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GEOSPATIAL ANALYSIS OF LAND USE AND LAND COVER DYNAMICS IN AKURE, NIGERIA

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Abstract

This study uses remote sensing and GIS techniques to provide effective way of analysing the Landuse and Landcover dynamics of Akure North and South Local Government Area in order to assess the rate of urban expansion and loss of vegetation in two local government areas. The use of multi-temporal and multi-source satellite imageries of Landsat data for 1991, 2002 and 2016 were used for the study. Supervised digital image classification method using IDRISI 17.0 server edition software and five landuse and landcover types were detected and captured as polygon. The results obtained shows that the built-up land and agricultural land have increased by 151.52km² (71.57%) and 400.81km² (44.89%), while forest land, bare rock and water body are reduced by (-20.59%), (-1.20%) and (-19%) between 1991 and 2016. It was concluded that substantial land use/land cover (LULC) changes have taken place and the built-up land and agricultural land have continued to expand over the study period; while the forest land, bare rock and water body have decreased. It was noted that the development of the urban built-up areas has resulted into reduction of the land under agriculture and other natural vegetation. It was recommended that monitoring of LULC through remote sensing and GIS should be institutionalized at local and state levels in order to provide co-ordination in environmental monitoring at all levels.

Keywords: Forest land, Water body, Bare rock, Land use, Environment, Land cover

Introduction

Land cover refers to the vegetation (natural and planted), water, bare rock, sand and similar surface and also man-made construction that occur on the earth surface, while land use refers to a series of operations on land, carried out by humans with the intension to obtain products and /or benefit through using land resources including soil resources and vegetation resources which is part of land cover (Debie, Leeuwen&Zuidema1996). With this, perspective change is defined as an alteration in the surface component of the landscape and is only considered to occur if the surface has a different appearance when viewed on at least two successive occasions (Lemlem, 2007).

The natural environment particularly in Nigeria is gradually going into extinction at a rapid rate due to increasing population which is accompanied by demand for resources. The need for more habitats, places to live and protect ourselves from the various factors of environment has led to the destruction of natural resources. Due to serious anthropogenic activities, the earth surface is being significantly altered in several ways. Forest and vegetation covers are getting depleted day by day at a greater rate. Thus we can recognize a defined change pattern of land of a particular area with time and can define the rate of change, direction of change and growth rate along with many more factors (Mengistu& Salami, 2007).

Adebayejo and Abolade (2006) used satellite imageries of 1978 and 1995 and updated topographical maps of 2003 to study urban expansion of Ogbomoso town in Oyo State. Oyinloye (2010) studied the spatial growth of Akure, Ondo State using the satellite imageries of 1972, 1986 and 2002. The results for both cities showed that there has been a rapid conversion of agricultural areas to urban (non-agricultural) land uses. Urban expansions of these cities have destroyed fertile agricultural lands which cannot be recovered, but the residential land use continues to spread to and beyond the hitherto distant location relative to the city core.

The growing population and increasing socio-economic necessities create a pressure on land use/land cover. This pressure results in unplanned and uncontrolled changes in land use/land cover (Seto, Fragkias, Guneralp&Reily, 2011).The land use / land cover (LULC) alterations are generally caused by mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems such as landslides, floods etc.
According to Igbokwe, (2010) land use information should form part of the environmental data which are kept in the form of inventories/infrastructures in many advanced and emerging economics. Most landuse change factors such as water flooding, air pollution,

urban sprawl, soil erosion and deforestation occur without clear and logical planning which results in serious environmental degradation with notable consequences globally.

Similarly, Lambin&Ehrlish (1977) study on landcover changes in sub-Sahara Africa analyzed ten years of daily continental scale satellite remote sensing data from the National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (AVHRR). Deviation from the seasonal trajectory of the land surface characterized by its brightness temperature and vegetative index were interpreted in terms of land cover change on a yearly basis from 1982-1991.
The objective of this study is to assess the trend of change between land use / land cover (LULC) categories using GIS and Remote sensing techniques for Akure, Nigeria between 1991 and 2016 for which satellite data coverage was available for the area.

Materials and Method

Study Area

This study was carried out in Akure Metropolis covering two local government areas (LGAs) in Ondo State namely: Akure North and Akure South as shown in figure 1 below. These two LGAs make the most part of the popular ancient city.The metropolis lies between latitude 7° 07′ and 7° 37′ North of the equator and longitude 5° 06′ and 5° 38′ East of the Greenwich Meridian. It covers an approximate area of 991square kilometres. Akure metropolis enjoys tropical climate with two distinct seasons, the rainy season (April-October) and the dry season (November-March) (NPC, 2006). Temperature ranges between 22^{o}C and 30^{o}C coupled with high humidity. The south-westerly winds and the north east trade winds blow in the rainy and dry seasons respectively. This zone is characterizedby fertile agricultural lands, the major cash crop is cocoa, which provides about 90% of the annual revenue of Ondo state. Timber is another important source of wealth of the rainforest belt which includes Iroko, Mahogany, Obeche, Dantaand Opepe. These trees usually big in width sometimes up to 15 to 20 metres high and provide the basis for the prosperous lumbering and wood processing industries found all over the state. Akure is about 350metres above the sea level and is dominated by chains of rugged hills and rock formations with some low-lying flood plains in-between. The topography is gently undulating, consisting of gravel, lateritic soil, alluvial soil, clay and top-soil and low lying outcrops at the lowland area (NPC, 2006).

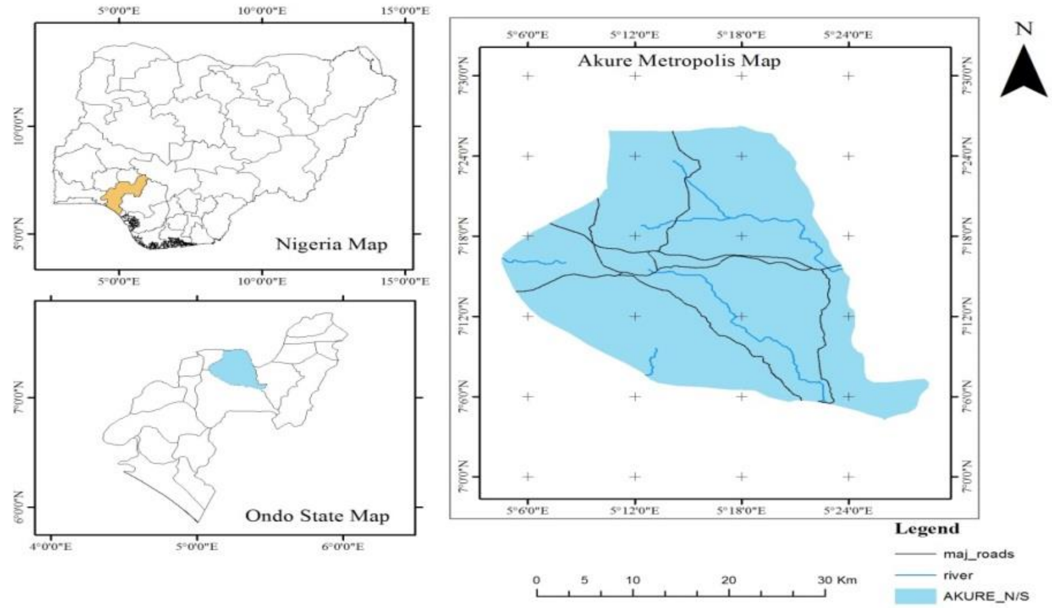

Figure 1: Map of Ondo state Showing Akure North and South L.G.A.
Source: Modified and Adapted from Ondo state Ministry of Lands and Planning

Methods

Data Acquisition

Both primary and secondary data with spatial and non-spatial attributes were utilized. Those data include: Landsat images of 1991, 2002 and 2016 comprising of different bands including band 4- 3-2 and band 5- 4-3. The topographic map of Akure at scale 1:50000 was also used for the study. The images were enhanced, geo-referenced, classified and digitized. A supervised classification was performed on colour composites of band 2-3-4 and 3-4-5 the following landuse and landcover classes are identified; built-up land, forest land, bare rock, and agricultural land. The spatial resolution of TM, ETM^+ and OLI images are 30m for band under consideration. The pre-processing procedures to correct for geometric and radiometric errors as well as calibration of the images to percent reflectance were carried out. The selected images were geo-referenced in decimal degree coordinate system and rectified to correspond to the WGS1984 and UTM Zone 31N Coordinate System.The degree of change for different year interval (1991-2002, 2002-2016 and 1991-2016) was calculated by subtracting the area of each land use/land cover type of recent year from the former i.e. 2002-1991. The percentage of change was calculated by dividing the degree of change of each land use/land cover category by the value of the base year, then multiplying the result by 100. Annual frequency of change was obtained by dividing the degree of change of each land use/land cover category by the number of years between the periods under consideration.

Table 1: Characteristics of data

S/N	Data Type	Source	Year	Resolution/ Scale	Purpose
1	Landsat TM	www.glovis.usgs.gov	1991	30m	Landuse/Land cover characteristics
2	Landsat ETM+	www.glovis.usgs.gov	2002	30m	Landuse/Land cover characteristics
3	Landsat 8 OLI	www.earthexplorer.usgs.gov	2016	30m	Landuse/Land cover characteristics
4	Google Earth	www.googleearth.com	2016	1m	Visual interpretation and validation
5	Topographic map	www.Gadm .com	2016	1:50000	Extraction of study area map

Software Requirement and Data Processing

Different types of software were used for this research, which include: IDRISI 17.0, Selva Edition, ArcGis Version 10.3, Microsoft Office note. The image processing procedures used for the study includes delineation of the study area, image pre-processing, and the design of classification, image classification, analysis of the land use/land cover dynamics as well as the comparison of the changes between different years under consideration.

Satellite Data Processing

Knowledge of both Remote Sensing and Geographical Information Systems (GIS) was used to generate the land cover maps of the period in consideration (1991 – 2016) and to calculate the area in square kilometers of each land use type for each year in order to determine the change and percentage of change in the total area covered by that land use type. The first step taken during the course of this work, involved the extraction of the Area of Interest (AOI) in the study area. This was imperative granted that the images which were acquired covered Akure-North and Akure-South LGA (the study area). The geographical coordinates of the study area were extracted from the vectorised map of the same. The coordinate was input in IDRISI environment using image windowing in the window toolbox. The output of this operation was an extract of the study area of the three image bands.

Colour composite creation was carried out using the false colour composite of band 4-3-2 for landsat image 1991 and 2002 while false colour composite of band 5-4-3 was used for landsat image 2016. The image classification process after establishment of the false colour composites involved creation of the map list, sample set creation and classification domain creation.

Having undertaken the above stated steps and assigned commensurate number of pixels to various land use/land cover classes,each image was separately classified using the supervised classification maximum likelihood algorithm in IDRISI 17.0 Selva edition. Four separable land use/cover categories have been identified in this study for landsat image TM 1991 ETM+ 2002 and OLI 2016 such as built-up land, forest land, bare rock, and agricultural land. The classification made it possible to capture each land use type in polygons and calculations of the areas in square kilometres of each landuse/landcover was easily determined.

Rate of change of land use/land cover between 1991 and 2016

The change analysis panel provides a rapid assessment of quantitative change by graphing gains and losses by land cover categories. Landuse/Landcover classification used in this study was based on four categories which are, Built-up land, forest land, Bare rock, and agricultural land. The supervised classification through maximum likelihood algorithm was applied to perform image classification. This classification has been found to be the most commonly and widely used classifier. (Diallo *et al.,* 2015; Dewan&Yamaguch, 2009; Vatsavai*et al.,* 2011). The supervised classification requires training areas for each category and the training areas were used to define spectral reflectance pattern or signature of each LULC category, following by the signatures would then be used in classifying the pixels into a certain category which has the same spectral patterns using the classifier algorithm. The training areas of each category were created with the assistance of visual analysis on the images via the colour composite (Band 2-3-4 and 3-4-5) and also using the ancillary information from the digital land use map and Google Earth. Anderson *et al.,* (1976) classification scheme was adopted in this study and five categories of classes of land use/land cover were identified which include; built-up land, forest land, bare rock, agricultural land and water bodyfor 1991 and 2002 landsat images and 2016 image. Accuracy assessment is the agreement between a standard assumed to be correct and a classified image of unknown quality. This is performed by comparing the map created by remote sensing analysis to a reference map based on a different information source. One of the primary purposes of accuracy assessment and error analysis in this case is to permit quantitative comparisons of different interpretations. Classifications done from images acquired at different times, classified by different procedures, or produced by different individuals can be evaluated using a pixel-by-pixel, point-by-point comparison. The results must be considered in the context of the application to determine which one is the "most correct" or "most useful" for a particular purpose (Campbell &Masser, 1995).

Results and Discussion

Class Statistics in Square Kilometer (Km^2) and Percentage (%)

It can be seen in table 3 that, in 1991 built-up land occupied about 1.466% (27.624Km^2) of the total 1883.575 Km^2 of the study area. Forest land occupied 85.371% (1608.038Km^2), Bare rock and Agricultural land cover 4.404% (82.957Km^2) and 8.757% (164.956Km^2) respectively. The result for 2002 shows that built-up land has increased to 3.526% (66.432Km^2), Agricultural land also increased to 28.617% (539.026Km^2), while forest land reduced to 63.466%

(1195.442Km²) and bare rock reduced to 4.389% (82.670Km²). In 2016, the results show that the built built-up land increased from 3.526% in 2002 to 11.173% (210.470Km²) and agricultural land also increased to29.883% (562.873Km²) while forest land and bare rock 54.578% (1028.019Km²) and 4.364% (82.213Km²) respectively.

Accuracy Assessment

Three different satellite imageries acquired in 1991, 2002 and 2016 were classified with an average kappa coefficient and overall accuracy of 0.8866 and 80.54% respectively as shown in Table 2.

Table 2: Image classification Kappa coefficient and overall accuracy of different image used

Year	Kappa Coefficient	Overall Accuracy (%)
1991	0.8758	80.74
2002	0.8845	79.78
2016	0.8995	80.98
Average	0.8866	80.50

The land use/land cover changes of the study between 1991 and 2016 was analyzed and calculated from the classified multi-date imageries of 1991, 2002 and 2016. Four categories of land use/land cover class were used for the change analysis. In addition, general comparative analyses were carried out on all the participating class in order to determine and appreciate the dynamic nature of the study area.

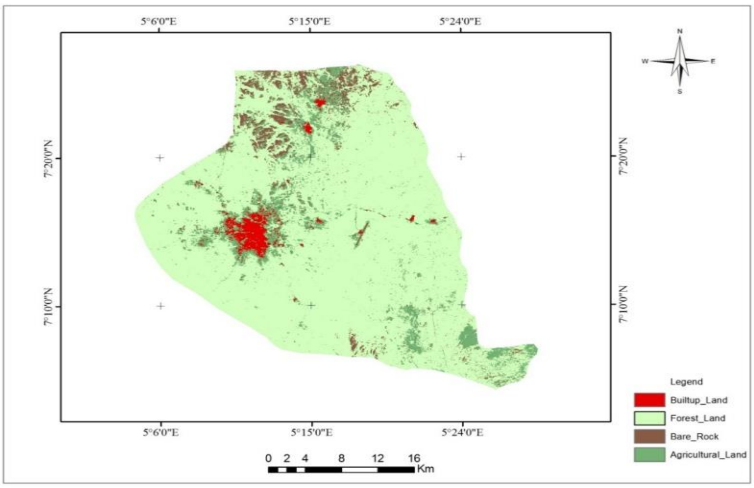

Figure 2: Land use / Land cover map of Akure 1991
Source: Researcher fieldwork, (2016).

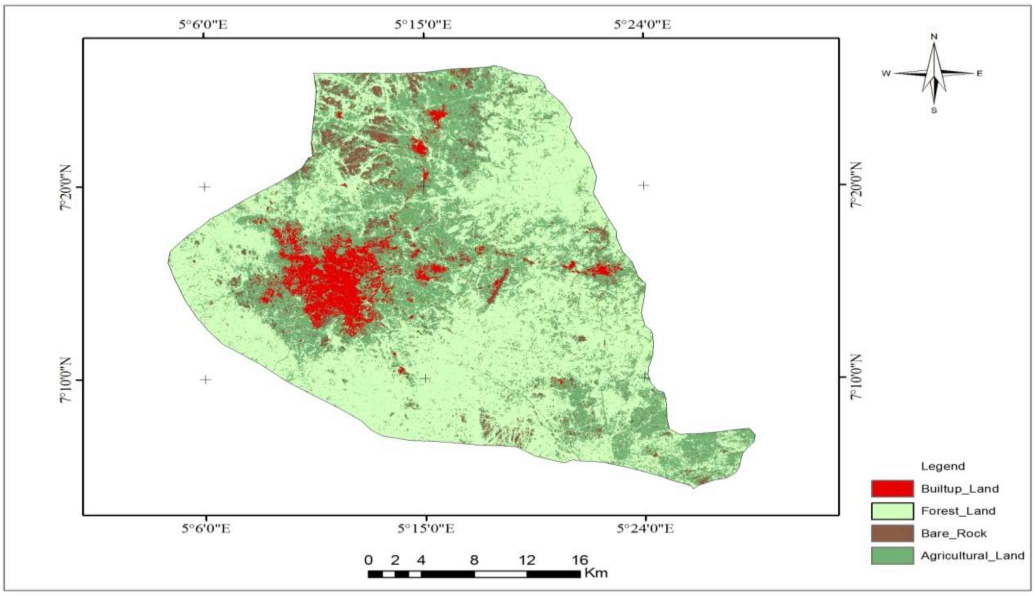

Figure 3: Land use / Land cover map of Akure 2002.
Source: Researcher fieldwork, (2016).

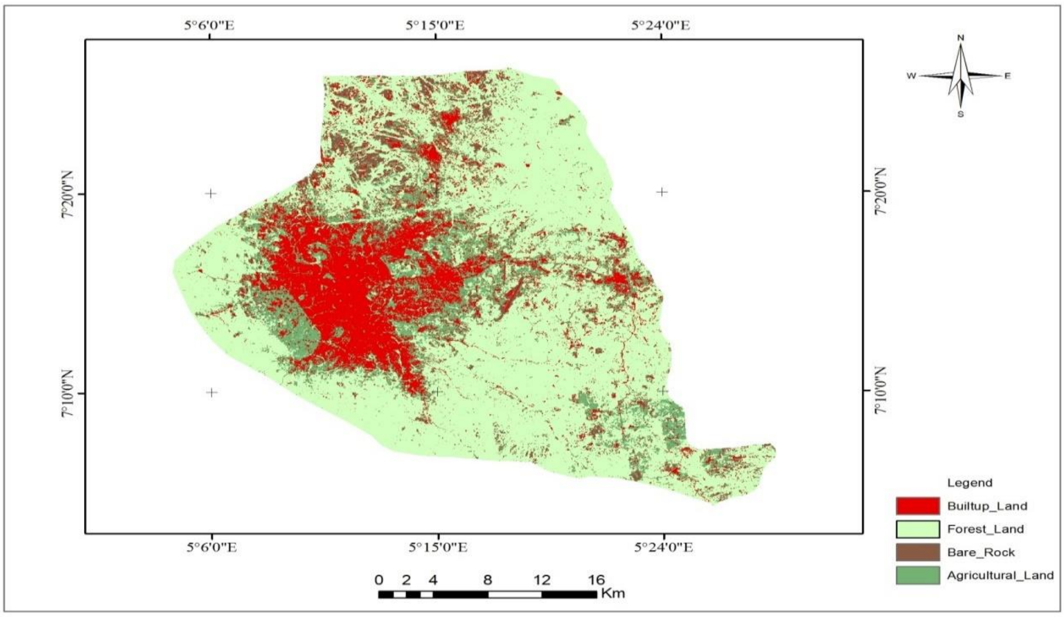

Figure 4: Land use / Land cover map of Akure 2016
Source: Researcher fieldwork, (2016).

Table 3: Class statistics in Square Kilometer (Km²) and Percentage (%)

LULC CLASS	1991		2002		2016	
	km²	**%**	**km²**	**%**	**km²**	**%**
Built-up Land	27.62	1.46	66.43	3.53	210.47	11.17
Forest Land	1608.04	85.37	1195.44	63.46	1028.02	54.58
Bare Rock	82.96	4.40	82.67	4.39	82.21	4.36
Agricultural Land	164.96	8.76	539.03	28.62	562.87	29.88
Total	1883.57	100.00	1883.57	100.00	1883. 57	100.00

Source: Researcher fieldwork, 2016

Table 4: Land use/land cover changes of Akure between 1991 and 2016

LULC CLASS	1991-2002		2002-2016	
	Diff. in Area		Diff. in Area	
	(Km²)	%	(Km²)	%
Built-up Land	38.81	2.07	144.04	7.64
Forest Land	-412.60	-21.91	-167.42	-8.88
Bare Rock	-0.29	-0.01	-0.46	-0.03
Agricultural Land	374.07	19.36	23.84	1.26
Total	-0.01	-0.49	0	-0.01

Source: Researcher fieldwork, (2016).

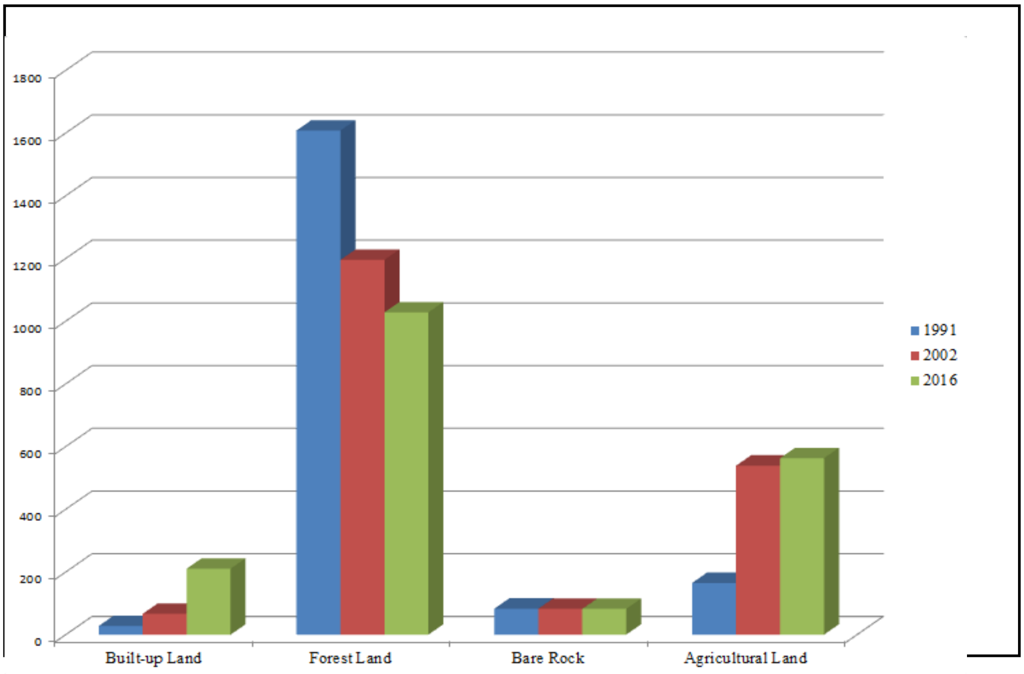

Figure 5: Comparative analysis of landuse/landcover change between 1991, 2002 and 2016
Source: Researcher fieldwork, 2016

Rate of Changes of LULC between 1991 and 2016

Land use / land cover change is a gradual and constant process in every given geographical unit. However, past studies as indicated in the literature reviewed show that spatial analysis of change is quite complex and depends on different data sets. In Akure, (the study area) land use/land cover change is visible and well pronounced using remote sensing techniques. Utilizing multi-date satellite imageries of Akure between 1991 and 2016, i.e. a period of 25 years shows that landuse/landcover has witnessed change in pattern, structure and extent.

Table 5 shows the Degree, Annual frequency and percentage of change between 1991 and 2002. In details, built-up land, and agricultural land recorded a degree of change of 38.81 and 374.07, (km²) respectively, an annual frequency of 3.53 and 34.01, (km²) respectively and percentage of change of 41.27 and 53.14, (%) respectively, while forest land and bare rock recorded a degree of change, annual frequency and percentage of change of -412.60 and -0.29 (km²), -37.51 and -0.02 (km²) and -14.72 and -0.18 (%) respectively. These indicate that between 1991 and 2002, forest land and bare rock recorded a negative degree and annual frequency of change as presented in Table 5 and 7.

Table 5: Degree, Annual Frequency and Percentage of Change Between 1991-2002

LULC CLASS	1991	2002	Degree	Annual Frequency	Percentage of Change
	(%)	(%)	(Km²)	(Km²)	(%)
Built-up Land	1.46	3.53	38.81	3.53	41.27
Forest Land	85.37	63.46	-412.60	-37.51	-14.72
Bare Rock	4.40	4.39	-0.29	-0.02	-0.18
Agricultural Land	8.76	28.62	374.07	34.01	53.14
Total	100.00	100.00	-0.01	0.01	79.51

Source: Researcher fieldwork, 2016

Table 6: Degree, Annual Frequency and Percentage of Change Between 2002 and 2016

LULC CLASS	2002	2016	Degree	Annual Frequency	Percentage of Change
	(%)	(%)	(Km²)	(Km²)	(%)
Built-up Land	3.53	11.17	144.04	10.29	51.46
Forest Land	63.46	54.58	-167.42	-11.96	-7.53
Bare Rock	4.39	4.36	-0.46	-0.03	-0.28
Agricultural Land	28.62	29.88	23.84	1.70	2.16
Total	100.00	100.00	0	0	45.81

Source: Researcher fieldwork, 2016

In details, built-up land and agricultural land recorded a degree of change, annual frequency and percentage change of 144.04 and 23.84 (km²) respectively and 51.46 and 2.16 (%) respectively while forest land and bare rock recorded degree of change, annual frequency and percentage of change of -167.42 and-0.46, (km²) and -7.53 and -0.28 (%) respectively as shown in Table 6.

Table 7: Degree, Annual Frequency and Percentage of Change Between 1991 and 2016

LULC CLASS	1991	2016	Degree	Annual Frequency	Percentage of Change
	(%)	(%)	(Km²)	(Km²)	(%)
Built-up Land	1.46	11.17	182.85	7.31	76.80
Forest Land	85.37	54.58	-580.02	-23.20	-22.00
Bare Rock	4.40	4.36	-0.75	-0.03	-0.45
Agricultural Land	8.76	29.88	397.91	15.92	54.67
Total	100.00	100.00	-0.01	0.00	109.02

Source: Researcher field work 2016

As shown in Table 7 above, the built-up land and agricultural land recorded in degree of change and percentage of change of 182.85 and397.91 (km²) and 76.80 and 54.67(%) and an annual frequency of 7.31 and15.92(km²) respectively, while forest land and bare rock were recorded in degree, annual frequency and percentage of change of -580.02 and -0.75, (km²) and -22.00 and-0.45, (km²) and -23.20 and -0.03, (%) respectively. The above figures indicate that between 1991 and 2016 forest land and bare rock recorded negative degree of change and percentage of change. This further shows that built-up land and agricultural land gain more land from other landuse while forest land and bare rock lost land to other landuse with respect to their degree of change as illustrated in Table 7.

Change Detection Analysis Using LCM Method

A number of Land Use Cover Changes (LUCC) models have been developed; however, it is difficult to compare which one gives more accurate representation (Webster & Wu 2009). Among the numbers of land use modelling tools and techniques, the commonly used models is the modelling techniques embedded in IDRISI. These are Land Change Modeler (LCM), Cellular Automata (CA), Markov Chain, CA_Markov, GEOMOD and STCHOICE (Eastman&Fulk, 1993). Land Change Modeler was used to analyze the land use/cover changes for various classes during the period 1991-2016.

Prediction of Land use/Land cover Changes Based on Land Change Modeler (lcm)

Markov Chain determines the amount of using the earlier and later land cover maps along with the date specified. The procedure determines exactly how much land would be expected to transition from the later date to the predicted date based on a projection of the transition potentials into the future and creates a transition probabilities file. The transition probabilities file is a matrix that records the probability that each land cover category will change to every other category. A Markov Chain is a random process where the following step depends on the current state. Markov produces transition matrices from two different dates (1991 and 2016). In table 7, the rows stand for the older land use and land cover categories and the columns stand for newer land use and land cover categories.

Table 8: Markov Prediction to 2050 based on Land use / land cover maps of 1991 and 2016

LULC CLASS	Built-up Land	Forest Land	Bare rock	Agricultural Land
Built-up Land	0.8872	0.0019	0.0095	0.1011
Forest Land	0.0671	0.5914	0.0175	0.3225
Bare Rock	0.0501	0.3920	0.0956	0.4493
Agricultural Land	0.2877	0.1317	0.0642	0.5103

Source: Researcher fieldwork,(2016).

From Table 8 above, it was shown that all over the years there are significant changes in land use/cover categories especially for agriculture land and built up areas.

Table 9: Projected Land use and Land cover statistics of the study area for 2050

LU/LC CLASS	Built-up Land	Forest Land	Bare rock	Agricultural Land	Total
Area (Sq. Km.)	368.846	761.252	63.271	690.206	1883.57
Area (In %)	19.58	40.42	3.36	36.64	100

Source: Researcher fieldwork,(2016).

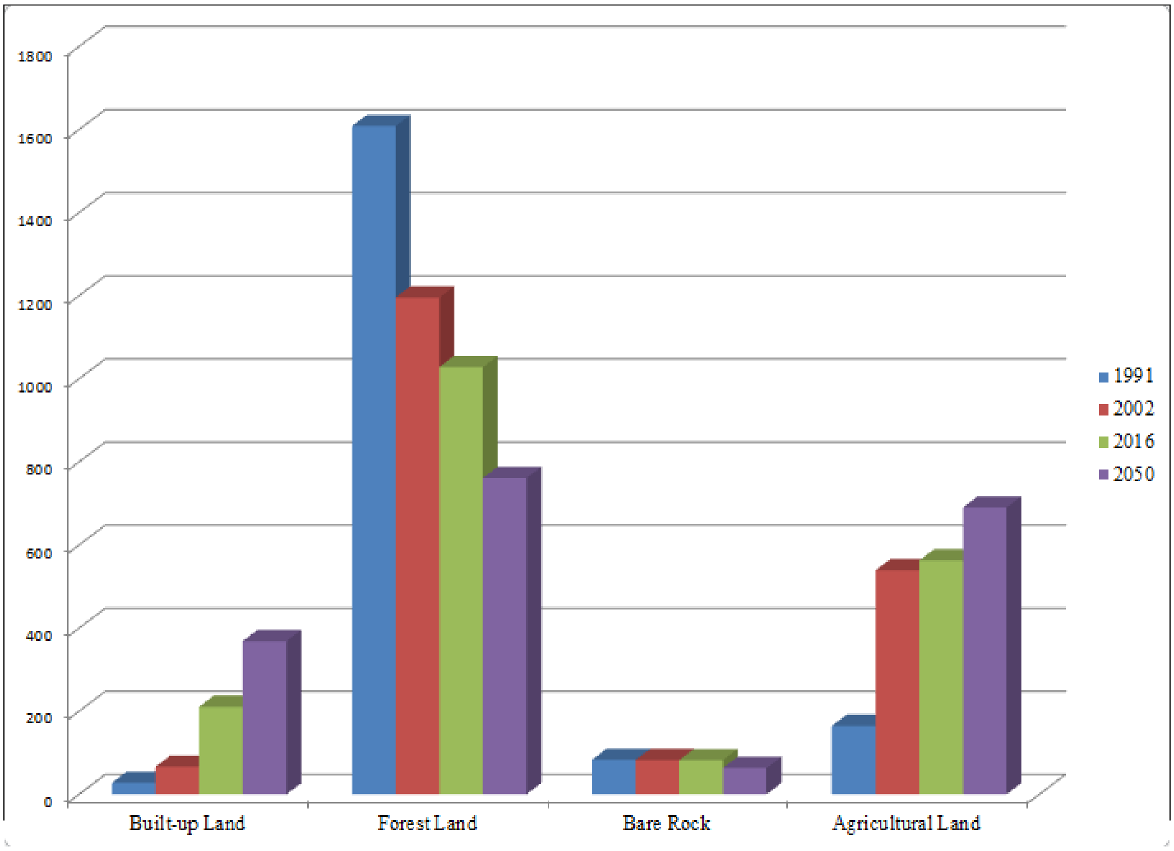

Figure 6: Landuse/Landcover in the year 1991, 2002, 2016 and 2050.
Source: Researcher fieldwork, 2016

The visualized changes in the multi date images in 1991, 2002 and 2016 using the automated IDRISI changes detection statistics has shown he spatial changes observed in the study area over past two decades was as a result of different factors which include; population increase, urban expansion, the conversion of Akure to state capital of Ondo state which lead to increase in demand of lands, political structure and social-economic activity.

Conclusion

The post classification analysis of the land use/land cover dynamics using satellite data together with GIS indicate increased land use/land cover changes in the city. This has been induced by rapid urban development and concentration of people between the years 1991 to 2016. The analysis reveals that urban areas have increased significantly leading to the destruction of natural vegetation such as the forest and farmland leading to ecological disruptions. This study has shown that lack of relevant spatial information crucial for planning may be improved with remote sensing data, which can provide opportunities for periodical survey of land use/land cover changes and their spatial distribution.

REFERENCES

Adebayejo, A.T. &Abolade, O. (2006). Household Response to Urban Encroachment on Rural Hinterland in Ogbomosho Urban Fringe. A paper presented to the PROPODE workshop on Urban Population Development and Environment Dynamics in Developing Countries Nairobi, Kenya.

Anderson, J. R., Hardy, E. E., Roach, J. T. &Witmer, R. E. (1976). A Land Use and Land Cover Classification System for use with Remote Sensing Data as presented by U.S. Geological Survey Serial 671 in paper 964.

Campbell, H. &Masser, I. (1995). GIS and Organisations: How Effective are GIS in Practice.London: Taylor and Francis.

Debie, C. A., Leeuwen, J. A. V. &Zuidema, P. A. (1996). A book on Land Use Database: Knowledge based Software Program for Structured and Retrieval of User defined.

Dewan, A.M. & Yamaguchi, Y. (2009). Land use and land cover change in Greater Dhaka Bangladesh Using Remote Sensing to Promote Sustainable Urbanization. *Journal of Geosciences and Geomatics.* Vol 5, No. 2. Pp. 46-58.

Diallo, M.D., Stephen, A.W., Aly, D., Minda, M.S., Ousmane, N., Alfred, K.T., Theiro, N., Mamadou, G., Seynabou, S., Aliou, D. &Aliou, G. (2015). Soil Suitability for the production of Rice, Groundnut and Cassava in the Peri-urban Niayes zone, Senegal. Soil and Tillage Research. vol. 155. Pp 412-420.

Eastman, J.R. &Fulk, M. (1993). Long Sequence Time Series Evaluation using Standardized Principle Components. Photogramm. Eng. Rem. Sens. 59:991–996

Igbokwe, J.I. (2010). Geospatial Information, Remote Sensing and Sustainable Development in Nigeria 15th Inaugural Lecture from Nnamdi Azikwe University, Awka, held on Wednesday 19th may 2010.

Lambin, E. F. &Ehrlish, T. (1997). Modelling and Monitoring Land Cover Change Processes in Tropical Regions. Progress in Physical Geography 21(3):375–39.

Lemlem, A. (2007). Assessing the Impact of Land Use and Land Cover Change on Groundwater Recharge Using Remote sensing and GIS: A Case study of Awassa Catchment Ethiopia. M.Sc. Thesis, Addis Ababa University, Ethiopia.

Mengistu, A.D. & Salami, A.T. (2007). Application of Remote Sensing and GIS in Land Use/Land Cover Mapping and Change Detection in a Part of South Western Nigeria. *African Journal of Environmental Science and Technology* Vol. 1 (5), Pp. 99-109.

National Population Commission (NPC) (2006). Population and Development Review. Published by Population Council (www.jstor.og/stable) Vol. 33, No. 1. Pp. 206-210.

Oyinloye, M.A. (2010). Spatial Analysis of Urban Growth in Akure, Nigeria. PhD. Thesis from the Department of Urban and Regional Planning, Federal University of Technology, Akure.

Seto, K. C., Fragkias, M., Guneralp, B. &Reily, M.K. (2011). A Meta-analysis of Global Urban Expansion. Plos One6(8): e23777. doi: 10.1371/journal.pone.00237777.

Vatsavai, R., Tuttle, M., Bhaduri, B., Bright, E., Cheriyadat, A., Chandola, V. &Graesser, J. (2011). Rapid damage assessment using high resolution remote sensing imagery: Tools and Techniques. International conference on Geoscience and Remote Sensing Symposium (IGARSS) pp 1445 - 1448

Webster, C. &Wu, F. (2009). Informality and the Development and Demolition of Urban villages in the Chinnese, Peri-urban Area 'Urban studies in Press'.