

# **ASSESSMENT OF URBAN LAND USE AND ENVIRONMENTAL SENSITIVE AREA DEGRADATION IN AKURE, NIGERIA USING REMOTE SENSING AND GIS TECHNIQUES**

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## **Abstract**

The use of satellite imageries and spatial analysis techniques have not been comprehensively explored and exploited in capturing baseline information for monitoring of ecologically fragile areas in most developing countries including Nigeria. This study used Landsat imageries of Akure 1986, 2002 and 2011, and topographical map, DEM, GPS points, mean annual rainfall data and structured questionnaire. Image classification was performed using supervised classification technique to capture the urban land use change over the study period. The wetlands were buffered to the radius of 200m to select the target population for questionnaire administration using ArcGIS 9.3. The responses obtained were analyzed using SPSS 17.0. DEM was subjected to spatial analysis using spatial analyst extension of the ArcGIS 9.3 and Global Mapper 13 to identify the watersheds, generate flow direction, flow accumulation and to generate the basin levels. The mean annual rainfall data, drainage basin data and elevation data were integrated and reclassified. These data were subjected to multi-criteria analysis and map overlay operation to generate flood vulnerability index map. The finding observed that area with high vulnerability to flooding occurred along the streams or river channels flowing from the eastern region of the study area towards the northwest region where physical planning standards especially on setbacks were compromised.

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**Keywords:** Environmental Degradation, GIS, Satellite Imageries, Ecological Sensitive Area, Physical Planning, Flood Vulnerability Index Map

## **Introduction**

Environmental degradation is more prominent in areas within the wetlands systems than any other ecosystem on earth because they provide many services that contribute to human well-being and poverty alleviation without a sustainable use of the ecosystem (UN Millennium Ecosystem Assessment Board, 2005). Apparently, the wetlands have been increasingly susceptible to intense pressure from multiple human activities such as water diversion, pollution from agricultural wastes, over-exploitation of natural resources, and reclamation for construction purpose. In wetland loss, there is always a chain reaction, because the damage of one aspect of wetland will not only affect the wetland but has a devastating effect on the entire wetland ecosystem and by extension human and animal population. For instance, wetland loss poses threats and dangers to wildlife as well as human population due to its function as a natural protection against flooding by acting as giant pads that soak up the excess rain and surface water being aggravated by the resultant effects of climate change.

In the recent times, studies have shown that a large proportion of wetlands are fast degrading and going into extinction apparently due to drainage and land clearance as consequences of agricultural, urban and industrial development activities (Williams, Pierrehumbert and Hubber, 2009; Tijani, Olaleye and Olubanjo, 2011). Thus, wetlands degradation could be consequential of either direct or indirect impact of activities on the wetland ecosystem. Activities that occur within the wetlands such as draining and dredging have direct impact on wetland loss or degradation. On the other hand, impacts caused by inputs of storm water, pollutants generated by urbanization, agriculture or other activities within the contributing areas are referred to as having indirect impact on the wetlands.

The Nigeria's wetland resources are currently being threatened by some anthropogenic and bio-geophysical factors, which include increased population pressure, rapid urbanization, mining and pollution among others. Therefore, at present and for the near future, human activities will continue to adversely affect wetland ecosystems if not controlled and regulated. Nigeria has made effort as far back as 1988 by promulgating Federal Environmental Protection Agency (FEPA) Decree No. 59 that provides the legal framework for the implementation of the policies on environmental protection, natural resources conservation and sustainable development. Nonetheless, these efforts are largely uncoordinated. The present state of wetlands in Nigeria tends to be far away from achieving United Nations

Millennium Development Goal (MDG) 7 that aims to ensure environmental sustainability, by integrating the principle of sustainable development into the country policies and programs, reverse the loss of environmental resources, and reduce biodiversity loss. For example, Nigeria is fast degrading her wetlands as a number of anthropogenic and biophysical factors is seriously threatening the rich wetlands (Nwankwoala, 2002). In addition, a great deal of the hydrological and water resources problems currently experienced in Nigeria are the resultant effects of wetland degradation in the country (Nwankwoala, 2002). The challenges posed by the degradation can better be understood and better appreciated when viewed against the backdrop of the benefits derivable from the wetlands.

Wetland as a vital environmental sensitive area in growing urban centers has been seriously under degradation as evident in medium sized and big cities in Nigeria due to increasing population pressure. According to the World Urbanization Prospects (2011), Nigeria has about 49.6% of its population as urban and 3.8% rate of urbanization. With this rapid rate, Nigeria's wetland resources are vulnerable to unprecedented conversion to agricultural lands and reclamation for residential building constructions. The dynamic nature of the wetland resources' degradation in Nigeria in general and particularly in Akure has rendered the use of exploratory approach that is common in wetland studies inadequate. Also, the use of satellite imageries, GIS and spatial analysis techniques have not been comprehensively explored and exploited particularly in capturing baseline information that are germane to monitoring, conservation and sustainable management of ecologically fragile areas such as wetland in the growing urban environments.

Studies have shown that two major rivers run through Akure. They include Ala River and River Elegbin (Akinseye, 2006). Wetlands often are found in strips and in large quantity around these two water bodies of which quite a substantial proportion has been committed into various uses including dumpsites, housing construction and agriculture with little or no effort on their preservation and sustainability. The State Environmental Protection Agency, which later became the Department of Environment was established in 1992 and saddled with the responsibility of management of the environment. The Department made considerable impacts in the State as a whole but was constrained with paucity of fund and as such has not performed well in the protection of wetland ecosystem within Akure (Akinseye, 2006).

The rapid nature of urban encroachment on the wetlands in Akure and the emerging devastating consequences on the lives and properties of the urban dwellers is becoming a serious environmental issue. Hence, there is need to prevent future calamity arising from unsustainable conversion of wetlands to urban built-ups and practice of urban agriculture. This study thus

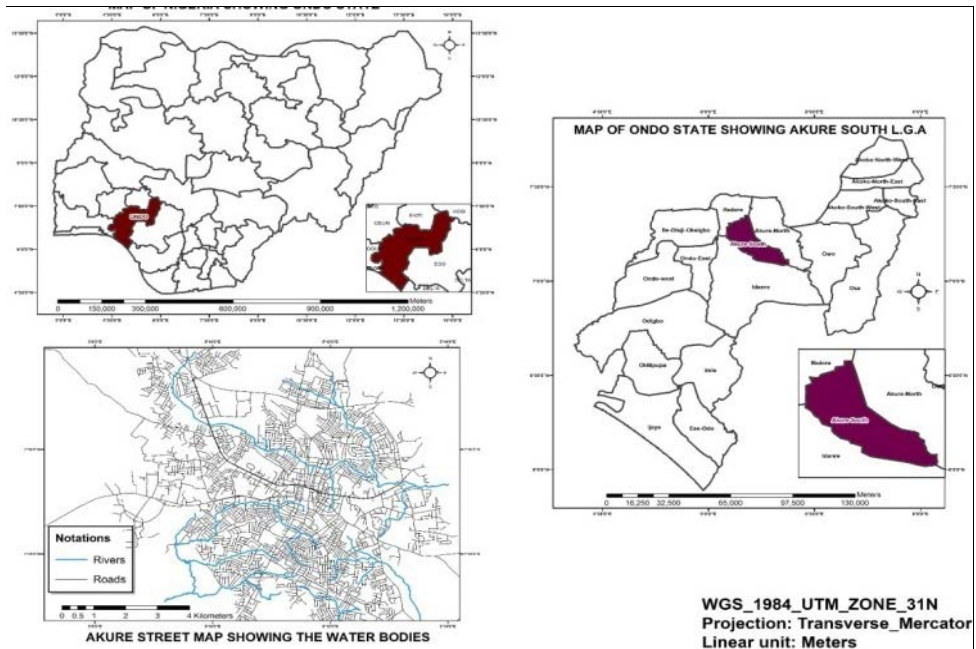
adopts the use of satellite imageries, GIS and spatial analysis to map the spatial distribution of wetlands. It also seeks to determine the urban expansion rate and temporal changes in the wetlands ecosystem and evaluate the potentials of wetlands in flood attenuation and predict the vulnerability of some areas to flooding in the city. In addition, it investigates the level of compliance of urban development to town planning laws and regulations in a bid to ensuring environmental sustainability.

## **Materials and Methods**

### **Research Locale**

Akure, the capital of Ondo State is situated about 282 Km away from Abuja, the capital city of Nigeria. Akure is also the Headquarters of Akure South Local Government Area. It lies on latitude 7.25°N and longitude 5.19°E (Fig. 1). The city is located on 396 meters high above sea level. According to 2006 Nigerian Population Census, Akure has a population of 360,268. Thus, the current estimated population is about 495,000. The increase in the annual growth of the city's population could be attributed to her role as administrative and economic nerve centre of the state thereby attracting a large spectrum of immigrants (Oyinloye and Kufoniya, 2011). The outburst in the population growth of the city can also be connected with the recent categorization of Ondo state as an oil-producing state and Akure as a Millennium Development City. The emerging development has multiplier effects on land prices and subject land acquisition for urban development particularly residential to the interplay of market forces, a situation that put some urban dwellers at disadvantage.

High temperatures and high humidity with two distinct seasons characterize the climate of Akure, namely wet and dry seasons. Wet season lasts for about seven months (April to October) with an annual rainfall of about 1524mm. Annual temperature ranges between 28°C and 31°C with a mean annual relative humidity of about 80%. With increasing demand for land, wet climate and unsustainable use of the wetlands in Akure, there is a serious need to be proactive in putting in place measures that will re-direct development away from the ecologically fragile areas, hence the need for this study.



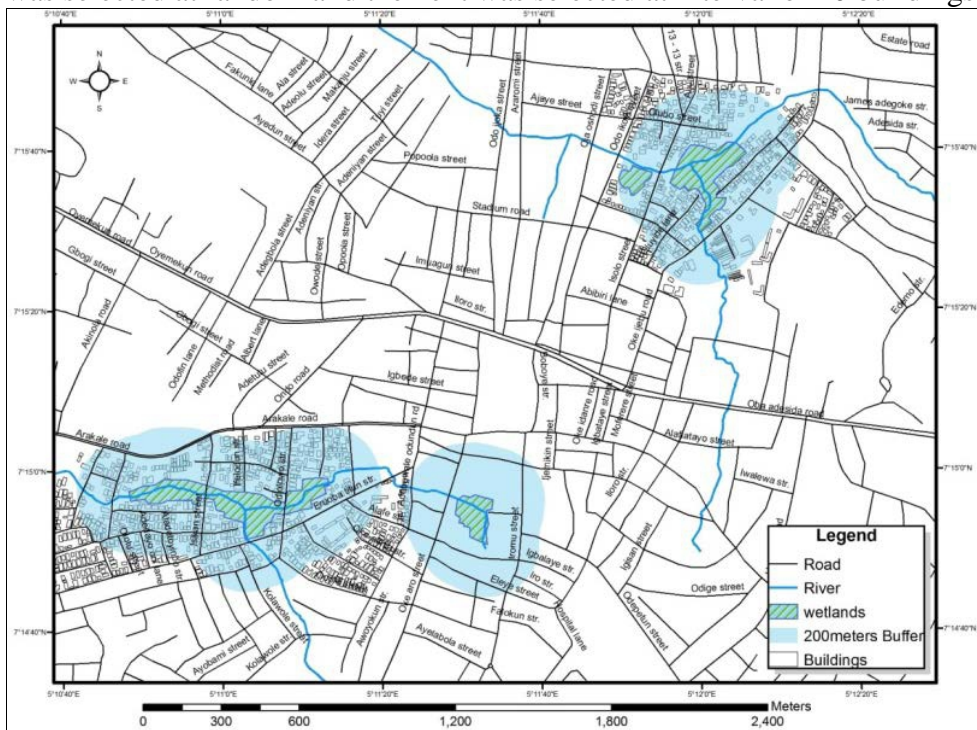
**Figure 1:** Map of Nigeria showing Ondo State and Map of Ondo State showing Akure South Local Govt Authority

### Database Description

For this study, data were sourced from both primary and secondary sources. Primary data were obtained from the targeted population using structured questionnaire designed to elicit information on the effects of the built environment on the wetland ecosystem. The study focused more on the wetlands within the core area of the city because it is the most vulnerable due to the high concentration of population around the Central Business District, where commercial activities and residential buildings are competing for the available space. Ajibola, Adewale and Ijasa (2012) observed that many wetland losses all over the world are direct result of economic activities engaged in by man.

This is exemplified in Isikan and Isolo areas where the high rate of commercial and economic activities resulting from the presence of markets has attracted quite a large population over the years. For this study, the target population is the households within 200meters radius from the wetlands or water body (Fig. 2) at both Isikan/Odole and Isolo/Oke-Ijebu which comprises of 933 buildings. The selection of respondents was carried out using the simple/proportional random sampling. A 10% sample size of the entire building population was adopted. Isikan/Odole has 543 buildings within 200m radius from its wetland while Isolo/Oke-Ijebu has 390 buildings within 200m radius of its wetland. Therefore, 54 and 39 buildings were sampled in Isikan/Odole and Isolo/Oke-Ijebu respectively. This implies

that 93 buildings were sampled for this study. Each of the respondents was selected at an interval proportional to the building population but the first was selected at random and the next was selected at interval of 10 buildings.

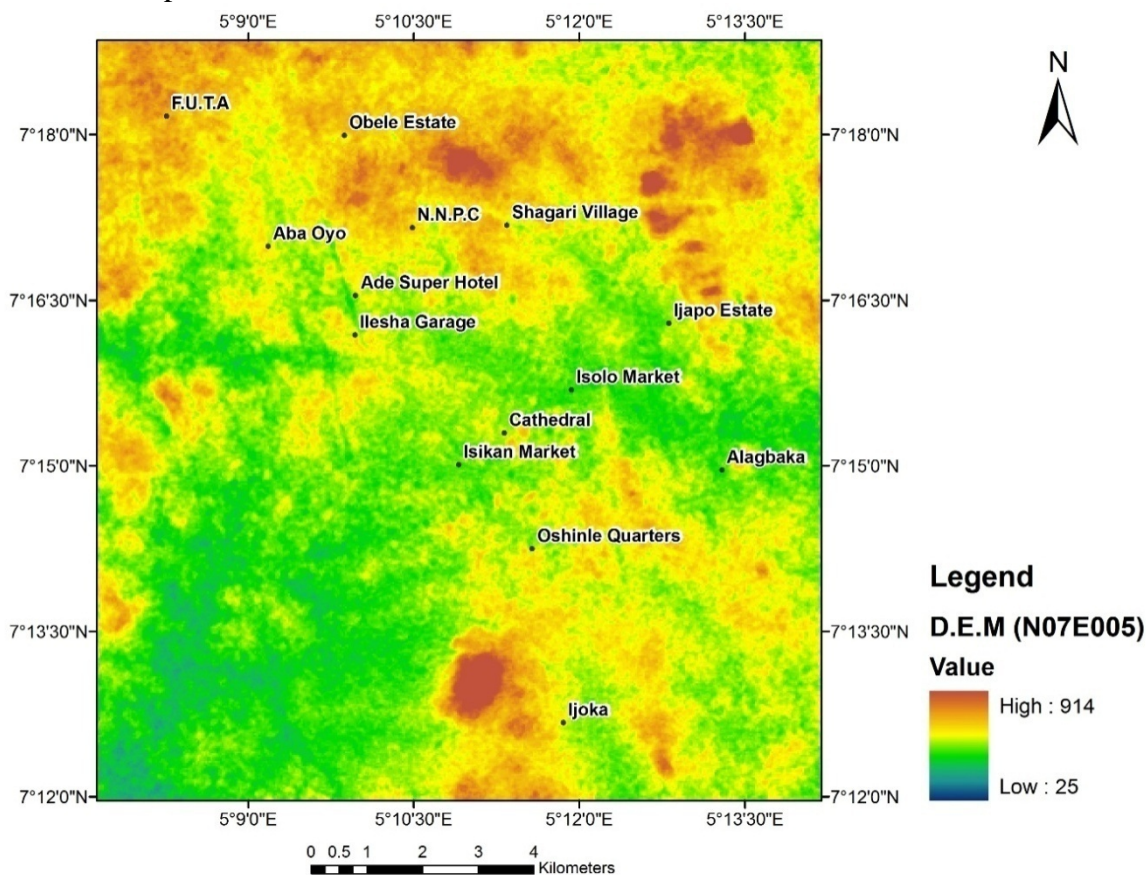


**Figure 2: 200m buffer around the selected wetlands**

The secondary data, which include satellite imageries of Akure such as Landsat Thematic Mapper (TM) 1986, Enhanced Thematic Mapper (ETM+) 2002 and 2011 were obtained from the Global Land Cover Facility (GLCF). Topographic map of Akure was generated from the satellite imagery acquired through on-screen digitizing of roads, rivers and buildings. Digital Elevation Model (DEM) at 90 meters spatial resolution was also acquired, to know the various elevations, generate a contour map, locate the various watersheds within the city and identify various basin levels for further analysis on the identification of areas vulnerable to flooding from excess storm water runoffs. In addition, rainfall data were collected from the Nigerian Meteorological Agency (NIMET). Global Positioning System (GPS) receiver was used to obtain the geographic coordinates of the wetlands and some notable landmarks within Akure metropolis. The satellite imageries were loaded and displayed in the GIS environment using Idrissi Selva 17.0. The imageries were enhanced, filtered, georeferenced and resampled using digital image processing techniques. Subsequently, land use/cover classes were defined as settlement, vegetation, bare surface/rock

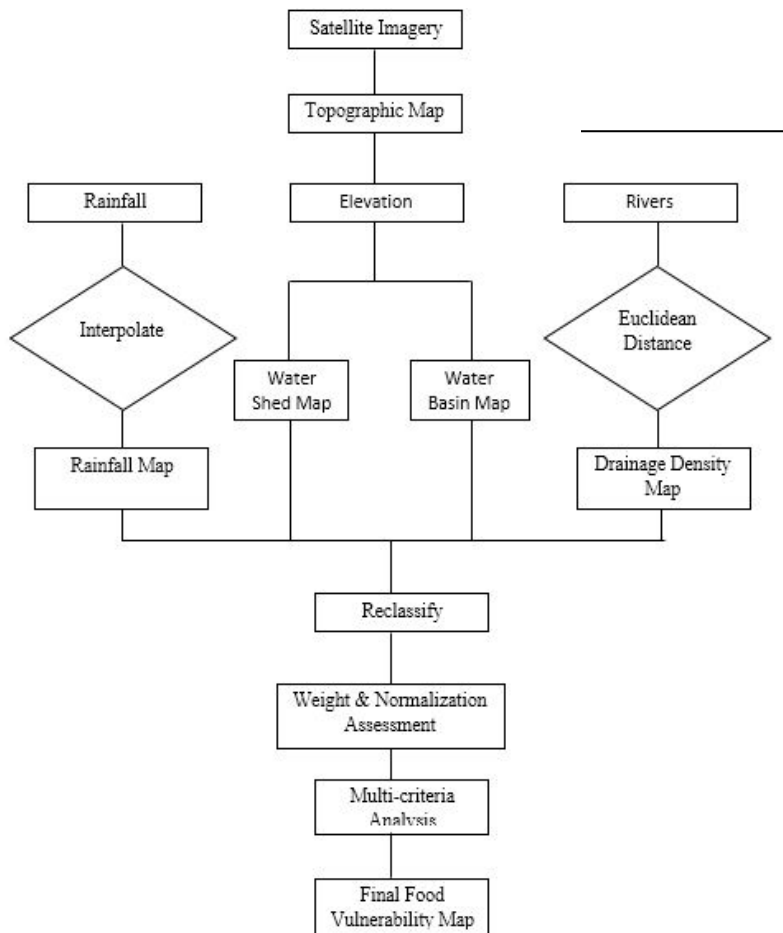


outcrop and riparian vegetation (wetlands and vegetation along river channels), followed by the training of the system with samples of these land use/cover features. Supervised classification was carried out on each of the imageries to produce land use/cover classified images that facilitated the determination of land use/cover changes and reduction in the riparian vegetation overtime. The ArcGIS 9.3 and Global Mapper 13 were used for the spatial analysis. The Digital Elevation Model (DEM) (Fig. 3) was also subjected to some spatial analysis using the spatial analyst extension of the ArcGIS 9.3 and Global Mapper 13, to identify the watersheds, generate flow direction, flow accumulation and to generate the basin levels. In addition, building encroachment on setbacks from water bodies was observed through buffers created along every river and stream channels at 30meters on both sides of the river as stipulated by the State Ministry of Physical Planning and Urban Development.



**Figure 3: Digital Elevation Model (DEM) for the Study Area**

Source: Global Land Cover Facility (GLCF) University of Maryland, USA (2013).



**Figure 4: Analytical Procedure for the Flood Vulnerability Analysis**

## Results and Discussion

Akure is endowed with wetland resources located at Gbogi, Isikan, Oke Aro, Alagbaka, Isolo/Oke-Ijebu, Ijapo, Odole/Odiolowo, Erekesan, Idi-Agbe, Oke Igan and Ayetoro (Fig. 5). Analysis revealed that 56% of the inhabitants around wetlands were non-indigenes against 44% that were indigenes of the city (Table 1). This observation may largely be explained by the fact that Akure doubles as the State capital of Ondo State and a Millennium Development City where majority of commercial activities of the state is domiciled. Its position as a commercial nerve centre attracts migrants from different parts of the country to the city, which consequently triggers the rate of urban growth.

The study also revealed that the highest proportion of the respondents (42%) claimed to have Secondary School Certificate Examination (S.S.C.E) and 17% possessed Ordinary National Diploma/Higher National Diploma. Only 10% have university degrees. However, 16% had only primary school





Civil Servant	6	6.5
Artisan	26	28.0
Others	4	4.3
<b>Total (N)</b>	<b>93</b>	<b>100.0</b>
<b>Average monthly income (₦)</b>		
Under 1800	72	77.4
18001-36000	14	15.1
36001-54000	7	7.5
<b>Total (N)</b>	<b>93</b>	<b>100.0</b>
<b>House Ownership</b>		
Owner Occupied	59	63.4
Tenant	34	36.6
<b>Total (N)</b>	<b>93</b>	<b>100.0</b>
<b>Mean of Land Ownership</b>		
From Government	78	84.8
Bought from previous owners	9	9.1
Inheritance	9	11.3
<b>Total (N)</b>	<b>93</b>	<b>100.0</b>
<b>Monthly rent paid (₦)</b>		
Under 1000	7	8.8
1001-2000	6	7.5
2001-3000	80	100.0
Above 3000		
<b>Total (N)</b>	<b>93</b>	<b>100.0</b>

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Source: Fieldwork, 2013

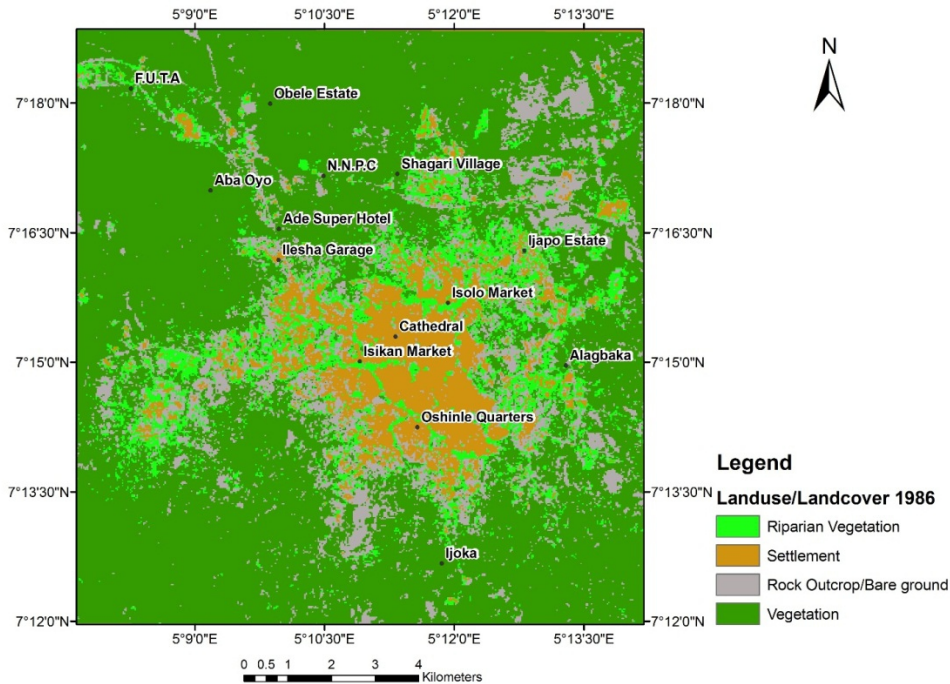
Again, 33.3% of the respondents engaged in trading while 28% were artisans. 5.4% and 6.5% were employed in farming and civil service respectively. However, 22.6% of the respondents were unemployed (Table 1). Educational status appears to have a correlation with occupation in the study area. This is aptly demonstrated by the fact that only few respondents were engaged in the civil service since most of them had S.S.C.E and below. In Nigeria, the minimum monthly wage is about NGN18,000 (National Minimum Wage Amendment Act, 2011). The proportion of the sampled respondents within this class is about 77.4% while others are within the category of the medium income but of a different monthly income. The next to the highest proportion of is 15.1% that earned between NGN18001-36000 monthly, while the remaining 7.5% of the respondents earned between NGN36,001 and 54,000 (Table 1). This result shows that most households in the study area are low-income earners.

The study also showed that most dwellers (63.4%) were tenants while 36.6% owned their houses. A large proportion (84.4%) of those that owned their own houses claimed to have bought the land from previous owners

while 9.1% inherited the land. Only 6.1% of the respondents acquired such land from the government (Table 1). It portends that private developers have stronger control over land than the government in the study area. This implies that land values may be subject to the interplay of market forces that often deprives the low-income earners access to land for building construction.

The rental value of buildings in the study area was taken into consideration, because it could be responsible for influx of people into areas if the rental value happened to be relatively low and highly affordable. The highest proportion (72.5%) of the respondents paid about NGN1001-2000 as monthly rent. However, 11.3% paid less than NGN1000 Naira monthly while 8.8% paid between NGN2000 and NGN3000. Only 7.5% paid above NGN3000 monthly (Table 1). This findings indicates that a bulk of the inhabitants in these areas pay below NGN2000 per month suggesting that quite a majority of the people around in the study area are low income earners.

The results of land use/land cover analysis as presented on Table 2, Figures 6 and 7 showed that riparian vegetation as a typical ecological sensitive area covered 14.68 sq. km in 1986 but increased to 33.23 sq. km in 2002 with average rate of 7.9% per annum. In addition, settlements expanded in areal extent from 15.74sq. km in 1986 to 24.65sq. km in 2002. It could be noticed that the rate of urban expansion per annum was estimated at 3.5%, faster than that of Ibadan metropolitan city (3.0%) within the same period as reported by (Oyinloye, 2003; Adegboyega, 2010). It lends credence to the observation made by UN-HABITAT (2008) that African cities with less than 500,000 inhabitants are absorbing two-third of all urban population growth. Rock outcrop/bare ground recorded a remarkable increase of 39.84sq. km within 16 years with highest average rate of change (12.2%) over other land use/cover types in the area. Vegetation was observed to have declined by 67.3sq. km, recording the lowest average rate of change over the period. The pattern of change is observed to be conversion of area covered with vegetation to other land use/land cover types.



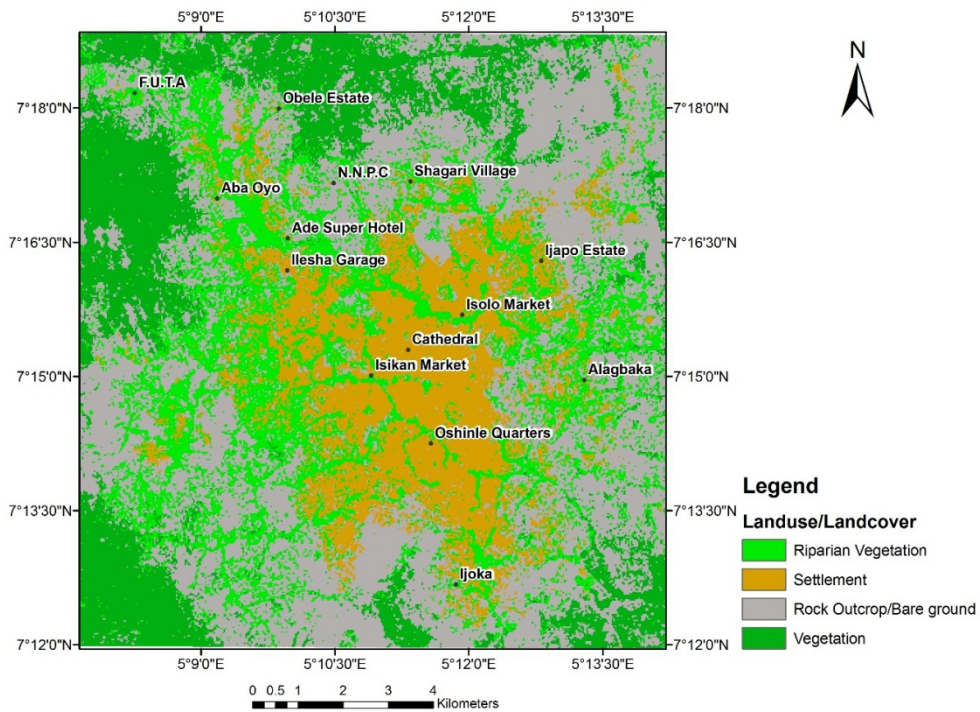
**Figure 6: Land Use/Land Cover Map of Akure in 1986**  
 Source: Authors' Image Analysis, 2013

**Table 2: Land Use/Land Cover (LULC) Change in Akure Metropolis between 1986 and 2002**

LULC Types	1986		2002		Change between 1986 and 2002		Average rate of Change	
	SQ. KM	%	SQ. KM	%	SQ. KM	%	SQ. KM/Yr	%
Riparian Vegetation	14.68	9.96	33.23	22.54	+18.55	+126.36	+1.16	+7.9
Settlements	15.74	10.68	24.65	16.72	+8.91	+56.61	+0.56	+3.5
Rock Outcrop/Bare ground	20.4	13.83	60.24	40.87	+39.84	+195.29	+2.49	+12.2
Vegetation	96.6	65.53	29.30	19.87	-67.3	-69.67	-4.21	-4.4
<b>Total</b>	<b>147.42</b>		<b>147.42</b>	<b>100</b>	.....	.....	.....	.....

Source: Fieldwork, 2013

**Figure 7: Land Use/Land Cover Map of Akure in 2002**



Source: Authors’ Image Analysis, 2013.

However, as revealed in Table 3, riparian vegetation had declined in size from 33.23 sq. km in 2002 to 17.95 sq. km in 2011. Vegetation increasingly reduced from 29.30 sq. km in 2002 to 14.12 sq. km in 2011. In addition, settlements tremendously increased in area by 27.46 sq. km within the period, indicating extension of urban influence on the other land use/land cover types, particularly vegetation and riparian vegetation that comprises of wetlands and wetland strips (Figure 8). Rock outcrop/bare ground increased from 60.24 sq. km in 2002 to 63.23 sq. km in 2011. This may be attributed to anthropogenic activities that relate to urban expansion, widening of transport facilities and other impervious surfaces.

**Table 3: Land Use/Land Cover Change in Akure Metropolis between 2002 and 2011**

LULC Types	2002		2011		Change between 2002 and 2011		Average rate of Change	
	LULC area	%	LULC area	%	SQ. KM	%	SQ. KM/Yr	%
Riparian Vegetation	33.23	22.5	17.95	12.1	-15.28	-	-1.70	-5.12
Settlements	24.65	4	52.11	8	+27.46	45.98	+3.05	+12.



Rock ground	Outcrop/Bare	60.24	16.7	63.23	35.3	+2.99	+111.	+0.33	4
			2		5		4		+0.5
Vegetation		29.30	40.8	14.12	42.8	-15.18	+4.96	-1.69	5
			7		9				
			19.8		9.58		-		-5.76
			7				51.81		
<b>Total</b>		<b>147.4</b>		<b>147.4</b>		.....	...	...	.....
		<b>2</b>	<b>100</b>	<b>2</b>	<b>100</b>	..			

Source: Fieldwork, 2013

The results of the analysis of extent of development compliance with the physical planning regulations were presented on Table 4. It was observed that a large proportion (54.8%) of the house owners in the study area did not secure approval from appropriate regulator while 45.2% of the house owners claimed to have secured proper approval. This observation indicates that most house owners in the study area are low-income earners that seek to locate their dwellings within marginal land because of their inability to compete favourably for well-drained sites of higher rental values. Perhaps such properties might not have ordinarily met the necessary planning standards that would have qualified them for approval by the appropriate regulators. Despite this shortcoming, 61.3% and 25.8% of the buildings were used for residential and mixed uses respectively. In like manner, 7.5% and 4.3% were deployed for commercial and religious purposes correspondingly. However, 1.1% was deployed for educational uses.

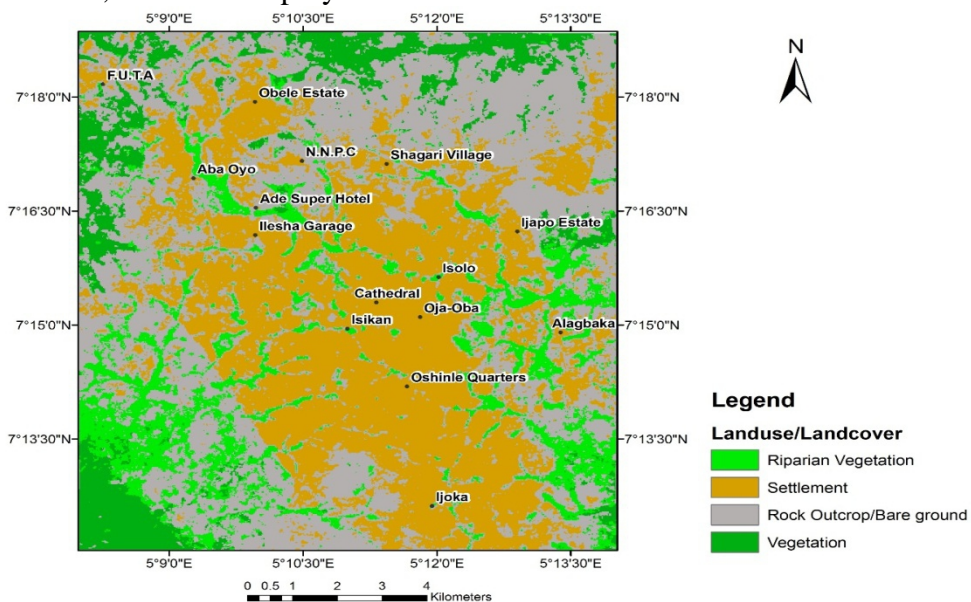


Figure 8: Land Use/Land Cover Map of Akure in 2011

Source: Image Analysis, 2013

About 54% of the respondents deployed the wetland for property development while 19.4% used it as refuse dump sites. Fieldwork also shows that 10.8% of the respondents utilized it for either fish farming or crop farming while 3.2% engaged it for recreational purposes. The implication of this scenario is that the more the developmental activities on the wetlands and around the rivers/streams that drain the study area, the greater the impervious surfaces and the more vulnerable the area to flooding because of the increasing storm water from the rain and increased water from human activities. Table 4 also provides insight to the condition of the drainage as it has a vital role to play in the occurrence of flooding. 33.3% of the respondents claimed that the study area had no drainage system while 31.2% opined that the existing drainage system was in a poor state such that it facilitated overflow of water on the roads even with a little downpour. Only 7.5% of the respondents concluded that the study area had good drainage while 26% believed the condition of drainage system was only fair. It was revealed that there was a serious disregard to the standard setback from wetland or river as stipulated by the Ministry of Physical Planning (Table 4). 57.5% of the respondents attested to the fact that sinking of buildings was a prominent issue in the study area. 29.8% claimed that the closeness of their houses to the wetland/river had reduced their properties' values while 12.6% declared that there had been occurrences of building collapse in the area. The table further showed strong tendency for the susceptibility of the area to devastating flood as 62.4% of the residents asserted to have been experiencing flooding while 37.6% declared that they had never experienced such environmental hazard because their buildings were relatively farther away.

Field observations established that some of the residents abandoned their houses and temporarily moved their valuable properties on the roadsides whenever it rained against the impending submergence of the buildings by floods. The average flood height experienced by the residents lends credence to the impending devastating effects of flood on the lives and properties of the inhabitants as 65.6% claimed to have experienced below window-level flooding, suggesting that the flood water flew into their residences through the doors. Another 23% experienced window level flooding while 11.5% experienced above the window level (Table 4). This suggests that the destruction of wetland ecosystem in the study area has heightened the possibility of floods in the rainy periods and so more houses are becoming vulnerable to flood. Again, 40.7% of the urban dwellers were of the opinion that the duration of subsidence of storm water took few hours after the rain before absorption by the ground and 22% noted that it took one day for the storm water to be completely subsided. In addition, 19.8% asserted that the storm water subsided immediately the rain stopped while



14.3% claimed that it took 2 to 5 days for the storm water to subside. However, 3.3% lamented that the storm water occasionally lasted for a week and above for the water fully subside. The emerging situation depicts a serious neglect of town planning laws that supposed to direct development to where it is desired and appropriate.

**Table 4: Physical Planning Attributes and Degree of Compliance**

<b>Physical Planning Variables</b>	<b>Frequency</b>	<b>%</b>
<b>Development Approval status</b>		
Yes	14	45.2
No	17	54.8
<b>Total (N)</b>	<b>31</b>	<b>100</b>
<b>Use of Building</b>		
Residential	57	61.3
Commercial	7	7.5
Mixed use	24	25.8
Religious	4	4.3
Educational	1	1.1
<b>Total (N)</b>	<b>93</b>	<b>100</b>
<b>Drainage condition</b>		
Good	7	7.5
Fair	26	28.0
Poor	29	31.2
No drainage	31	33.3
<b>Total (N)</b>	<b>93</b>	<b>100</b>
<b>Usage of Wetlands</b>		
Agriculture	5	5.4
Property development	50	53.8
Aquaculture	5	5.4
Refuse dump	18	19.4
Recreation	3	3.2
No use	12	12.9
<b>Total (N)</b>	<b>93</b>	<b>100</b>
<b>Effect of building close to wetland</b>		
Low Property value	26	29.8
Sinking Buildings	50	57.5
Collapse of buildings	11	12.6
<b>Total (N)</b>	<b>87</b>	<b>100</b>
<b>Flooding experience</b>		
Yes	58	62.4
No	35	37.6
<b>Total (N)</b>	<b>93</b>	<b>100</b>
<b>Average Flood height experienced</b>		
Below window level	61	65.6

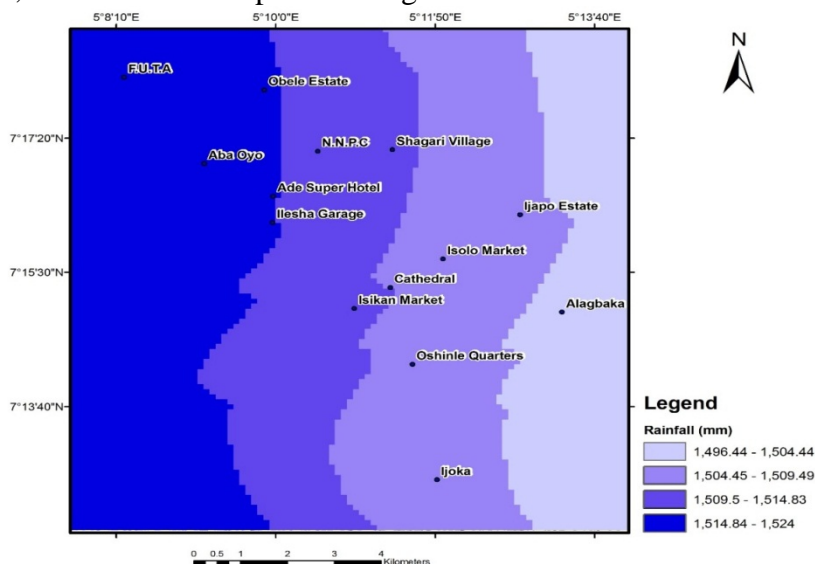
Window level	21	23.0
Above window level	11	11.5
<b>Total (N)</b>	<b>93</b>	<b>100</b>

**Duration of storm water sink after rainfall**

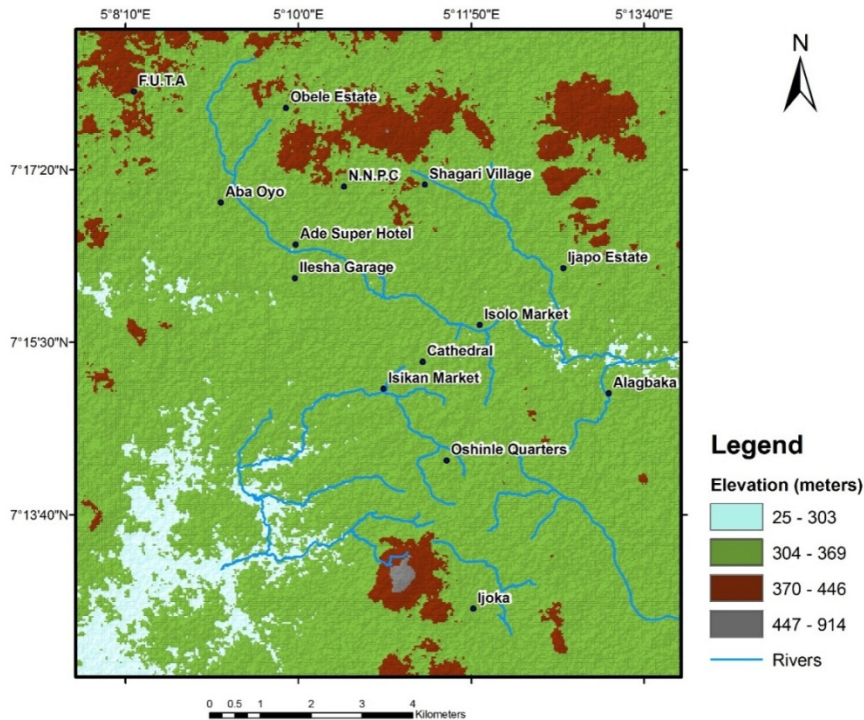
Few hours after rain	37	40.7
1 day after	20	22.0
2-5 days after	13	14.3
1 week and above	3	3.3
Immediately after rain	18	19.8
<b>Total (N)</b>	<b>91</b>	<b>100</b>

Source: Fieldwork, 2013

In view of the degenerating situation, the study attempted to model vulnerability of the areas susceptible to flooding. To achieve this, data layers that include annual mean rainfall data, digitized rivers/stream channel data, slope data, elevation data and watershed data were generated. Figure 9 showed the annual mean rainfall distribution in the study area. Places such as Federal University of Technology Akure (FUTA), Aba-Oyo, Ilesa Garage, Orita Obele and Ade Super Hotel area experienced the highest mean annual rainfall of about 1514mm. Locations like Ijapo Estate, Isolo Market, Anglican Cathedral, Ijoka and Oshinle Quarters recorded mean annual rainfall ranging between 1504mm and 1509mm while places like Isikan Market area and Shagari Village area experienced mean annual rainfall greater than 1509mm but less than 1515mm. Most of these areas are on the elevation range between 304 meters and 369 meters, which are also drained by rivers, and streams as depicted in Figure 10.



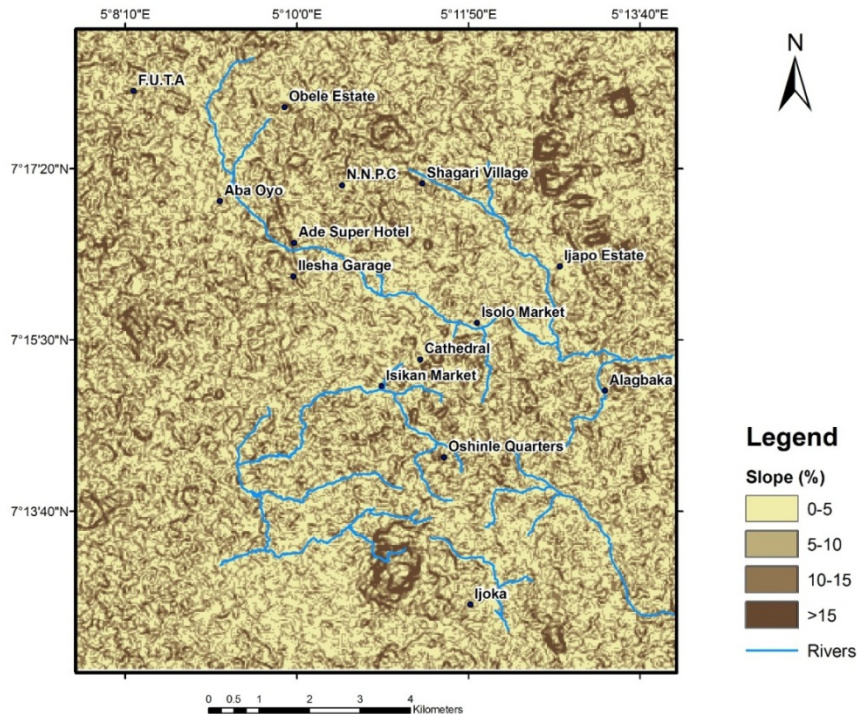
**Figure 9: Annual mean rainfall in Millimeters**  
Source: Fieldwork, 2013



**Figure 10: Elevation and River/Stream Channels within the Study Area**  
 Source: Authors’ Image Analysis, 2013

The research found out that the areas were characterized by flat or gentle, steep and very steep slope as revealed by Figure 7, which represented slope in percentage values with contours ranging from light yellow to brown. Thus, the Figure showed that areas within 0% to 10% exhibited a flat or gentle slope; areas within 10% to 15% had a steep slope while areas with values greater than 15 % could be referred to as very steep.

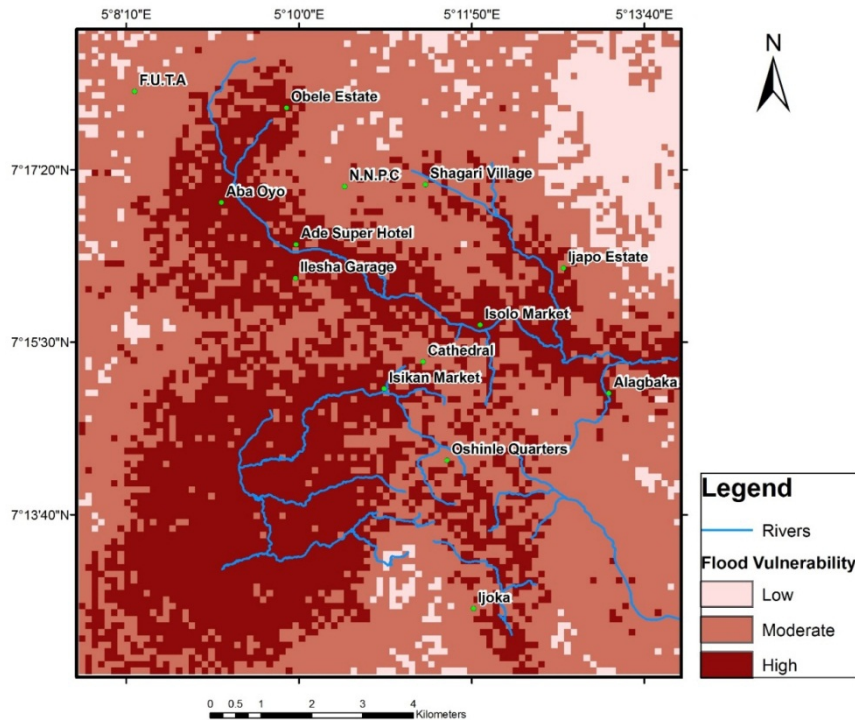
As shown in Figure 10, rivers/streams were observed to have been flowing from the very steep slope down to the areas characterized by gentle slope that is naturally suitable for habitation and rich wetland resources. Further, the southern part of the study area was found to have larger proportion of watershed compared to other locations (Figure 11). This implies that they have more pour points that result into more stream channels around the area. The watershed forms a river or a stream because when water falls on a hillside, the water flows down and accumulates into a stream, which is responsible for the more streams formation around the southern region.



**Figure 11: Slope in Percentage and the River Channels within the Study Area**

The study therefore attempted to model the vulnerability of the areas susceptible to flooding by integrating the datasets described in the previous paragraphs. The datasets include elevation, drainage density and annual mean rainfall data. Different weights were assigned to each of the datasets, based on their potentials to contribute to the occurrence of flooding. The areas vulnerable to flooding were ranked as high, medium and low vulnerability as shown in Figure 12.

Based on this vulnerability analysis, the area with high vulnerability to flooding were observed to have occurred along the streams or river channels, flowing from the eastern region of the study area towards the northwest region where the standard setbacks had been compromised by physical planning practices. These include locations such as Obele Estate, Aba Oyo, Ade Super Hotel, Isolo, Isikan and Ijapo Estate. Areas around the southwest region of the study area also have high vulnerability to flooding that may be attributed to excess watersheds and streams. Also from the elevation map and the digital elevation model, this region constitutes a bulk of the lowest altitudes above sea level. Places around FUTA and NNPC recorded medium vulnerability to flooding while low vulnerability is very prominent around the northeast area of the study area



**Figure 12: Flood Vulnerability Index of the Study Area**

Source: Fieldwork, 2013

It was observed that some precautionary approaches had been taken to avoid or reduce inundation in the study area. These include dredging of some water bodies and creating floodwalls or levees that could temporarily withstand the envisaged inundation. These processes have resulted into converting some small streams into mere drainage channels while others have been straightened from its original course, all with the aim of reducing the occurrence of flooding. However, when such channels could no longer accommodate the volume of water due to increased stream velocity, storm water will have to flow under pressure with a high possibility of forcefully breaking through the walls. Again, most floodwalls constructed within the study area often have the base of the water body converted to an impervious surface through concrete filling. This further affects water absorption by the soil.

The construction of floodwalls seems to encourage the people to settle in the floodplains. These floodwalls give them a false sense of security against flooding not knowing that they have the tendency of increasing the destructive power of flooding. However, some scholars have observed that such a manipulation of the river is an ill-advised fight against nature. They argue against further development in areas prone to flooding, pointing out



that levees raise rivers height by hemming them instead of allowing them to spread out across floodplains. When a river is confined, a levee makes it run faster and thereby increases its destructive power. This was confirmed from the respondents during the questionnaire administration that ever since the levee was constructed, it had only increased their susceptibility to flooding.

## **Conclusion**

This study has demonstrated the capability of satellite imagery and GIS techniques in analyzing wetland degradation that has been occasioned by swift urban development. It has not only established that a large proportion of the wetlands have been lost to urban development but some areas have been made vulnerable to flooding than other. The effect of the degradation is in the incessant flooding often experiences in these settlements. No doubt, this problem portends great danger to lives and properties. The need to curb this problem is urgent and imperative if events that are more grievous are to be avoided. Again, it is very expedient to know that the protection of wetlands goes beyond mere channelization of some water bodies or building of floodwalls, rather, wetland misuse should be strictly addressed. Finally, it is canvassed that government at all levels must commit sizeable resources on research and development on wetland management. Such research should evolve proper monitoring and evaluation system for wetland management while addressing the issue of appropriate usage for this fragile ecosystem.

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