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Spatio-Temporal Analysis of Urban Land Cover Growth Dynamics in Akure South Metropolis, Ondo State Nigeria

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Abstract: This study focuses on the spatio-temporal analysis of urban land cover growth dynamics in Akure south Metropolis using medium resolution multi-temporal images (Landsat MSS1986, TM2000 and ETM2015). Spatio-temporal analysis of urban land cover growth changes in a GIS environment involves processes which use spatial data collected over a period of time to envisage the extent of urban growth in an area. Remote sensing and GIS provides an easy environment that could complement the available tools for urban planning and environmental management in Akure Metropolis. Handheld GPS Map 76x was used in obtaining the data used for ground truthing. The images were processed (supervised classification) using ArcGIS 10.2.1 and land cover maps for each study year were produced. The result of the analysis in table 7 shows that urban area steadily increased from 4.8% in 1986 to 9.5% in 2000 and 17.3% in 2015 while vegetation (including forests and scrubs) decreased in an uncontrolled manner from 79.4% in 1986 to 60.5% in 2000 and 51.7%. The study recommended that spatio-temporal analysis of urban land cover growth dynamics should be carried out to progressively study the rate and pattern of growth.

Keywords: Spatio-Temporal Analysis, Land Cover Growth Dynamics, Landsat, Supervise Classification, GPS, Remote Sensing/GIS

1. Introduction

Research on spatio-temporal dynamics on urban land cover growth have been a critical issue from time immemorial in the ever dynamic environment in which we live and it is becoming more serious in this time when there are technological development in the approaches and equipment obtainable to measure and monitor our environment. This issues of urban land cover growth and their effects on the environment and other land use types has spawned quite a lot of interest all over the world [1].

Land cover growth pattern in region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to massive agricultural and demographic pressure. Hence, information on land use / land cover and opportunities for their optimal use as essential for the choice, development and execution of land use structures to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population [1].

Many of the farmlands, wetlands, and forests that formed Nigeria in past decades have been transformed during the past 60 years into human settlements of which Ondo state is not and exception. It has been noted that most of Nigeria's towns are growing rapidly without proper planning [10]. Almost everyone has seen these changes to their local environment but without a clear understanding of their impacts. It is not, until a study on spatio-temporal analysis of urban land cover growth dynamics, which we can begin to analyze the changes that have occurred over time [6].

The integration of remote sensing and geographic information systems (GIS) has been widely applied since its recognition as a powerful and effective tool in detecting urban land-use and land- cover change [4]. Satellite remote sensing collects multispectral, multiresolution and multitemporal data, and turns them into information valuable for understanding and monitoring urban land cover growth processes and for building urban land-cover datasets. GIS technology provides a flexible environment for entering, analyzing and displaying digital data from various sources necessary for urban feature identification, change detection and database development [9]. In spite of this however, few of the urban growth studies have been directed towards satellite based post-change detection environmental impact analysis, especially in the tropical regions due to probably to the previously high cost of remote sensing data [9]. There is great need to conduct such studies as a way of contributing to developing an effective procedure using the existing methods of remote sensing and GIS for studying urban land cover growth dynamics especially in tropical regions like Akure.

Since the 1970s the USGS has made available multispectral medium resolution synoptic coverage of the whole world breaking them into paths and rows. These images (Landsat) have been of incredible help to monitor and understand changes going on in the environment.

Urban growth has been speeded up, and extreme stress to the environment has occurred [7]. This is particularly true in regions such as Akure metropolis where massive agricultural land is disappearing each year, converting to urban or related uses [5]. This entails the removal of natural land cover and the introduction of urban materials in form of clearance of natural vegetation; reclamation of swampy areas; construction of buildings, roads, and other concrete surfaces like parks and pools [7].

Akure has reportedly been growing rapidly owing to favourable socio-economic, political, and physical factors. This growth became so pronounced when the city was accorded the status of a state and Local Government headquarters. Evaluating the magnitude and pattern of Akure urban growth is an urgent need [5]. This is to generate information that could help in tackling some of the problems that accompanied rapid urban growth. Furthermore, because of the lack of appropriate land-use planning and the measures for sustainable development, rampant urban growth has been creating severe environmental consequences such as urban flood, erosion and pollution problems. Thus, there is a need to assess the environmental impact of the rapid urban expansion [1].

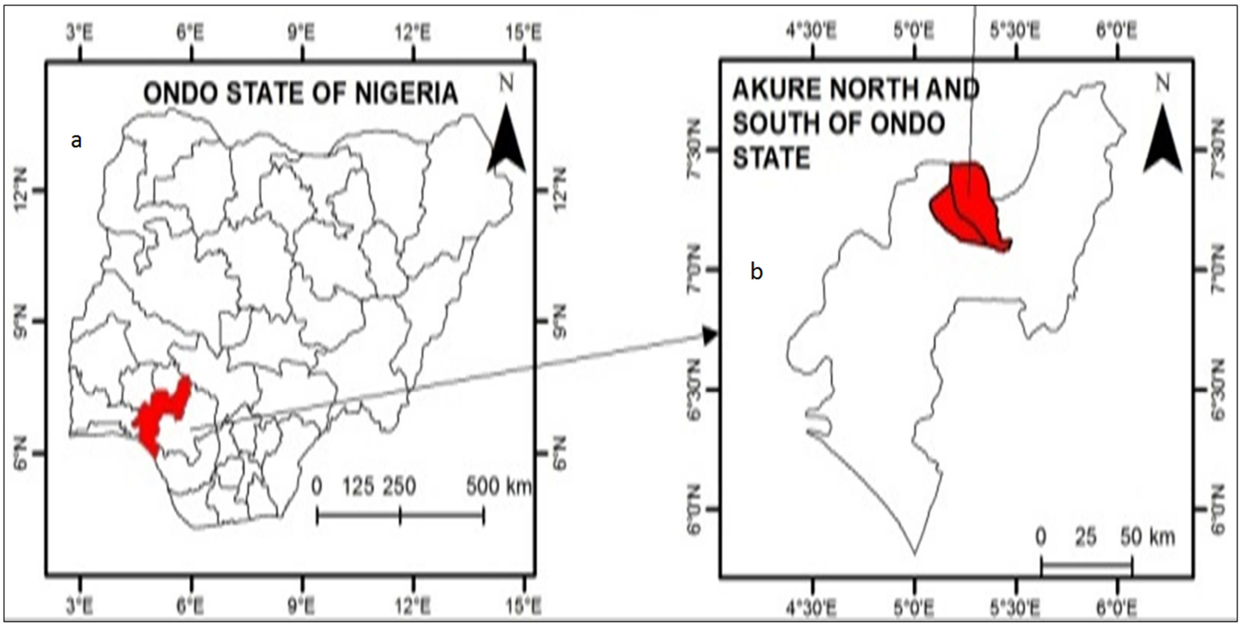

Figure 1. *Map of Nigeria showing Ondo State (a), Ondo State showing Akure South indicated by an arrow and Akure North (b).*

2. Study Area

Akure is the capital of Ondo state which is located along latitude 7°15'00"N to 7°18'22".32N and longitude 5°09'12"E to 5°14'10"E. The town is situated in the tropic rainforest zone in Nigeria. The city comprises of two local government areas- Akure South and Akure North Local Government area. Akure is the trade centre for a farming region where cocoa, yams, cassava, corn and tobacco and cotton are grown.

The study area, Akure South Local Government area is located within Akure covering an area of 331km^2 with a population of 353,211 as at the 2006 census.

3. Methodology

The methodology adopted here made use of medium resolution multi-temporal images (Landsat MSS1986, TM2000 and ETM2015) of Akure metropolis captured and added to ArcGIS 10.2.1 for supervised classification. The coordinate (primary data) obtained using Handheld GPS 76X was use for ground truthing while Landsat satellite images (secondary data) covering Akure South was used in studying spatio-temporal urban growth dynamics for the past 29 years (1986-2015). This section focus on the fundamentals principles, methods and procedures that were adopted in the study. Figure 2 shows the methodology flow chart.

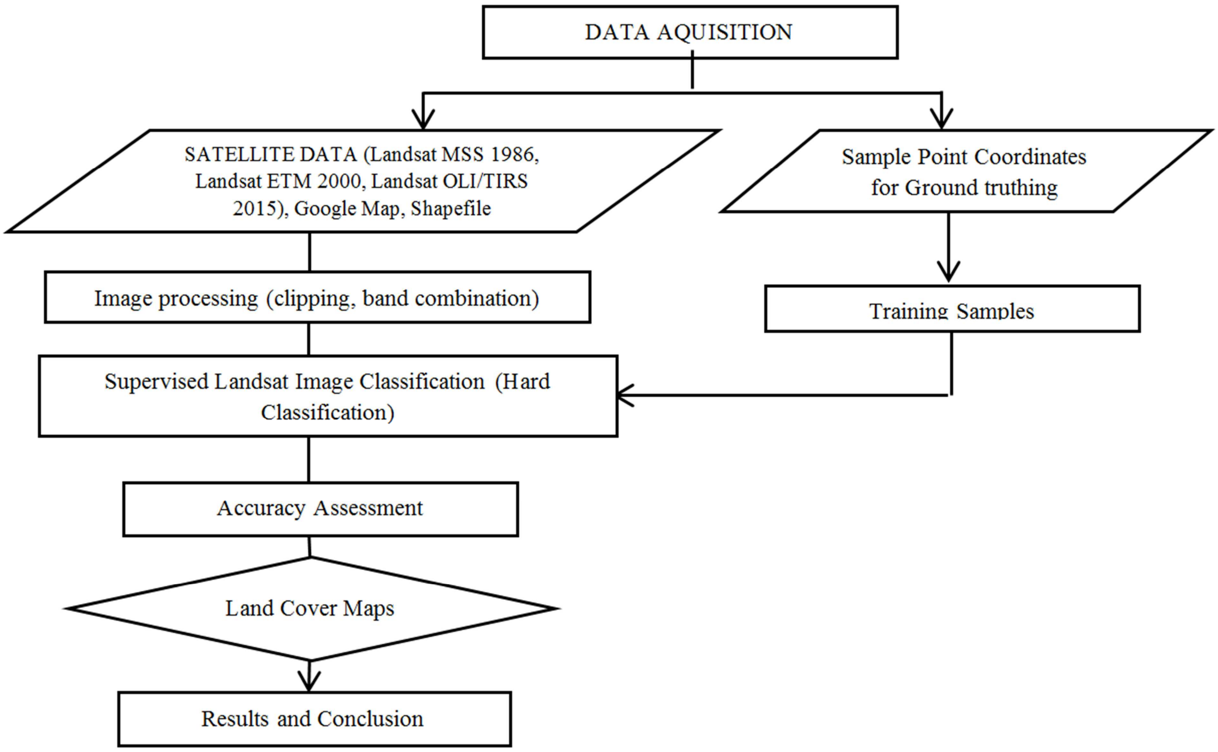

Figure 2. *Showing methodology flow chart.*

4. Data Processing

The images and shapefiles used in the study were all pre-processed and as such there was no need for geo-referencing and rectification.

4.1. Creation of Composite Band for Each Landsat Satellite Images

In creating a composite, a number of bands (usually 3 and above) in a multispectral satellite image are combined together to form multiband images. A composite image enhances visualization of features in the image. Table 1 below shows the bands used for creating a composite in each image while figure 3 shows composite image for each year of study.

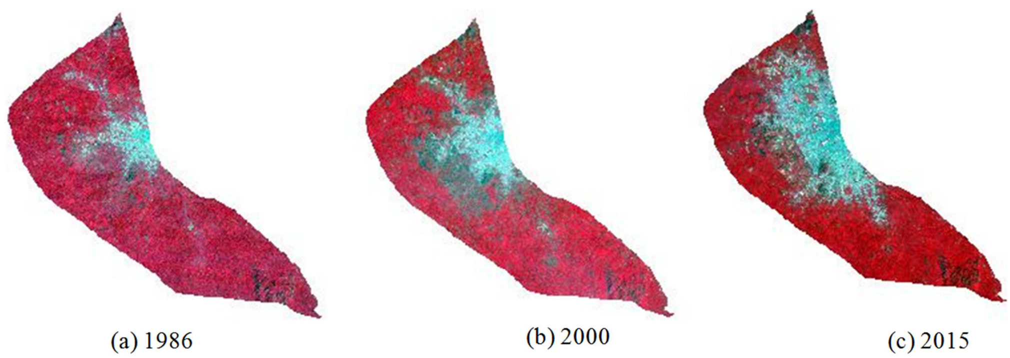

Figure 3. *Showing RGB Composite images (Source: http//www.diva-gis.org/datadown).*

Table 1. *Landsat Band Combinations.*

Image	1986 (Landsat TM)	2000 (Landsat ETM)	2015 (Landsat OLI/TIRS)
Spectral band combination	4,3,2	4,3,2	5,4,3
Spectral band names	NIR, Red, Green	NIR, Red, Green	NIR, Red, Green

The bands chosen are well suited for studying land cover and vegetation characteristics. Vegetation appears in different shades of red. Deep red colour indicates thick forests/ healthy vegetation, while lighter tones indicates scrubs, bushes, grasses, etc. Rocks can also be easily detected from these composite. Bare soil and patches appear as brown or light brown. Urban areas appear as cyan blue (densely populated areas appear as light blue)

4.2. Image Classification

Image classification and interpretation was performed using Supervised Classification on ArcGIS 10.2. Using reference image (Google Maps) and the ground truthing data, training samples were gathered from more than 20 points as signatures for each Landsat satellite images. The training points were proportionally distributed to each cover types with at least 10 points per cover type.

The images were classified under the following classes as shown in the table below.

Table 2. *Showing Land cover class description.*

Land Cover Class	Description
Urban Area	This classes includes urban fabric, industrial, commercial, and other related built up areas of non-agricultural, vegetated areas
Forest	It comprises forest land, shrub and other mixed forest land, herbaceous vegetation associations
Scrubs	Heterogeneous agricultural areas, thick bushes. Non-forest
Grassland/Bare surfaces/soil	Grasslands, sparsely vegetated areas, open spaces with little or no vegetation. Transport units (roads) also fall under the category of bare surfaces
Rocks	Bare (exposed) rocks
Water	Rivers, Lakes, ponds

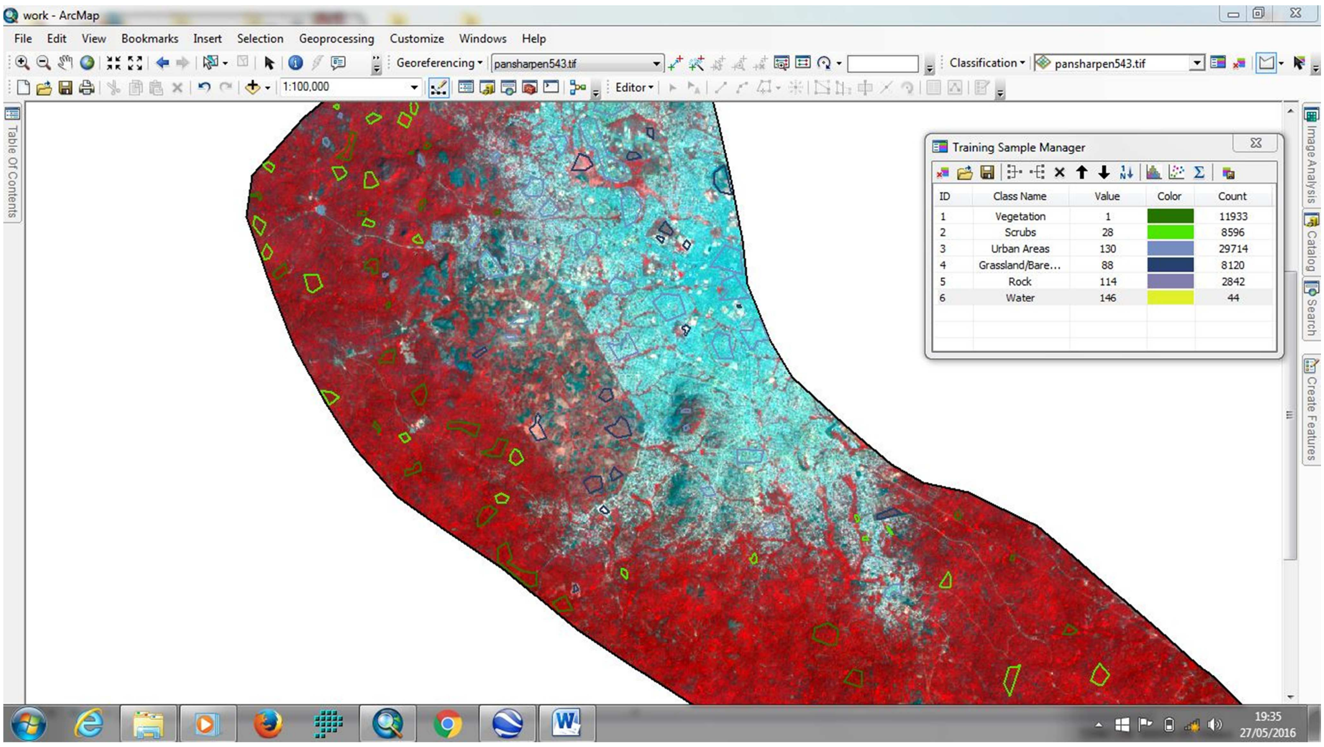

Figure 4. *Showing training sites and training sample manager during supervised classification.*

4.3. Area Calculation

After classification the area (in hectares) covered by each land cover class was calculated with the field calculator on ArcMap using the formula

Area (hectares) = (COUNT * SQUARE OF CELLCIZE OF CLASSIFIED IMAGE)/10000

Where, COUNT is the number of pixels in a class. The count value for each class was gotten from the attribute table of the classified map. The cell size for the year 1986 image was 28.5 by 28.5m, while those for years 2000 and 2015 were 15 by 15m.

4.4. Accuracy Assessment

The final stage of image classification usually involves an accuracy assessment. Traditionally this is done by generating a random set of locations to visit on the ground for verification of the true land cover type. In the course of this study shapefiles of reference points for each year were created. Over 280 points were picked in each year. These shapefiles were then converted from vector to raster format after which the classified images were combined with their corresponding reference raster image. The attribute table of the combined raster was then used to create a pivot table under the data management toolset. The pivot table created was exported in excel format and used to obtain the errors of commission and omission, producer's accuracy, user's accuracy, the overall accuracy and the kappa coefficient. The overall accuracy for the year 1986 classified image was calculated to be 0.74829932 while its Kappa Coefficient was 0.689492764.

For the year 2000, the overall accuracy calculated was 0.810035842 and the kappa Coefficient was gotten as 0.763396643. Likewise the overall accuracy gotten for 2015 was 0.876325088 while the kappa coefficient was gotten to be 0.845509561.

Table 3. *Accuracy Table for 1986 classification map.*

Land cover	Forest	Scrubs	urban area	grass/ bare surface /soil	Rock	water
Error of Commission (%)	23.53	25	17.81	25.0	36.17	40.00
Error of omission (%)	13.33	30	1.64	50.8	26.83	45.45
Producer's accuracy (%)	86.67	70	98.36	49.2	73.17	54.55
Users accuracy (%)	76.47	75	82.19	75.0	63.83	60.00

Table 4. *Accuracy Table for 2000 classification map.*

Land Cover	Forest	Scrubs	urban area	grass/bare surface/soil	rock	water
Error of commission (%)	20.27	9.62	4.92	24.14	55.00	35.71
Error of omission (%)	1.67	21.67	3.33	24.14	70.97	10.00
Producer's accuracy (%)	98.33	78.33	96.67	75.86	29.03	90.00
Users accuracy (%)	79.73	90.38	95.08	75.86	45.00	64.29

Table 5. *Accuracy Table for 2015 classification map.*

Land cover	Forest	Scrubs	grass/bare surface/soil	rock	urban area	water
Error of Commission (%)	10.94	7.41	15.87	19.44	4.92	20.00
Error of omission (%)	5.00	16.67	11.67	27.50	3.33	66.67
Producer's accuracy (%)	95.00	83.33	88.33	72.50	96.67	33.33
User's accuracy (%)	89.06	92.59	84.13	80.56	95.08	20.00

5. Presentation of Result

This section presents the results and discussion on the generated land cover maps from classification of Landsat images. It includes assessment of the maps' accuracy, analysis of the nature, extent and rate of land cover change maps and statistics. Besides, spatial analysis of change detection and patterns, spatial transition of land use/land cover change analysis using the Land Change Modeller extension for ArcGIS was also performed.

The results obtained from the classification of the images are presented below:

Figure 5A and B Shows the land cover map of 1986 and 2000 obtained from Landsat composite image

Figure 6 Shows the land cover map of 2015 obtained from Landsat composite image

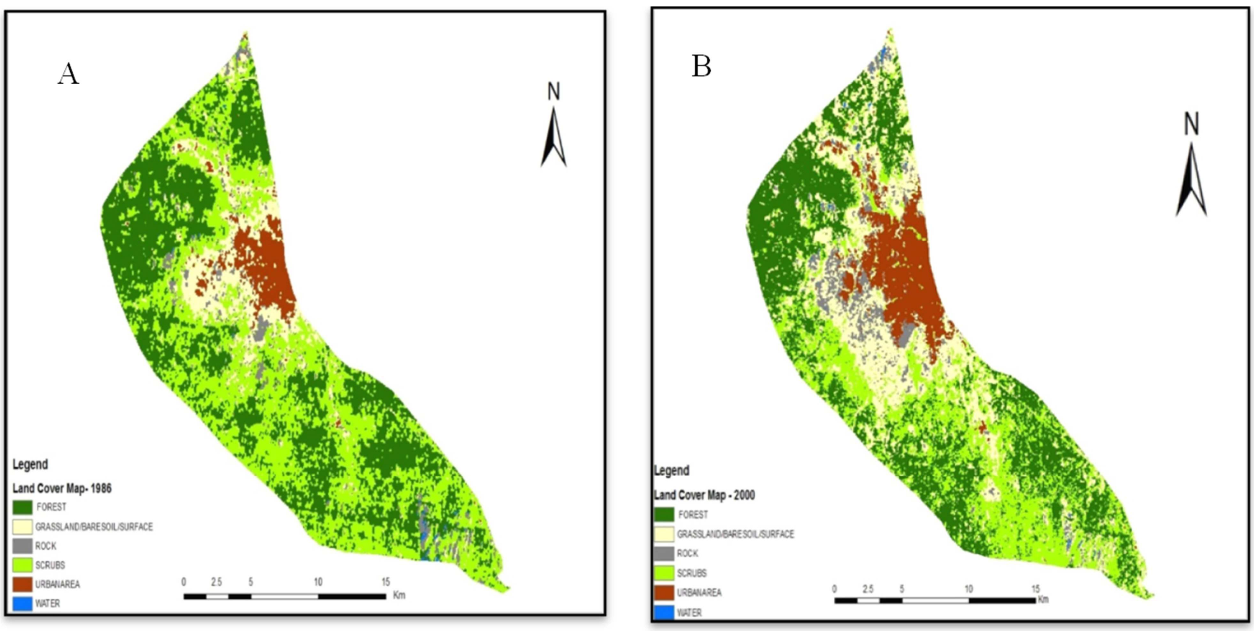

Figure 5. *Land and Cover Classification Map (A) 1986 and (B) 2000.*

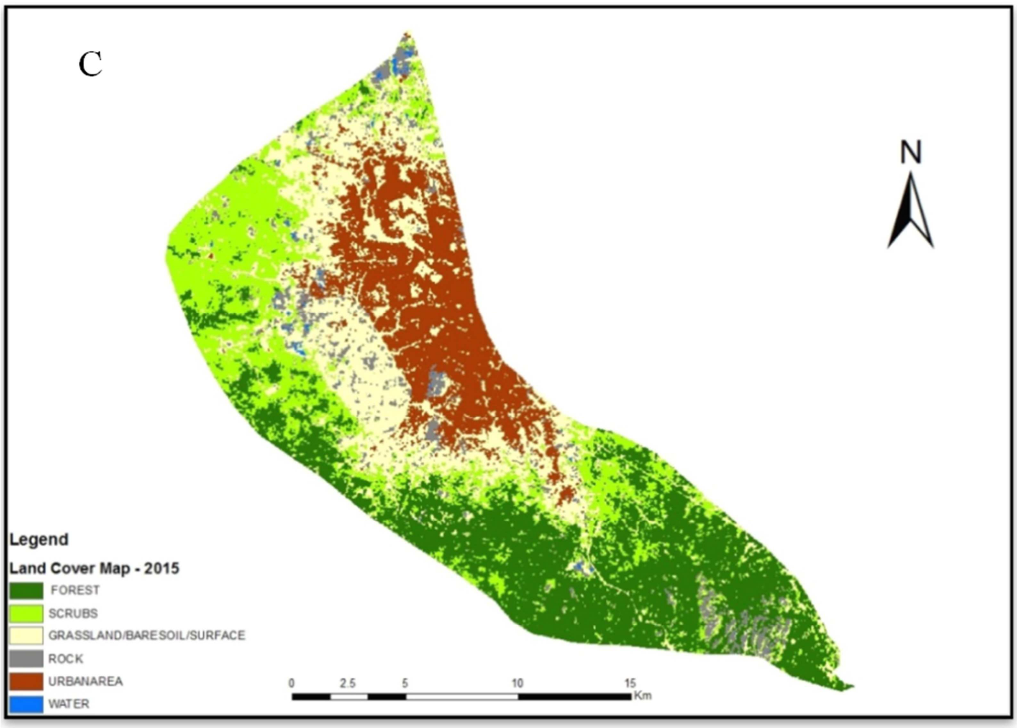

Figure 6. *Landsat Land Cover Classification Map for 2000.*

6. Discussion/Analysis of Result

6.1. Analysis of Land Cover Classification

The results as shown in Figure 5a, b, and 6 help to visualize the extent and nature of urban growth in the study area. In 1986, the urban area mainly covered the north eastern part of the map. The urban area spread out mainly upwards from the north eastern part of the metropolis in the northern direction in 2000. These areas were earmarked for the construction of Government Residential Areas (GRAs) and government ministries. Besides, the area was the location of Ijapo Estate, a notable residential estate in the city which attracted much influx into the area. The construction of Ilesha-Akure-Owo highway which passes through the north-eastern part of the city was another notable factor that plays a prominent role in attracting people to the area [3].

In 2015 the spread was diffused in all directions. This was probably due to congestion in this area and availability of cheap lands and good topography which favours construction in other parts of the city.

As shown in table 2, larger part of the study area was covered in thick vegetation in 1986. The forest and scrubs which made up the thick vegetation covered 12145.818 hectares and 13897 hectares respectively which totalled 79.384% of the whole study area. The urban area only covered 1572.435 hectares (4.793%), grassland or bare surface/soil covered 3713.932 hectares (11.32%), 1370.672 hectares (4.178%) was covered by rocks and water only covered about 106.080 hectares (0.323%).

In 2000, the extent of land covered by forest and scrubs reduced noticeably to 10640.228 and 9215.100 hectares respectively which made up 60.518% of the study area. Urban areas, grassland or bare surface/soil and rocks all increases to 3130.515 hectares (9.542%), 8114.467 hectares (24.732%) and 1654.718 hectares (5.043%) respectively. Water bodies also decreased in to 53.978 hectares (0.165%).

By the year 2015, the coverage of urban area had greatly increased to 5668.290 hectares (17.274%). Grassland or bare surface and rocks had also increased covering 8276.692 hectares (25.223%) and 1821.667 (5.552) hectares respectively. Forests and scrubs continued to experience a decrease in area covering 9564.480 hectares (29.148%) and 7393.635 hectares (22.532%) respectively. This confirmed what was obtained by [5].

Table 6. *Overall amount and extent of land cover classes from 1986 to 2015.*

LAND COVER TYPE	1986		2000		2015	
	AREA (ha)	%	AREA (ha)	%	AREA (ha)	%
FOREST	12145.818	37.022	10640.228	32.431	9564.480	29.148
SCRUBS	13897.679	42.362	9215.100	28.087	7393.635	22.532
URBANAREA	1572.435	4.793	3130.515	9.542	5668.290	17.274
GRASSLAND/BARESURFACE	3713.932	11.321	8114.467	24.732	8276.692	25.223
ROCK	1370.672	4.178	1654.718	5.043	1821.667	5.552
WATER	106.080	0.323	53.978	0.165	88.808	0.271
TOTAL	32806.615	100.000	32809.004	100.000	32813.573	100.000

6.2. Change Detection Analysis from 1986 To 2015

The change detection analysis for 1986–2000, 2000–2015, and 1986–2015 are presented in Table 7, Figure 7 and Figure 8. From the table and figures, the percentage increase of urban area was higher between 2000 and 2015 than between 1986 and 2000.

Thick vegetation was rapidly depleted and taken over by light vegetation and built-up land uses as indicated by the negative index throughout the studying period.

Table 7. *Amount of Land Cover Change.*

Landcover	Changes from 1986 - 2000	% increase / decrease	Changes from 2000 - 2015	% increase / decrease	Changes from 1986-2015	% increase / decrease
	ΔA (ha)		ΔA (ha)		ΔA (ha)	
FOREST	-1505.591	4.592	-1075.747	3.283	-2581.338	7.87
SCRUBS	-4682.579	14.275	-1821.465	5.555	-6504.044	19.83
URBAN AREA	1558.080	-4.749	2537.775	7.733	4095.855	-12.48
GRASSLAND/BARESURFACE/SOIL	4400.535	-13.412	162.225	0.491	4562.760	-13.90
ROCKS	284.046	0.865	166.950	0.508	450.996	-1.37
WATER	-52.102	0.159	34.830	0.106	-17.272	0.05

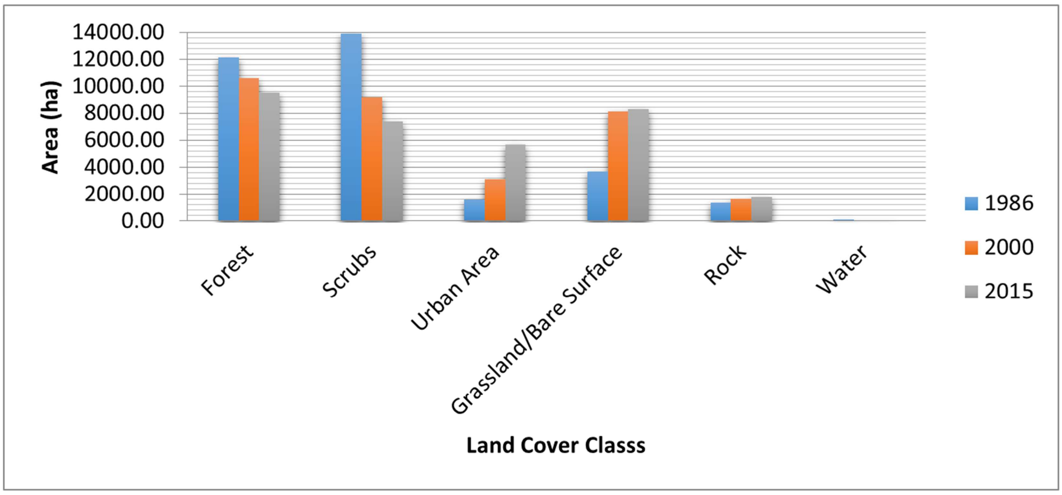

Figure 7. *Nature of Relative Land Cover Changes 1986 to 2015.*

The chart above represents the nature of the relative land cover changes. It shows that from 1986 to 2000 and then to 2015 (represented by the blue, red and green bars respectively) forest and scrub areas kept decreasing while the urban area increased. Grassland or bare surface/soil also increased through the years with only a minimal increase in 2015. The exposed rock surfaces also increased through the years.

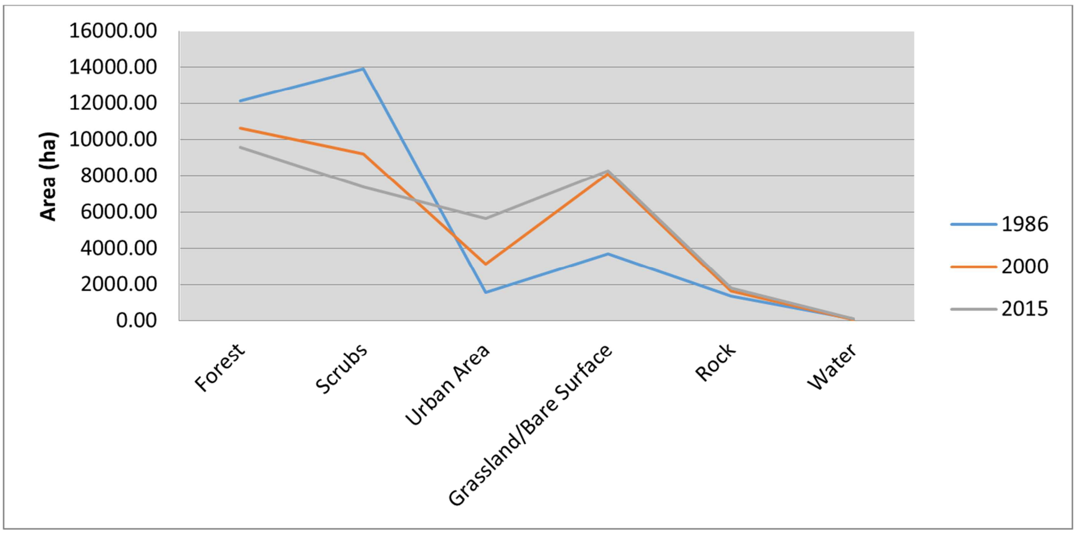

Figure 8. *Temporal Patterns of Land Cover Growth.*

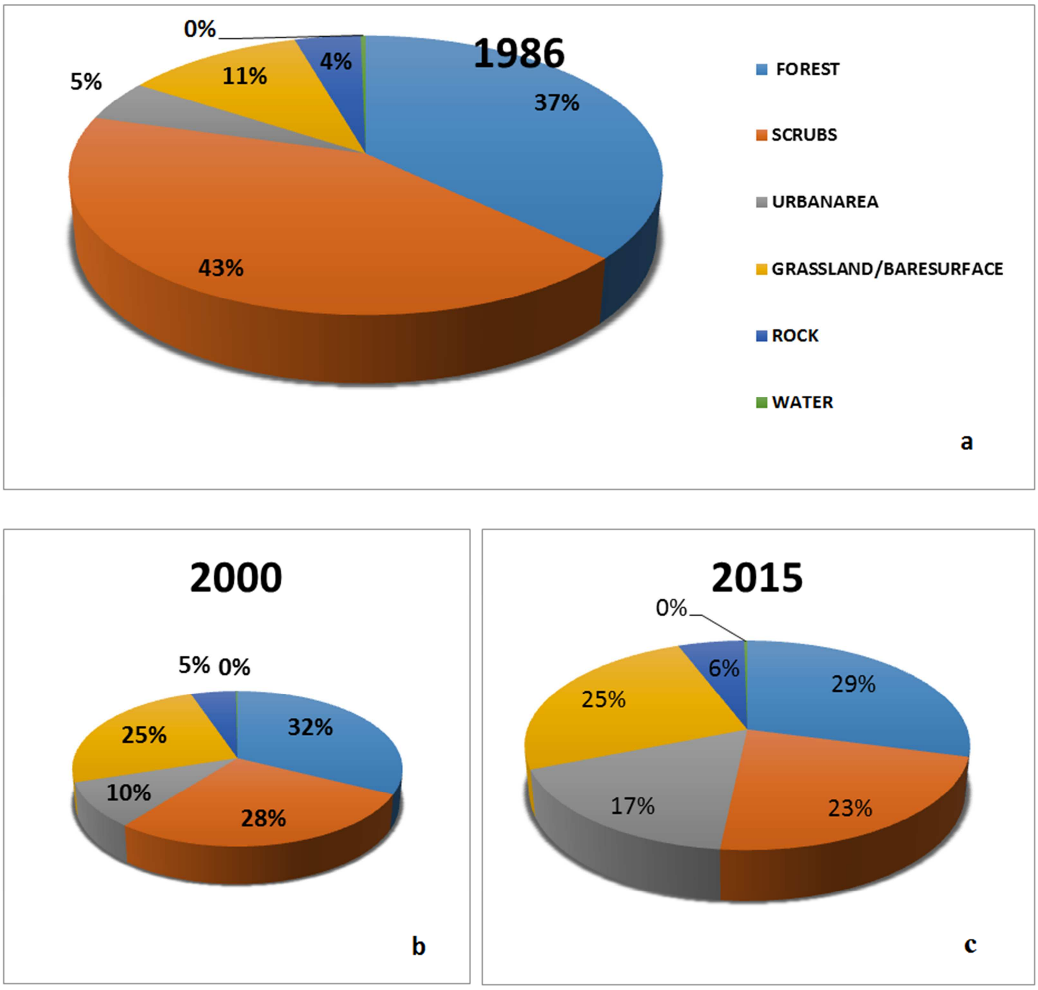

Figure 9. *Pie chart showing percentage of area covered by each class (a) 1986 (b) 2000 (c) 2015.*

7. Conclusions

This study has revealed that data acquired from remote sensing, integrated with GIS can play a vital role in understanding the nature and extent of urban growth dynamics, that have occurred over time. The analyses provide valuable consciousness into the magnitude and nature of changes that has occurred in Akure South from 1986 to 2015 and lays basis for further research to be conducted.

The dynamics of urban land cover growth pattern have been identified by analysing the multi-temporal satellite images of 1986, 2000 and 2015 in a GIS environment. The measureable indications of land use dynamics exposed the growth of built-up areas as a result of urban growth. Conversions of land from forests and scrubs to urban land represent the most noticeable land cover change which conform with [5]. Grassland, Bare surfaces and rocks were also renowned to have increased. This was attributed to clearing of land for development and construction purposes. In order to decrease the intense land use/ land cover change and opposing environmental impacts of urban expansion and increasing built up surfaces, the current growth pattern needs to be managed through effective land use planning and management. This would be gainful to reserve the forest and other vegetation types (especially agricultural lands) in the region and further decrease environmental decay in the form of soil erosion and pollution. It is hereby recommended that; more comprehensive and regular study should be carried out regularly to gradually study the rate and pattern of growth.

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