OPEN TRANSACTIONS ON GEOSCIENCES
ISSN(Print): 2372-6458 ISSN(Online): 2372-6466
DOI: 10.15764/GEOS.2015.01002
Volume 2, Number 1, March 2015

OPEN TRANSACTIONS ON GEOSCIENCES

Riparian Corridors Encroachment and Flood Risk Assessment in Ile-Ife: A GIS Perspective

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Abstract:

Recent development and expansion of paved surfaces as a result of urban growth has resulted in encroachment of riparian corridors, the immediate effect of which poses flood risk to affected areas. Geographic Information System (GIS) method was employed in this study to determine the level of encroachment as well as areas susceptible/at risk to flood and flooding. Results from the study indicated that urban and agricultural land uses had encroached significantly on the riparian corridor and had disrupted the ecosystem services of the corridor. Results also indicated that major parts of the watershed had low flood risk but serious encroachment exists therein. Buildings as many as1129 had already encroached into the 30metres minimum setback standard which are mainly riparian corridor and the buildings which had encroached into the corridor fall within the high flood risk zone of the watershed.

Keywords:

Flood Risk; GIS; Riparian Corridor; Watershed

1. INTRODUCTION

Studies have shown that riparian habitats are very important for water quality, flood and erosion control. "'Riparian ecosystems' are the complex assemblage of organisms and their environment existing adjacent to and near flowing water." Malanson offers an attractively simple definition: "the ecosystems adjacent to the river"[1]. Riparian zones are sometimes used interchangeably with floodplains. As riparian zones, floodplains are usually defined as ecotones between terrestrial and aquatic realms [1, 2] that extend from the low-water mark to the high-water line and also include the terrestrial vegetation influenced by elevated groundwater tables or extreme flood [3]. Groundwater nutrients can be retained in a riparian habitat as a result of plant uptake, microbial processes and organic matter absorption [4]. Nutrient uptake as well as removal by soil and vegetation in riparian habitats prevents outputs of agricultural lands from entering the stream channel [5, 6].

The delineation and extent of riparian areas vary in part because of their inherently complex and dynamic character. Streams and riparian areas are interactive and thus, stream processes influence the extent and character of riparian systems and riparian vegetation influences stream channel processes, because of these interactions, resource managers often lack the necessary maps and data on the extent and character of riparian areas essential in managing and restoring these complex ecosystems [7]. However, a Geographic Information System (GIS) approach can be utilized to present a fixed-width buffer of riparian areas, which could be used in assessing encroachment [8]. The effectiveness of various buffer widths zones for flood reduction and the preservation /protection of water quality have received much attention from the scientific and regulatory community, fixed buffer width of 100 ft or 30 metres is most widely used option where variable buffer could not be achieved. While buffer of less than 100ft could be accepted for flood reduction function, water quality protection requires a minimum of 100 ft. The buffer applies to all perennial and intermittent streams. However, a general recommended buffer width is shown in **Table 1** below.

Table 1. General recommended widths of buffer zones.

Function	Description of Buffer Type	Recommended Width
Water Quality Protection	Buffers, especially dense grassy or herbaceous buffers on gradual slopes, intercept overland runoff, trap sediments, remove pollutants, and promote ground water recharge. For low to moderate slopes, most filtering occurs within the first 10 m, but greater widths are necessary for steeper slopes, buffers comprised of mainly shrubs and trees, where soils have low permeability, or where non-point source loads are particularly high.	5 to 30 m
Stream Stabilization	Buffers, particularly diverse stands of shrubs and trees, provide food and shelter for a wide variety of riparian aquatic wildlife.	10 to 20 m
Riparian Habitat	Riparian vegetation moderates soil moisture conditions in stream banks, and roots provide tensile strength to the soil matrix, enhancing bank stability. Good erosion control may only require that the width of the bank be protected, unless there is active bank erosion, which will require a wider buffer. Excessive bank erosion may require additional bioengineering techniques.	30 to 500 m +
Flood Attenuation	Riparian buffers promote floodplain storage due to backwater effects, they intercept overland flow and increase travel time, resulting in reduced flood peaks.	20 to 150m
Detrital Input	Leaves, twigs and branches that fall from riparian forest canopies into the stream are an important source of nutrients and habitat.	3 to 10m

Source: Jontos 2004 (modified after Fisher and Fischenich 2000)

Riparian habitats yield a range of ecosystem and human services including both those with use values as well as others with non-use values [9]. The benefits with use value arise from in-stream uses (such as fishing, swimming or boating); withdrawal for drinking and irrigation; flood mitigation; enhanced aesthetics; consumptive activities such as hunting; and non-consumptive activities such as bird watching. Riparian systems also provide non-use values such as future benefits (bequest value) and intrinsic values such as the knowing that a healthy ecosystem exists. The benefits of riparian habitats are as summarised in the **Table 2** below;

Table 2. Ecosystem services of the riparian zone.

No	Ecosystem services of riparian
1	Reducing flood risk by storing flood waters
2	Trapping /removing sediment from runoff
3	Stabilizing stream banks and reducing channel erosion
4	Trapping/removing phosphorus, nitrogen, and other nutrients that can lead to eutrophication of aquatic ecosystems
5	Trapping/removing other contaminants, such as pesticides
6	Maintaining habitat for fish and other aquatic organisms by moderating water temperatures and providing woody debris
7	Providing habitat for terrestrial organisms
8	Improving the aesthetics of stream corridors (which can increase property values)
9	Offering recreational and educational opportunities

(Source: Schueler 1995;Malanson, 1993)

The impact of climate change is becoming more pronounced in Nigeria in form of flooding affecting virtually every state, like the 2011 and 2012 flood incidents that occurred in many parts of Nigeria (Goronyo area in Sokoto, Bayelsa area in Bayelsa state, and Ibadan in Oyo State to name a few). Many areas which were not considered vulnerable were observed as vulnerable during the flood disaster. The deplorable situation could not be divorced from lack of planning and inadequate management of land and water resources. In Nigeria and some other developing nations, vegetative buffer programmes are rarely developed to fully consider the multiple benefits and uses that they offer to resource managers and to the general public [10]. Unplanned and unsustainable drainage system as well as inadequate riparian buffer width at the sub-basin level increases the risk of flood and associated hazards in many urban centres in the country [11]. Flooding is a natural feature of aquatic and riparian ecosystems. The frequency, duration and magnitude of floods help to determine both thephysical and biological characteristics of the riparian zone [12]. Manyriparian plants rely on cycles of flooding for seed dispersal and recruitment, while many fish species use riparian zones as nurseries, spawning grounds or feeding areas during high flows. A healthy riparian zone and a healthy stream system require the maintenance of the natural flow regime; of course, while floods are good for the stream and the riparian zone, they can be very damaging to human structures and activities. Removal of riparian vegetation, drainage of wetlands and development of floodplains leads to larger magnitude floods that cause greater damage to property [13]. The riparian zones along the river system in Ife Central local government as well as the neighbouring local governments are not maintained to comply with stipulated 30m local and international standards. This situation is not deviating for most cities across Nigeria.Developmental efforts are taking place along the buffer zones at the expense of the ecological services rendered by the riparian buffer zones. The effects of this are increased flood risk in the affected areas [14] and further compromise of the water quality in the streams, which in turn affects the ecosystem. In order to recommend a sustainable management strategy, this study assessed the level of encroachment on the riparian corridors in the local government. In order to reduce the risk of flooding, sustainable land and water management efforts has to be in place to restore and protect the riparian corridors.Risk has been part of man and it cannot be completely eliminated, as such it should be managed. Risk assessment is the first step in risk management. According to Kates and Kasperson [15], risk assessment comprises of three distinct steps, which are:

(i) An identification of hazards likely to result in disasters,

(ii) An estimation of the risks of such event,

(iii) An evaluation of the social consequences of the derived risk.

Flood risk involves both the statistical probability of an event occurring and the scale of the potential consequences [16]. In risk analysis, risk (R) is the product of probability of an event (P) and the consequential loss (L). This is represented as:

$$R = P \times L \tag{1}$$

All development of land within the floodplain of a watercourse is at some risk of flooding, however, small. The degree of flood risk is calculated from historical data and expressed in terms of the expected frequency 10 year, 50 year or 100 year flood [17]. In this study Geographic Information Systems (GIS) was used to assess the level of encroachment by development on the riparian corridors in order to determine the areas that should be protected from unsustainable land use and the areas to be restored as riparian corridor for sustainable ecosystem services and also determine areas of flood risk within the study space.

1.1 Study Area

The study area is Ife Central local government, which plays a prominent role in the educational, economic and socio-cultural development of Nigeria due to its historical, political, economic and cultural relevance. The study area is a section of the watershed which has a coverage of 197 km^2 and extends from latitude 7°26’56”N to 7°35’5”N and longitude 4°24’53”E to 4°39’13”E.

The climate of the study area is described as humid tropical environment [18]. The area is located in the cocoa belt of Nigeria. It falls within the tropical humid climate that is characterized by wet and dry seasons. The pattern of rainfall is characterized by the double maxima regime, the two periods of maxima rainfall being June/July and September/October. There are two seasons in the catchment, namely the wet and dry seasons. The geology of southwestern Nigeria is classified as basement complex. The geology of the area as reviewed by Rahaman [19] includes granite gneiss and schist epidiorite. The soil of the catchment is Alfisols with Ferruginous Tropical overlay in most cases. The soil belongs to Iwo Association at series level and as OxicTropudalf by the USDA system and it was derived from granite and gneiss parent materials [20]. Also the area is drained by a very large network of rivers such as Obudu, Opa, Esinmirin, Ominrin, Ogbe, Okun, Mokuro and other smaller tributaries (see Fig. 1). The rivers rise from the western upland and flow downward in the southwest direction. The catchment has a manmade reservoir whose dam was constructed in 1976 located within the campus of ObafemiAwolowo University, Ile-Ife. The surface area of the reservoir is about 0.5km^2 with a length of 1.8km and a depth of 8m while the maximum capacity is about 633 million gallons. The study area is undergoing rapid urbanization which is affecting the drainage system through unplanned development.

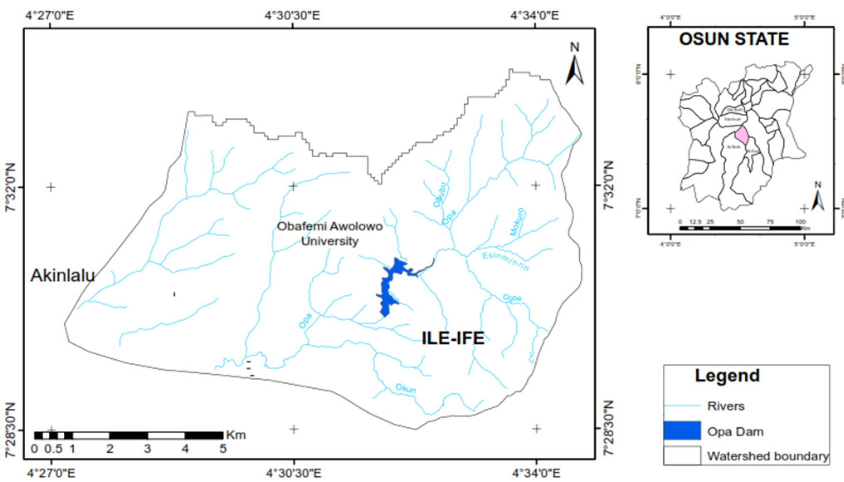

Figure 1. The Study Area.

2. MATERIALS AND METHODS

This section describes the sources and methods of data collection, processing, analysis and presentation. The study explored the use of topographic maps, satellite imageries, published and unpublished data for its successful implementation.

2.1 Maps and Satellite Imageries

Data set used in this study include: boundary map of the study area, 30m SRTM Digital Elevation Model (DEM), topographic maps, soil map, Landsat imageries and Google Earth image for updating. This data set is summarized in **Table 3** below. Analysis of the dataset was carried out using ArcGIS 10.0software.

Table 3. Data Used.

No	Data	Year	Source(s)
1	Boundary Map	December, 2012	Ife Central Local Government
2	Google Earth Image	June, 2013	Google earth website
3	SRTM DEM Image	January, 2010	http://glcf.umiacs.umd.edu.
4	Topographic Map Sheets	1964	Office of the Surveyor General of the Federation
5	Landsat satellite imageries	1986 and 2002	http://glcf.umiacs.umd.edu.
6	Soil map of Ile-Ife area	1962	Department of Soil Science, OAU

2.2 Watershed Boundary and Sub-basin Delineation

In order to delineate the watershed boundary and sub basins, an orthorectified 30m SRTM Digital Elevation Model (DEM) covering the study area in Western Nigeria obtained (http://glcf.umiacs.umd.edu.) was imported into ArcGIS 10.0 for further preprocessing. For the DEM to be used in watershed boundary and sub-basins delineation, it was first processed to create certain required layers such as flow direction, flow accumulation, stream, stream segments, slope grid, catchment grid delineation, catchment polygon, and drainage line and adjoint catchment layers. These layers were created using the ArcHydro extension in ArcGIS. The series of operations performed in order to extract the catchment's boundary and sub-basins were shown in **Figure 2**.

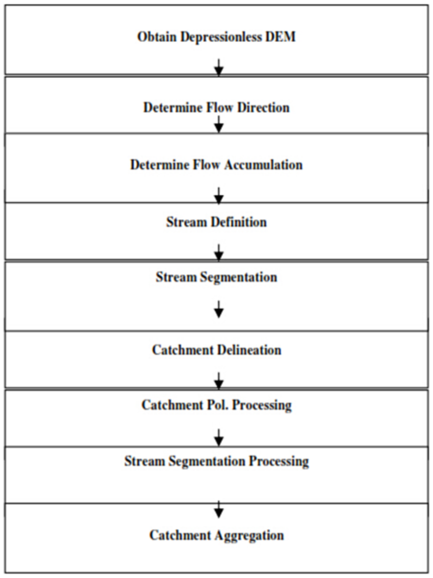

Figure 2. A Schematic diagram of the watershed boundary and stream delineation processes.

2.3 Stream Network Mapping, Identificationand Characterization

The scanned topographic sheets covering the study area was glued and georeferencedin ILWIS 3.3. The raster map wasimported into ArcGIS 10.0 where the watershed boundary layer was used to clip the raster. The stream network was then digitized and a stream vector layer wascreated in the geodatabase. The mapped streams was then identified using ground truth information and they were characterized based the stream length and order using Strahler Method

[21]. Stream length and order information is essential in riparian corridor management.

2.4 Riparian Corridors, Land Use Change and Building EncroachmentAnalyses

The Landsat imageries of 1986 and 2002 were classified to determine the land use/land cover types in the study area and the rate at which riparian vegetation is lost to urban development within a period of 16 years. The classified image was clipped by the study area boundary for further GIS analysis. The standard riparian corridors within the study area were identified from the stream network layer generated from the mapping exercise by buffering the stream by up to 40m from the stream. This 40m corridors that surround the streams should be conserved for ecological services in the undeveloped section of study area while a minimum riparian width of 30 metres could be allowed in the urban section. As such, double ring buffering of 30 and 40 m was created around the stream network in order to estimate changes in the areas covered under different riparian width for the two epochs.The high resolution IKONOS imagery of the watershed was imported into the ArcGIS 10.0, where the buildings constructed within less than 30m radius from the stream network of the watershed were digitized and stored as a building vector layer. GIS overlay analysis was performed using the multiple buffer rings and the building layers to clip and estimate the number of buildings within the buffer rings which violates the minimum 30m setback standard.

2.5 Analysis of Riparian Corridors for Protection and Restoration

The Digital Elevation Model of the study area was clipped and classified based on Natural Break (Jenks) into 3 classes (215 – 260; 261 – 300 and 301 – 415) metres in the ArcGIS 10.0. Overlay analysis was done using the buffer layers of 40 and 30 metres, land use/land cover layerand reclassified DEM layer to identify the suitable areas for protection and restoration. For riparian corridor protection in the undeveloped region, the chosen parameters were elevation between 215 and 300 metres because these are the areas plausible for urban development, land use other than urban, and a riparian buffer width of 40 metres. For riparian corridor restoration, the chosen parameters were elevation between 215 and 415 metres, all land use types except water body, riparian vegetation and light forest and a riparian buffer width of 30 metres.

2.6 Flood Risk Assessment

A Curve Number grid was created for the flood risk assessment using land use, soil and DEM layers. The Curve Number method was used to create 3 levels of vulnerability- high, medium and low. The buffer layers of 30m, 50m and 100m were overlaid on the curve number grid to determine various levels of flood risk. Three risk levels were generated based on the curve number and distance from the stream (High risk, Moderate risk and Low risk.

3. RESULT AND DISCUSSION

The raw Digital Elevation Model (DEM) that was subset to the study area is shown in **Figure 3**. The DEM is a raster image that has each pixel showing elevation values. The minimum elevation in the DEM is 194m while the maximum is 641m above the mean sea level.

Following the sequence of operations listed in **Figure 3**, the SRTM DEM was used to delineate the watershed and

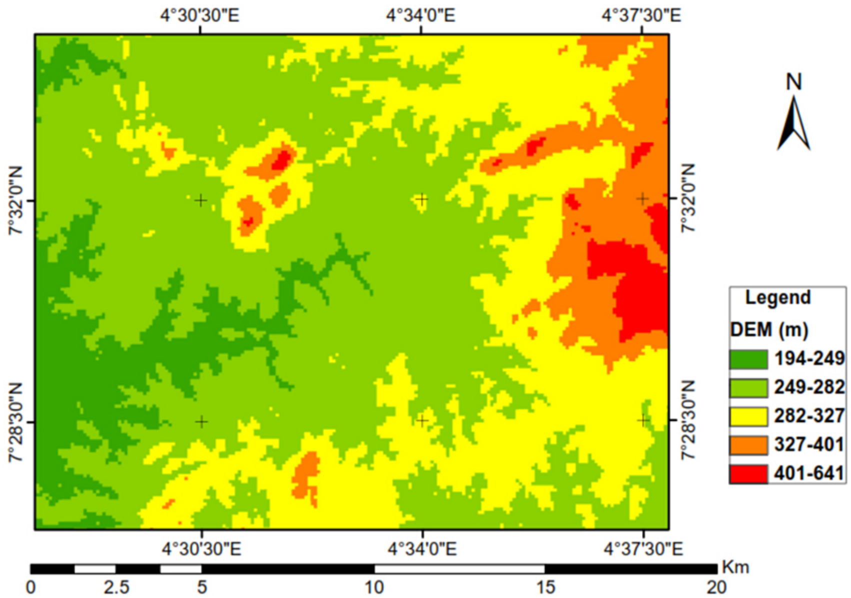

Figure 3. Digital Elevation Model (DEM) Extracted From SRTM DEM.

sub-basins within ArcGIS 10.0 using ArcHydro extension tools. The delineated catchment has 17 sub-basins which are shown in **Figure 4**. The watershed drains a total area of 197.2 Km^2. The study area in the watershed is 82.64Km^2.

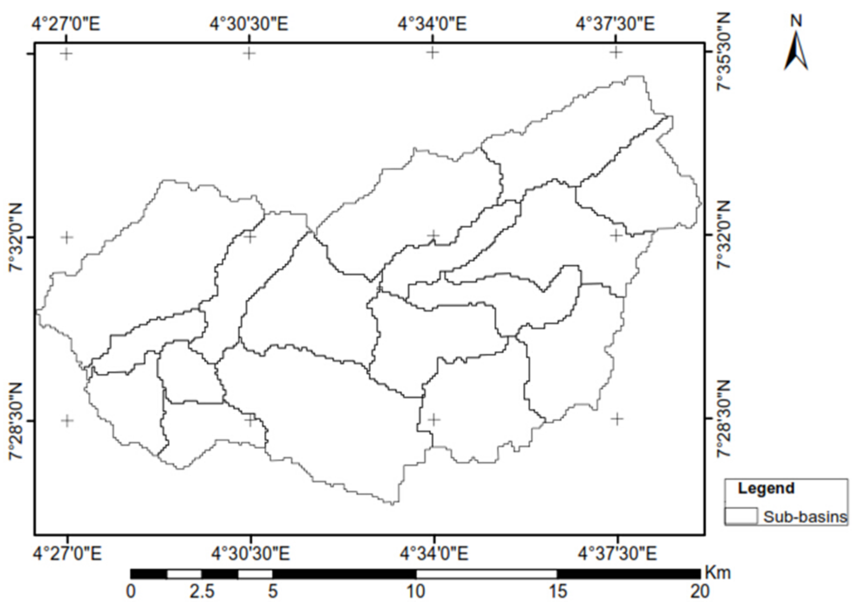

Figure 4. Delineated Catchment with Sub Basins in Ile-Ife.

Results from the study indicates that the drainage system of the watershed is dendritic due to the nature of the terrain which has a gentle slope extending from the southwest towards the north eastern direction as shown in **Figure 5** below. The rivers range from order 1 to order 4 using Shrahler ordering system [21]. The drainage density which is the ratio of total stream length to basin area is 1.70. This relatively low value means precipitation takes shorter time before it reaches the stream by surface run-off, throughflow and baseflow.The bifurcation ratio of the watershed which is the relationship between streams in different order is 1.76. This low value is an indication of shorter lag time, higher peak discharge and susceptibility to flooding [21].

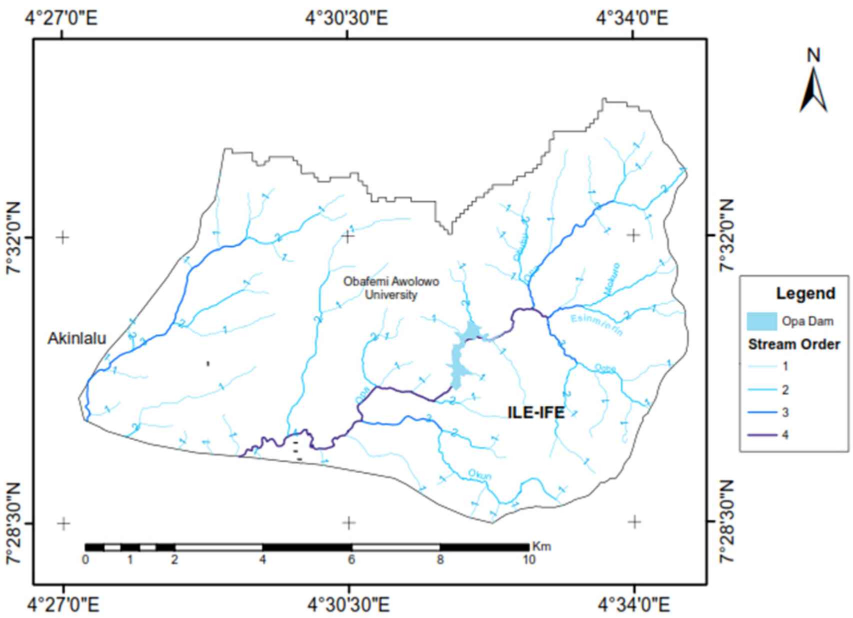

Figure 5. Drainage network in Ife Central Local Government.

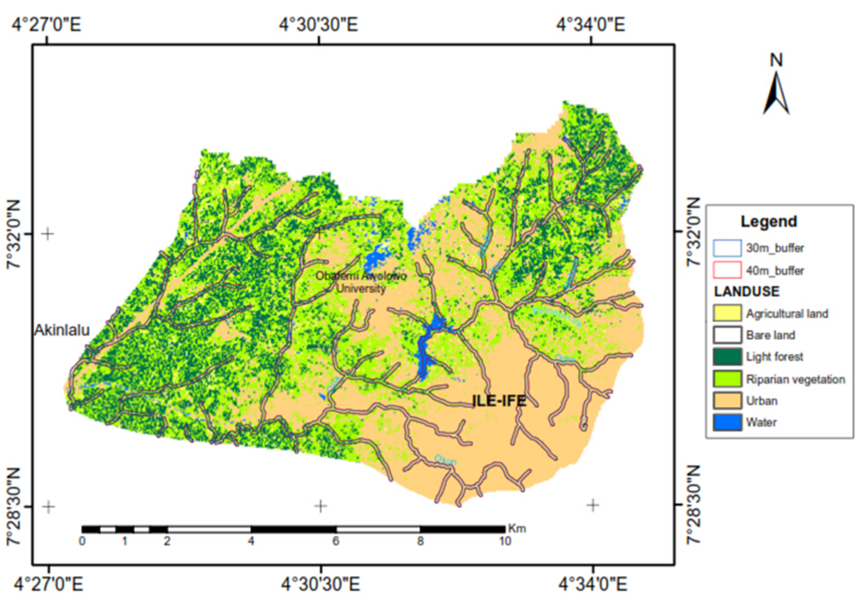

Figure 6. Land use/Land cover of Ife Central Local Government overlaid by 30m and 40m buffer ring to identify the land use type within the riparian corridor width.

The results of encroachment analysis show the number of building that has encroached on the minimum setback of 30m and acceptable distance of 40m for riparian corridor protection. 1129 buildings have encroached into the 30m minimum setback, 1357 buildings are within 40m setback distance from stream while 837 are within the 30 m and 40m distance. **Figure 9** and **Figure 10** show the distribution of the buildings within the riparian corridors. It could be

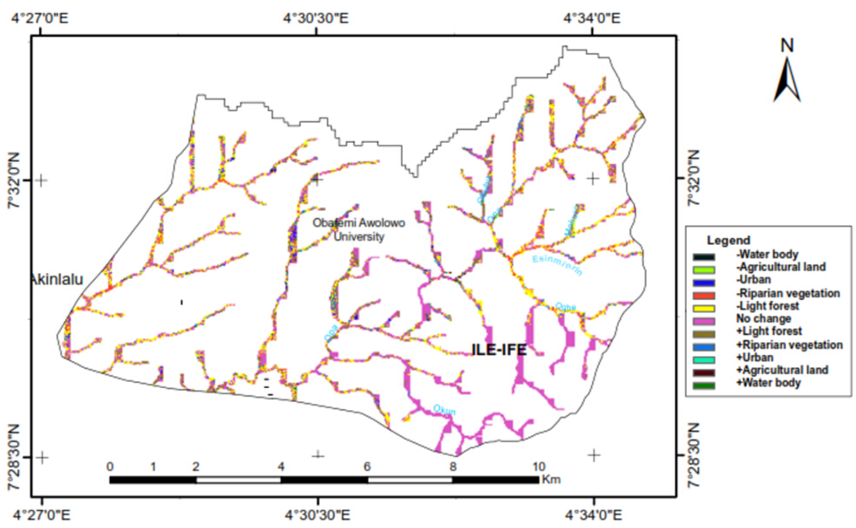

Figure 7. Land use change in the 30m to identify the land use type on within the riparian corridor width.

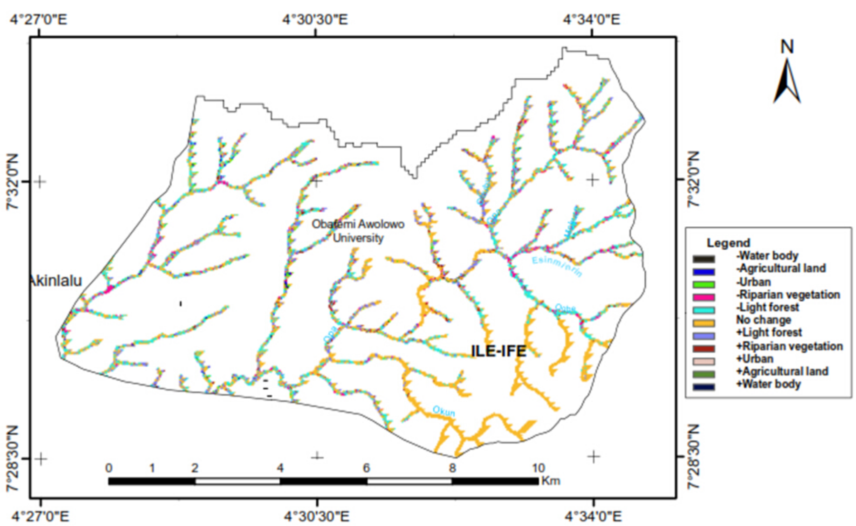

Figure 8. Land use change in the 40m to identify the land use type on within the riparian corridor width.

concluded from this result that there are a sizeable number of stream setback violators in the local government. This also shows that planning officials of the local government are not making any frantic effort to protect the riparian corridors. The recent increase in flood incident in the floodplain could not be divorced from this encroachment. The 4^{th} order stream in the watershed that is dammed for the university water supply has witnessed a tremendous deposition of various wastes from upstream which could have been sieved by riparian corridor if the stipulated standard buffer rule was adhered to, hence more has to be done to treat the water for improved water quality.

Table 4. Land use change within the 30m riparian corridor width. Negative (-) sign shows losses while Positive (+) sign shows gain.

Land Use Type	30m Buffer Width in 1986 (ha)	30m Buffer Width in 2002 (ha)	Land Use Change for 30m Width (ha)
Light forest	2976	2173	-803
Riparian vegetation	4017	3359	-658
Urban	3527	4973	1446
Bare land	212	22	-190
Agricultural land	153	330	177
Water body	217	245	28
Total Area	11102	11102	0

Table 5. Land use change within the 40m riparian corridor width. Negative (-) sign shows losses while Positive (+) sign shows gain.

Land Use Type	40m Buffer Width in 1986 (ha)	40m Buffer Width in 2002 (ha)	Land Use Change for 40m Width (ha)
Light forest	3412	2490	-922
Riparian vegetation	4491	3794	-697
Urban	3951	5570	1619
Bare land	216	27	-189
Agricultural land	174	338	164
Water body	259	284	25
Total Area	12503	12503	0

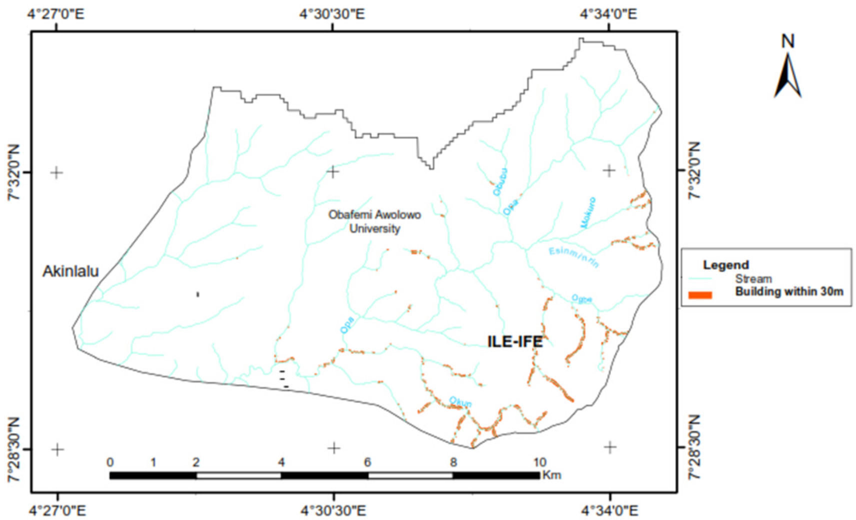

Figure 9. Buildings that have encroached into the 30m minimum setback from the riparian corridor.

3.1 Analysis of Riparian Corridors for Protection and Restoration

The reclassified Digital Elevation Model of the study area based on Natural Break (Jenks) is shown in **Figure 11**. The 3 classes are 215m – 260m; 261m – 300m and 301m – 415m. The result shows that the least elevation in the study area is 215 metres while the highest elevation is 450 metres. The riparian corridor protection zone in

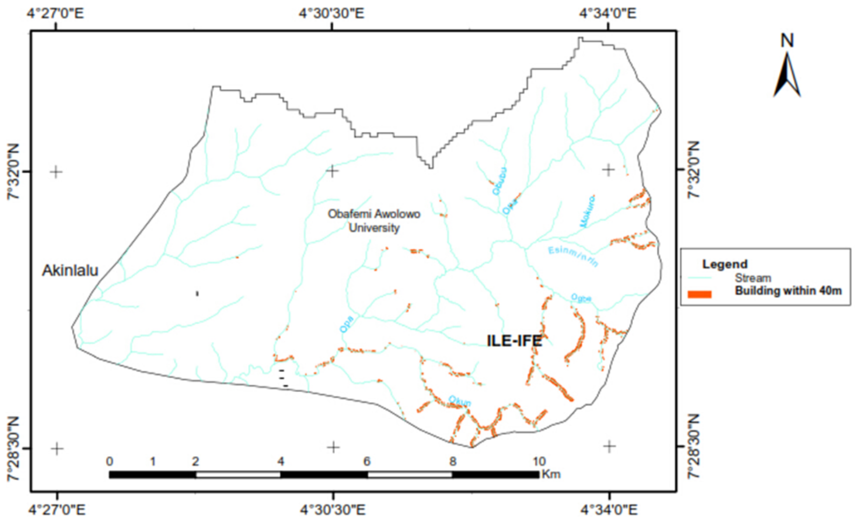

Figure 10. Buildings that have encroached into the 40m minimum setback from the riparian corridor.

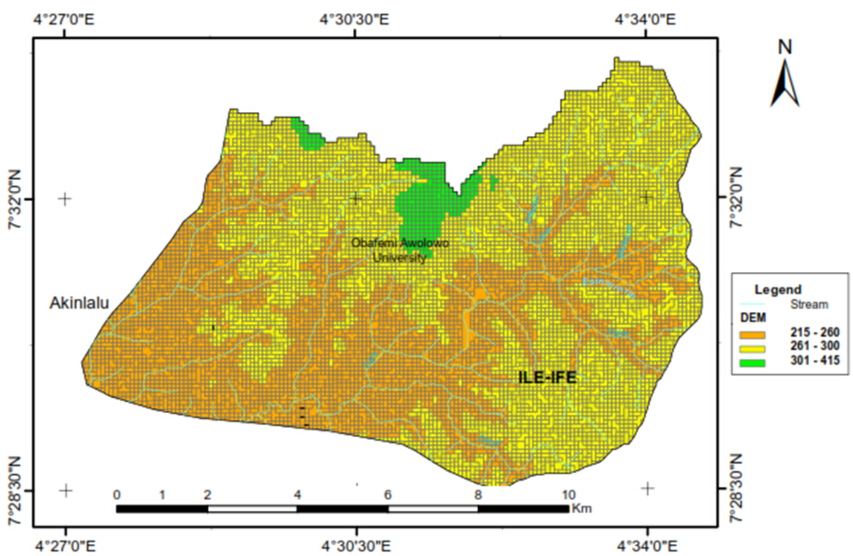

Figure 11. Reclassified Digital Elevation Model into natural break (Jenks).

the undeveloped region is shown in **Figure 12**. These are undeveloped areas with elevation between 215 and 300 metres with 40 metres width. The riparian corridor restoration zone is shown in **Figure 13**. These are areas with elevation between 215 and 415 metres, urban, bare and agricultural land use types within buffer width of 30 metres. The result revealed that there are many patches along the riparian corridors which should be protected from further encroachment while there is need to set a trade-off between the encroached building and riparian corridor restoration programme.

Re-establishing buffers where there are severe site restrictions should be considered under the 'maximum extent practicable' approach. Where minimum buffer widths are in place, these values should be seen as guidance principles within the context of urban redevelopment and should not preclude the possibility of redevelopment if specific buffer standards cannot be attained.

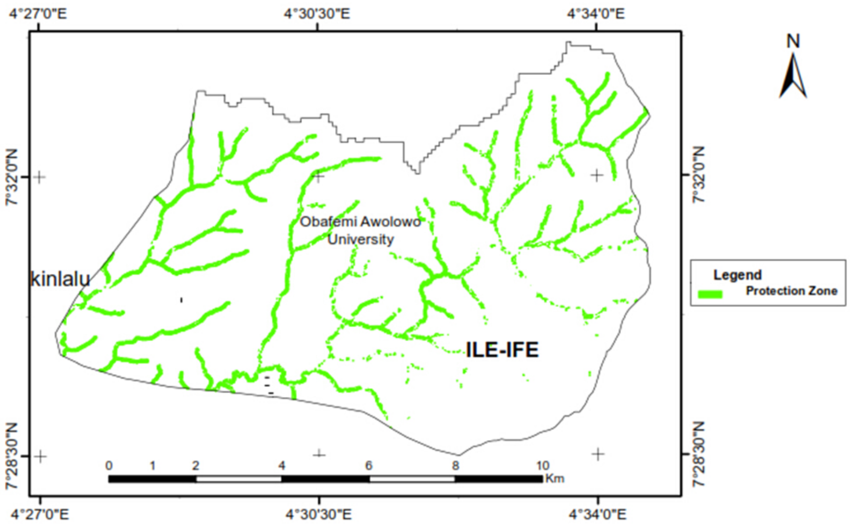

Figure 12. Riparian Corridors Protection Zone. These are areas that require protection from any developmental activities for sustainable ecosystem services provision.

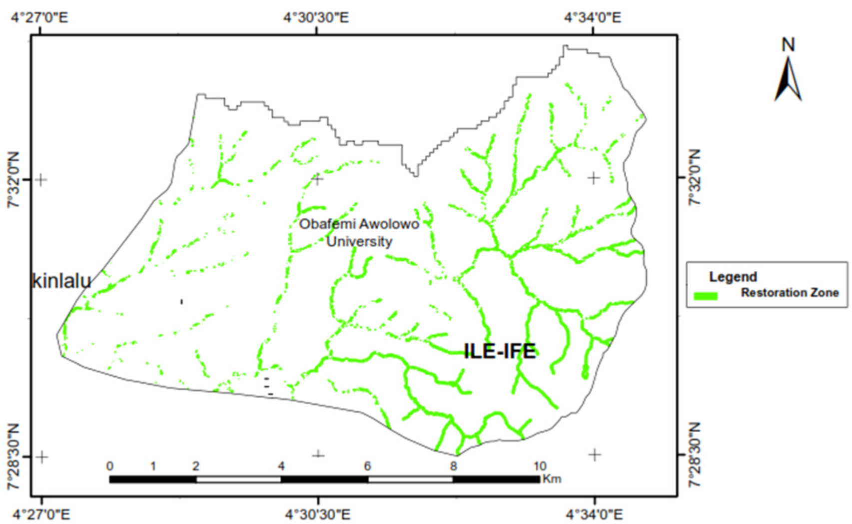

Figure 13. Riparian Corridors Restoration Zone. These are areas that require restoration by planting local riparian vegetation.

3.2 Flood Risk Assessment

Flood vulnerability and risk assessment was carried out using Soil Conservation Service (SCS) Curve Number (CN) model [22]. **Figure 14** shows the soil types found in the study area. Egbeda association is a moderately drained soil unlike the Iwo association which is well drained soil [23]. The eastern part of the study area is predominantly Iwo series while the western part is predominantly Egbeda series. The soil is found to range from moderate to well-drained soil. However, in the areas of lower elevation, the soils are poorly drained, especially in the riparian corridors.

Figure 15 shows the vulnerability levels in the watershed based on elevation, soil and land use type. The vulnerability of the study area to flooding is categorized into low, moderate and high based on the Curve Number

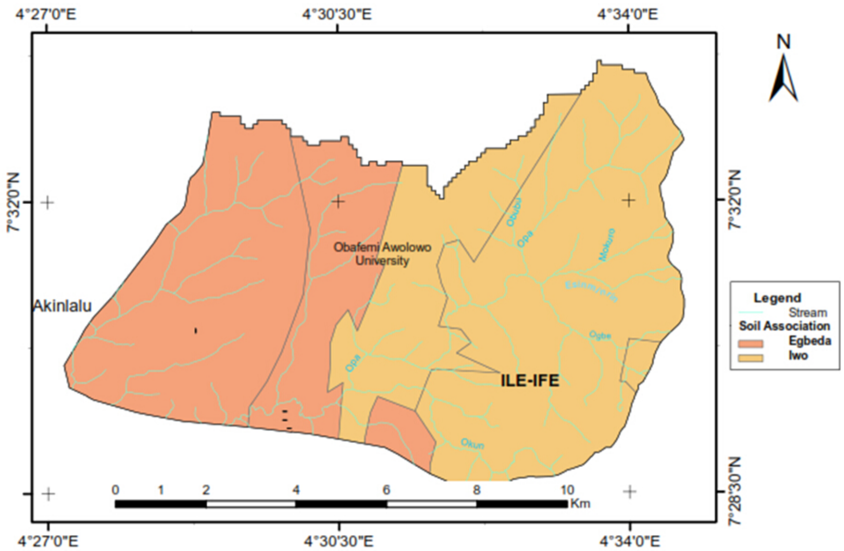

Figure 14. Soil associations found within the watershed in Ife Central LGA (Adapted from Smith and Montgomery, 1962).

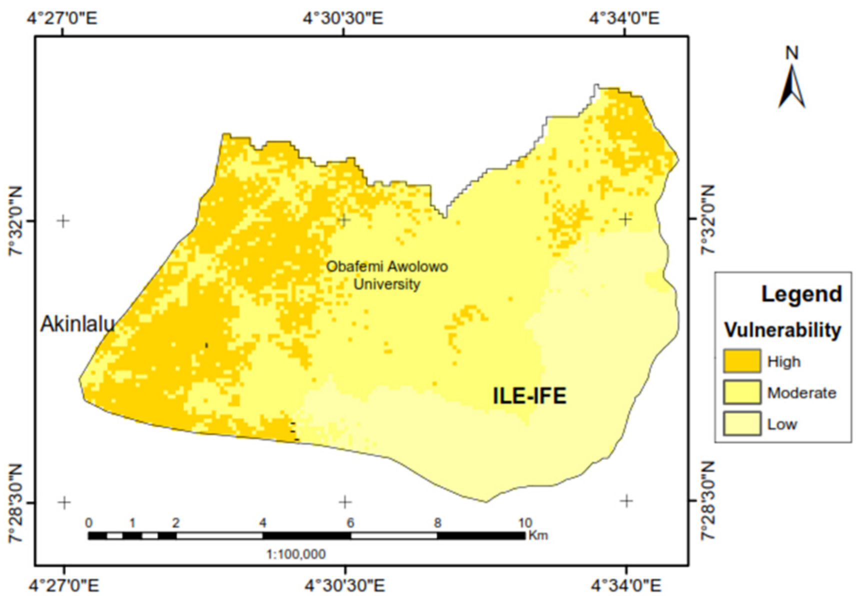

Figure 15. Flood vulnerability based on Curve Number in the watershed in Ife Central LGA.

model adopted. The North-eastern part of the watershed is considered to be of lower vulnerability despite the predominant urban land use type because it is situated on higher elevation and the soil is well drained. The vulnerability of the central part of the study area is moderate due to the combination of the factors while the highly vulnerable regions exist around the study area but more pronounced in the western part. The moderate drainage and lower elevation of the areas could easily explain this trend. Similarly, the presence of Opa reservoir in the central part of the study area explains the high vulnerability of the region.

The flood risk map generated from the analysis is shown in **Figure 16**, since risk is based on vulnerability and exposure factor. The zones are classified into High Risk Zone, Moderate Risk Zone and Low Risk Zone based on

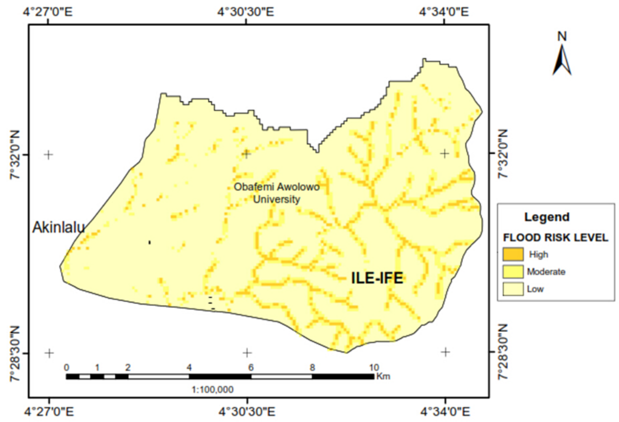

Figure 16. Flood Risk Zones found within the watershed in Ife Central LGA.

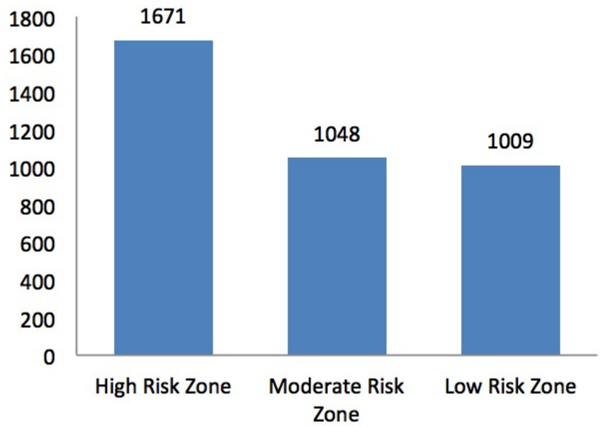

Figure 17. Number of buildings in different risk zones in Ife Central LGA.

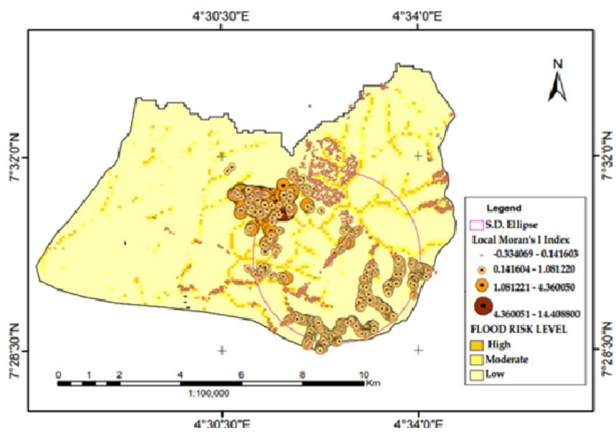

Figure 18. Cluster/Outlier Type (COType) of buildings in river proximities of Ife Central LGA.

exposure to river flooding and distances of 30m, 50m and 100m and beyond. Since stream flooding is the main hazard analysed, urban and agricultural areas that are closer to the stream or river body have higher level of flood risk while the risk reduces outwards away from the river floodplain and lowlands. Similarly, the result shows that places at lower elevation are at higher risk than places at higher elevation.

4. CONCLUSION AND RECOMMENDATIONS

From this study, it was discovered that Geographic Information System (GIS) is a viable tool in assessing and managing natural resources such as riparian corridors. Both the low and high resolution data could be combined to bring about meaningful products at lesser cost. It was also discovered that the encroachment of development on riparian corridors have a significant deleterious effects such as flooding which damages properties and results in poor water quality in the watershed's streams and reservoirs.

For a sustainable riparian corridor management, a concerted effort must be made to bring about restoration and protection by the people and the government. However, the following recommendations are put forth from the findings of this study;

1. There is need for government to embark or ecosystem management initiative which will aid sustainable development. This should involve appropriate understanding of the ecosystem services and the need to conserve the environment using among other appropriate methods, geospatial technologies.
2. There should be participatory resources management where the community will be involved in the protection and preservation of the resources.
3. There should be urban development policy review which will reward sustainable use of natural resources and impose penalty on environmental rules violators.
4. There should be investment by government in the assessment of natural resources at the local government level in other to evaluate the resources in each locality for socio-economic development.

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