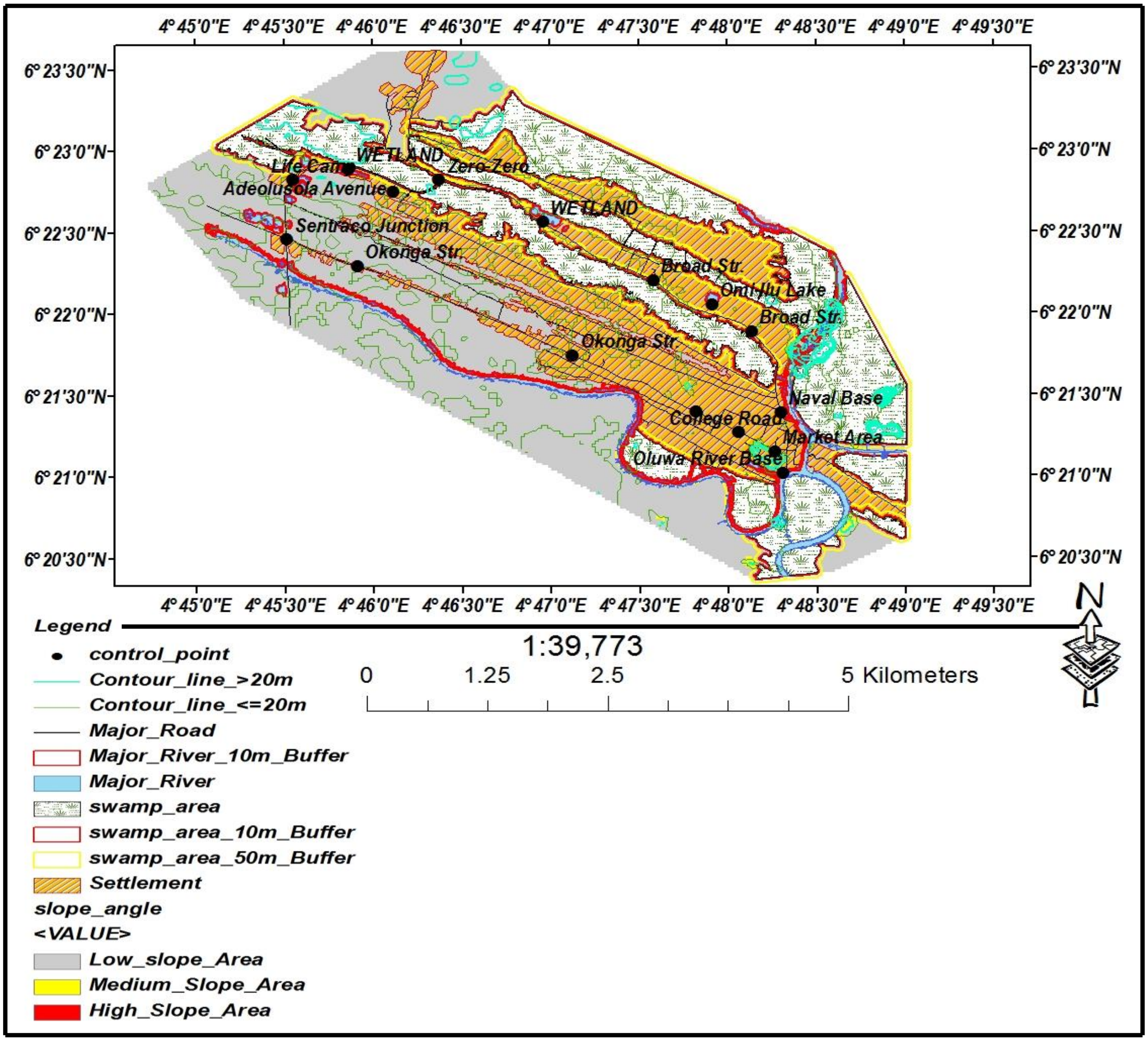

Figure 8. Flood risk Map B.

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Table 6. The spatial extent of the flood prone area within the residential area

Feature	Buffering Distance (m)	Identified Area (Sq km)	Risk Class Categories
Stream Buffer Zones	10	28.561561 (37.64%)	High
	50	15.947594 (21.02%)	Medium
	100	31.361918 (41.34%)	Low

Note: Total land Area is the estimated area cover by each of the buffering zones within the residential area which falls to the area with low elevation and very low slope angle.

4. Conclusion

This study has explored the advantages and importance of GIS in flood risk assessment and the ease of developing flood risk maps over the study area using remotely sensing data and GIS tool. Landsat images for 1986, 2000 and 2013 and SRTM DEM for the area were used in this research. It employed the scientific method of delineating drainage basins from the DEM data of the town. A total of 339 basins were delineated and stream network on the landscape of this area were carved. The resultant images for 1986, 2000 and 2013 showed a great reduction in vegetation and change in land cover by 75.04% between 1986 and 2000 and further reduction between 2000 and 2013. The change posed a risk of exposing the town to flooding. From the rainfall distribution data, the volume of runoff (as a function of coefficient of runoff and rainfall intensity) had increased over the years under study from 1986 – 2013 with no improvement on the drainage facilities. This had contributed significantly to the flooding.

A combination of the stream network and the slope of the area were used in developing flood risk zones for the town. Three zones were specified: high, medium, and low flood risk zones. The total area covered by the high risk zone was 28.5615 km^2 while the areas of the medium and small risk zones were 15.94759 km^2 and 31.3619 km^2 respectively. It is recommended that an increased awareness on the risk of flood be created among the populace of Igbokoda to guide them in further development while the buffered zones of the flood plain areas should be properly delineated and zoned for recreational centre to serve as tourist trap.

This research is a valuable tool that would help government agencies in planning towards flood management in the study area. Also, it provided data to assess the extent of urbanization and changes in land use. It had provided techniques in the identification and mapping out of flood risk zone that can be easily adapted to any area. Furthermore, it had provided database population distribution within flood vulnerable areas. Most importantly, the data supported useful flood extent mapping, damage assessment, vulnerability prediction and in planning preventive measures against flooding in any area. Consequently, the findings of this study should guide the government and Town Planning Authority of the area in land-use development and construction of viable drainage systems to enhance the evacuation of flood waters and sustainable development of the study area.

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