Journal of Earth and Atmospheric Research

SPATIO-TEMPORAL ASSESSMENT OF RIPARIAN VEGETATION DEGRADATION AND ITS ENVIRONMENTAL CONSEQUENCES IN OSOGBO CITY, NIGERIA USING SATELLITE IMAGERY AND GIS

Adegboyega, S. A.

Department of Remote Sensing & GIS, Federal University of Technology, Akure, Nigeria.

Article History
Received: May 5, 2018
Revised: June 20, 2018
Accepted: June 30, 2018

Keywords:
Riparian vegetation, Land use/land cover, GIS, urban encroachment, vegetation degradation, Multi-temporal images

ABSTRACT

In recent years, unprecedented riparian vegetation exploitation for urban development in Nigerian cities motivates this research. This study therefore assessed spatio-temporal changes of riparian vegetation and associated environmental consequences in Osogbo city. Landsat TM 1986, Landsat ETM+ 2000, Landsat OLI TIRS 2015 and a topographic map were utilized using GIS techniques. NDVI was carried out on the images to detect temporal riparian vegetation degradation trend. Land use/land covers were extracted from the images using supervised classification technique. 100m Buffers were created around river Osun within the urban section to detect the magnitude of urban encroachment. Stochastic Markov and cellular automata models were used to predict the level of riparian vegetation degradation in 2050.

The study found that NDVI values of the riparian vegetation showed dwindling mean values of 0.20, -0.05 and 0.17 in 1986, 2000 and 2015 respectively. Though, the pattern of land use/land cover change showed the predominance of riparian vegetation (37%) over forest (31%), sparse vegetation (13%), built-up (9%), bare ground (6%) and water body (4%) between 1986 and 2000 but the riparian vegetation receded at 2.63% per annum over fourteen years and at rate of 1.9% per annum between 2000 and 2015 was observed.

Given the emerging pattern of land use/land cover change that revealed predominance of built-up (41%) over other land use/land cover types {water body (5%), scattered cultivation (20%), shrubs and grassland (28%), bare ground (1%) and riparian vegetation (5%) in 2015, the study predicts a worse condition for the riparian vegetation by 2050 as most of the narrow strips of riparian vegetation observed along the river channels are vulnerable to depletion and probably triggers serious flooding in Osogbo City. The study advocates conscious implementation of land use zoning policy to conserve the fragile riparian vegetation and curtail vulnerability of the city to flash floods.

1.0 INTRODUCTION

Riparian zone, is all land directly adjacent to a watercourse including flood plains and wetlands (Parsons, 1991; Walker 1993). Riparian lands can also include unsteady streams gullies and dips which sometimes run with water (Askey-Doran et al., 1996). The riparian zone can also be seen as an interface between terrestrial and aquatic systems and is described as a series of transition area between two biomes or different patches of the landscape between these systems (Walker, 1993).

In recent times, uncoordinated developmental and agricultural activities which include increasing utilization of riparian vegetation for transportation corridors, food and shelter has been in existence for a long time (NRC, 2002) and has led to the degradation of riparian vegetation. Anthropogenic activities have continued to alter the vegetation in the riparian areas (Smith, 1989; Belskey et al., 1999) due to the various activities such as hydrologic and geomorphic activities (Poff et al., 1997; Clark et al., 1985, Schulz and Leininger, 1990), agriculture (Osborne & Kovacic, 1993; Kauffman & Krueger, 1984), urban recreation and industry (Zaimes, 2007) which often leads to loss of vegetation along riparian areas (Kageyama, 1994). Consequent upon this, the need arises to assess the level of degradation, monitor and create awareness about the possible catastrophic effects of depleting the riparian vegetation. To this end, Geographic Information System (GIS) and remote sensing techniques have been used by many authors in the study of environmental degradation (Aguda and Adegboyega, 2013; Schmidt & Udelhoven, 2012; Ndabula et al., 2011; Lennox et al., 2011). However, little or no attention has been focused on the spatio-temporal assessment of riparian degradation, particularly in a swift growing City of Osogbo.

In view of above, the study has attempted to assess the land use /land cover change, analyze the level of degradation of riparian vegetation in the study area and its environmental consequences, and develop riparian vegetation degradation index map.

1.2 STUDY AREA

Osogbo is the capital city of Osun State and lies within latitudes $04^{0}27'$N and 04^{0} 39'N, and longitudes 07^{0} 39'E and $05^{0}51'$E, (Figure 1).

Within Osogbo flows the River Osun which takes its source from Igede-Ekiti, Ekiti State with Erinle River and Oba River being its

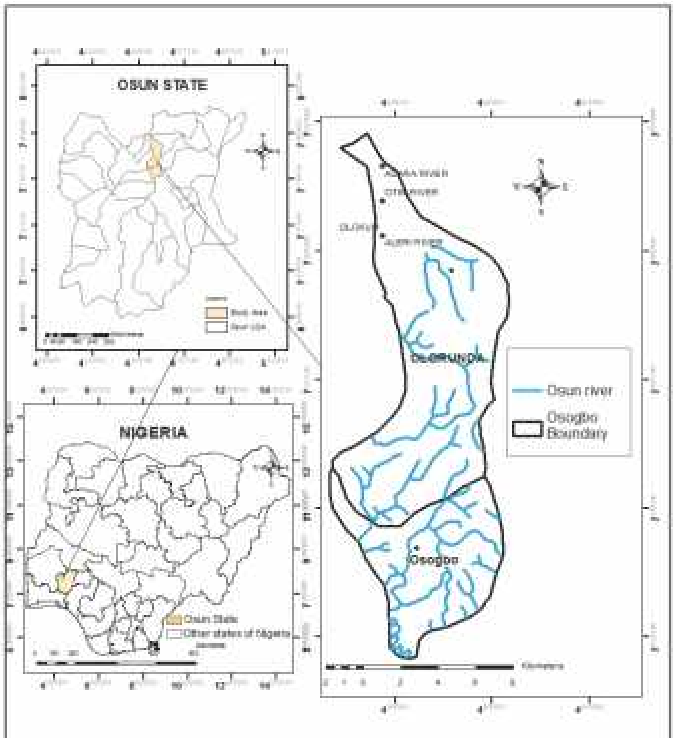


Figure 1: Location Map of the Study Area

tributaries. Its main source is at $08^{0}20'$N and $05^{0}16'$E

1.3 MATERIAL AND METHOD

1.3.1 DATA TYPES:

The study utilized both primary and secondary data. The primary data used include Geographic coordinates of some landmarks in Osogbo acquired using Garmin handheld GPS 76CSx with Universal Traverse Mercator Zone 31 (UTM Zone 31) as a Projection System. The secondary data used include Topographic map (1962) of Osogbo obtained from the cartographic section of the Osun State Ministry of Lands and Survey; Landsat TM 1986, ETM+ 2000), OLI 2015 and SRTM imagery from United States Geological Survey (USGS), and Administrative map of Osogbo (see Table 1).

Table 1: Description of Datasets

S/N	DATA	DATA FORMAT	SOURCES OF THE DATA	DESCRIPTION
1	GPS coordinates of landmarks in the study area	Numerical	Field Survey	The coordinates were used to locate the positions of landmarks
2	Topographic map (1962)	Digital Map	Osun State Ministry of Lands and Survey	The streams, rivers and lake in the Study Area were digitized from it.
3	Landsat TM (1986)	Digital Map	Digital web	Was used to determine the Land use/Land cover of Osogbo in 1986
4	Landsat ETM+ (2000)	Digital map	Digital web	Was used to determine the Land use/Land cover of Osogbo in 2000
5	Landsat 8 (2015)	Digital map	Digital web	Was used to determine the Land use/Land cover of Osogbo in 2015
6	Shapefile of the study area	Digital Map	RECTAS	To delineate the extent of the study area
7	SRTM	Digital Map	Digital web	The Digital Elevation Model was created from it.

Source: Author's Data Acquisition, 2016

DATA PROCESSING AND ANALYSIS

LAND USE/LAND COVER (LULC) CLASSIFICATION

The different LULC classes of the study area were grouped into six using Anderson et al. (1976) classification. The supervised classification was carried out using the Maximum Likelihood to identify different features and a composition of bands 3, 4 and 5 for Landsat TM and Landsat ETM+, and 4, 5 and 7 for Landsat 8. The spectral signature of each class was obtained from the images using Idrisi Selva by selecting Region of Interest (ROI) for each of the LULC category. The ROI helped in producing the map by defining areas in the map based on the training sites and the spectral homogeneity of the pixels of chosen area. The classification produced a good result after it was subjected to a confusion matrix. An overall accuracy of 72.92% and Kappa coefficient of 0.75 was obtained from the 1986 classes, 86.56% accuracy and Kappa coefficient of 0.80 for the 2000 classes and 86.02% overall accuracy, 0.81 Kappa coefficient for the 2015 classes (Table 2).

Table 2: Accuracy of Classification

Year	Kappa coefficient	Overall accuracy
1986	0.75	72.92%
2000	0.8013	86.56%
2015	0.8107	86.02%

POST CLASSIFICATION

The three independently classified images were then run for post classification comparison in order to produce a change detection analysis. By using the change detection statistical tool of the post classification, the matrix table of "from – to" change class was obtained.

ACCURACY ASSESSMENT

The accuracy assessment works by comparing classification with ROI or ground-truth data to evaluate how well the classification is representative of the real world. The Accuracy assessment of the classes was done using the confusion matrix technique. This was to be sure of a high level of accuracy in pixel selection and was shown in tables in square metres and percentages. Confusion matrix is given as:

ACC= TP+TN/(P+N) where TP = True positive, TN = True negative, P = Positive and N = Negative. User's accuracy (Pr) is given as Pr(Y = c / x = c), Producer Accuracy (Pr) is given as Pr(X = c / Y = c). Where X = estimator of particular land use, Y = random variable associated with the true unobserved land use and c is a class in the finite set of classes (Pontious and Millones, 2011)).

The Normalized Difference Vegetative Index (NDVI) was performed on all three images to examine the level of degradation of the riparian vegetation. Normalized Difference Vegetative Index is given as: (NDVI) = (NIR – R) / (NIR +

R), where NIR is Near Infrared, R is Red. Negative values simply refer to areas without healthy vegetation. For the Landsat TM 1986 and Landsat ETM+ 2000, bands 4 and 3 were inputed as NIR and R bands respectively. For Landsat 8, bands 5 and 4 were inputed as NIR and R bands respectively. The NDVI is a simple graphical indicator that is used to assess the healthiness of vegetation. Generally, (values approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1) (Earth observation.nasa.gov., 2014; Crippen, 1990).

From the classes created, the riparian vegetation was identified and digitized from each of the years using the polygon tool. The polygon shapefile created from the digitization was used to extract the riparian vegetation from the composite of each year.
The extracted feature was analyzed using the Normalized Difference Vegetative Index (NDVI) in Arcgis 10.2.

Band 4 (NIR band) and band 3 (Red band) were used in computing the NDVI for Landsat TM 1986 and Landsat ETM+ 2000 while Band 5 (NIR band) and band 4 (red band) were used to compute the NDVI for Landsat 8 2015.

A comparison was done between the mean values of the riparian vegetation from 1986 to 2000 and from 2000 to 2015. The level of degradation of the riparian vegetation was determined from the values obtained for the three years.

Delineation of Areas encroaching on the riparian buffer was carried out. The built-up areas encroaching on the riparian buffer were obtained by extraction. The rivers, streams and lakes were digitized from the base map and a buffer of 100 metres was carried out (Parkyn, 2004). The buffer then served as the extent of extraction for the built-up areas lying within it. The clip operation was performed and the built-up areas encroaching on the 100 metres buffer were obtained for years 1986, 2000, 2015 and a prediction of 2050.

To evolve the riparian vegetation degradation index map, a digital elevation model (DEM) was created from the SRTM image and the layers of the riparian vegetation for year 1986, 2000 and 2015 were overlaid on it. The elevation which the riparian vegetation laid was determined from the DEM. The river channels and layers of the riparian vegetation for the three years were overlaid from the earliest 1986 to the latest 2015 in order to observe the degradation of the riparian vegetation over the years.
The methodology adopted by the study was summarized and depicted by figure 2

RESULTS AND DISCUSSION

General Vegetation Condition of Osogbo City in 1986, 2000 and 2015

Table 3 showed NDVI result for the study area with 1986 recorded the highest mean of 0.25, -0.08 for year 2000 and 0.18 for year 2015. The actual minimum of the three years (1986, 2000, 2015) were -0.02, -0.33 and -0.02 respectively. The actual maximums were 0.46, 0.15 and 0.36 for the three years. The total numbers recorded were 298403, 158523 and 163250 for the years 1986, 2000 and 2015. It indicates that the vegetation has low green biomass in 1986 but

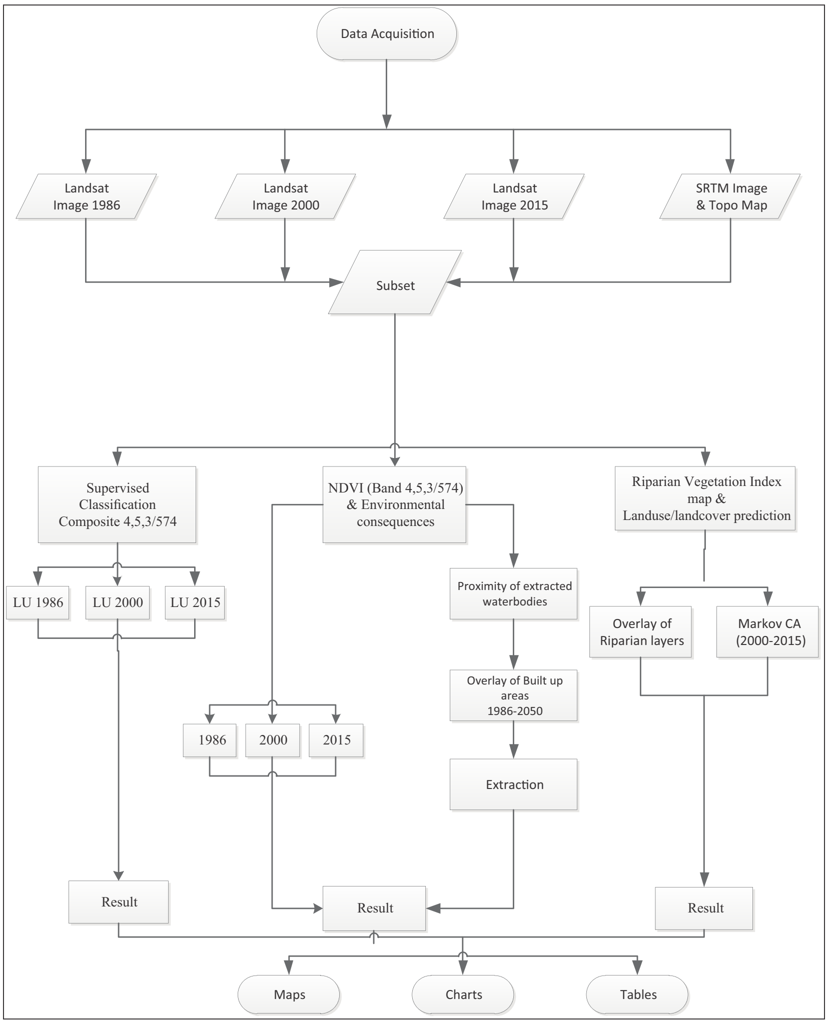


Figure 2: Work Flow Diagram

becomes lowest around Year 2000 and lower in 2015. Corroborating this, highest standard deviation of 0.08 was recorded in 1986, but gradually decreasing from 0.07 in 2000 to 0.05 in 2015, suggesting continuous loss of green biomass in the riparian zone induced by the anthropogenic activities in the study area. This is in agreement with findings of separate studies carried out by (Ezeomedo & Igbokwe, 2013; Fanan et al., 2011, Subedi et al., 2013) all found an increase in built-up and a decline in vegetation mostly due to the anthropogenic activities of the urban dwellers in order to meet their basic needs. Figures 3, 4 and 5 further shed more light on the vegetaion condition of the study area in 1986, 2000 and 2015 which was described as a high vegetation health. The greener parts of the figure showed high vegetation health while lighter green parts reflected a low vegetion health or no vegetation at all. Most of the dense and riparian vegetation appeared greener than the built-up area and water body appeared brighter.

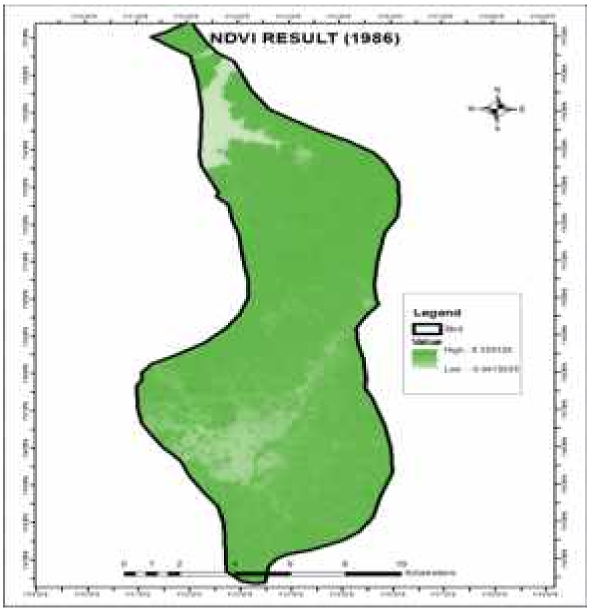
Table 3: NDVI Values for the Study Period.

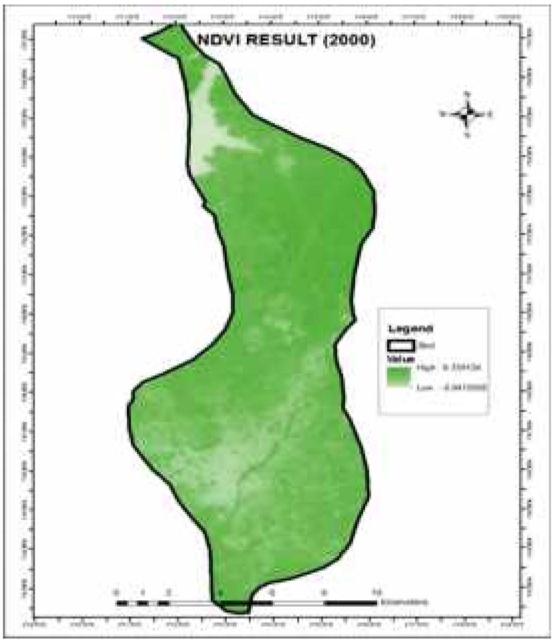
State of Riparian Vegetation in the Study area in 1986, 2000 and 2015

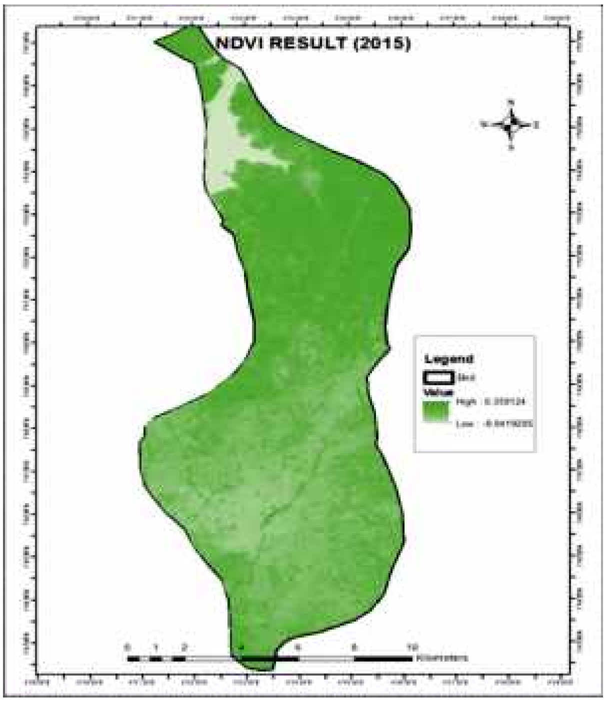
Table 4 specifically showed the NDVI values of the riparian vegetation in the study area. The NDVI results showed dwindling mean values of

	1986	2000	2015
Mean	0.25	-0.08	0.18
Actual minimum	-0.02	-0.33	-0.02
Actual maximum	0.46	0.15	0.36
Total number	298403	158523	163250
Standard deviation	0.08	0.07	0.05

Source: Author's Image Analysis, 2016



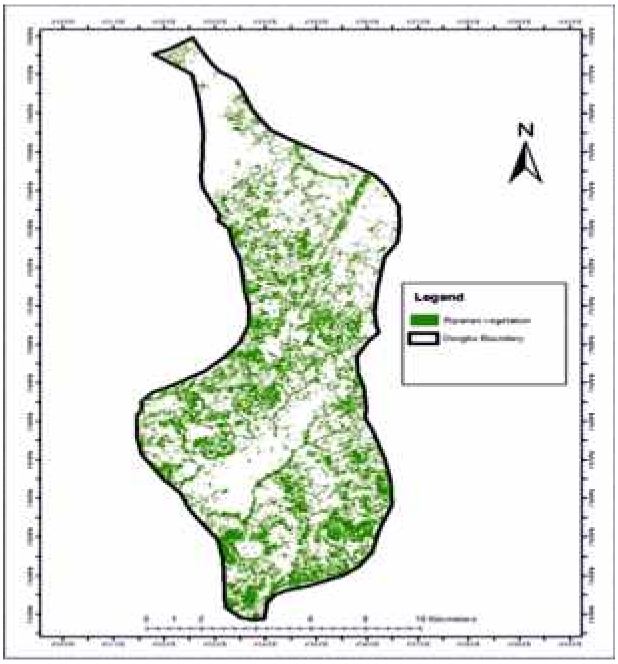


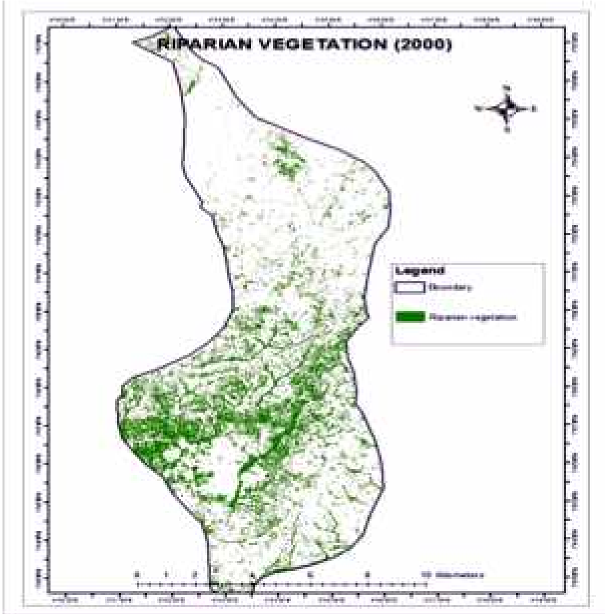


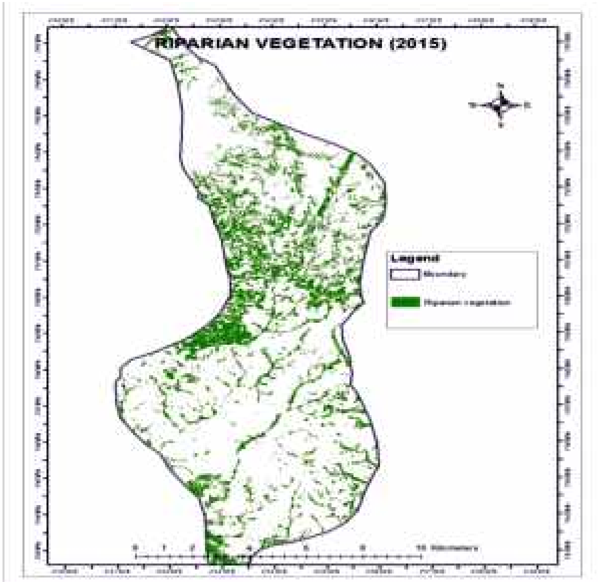
Figures 3, 4 & 5: NDVI results for year 1986, 2000 & 2015

0.20, -0.05 and 0.17 in 1986, 2000 and 2015 respectively. The actual minimum of the three years (1986, 2000, 2015) were 0.096, -0.39 and 0.04 respectively. The actual maximums were 0.47, 0.146 and 0.36 for the three years. The total numbers of counts recorded were 163709, 163619 and 147470 for the years 1986, 2000 and 2015. It suggests that though the mean value is at highest in 1986 but the green biomass is still low, lowest in 2000 and lower in 2015 (figures 6, 7 & 8). The results of standard deviation lend credence to the reduction in riparian vegetation with 0.19 in 1986, 0.12 in 2000 and 0.07 in 2015. Apparently, the highest NDVI mean value of the riparian vegetation in 1986 was accounted for by low urban influence around the riparian zones. The pattern of land use/land cover change corroborated this position as figure 9 showed the predominance of riparian vegetation over other land use/land cover categories. It occupied an area of of 51.4km2, equivalence of 37% of the total land cover of the study area, the forest was next with 43.22 km2 (31%), Sparse vegetation was 18.63 km2 (13%), built-up was 12.37 km2 (9%), bare ground was 8.54 km2 (6%) while water body occupied the least area with 6.23 km2 which was 4% of the total land cover area. In essence, there was no substantial development in the study area in 1986, which predated the emergence of Osogbo as the capital of Osun State in 1991. Development was mainly concentrated within Osogbo Local government Area (LGA), particularly around Kajola, Obalende, Egbetedo. The Osun groove was a major attraction of development in the area as a religious centre that attracted mainly indigenes to the area. There was luxuriant vegetation cover in Osogbo LGA much more than in Olorunda LGA in 1986 due to lower development as built-up and bare ground occupied smaller areas as shown in Figure 10.

Figure 11 depicted this situation in the year 2000 with brighter green colour spreading from the built-up areas to other land uses. The riparian vegetation had suffered degradation by loosing its green biomass to the increasing human activities due to the centrifugal forces of the







Figures 6, 7 & 8: Riparian vegetation maps of Osogbo in 1986, 2000 & 2015

Table 4: NDVI Values for Riparian Vegetation of the Study Area.

	1986	2000	2015
Mean	0.20	-0.05	0.17
Actual minimum	0.096	-0.39f	0.04
Actual maximum	0.47	0.146	0.36
Total number	163709	163619	147470
Standard deviation	0.19	0.12	0.07

Source: Author's Image Analysis, 2016

Figure 9: Land use/land cover classification of Osogbo in 1986

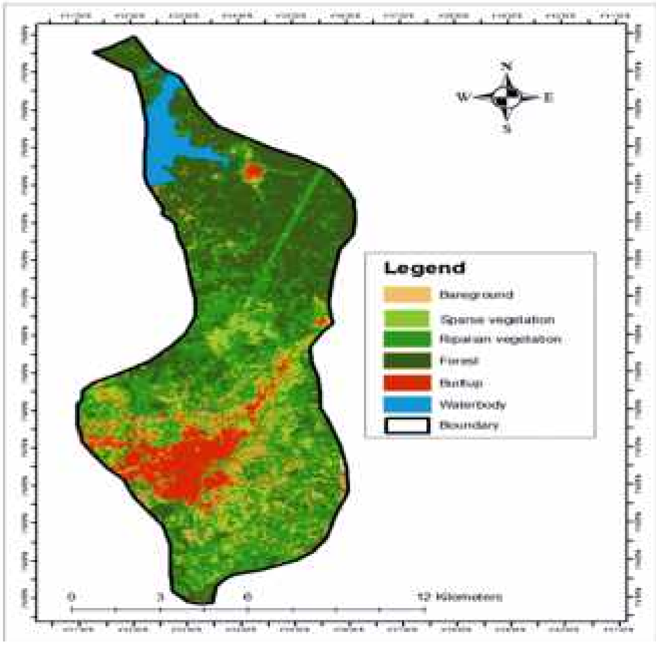


Figure 10: Classified Map of Osogbo in 1986

administrative status of the city. Thus, the riparian vegetaion had declined when compared to that of 1986 as shown in Figure 10. This might be attributed to a swift change in the pattern of land use/land cover change that was connected to increased development in Osogbo, consequent upon the creation of the Osun State in 1991 and emergence of Osogbo as its administrative centre. Conversion of vegetation to bare ground and built-up increased in areal extent more than in 1986. There was a significant increase in sparse vegetation. Development spread further into places like Ayetoro, Testing ground, Olonkoro and Igbona, which are places in Olorunda LGA. The increasing urban expansion was observed to have triggered the dwindling areal extent of the riparian vegetation as reflected in figures 12 and 13. Moreover, the result of change detection analysis as depicted in Tables 5 and 6 revealed a momentous negative change in riparian vegetation. Specifically, there was a decline of 49.03km2 (36.81%) in riparian vegetation between 1986 and 2000. The riparian vegetation was receding at 2.63% per annum over fourteen years. Also, a diminution of 37.36km2 (28.68%) in riparian vegetation between 2000 and 2015, at the rate of 1.9% per annum was observed. This agrees with Swift (1984) who reports in a study that the more the increase in development around riparian area, the more the land use change from natural vegetation to other uses and has often caused the degradation of riparian vegetation. It also aligns with Zaimes (2009) who affirms the complete removal or significant decrease in riparian vegetation in urban settlements which was attributed to activities such as logging, clearing, paving etc. Reduction in average values of NDVI from year to year has been observed to be low as a proof of degradation by (Svejcar, 1997). As the years went by, the researcher observed lower NDVI values which served as a proof of continuous degradation in the study.

By 2015, only thin stripes of vegetation that followed a linear pattern was left in Osogbo LGA and some parts of Olorunda LGA which has most of its land unexploited. The supporting vegetation had been removed in order to execute more development. This is evident in the emerging pattern of land use/land cover change as figure 14 revealed the predominance of built-

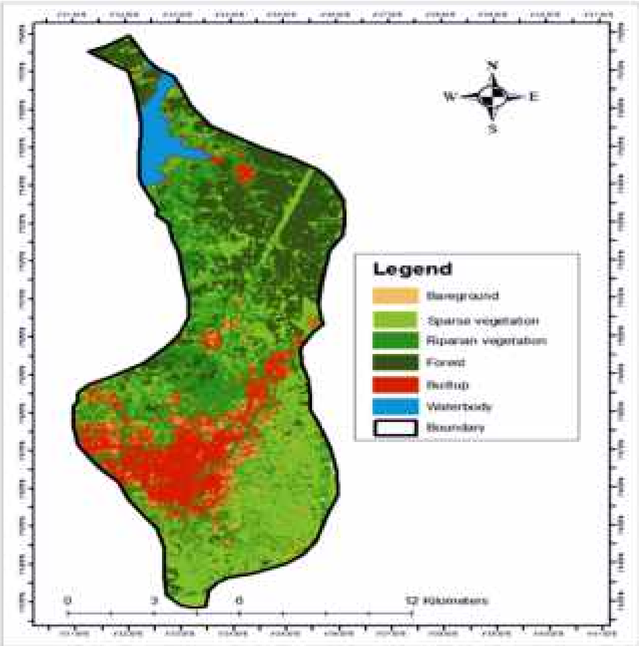


Figure 11 : Landcover map of Osogbo in 2000

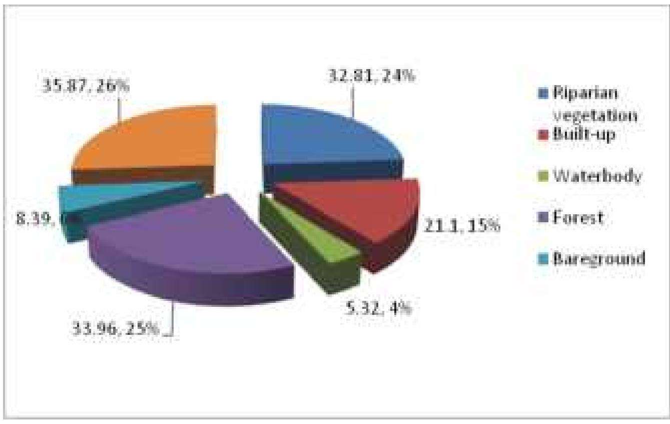


Figure 12: Land cover classification of Osogbo in 2000

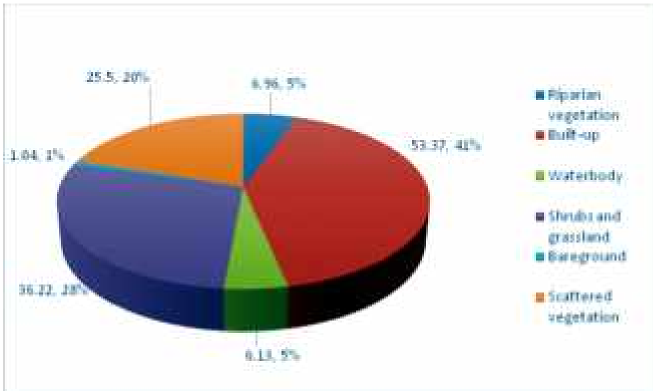


Figure 13: Land cover classification of 2015

Table 5: Change detected between 1986 and 2000

Classes	Change (km²)	Change (%)	Rate of Change per annum	
			Km²	%
Water body	-37.06	-27.83	2.65	-1.99
Built-up	+29.72	+22.32	2.12	+1.59
Bare ground	+15.49	+11.63	1.11	+0.83
Riparian vegetation	-49.03	-36.81	3.50	-2.63
Scattered vegetation	-0.54	-0.41	0.04	-0.03
Shrubs and grassland	+1.34	+1.00	+0.10	+0.07

Source: Author's Image Analysis, 2016

NB: Positive (+) Sign indicates increase in a particular LULC type,
Negative (-) Sign indicates decrease in a particular LULC type

Table 6: Change detected between 2000 and 2015

Classes	Change (km²)	Change (%)	Rate of Change per annum	
			Km²	%
Water body	-26.56	-20.39	- 1.77	- 1.36
Built-up	+26.05	+20	+1.74	+1.33
Bare ground	+4.07	+3.12	+0.27	+0.21
Riparian vegetation	-37.36	-28.68	-2.49	- 1.91
Scattered vegetation	-7.55	-5.80	-0.50	-0.39
Shrubs and grassland	+28.67	+22	+1.91	+1.47

Source: Author's Image Analysis, 2016

NB: Postive (+) Sign indicates increase in a particular LULC type,
Negative (-) Sign indicates decrease in a particular LULC type

up over other land use/land cover types in 2015 with serious adverse effect on the riparian vegetation. A tremendous increase in urban development over the study period was observed in Osogbo City. By 2015, most of the land in Osogbo LGA had been converted to man-made structures due to the urban expansion and in-fill development. The City had expanded beyond Ota-efun and Steel rolling mill, towards the shrubs and grassland thereby causing more degradation in the area. Most of the bare ground had been converted to built-up as evident in figure 14. A large reduction in riparian vegetation occurred in 2015 due to competitive demand for urban space to meet the housing needs of the growing population of the city. Similar finding was reported by Orimoogunje et al (2009) that the most significant contributors to wetlands degradation in Ilesa was the use of wetlands for settlement and agriculture which have ecological and socio-economic consequences on the functioning of the wetlands.

Riparian vegetation degradation index map for the Study Area

The trend of decline of riparian vegetation between 1986 and 2015 was shown in Figure 15. Much of the riparian vegetation existed in 1986, swiftly declined and degraded by 2000 in Osogbo LGA, which was rapidly developing at that time. By 2015, the riparian vegetation could

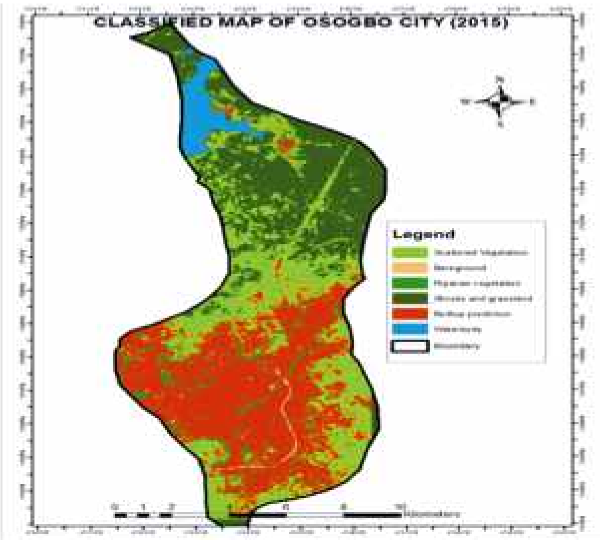
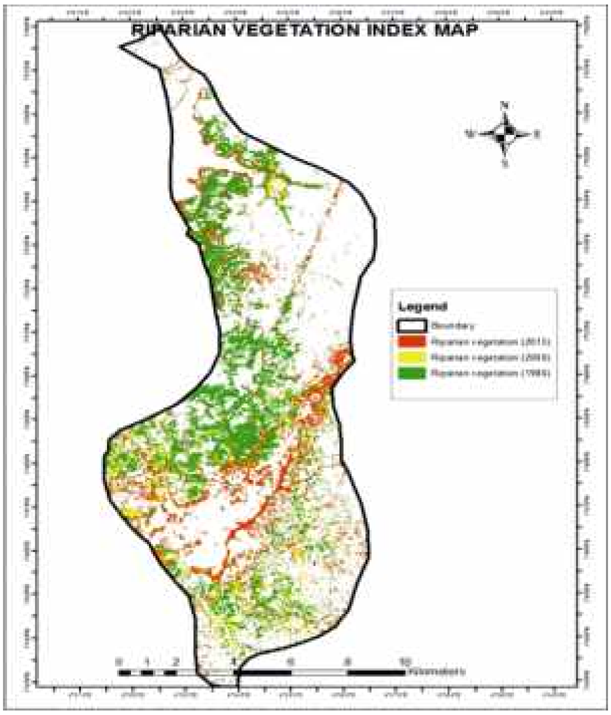
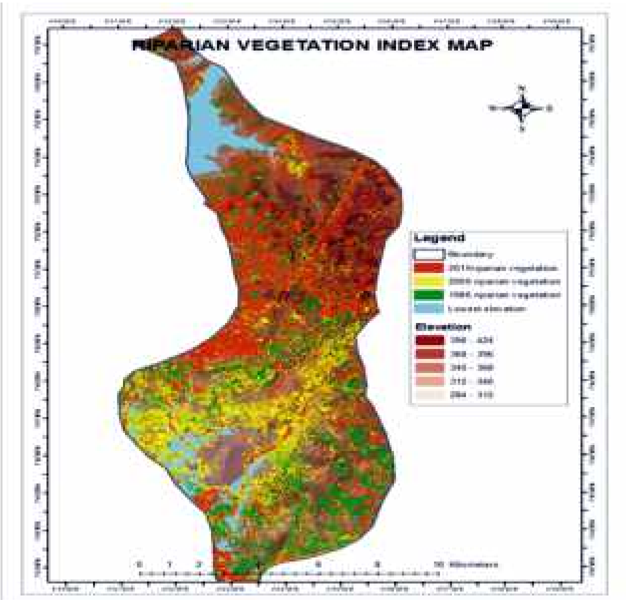


Figure 14: Classified Image of Osogbo in 2015

visibly observe to have drastically reduced when compared to that of year 2000. The riparian vegetation was observed to exist in both high and low elevations from the Triangulated irregular network (TIN) created for the three years studied. The TIN showed the movement of water from higher elevations to lower elevations. The removal of riparian vegetation allows for the weakening of the river banks thereby making areas with lower elevations vulnerable to flood (Figure 16). Smith (2013) observed that the removal of riparian vegetation could pave way for erosion and places with high level of degraded riparian vegetation had little resistance for erosion and flood. Further attempt was made to scrutinize the possible future scenario as figure 17 showed the predicted situation consequent upon uncontrolled removal of riparian vegetation in the study area by 2050. It indicates that riparian vegetation would have almost been depleted to the extent that water bodies would have less vegetation to support their banks thereby making the banks weak and subject more developed areas vulnerable to floods. From the TIN created, it was observed that the area most vulnerable to flood was in Osogbo Local Government Area. The area has the least elevation and is occupied by river, vegetation and built-up. About 6.8 km2 of the built up area was at risk of flood as shown in figure 18

Figures 20, 21, 22 and 23 showed the river channels within Osogbo and the riparian vegetation from 1986 to a predicted 2050. From the results, the riparian vegetation of 1986 seemed to be more abundant unlike that of year 2000. The places mostly without vegetation were places that had already experienced development. These places existed within and around Ataoja area of the study area. As development continued to spread out of those areas, the riparian vegetation began to reduce drastically as seen in figure 26. The vegetation around the rivers and streams were cleared and more development continued to take place. The supporting vegetation that made the riparian





Figures 15 & 16 : Riparian Vegetation Index Maps

Figure 17: Land cover classification of 2050

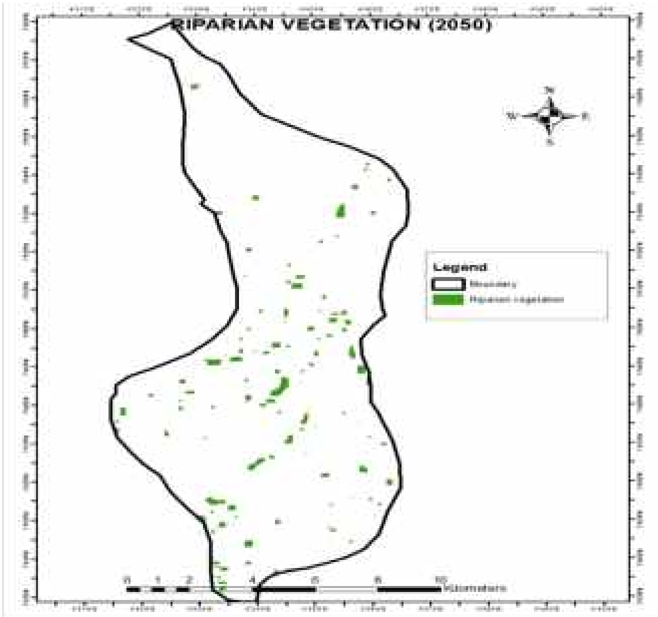


Figure 18: Predicted Riparian Vegetation for 2050

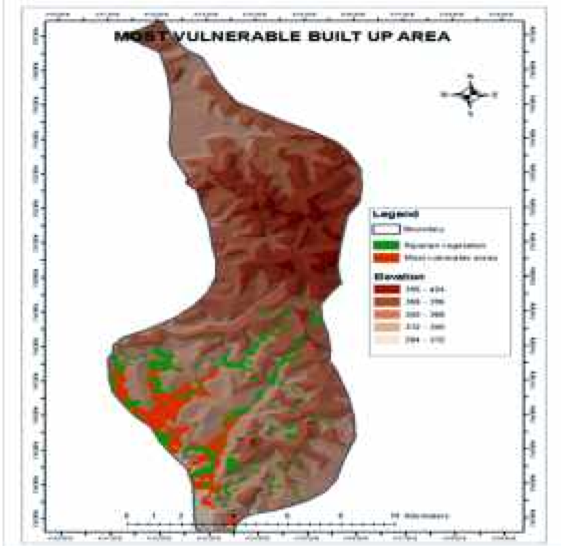
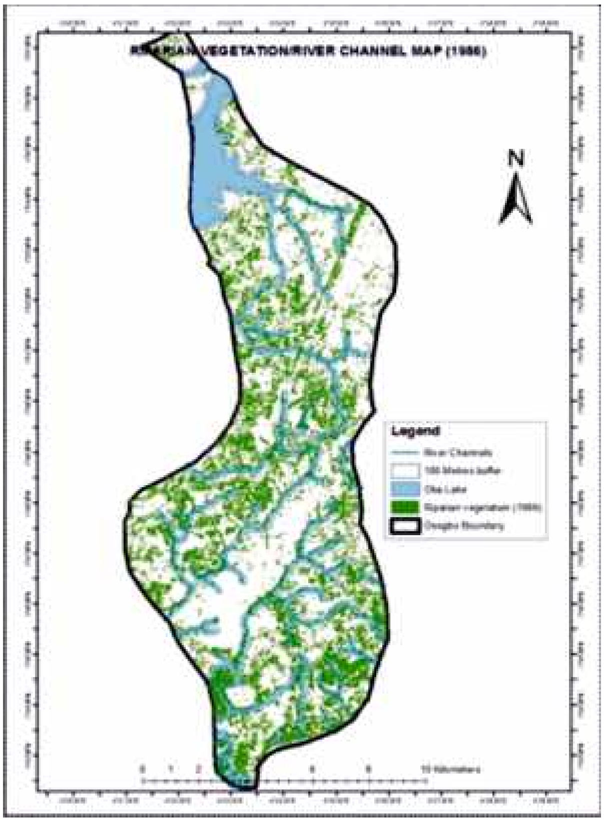


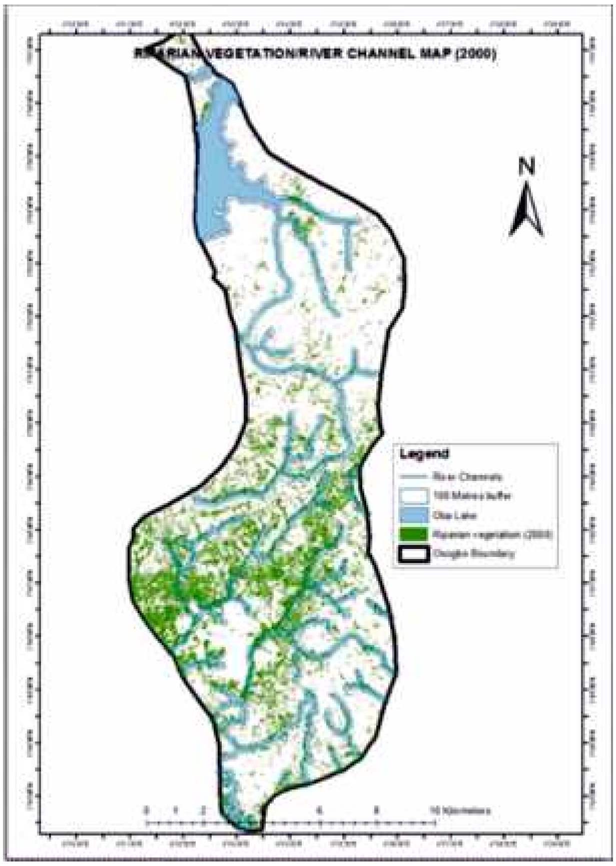
Figure 19: Areas most vulnerable to flood

vegetation more functional continued to be degraded. One of the implications of this is that the ecosystems were being destroyed and this is bad for the environment. By 2015, only a strip remained along the waterbodies in the developed areas,

The study observes a worse condition for the riparian vegetation in the study area by 2050. According to the results obtained from the analysis carried out, most of the narrow strips of riparian vegetation observed along the river channels for previous years have strong tendency to be removed for more infill development. The prediction of land use/land cover change appears to be similar in urban centres. Marwa et al. (2013) predicted an increased built-up and reduction in other land use classes especially riparian vegetation. Also, Sudhir et al. (2015) predicted an increase in built-up and a reduction in riparian vegetation.

As the urban expansion progresses, a case of congestion is predicted in the study area by 2050 and as people strive to meet their housing needs, rules guiding the encroachment of riparian zone may be further ignored. Land reclamation is expected along the river banks with the expectation to be safe because of the lower elevation of rivers. Given these scenarios, it may lead to low infiltration of water due to expected paved surfaces. Weaker banks are also expected because of the thin vegetation along the water bodies. This will finally reach a stage where the waters will move out of their original channels into the city thereby leading to uncontrolled flooding. The degradation of the riparian vegetation has grave consequences which may occur over a long period of time as humans continue to degrade it through their day to day activities. The consequences may be very



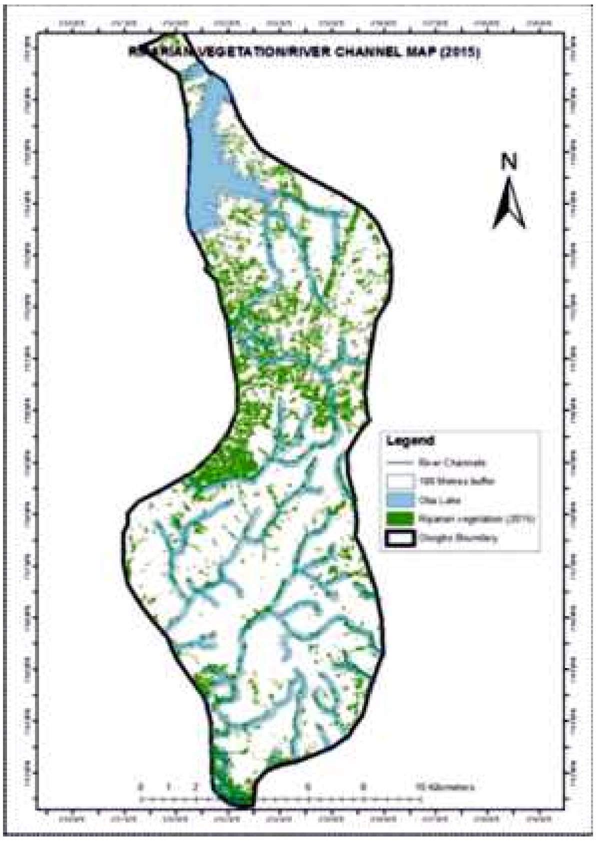


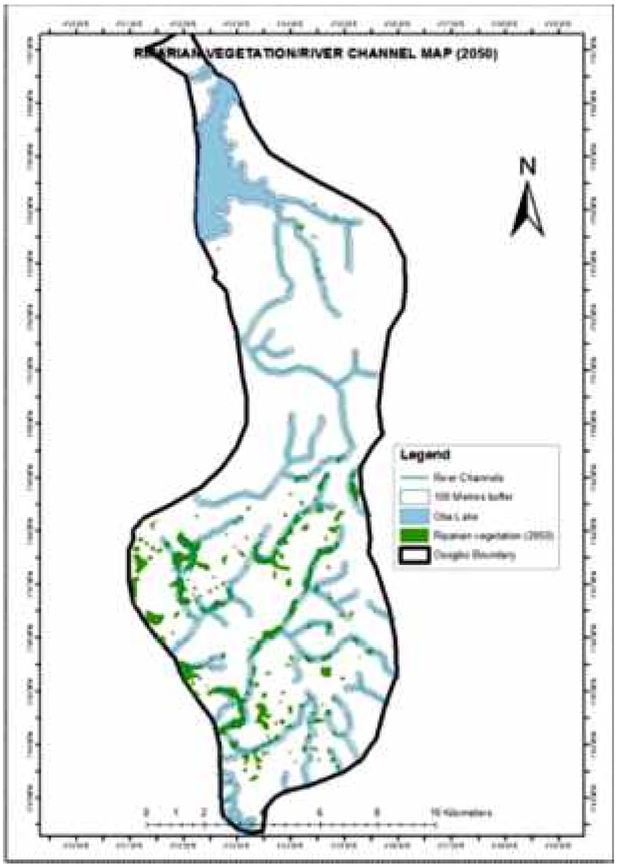
Figures 20 and Figure 21: The river channels and the riparian vegetation for 1986 and year 2000 respectively.

devastating when they finally appear.

CONCLUSION

The study observes continuous loss of green biomass in the riparian zone induced by the anthropogenic activities in the study area within the study period. The increasing urban expansion was observed to have triggered the dwindling areal extent of the riparian vegetation as a decline of 49.03km2 (36.81%) in riparian vegetation between 1986 and 2000 was observed. The riparian vegetation was receding at 2.63% per annum over fourteen years. Also, a diminution of 37.36km2 (28.68%) in riparian vegetation between 2000 and 2015, at the rate of 1.9% per annum was observed. The emerging pattern of land use/land cover change revealed





Figures 22 and 23: River channels and riparian vegetation Maps for 2015 and year 2050 respectively.

the predominance of built-up over other land use/land cover types in 2015 due to competitive demand for urban space to meet the housing needs of the growing population of the city, with serious adverse effect on the riparian vegetation. The study observes a worse condition for the riparian vegetation in the study area by 2050 as most of the narrow strips of riparian vegetation observed along the river channels for previous years have strong tendency to be removed for more infill developments. This will finally reach a stage where the waters will move out of their original channels into the city thereby leading to uncontrolled flooding. The degradation of the riparian vegetation has grave consequences which may occur over a long period of time as humans continue to degrade it through their day to day activities. The consequences may be very devastating when they finally appear. The study advocates conscious implementation of land use zoning policy to conserve the fragile riparian vegetation and curtail the vulnerability of the city to flash floods.

ACKNOWLEDGEMENTS

I profoundly appreciate my distinguished colleagues in the Department of Remote Sensing and GIS, FUTA, for their immense contributions to the successful completion of this research work. Also, I sincerely recognize the contributions of my students; Ademola Adesina, Adebayo Quadri and Odo Moses for the research assistance rendered in the course of executing this research.

REFERENCES

Aguda, A.S and Adegboyega, S.A. (2013), Evaluation of Spatio-Temporal Dynamics of Urban Sprawl in Osogbo, Nigeria using Satellite Imagery & GIS Techniques. International Journal of Multidisciplinary and Current Research, July-August Issue, pp 66-95.

Anderson, J., Hardy,E., Roach, J. and Witmer, R. (1976), A landuse and landcover classification system for use with remote sensor data. Geological survey professional paper 964.United State government Printing Office, Washington. Vol 37, Pp 57-72

Askey-doran, M., Bunn, S., Hairsine, P., Price, P., Prosser, I.and Rutherford, I. (1996), Riparian Management Fact Sheet 1. Managing Riparian Lands. Land & Water Resources Research & Development Corporation.

Belsky, A.J., Matzke, A. and Uselman, S. (1999), Survey of livestock influences on stream and riparian ecosystems in the Western United States. Journal of Soil and Water Conservation 54:419-431.

Clark, E., Haverkamp, J. and Chapman, W. (1985), Eroding soils: the off-farm impacts. The Conservation Foundation, Washington, D.C. 252 pages.

Crippen, R. (1990), Calculating the vegetation index faster. Remote Sensing of Environment, 34, 71-73.

Ezeomedo, I. and Igbokwe, J. (2013), Mapping and analysis of landuse and landcover for a sustainable development using high resolution satellite images and GIS. Environment sustainability. May 6-10, Abuja

Fanan, U., Dlama, K. and Oluseyi, I. (2011), Urban expansion and vegetal cover loss in and around Nigeria's Federal Capital City. Journal of ecology and natural environment. Vol 3(1). pp. 1-10.

Kageyama, Y. (1994), Revegetação de áreas degradadas: modelos de consorciação com alta diversidade. In: simpósio sul-americano, 1; simpósio nacional sobre recuperação de áreas degradadas, 2., 1994

Kauffman, J. and Krueger, W. (1984), Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management .37: pp 430-438.

Lennox, M., Lewis, D., Jackson, R., Harper, J., Larson, S. and Tates, K. (2011), Development of Vegetation and Aquatic Habitat in Restored Riparian Sites of California's North Coast Rangelands. Journal for society and for ecological restoration. Restoration Ecology. Vol. 19, No. 2, pp. 225–233

Ndabula, C., Averik, P., Jidauna, G., Abaje, I., Oyatayo, T. and Iguisi, E. (2011), Analysis of the Spatio-Temporal Dynamics of Landuse/ Landcover Stuctures in the Kaduna Innercore City Region, Nigeria.

NRC. (2002), Riparian areas: functions and strategies for management. National Academy Press. Washington, DC.

Orimoogunje, O., Oyinloye, R., Soumah, M. 2009. Geospatial mapping of wetlands potential in Ilesa, southwestern Nigeria. FIG Working Week: Surveyors key role in accelerated development Eilat, Israel.

Osborne, L. and Kovacic, D. (1993), Riparian vegetated buffer strips in water quality restoration and stream management. Freshwater Biology. pp 29:243-258.

Parkyn, S. (2004), Review of riparian buffer zone effectiveness. MAF technical paper No. 2004/05. Ministry of Agriculture and Forestry, Wellington.

Parson, A. (1991), The Conservation & Ecology of Riparian Tree Communities In the Murray Darling Basin, NSW A Review. NSW NPWS Hurstville.

Poff, N., Allan, J., Bain, M., Karr, J., Prestegaard, K., Ritchter, B., Sparks, R. and Stromberg, J. (1997), The Natural Flow Regime. A paradigm for river conservation and restoration. Bioscience,47,769-784

Pontious, R. and Millones, M. (2011), Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. Journal of remote sensing. Vol. 32. pp. 4407-4429.

Schmidt, M. and Udelhoven, T. (2012), Analysing and quantifying vegetation responses to rainfall with high resolution spatio-temporal time series data for different ecosystems and ecotones in Queensland. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Volume XXXIX-B8, 2012

Schulz, T. T., and W. C. Leininger. (1990), Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43:295–299.

Smith, J. J. (1989), Recovery of riparian vegetation on an intermittent stream following removal of cattle. Pp. 217-221 in Proceedings of the California riparian systems conference: Protection, management, and restoration for the 1990's. D. L. Abell (tech coord.), Davis, CA. Sept 22-24, 1988. USDA For. Sew. Gen Tech Rep. PSW 110. Berkeley, CA.

Subedi, P., Subedi, K. and Thapa, B. (2013). Application of hybrid cellular automaton Markov (CA-Markov) model in land-use change prediction: a case study of saddle creek drainage basin, Florida. Appl. Ecol. Environmental Sci. pp 126-132. In urban sprawl modelling using cellular automata.

Smith, J.D. (2013), The role of riparian shrubs in preventingfloodplain unraveling along the Clark Fork of the Columbia river in the Deer Lodge Valley, Montana. In: Bennett, S.J and Simon, A. (Eds.) Riparian Vegetation and Fluvial Geomorphology.The American Geophysical Union Book Series.

Svejcar, T. (1997), Riparian zones : 1) what are they and how do they work. Rangelands. Vol 19(4). pp. 4-7. In Riparian Ecosystems of North Dakota.

Swift, B. 1984. Status of riparian ecosystems in the United States. Water Resources Bulletin 20:223-228.

Walker, K. (1993), Issues in the Riparian Ecology of Large Rivers. In Proceedings of the 1993 workshop. Ecology &

Management of Riparian Zones. Marcoola QLD. Bunn, S., Pusey, J., Price, P, (eds) LWRRDC.

Zaimes, G. (2007), Human alteration to riparian areas. In: Zaimes G. (editor), Understanding Arizona's Riparian Areas. University of Arizona Cooperative Extension, Publication # AZ1432. pp. 83-109.

Zaimes, G. (2009), Human alterations to riparian areas. Chapter 7 pp84-110 https://cals.arizona.edu/extension/riparian/pub/UARA_07-17-07_chapter7.pdf

Earthobservation.nasa.gov.,(2014) Http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php 2014 accessed April 2016.