Forests and Forest Products Journal

RESEARCH ARTICLE

Geospatial Assessment of Akure Forest Reserve in Ondo State, Nigeria

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Abstract

Land Use Land Cover (LULC) changes is one of the significant factors that determines the interaction between humans and its environment in the tropics. In Nigeria, the effect of these anthropogenic activities has led to deforestation and consequent degradation. However, there is dearth of information on the dynamics of many forests cover in Southwestern Nigeria, especially in Akure Forest Reserve. Therefore, this study aimed at assessing the LULC change of Akure forest reserve. Landsat imageries (5 TM of 1984, 7 ETM+ of 2000, and 8 OLI/TIRs of 2016 and 2021were obtained and processed. The processed imageries were analyzed using supervised Maximum Likelihood Classification algorithm to determine LULC classes of Akure forest reserve. The LULC classification followed Anderson darling categorization. Five LULC classes were used: Dense Forest (DF), Less Dense Forest (LDF), Built-Up (BU), Bare Land (BL) and Water Bodies. Normalized difference Vegetation Index (NDVI) was used to determine the greenness of the reserve. Dense Forest has drastically reduced from 82.6% observed in 1984 to 26.41% in 2021, indicating high level of forest deforestation and degradation, while an upsurge was observed in LDF from 1984 (14.19%) to (55.03%) in year 2021. Changes in BU fluctuated between 0.51% in 1984 and 3.16% in 2021. The highest (0.4) and lowest (0.3) NDVI were recorded in 2016 and 2000. Dense forest cover in Akure Forest Reserve has been converted to agricultural activities. Therefore, there is need for conservation of the forest resources to preclude depletion.

Keywords: Forest cover, Image classification, Land use, Akure Forest Reserve

Cite this article as: *Akintunde-Alo, D.A. and Komolafe, O.O. (2022). Geospatial Assessment of Akure Forest Reserve in Ondo State, Nigeria. Forests and Forest products Journal, 15: 01-13.*

INTRODUCTION

Forests are vital renewable natural resources that play an important part in environment preservation which also make available a safe anchorage for diverse lifeforms (Singh *et al*., 2016). Forest is a vegetal community with a tree canopy covering over 10% (0.5 hectares) of the land area (FA0 2020; Singh *et al.,* 2006). In Nigeria, natural forest occupied 349,278 km^2, accounting for nearly 35% of the land mass of the country of 997,936 km^2 (Nweze, 2003). Forest cover of 14.9 million hectares in 1960, drastically reduced with a net loss of 4.8 million hectares between 1960 to 1980 and even reduced more between 1990 to 1996, reducing to 9.5 million hectares (Gbiri and Adeoye 2019). According to Joshi *et al.* (2016), Land use land cover (LULC) process deals with the examination of the disparity in properties of the physical land surface of an area, as it changes from one LULC with the way the biological and physical features of the land are being used (Turner *et al*., 1995). It was asserted by Alo *et al.* (2020) that formulating policies and decision-making is by understanding the forest cover dynamics. Diverse land cover changes pattern is produced in a highly dynamic manner by distinct scales (Kpienbaareh *et al*., 2022).However, interaction between LULC and Climate change is a result of various human activities (Mahmood *et al*. 2010), the LULC induces changes in climate due to various decisions taken by a man in meeting various needs and aspirations (Akintuyi, *et al*., 2021). The use of Geographical Information Systems (GIS) and Remote Sensing (RS) for LULC assessment has shown to be tremendously promising over time (Walker *et al.,* 2021) as the RS technology has evolved into a critical tool for stakeholders to assess and anticipate LULC as they extend over time. Advances in RS technologies are helping developing cities with limited resources to significantly improve their environmental resource monitoring as reported by (Aliyu and Botai, 2018). Sustainable forest resource management has long been a priority due to its potential impact on biological variety and relevance in maintaining global ecological functioning. This sustainability can also be achieved by consistent examination of changes in LULC changes assessment for potential adjustment or development (Lambin *et al*, 2001). Land has been used for several purposes such as construction and agricultural purposes (Shiferaw and Singh 2011). Inadequate documentation of this LULC of many forests has resulted in poor planning and management decision. The rate of forest cover lost is at an alarming rate which directly affects regional climate (Pielke *et al*, 2011) and global warming (Lambin *et al*, 2003). Therefore, this study focused on the dynamic changes in Akure forest reserve between 1984 to 2021 and propose effective forest management approach for the reserve.

METHODOLOGY

Study Area

Akure forest reserve is geographically situated in a humid rainforest zone of Akure south local government area of Ondo State, Nigeria. . It is located between the latitudes of 7°11'40'' - 7°21'60''N and the longitudes of 5°00'00'' - 5°04'80'' (Figure 1). It was gazetted in 1936 with a land area of 66km^2. The forest reserve is bounded by Osun State in the northeast. Five Local government areas in Ondo State shares boundary with the forest, which includes: Oke-Igbo, Ifedore, Akure South, Ile-Oluji, Idanre and Ondo East. The forest is bordered by a river on one side. Mean daily temperatures range from 21°C to 29°C, and the annual rainfall averages 2000mm in the south and 1500mm in the north, with a relative humidity of 80-85% (Gbiri and Adeoye, 2019).

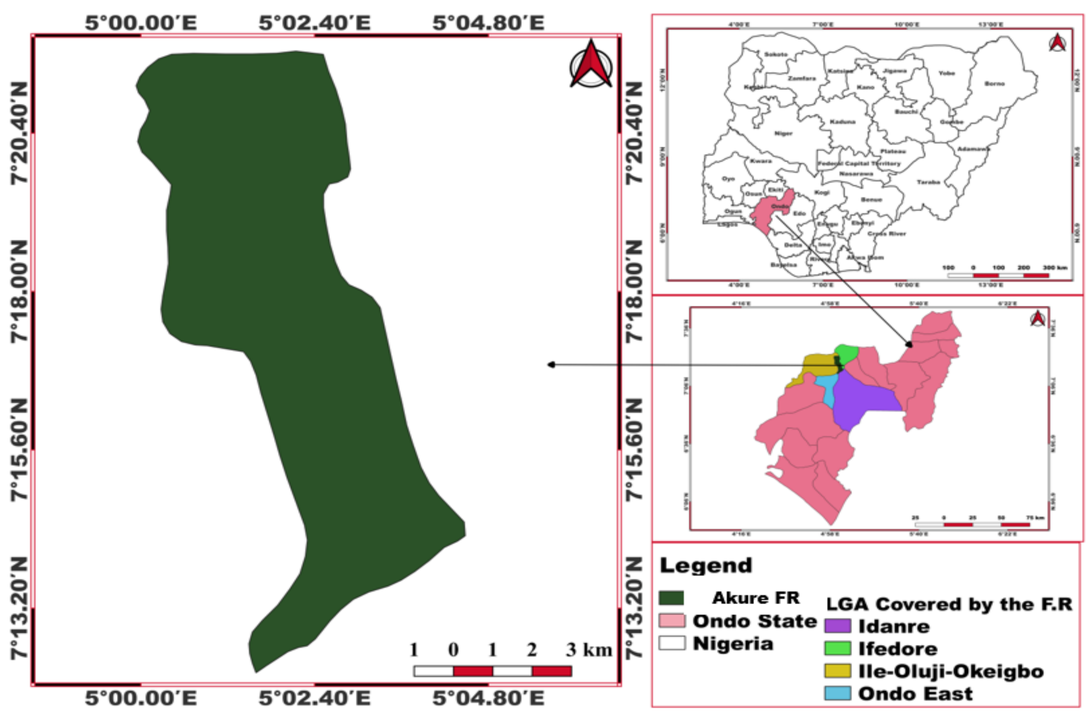


Figure 1: Akure Forest Reserve

Data Collection

The Landsat satellite imageries of 1984, 2000, 2016 and 2021 were obtained from United States Geological Survey website (www.earthexplorer.usgs.gov). The dates of the images selected were based on the availability of cloud free scenes. A threshold of 2% maximum cloud cover was used to select images for the respective years. The summary of the Landsat data downloaded is presented below in Table 1

Table 1: Summary details of the Satellite Imagery acquired

Satellites	Month/Year	Sensor Identify	Path/Row	Spatial Resolution
Landsat 5	12/1984	T/M	190/55	30m
Landsat 7	12/2000	ETM	190/55	30m
Landsat 8	12/2016	OLI/TIR	190/55	30m
Landsat 8	12/2021	OLI/TIR	190/55	30m

Where: (TM, ETM and OLI/TIR) are 'Thematic Mapper'; 'Enhanced Thematic Mapper; 'Operational Land Imager/Thermal Infrared Radiation'.

Methods of Data Analysis

The data acquired were analysed using Quantum GIS (QGIS) 3.24.1 software and ArcGis 10.8 software. Image masking was carried out on the imageries of the year 2000 and 2010 respectively on QGIS using the fill no data tool. The classification for this study uses Anderson's (1976) image classification scheme of land cover techniques which classifies entire pixel of the image or themes as shown in Table 2.

Table 2: Anderson *et al.* (1976) image classification categorization

LULC Classes	**Description**
Dense Forest	Mixed forest
Less Dense Forest	Agricultural land, Nurseries
Built Up	Residential, Industrial area, Commercial areas and transportation
Bare Land	Barely exposed rock, sandy areas, transitional area and open land
Water Bodies	Streams, Lakes, Dam, Pool and Reservoir

In classifying the imageries, the image was exported into the ARCGIS 10.8 using the add data tools. The bans that described the vegetation phenoogy for each Landsat images were used. Therefore, Landsat TM and ETM band combination of 2 (green band), 3 (Red band) and 4 (Near Infrared band) were used while for Landsat OLI/TIRS imagery, bands combination of 3 (green band), 4 (Red band) and 5 (Near Infrared band) was used in applying false colour composite (FCC) to select the region of interest for the land cover category. The three bands selected for TM, ETM and OLI/TIRS are bands combination that will allow vegetation (shades of red) to be readily detected in the image, soils (dark or light brown), water (dark-bluish or cyan) and urban areas (cyan blue, yellow or grey). For each class, training samples of 30 were randomly picked making total of 150 training samples. The signature file was created and the maximum likelihood classification (MLC) method of the supervised algorithm was used in assigning pixel to the class with the highest likelihood by a normal distribution from the training sample.

Change Detention Analysis

Change detention examination was carried out to determine the rate of changes. The changes between 1984 to 2000, 1984 to 2016, 1884 to 2021, 2000 to 2016, 2000 to 2021 and 2016 to 2021 were determined for the study area. The percentage change for each year and the rate of change between the years were all calculated using the formula below.

$\Delta = Y_2 - Y_1$

Average rate of change was computed using this formula $= \frac{Y_2 - Y_1}{T_2 - T_1}$

$\%\Delta/\text{year} = \frac{Y_2 - Y_1}{Y_1} \times 100$

Where Δ represents change; Y_2 and Y_1 are the area sizes in the initial year T_1 and final year T_2 respectively

Normalize Difference Vegetation Index (NDVI)
NDVI was used in determining the concentration of the greenness of the study area. The range value of NDVI ranges between +1 and -1. NDVI higher value refers to healthy and dense vegetation while the lower value shows scant vegetation. NDVI was computed following Rouse *et al.*1974

$$(\text{NDVI}) = \frac{NIR - Red}{NIR + Red}$$

Accuracy Assessment

To determine the quality of the image analysis from the remotely sensed data. Accuracy assessment was carried out to determine if the pixel were rightly sampled into the correct land cover classes. For each class, 50 random points was selected making total of 200 points for the classified image for each year. Google earth pro using historical imagery data of 1984, 2000, 2016 and 2021 was used as a reference data to verify the accuracy of the classification carried out. The accuracy metrics such as overall, user's, producer's accuracy and kappa coefficient for each year classification was computed using the formula below

$$\text{Users Accuracy} = \frac{\text{Total Number of correctly Classified Pixels in each category}}{\text{Total Number of Classified Pixels in that category (Row Total)}} \times 100$$

$$\text{Producer Accuracy} = \frac{\text{Total Number of correctly Classified Pixels}}{\text{Total Number of Reference Pixels in that Category}} \times 100$$

$$\text{Overall Accuracy} = \frac{\text{Total Number of correctly Classified Pixels (Diagonal)}}{\text{Total Number of Reference Pixels}} \times 100$$

$$\text{Kappa Coefficient (T)} = \frac{(TS \times TCS) - \sum(\text{Column Total} \times \text{Row Total})}{TS^2 - \sum(\text{Column Total} \times \text{Row Total})} \times 100$$

RESULTS

The results of the change analyses are presented in Figures 2 to 5. The Figures respectively show the pattern of LULC of 1984, 2000, 2016 and 2021 for the study area. The maps showed that vegetation cover of the study area in 1984 was relatively higher (Dense Forest 54.51 km^2) than year 2000 (Dense Forest 31.53 km^2). The forest loss continued till 2016 when dense forest reduced to 26.2 km^2 and then to 17.4 km^2 in 2021. The entire study area covered a land area of approximately 66 km^2. The dense forest was assigned using deep dark green, less dense forest was assigned using light green while built-ups, bare land and water bodies were assigned using red, light orange and blue colours respectively. Table 3 shows the area and the percentages of all the LULC of the forest reserve for the year assessed. In 1984, the area occupied by dense forest was 82.6% while the less dense forest accounted for 14.9% of the forest land. The built-ups and bare land in 1984 were 0.51% and 2.66% respectively. However, there was a reduction in the area occupied by the dense forest from 82.6% observed in the year 1984 to 47.8% in the year 2000, this accounts for about 34.8% of the dense forest cover loss between the period of sixteen (16) years. Between the period of 5 years, 5.6% of the forest cover was lost as the percentage of dense forest in 2016 and 2021 accounted for 40.6% and 26.4% respectively. This was a result of an increment observed in the percentage of less dense forests from 1984 to 2021. The area covered by the built-up keeps increasing. The percentage of built-ups in 1984, 2000, 2016 and 2021 was 0.5%, 0.72%, 1.23% and 3.2% The bare land also increased from 1986 to 2000 but decreased from 36.6% in 2000 to 6.5% in 2016 while a surge increase was observed in the year 2016 to 2021 as the percentage of bare land was 13.9%. In the year 2016 and 2021 water bodies were found in the imagery and the classification indicated that the water bodies covered an area of 1.47 % and 1.5% in the year 2016 and 2021. A validation check using Google Earth historical imagery ascertained the presence of the water bodies in the two imageries which was not found in 1984 and 2000 classification.

Table 3: Land Cover Classification for the Study Area (1984, 2000, 2016 and 2021)

	1984		2000		2016		2021	
LULC	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Built-Ups	0.33	0.51	0.48	0.72	0.81	1.23	2.08	3.16
Bare Land	1.76	2.66	24.13	36.62	4.28	6.50	9.16	13.90
Less Dense Forest	9.36	14.19	9.77	14.83	33.05	50.17	36.25	55.03
Dense Forest	54.51	82.64	31.53	47.83	26.77	40.64	17.40	26.41
Water bodies	N.A	N.A	N.A	N.A	0.97	1.47	0.99	1.50

Where: N.A means not available

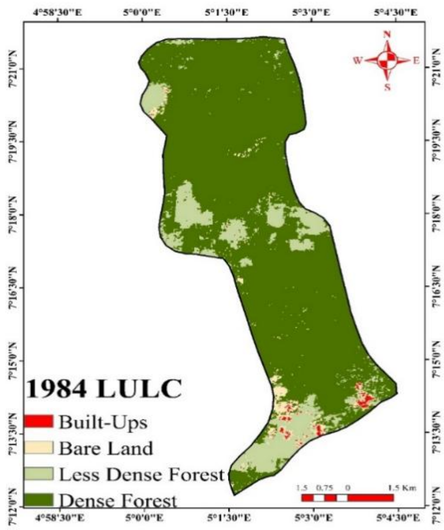


Figure 2: LULCC for 1984

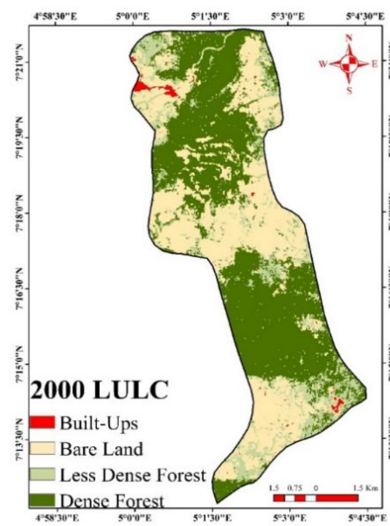


Figure 3: LULCC for 2000

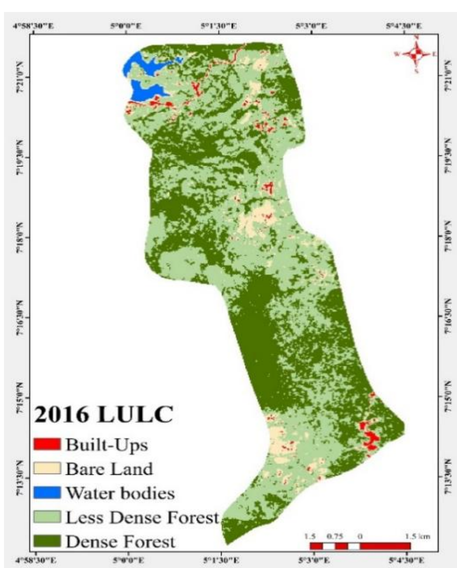


Figure 4: LULCC for 2016

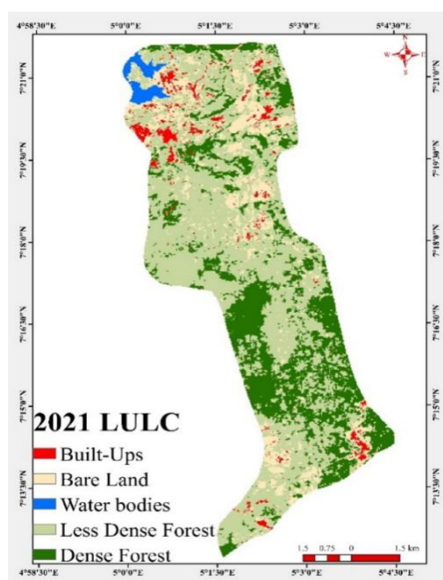
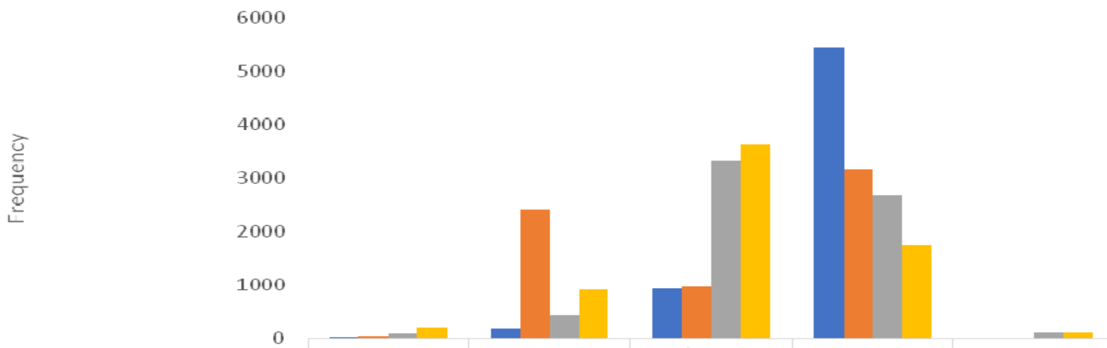


Figure 5: LULCC for 2021

Figure 6 presents the quantity of land use categories for 1984, 2000, 2016 and 2021 in distinct multiple charts. It is fundamental to compare between green cover areas and areas subjected to changes in per hectare proportions. Dense forest decreases as the year increases. It decreased with a net loss of 2298 hectares between 1984 to 2000. A further decrease was observed between the year 2000 to 2016 accounting for a dense forest cover loss of about 476 hectares within 16 years. A surged decrease was observed between the year 2016 and the year 2021, this amount to about 937 hectares of loss in the area covered by the dense forest within 5 years. However, the built-up increases throughout the year assessed for this study with an erratic increment observed in the year 2016 to 2021 with a positive change value of 127 hectares while water bodies in the year 2016 and 2021 accounted for 97 hectares and 99 hectares.



	Built-Ups	Bare Land	Less Dense Forest	Dense Forest	Water Bodies
Area Hectare (1984)	33	176	936	5451	0
Area Hectare (2000)	48	2413	977	3153	0
Area Hectare (2016)	81	428	3305	2677	97
Area Hectare (2021)	208	916	3625	1740	99

Figure 6: Land use categories of 1984, 2000, 2016 and 2021in hectares using distinct multiple charts

Land Use Land Cover Change trend

Table 4 shows the result of the change detection analysis for the study area. The trend of change from 1984 to 2000 shows that the dense forest had a negative change with a decrease of -1.44km^2/year. Less dense forest had an increase of 0.03 km^2/year, while the built-up and bare land had an increase of 0.01 km^2/year and 1.40 km^2/year respectively as shown in Figure 7. The trend of change from 1984 to 2016, the dense forest had a negative change with a decrease of -0.87 km^2/year while less dense forest, bare land and built-ups had an increase of 0.74 km2, 0.08 km^2/year and 0.02 km^2/year respectively (Figure 8). The trend of change from 1984 to 2021 shows that the dense forest had a negative change with a decrease of -1.00 km^2/year while the less dense forest, bare land and built-ups had an increase of 0.73 km^2/year, 0.20 km^2/year and 0.05 km2/year respectively (Figure 9). The land cover change trend observed from 2000 to 2016 indicates that the dense forest and the bare land decreased with a negative value of -0.30 km^2/year and -1.24 km^2/year while less dense, built-up and water bodies increase by 1.46 km^2/year, 0.02 km^2/year and 0.06 km2/year respectively (Figure 10). Figure 11 shows the trend of change for the year 2000 to 2021. It was observed that the dense forest and bare land had a negative value of -0.67 km^2/year and -0.71 km^2/year while less dense forest, built-up and water bodies increased by 1.26 km^2/year, 0.08 km^2/year and 0.05 km^2/year. The built-ups, bare land and water bodies increase by 0.25 km^2, 0.98 km^2/year and 0.00 km^2/year respectively in the year 2016 to 2021(Figure 12).

Normalized Difference Vegetation Index (NDVI).

Figure 13 to 16 shows the NDVI for all the years examined in this study. The NDVI has been frequently utilized to examine the relationship between spectral variability and vegetation growth rate changes which has been generally accepted as a standardised way of measuring healthy vegetation for precision farming and use in measuring biomass. The highest NDVI was observed in the year 2016 followed by 2021 with a value of 0.409 and 0.401respectively (Figures 15 and 16). The lowest NDVI value was observed in the year 2000 (Figure 14)

Table 4: Change detection analysis for the study area

LULC	Δ 2000-1984	Rate of Δ 2000-1984	Δ 2016 - 1984	Rate of Δ 2016 - 1984	Δ 2021 - 1984	Rate of Δ 2021-1984	Δ 2016-2000	Rate of Δ 2016-2000	Δ 2021-2000	Rate of Δ 2021 - 2000	Δ 2021 - 2016	Rate of Δ 2021 - 2016
Built-Ups	0.15	0.01	0.48	0.02	1.75	0.05	0.33	0.02	1.60	0.08	1.27	0.25
Bare Land	22.37	1.40	2.52	0.08	7.40	0.20	-19.85	-1.24	-14.97	-0.71	4.88	0.98
Less Dense Forest	0.41	0.03	23.69	0.74	26.89	0.73	23.28	1.46	26.48	1.26	3.20	0.64
Dense Forest	-22.98	-1.44	-27.74	-0.87	-37.11	-1.00	-4.76	-0.30	-14.13	-0.67	-9.37	-1.87
Water Bodies	0.00	0.00	0.97	0.03	0.99	0.03	0.97	0.06	0.99	0.05	0.02	0.00

Where LULC= Land use land cover; Δ = Change in (Km^2)

Table 5: Forest cover change and percentage rate of change per year in Akure Forest Reserve

LULC	Δ 2000-1984	2000-1984 %Δ/year.	Δ 2016 - 1984	2016 - 1984 %Δ/year.	Δ 2021 - 1984	2021 - 1984 %Δ/year.	Δ 2016-2000	2016 - 2000 %Δ/year.	Δ 2021-2000	2021 - 2000 %Δ/year.	Δ 2021 - 2016	2021 - 2016 %Δ/year.
Built-Ups	0.15	45.45	0.48	145.45	1.75	530	0.33	68.75	1.60	333.33	1.27	156.79
Bare Land	22.37	1271.02	2.52	143.18	7.40	420	-19.85	-82.26	-14.97	-62.04	4.88	114.02
Less Dense Forest	0.41	4.38	23.69	253.10	26.89	287.29	23.28	238.28	26.48	271.03	3.20	9.68
Dense Forest	-22.98	-42.16	-27.74	-50.89	-37.11	-68.08	-4.76	-15.09	-14.13	-44.81	-9.37	-35
Water bodies	-	-	0.97	-	0.99	-	0.97	-	0.99	-	0.02	2.06

Where Δ = change in year ($Y_2 - Y_1$), %Δ/year. = Percentage change/Year $\left(\frac{Y_2 - Y_1}{Y_1} \times 100\right)$ (Km^2)

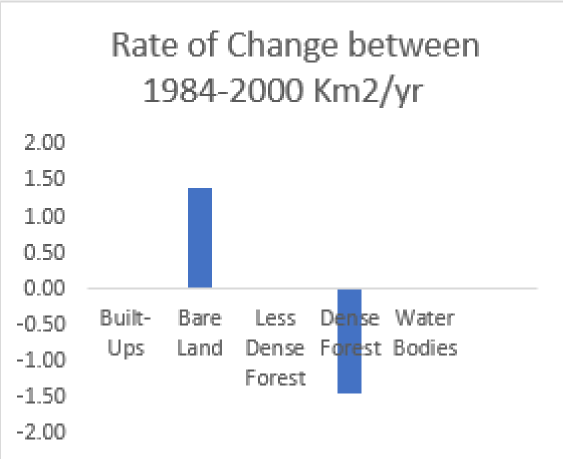


Figure 7: Land Cover trend between 1984 and 2000

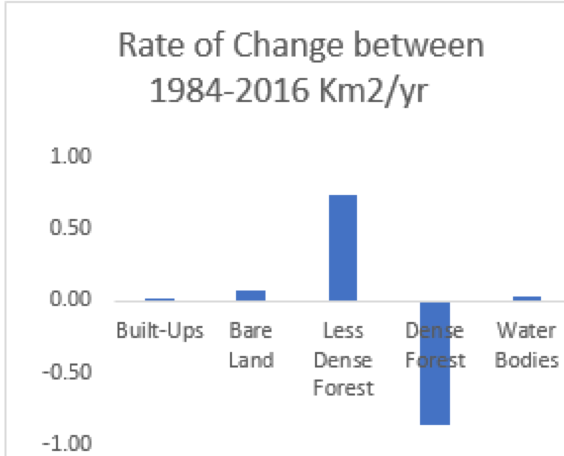


Figure 8: Land cover trend between 1984 and 2016

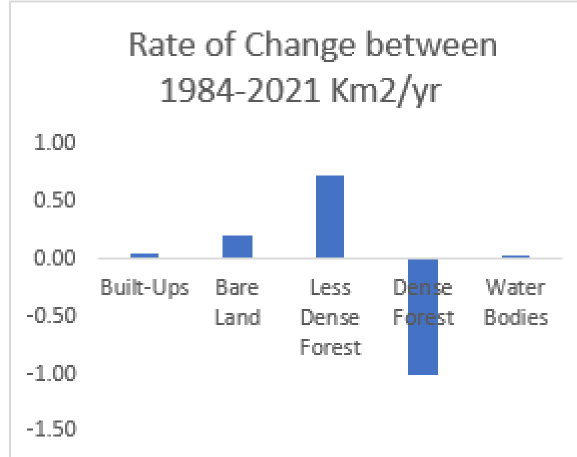


Figure 9: Land cover trend between 1984 and 2021

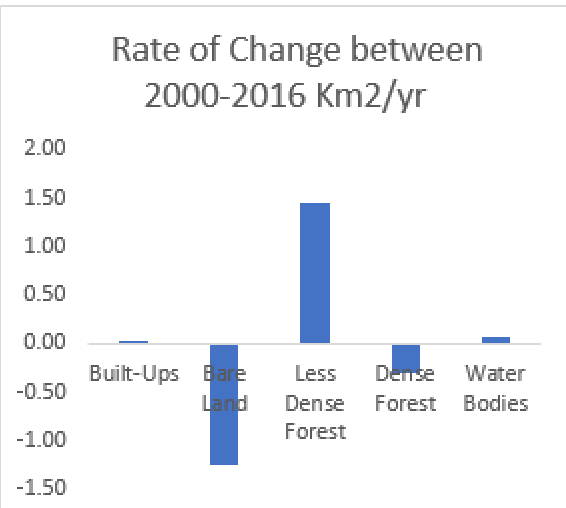


Figure 10: Land cover trend between 2000 and 2016

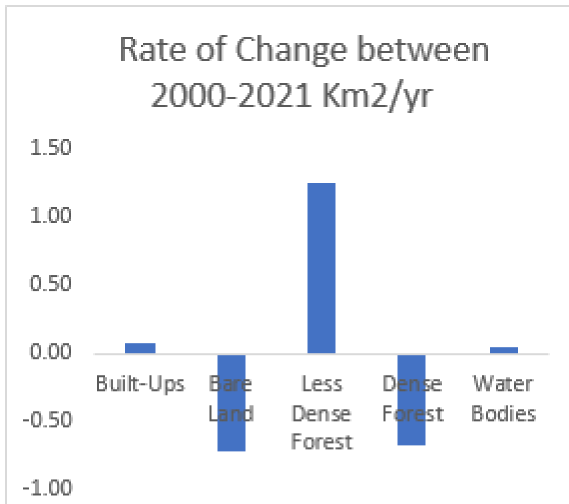


Figure 11: Land cover trend between 2000 and 2021

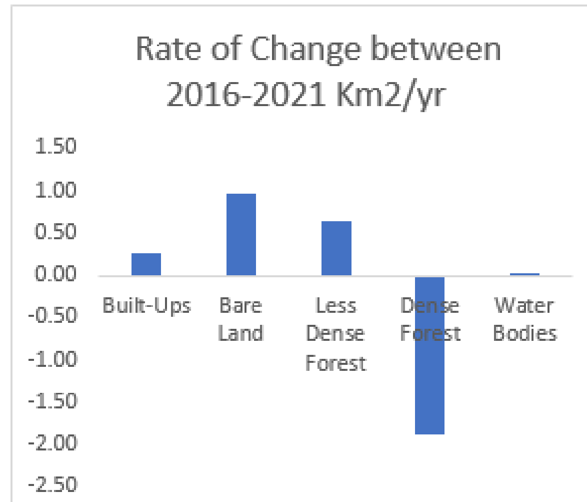


Figure 12: Land cover trend between 2016 and 2021

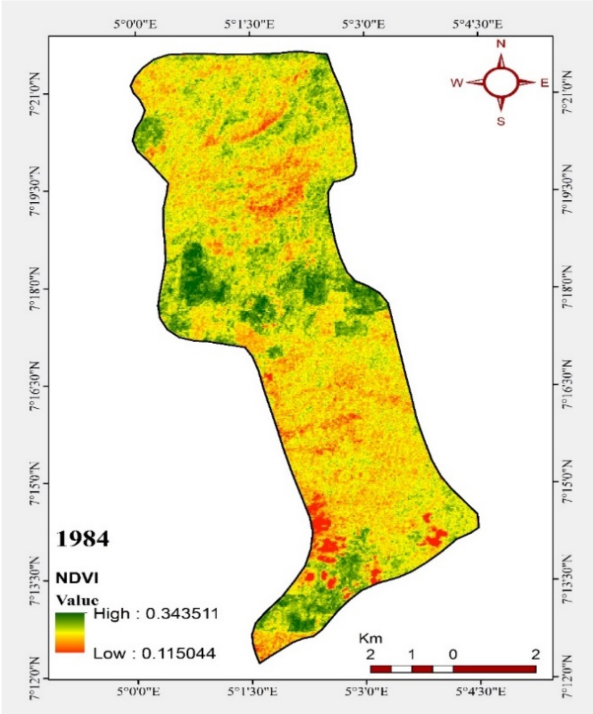


Figure 13: NDVI for 1984

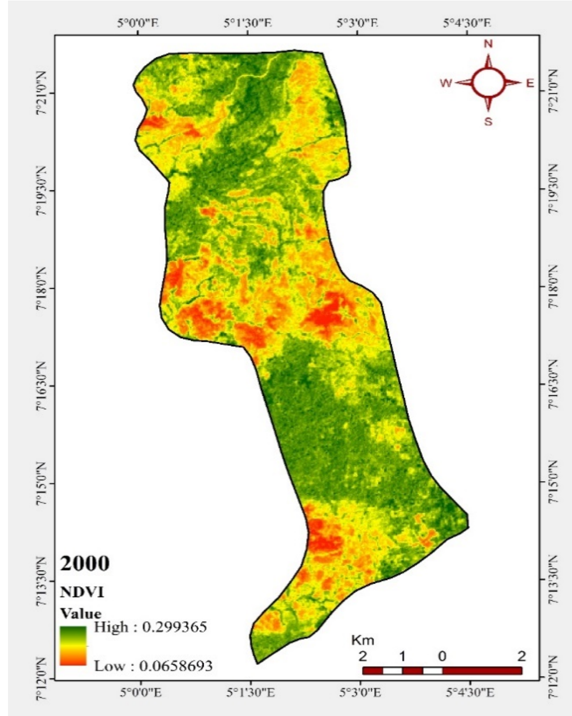


Figure 14: NDVI for 2000

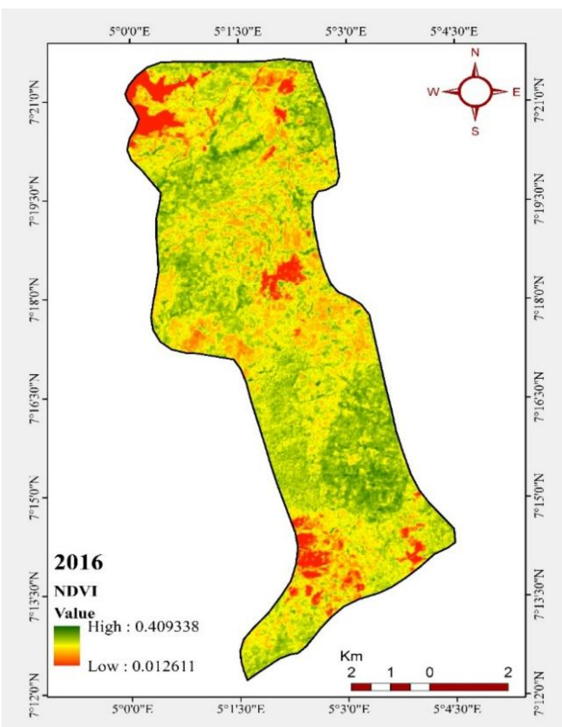


Figure 15: NDVI for 2016

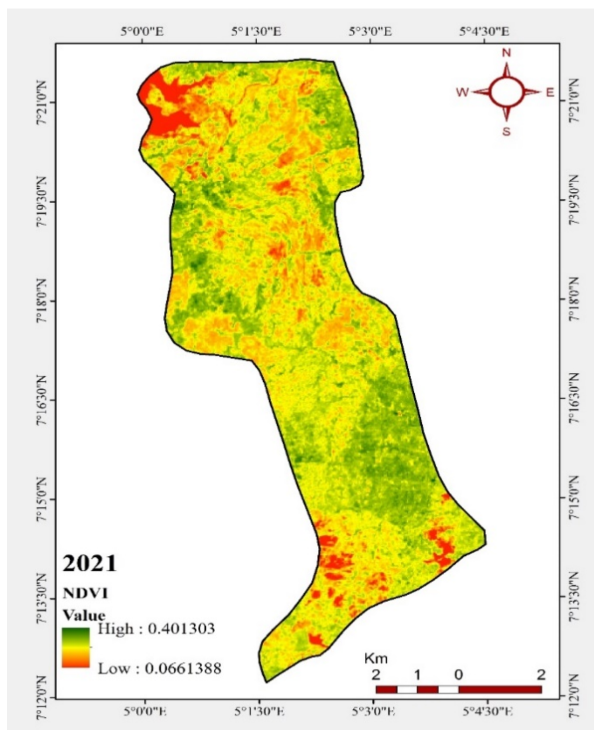


Figure 16: NDVI for 2021

Accuracy Assessment of the Images

The error matrix is summarized in table 6. The error matrix was carried out by linking the land cover classification result to geospatial data that are assumed to be true. The (user's, producer and overall) accuracy with kappa statistic (k) for the year examined was computed as shown in table 6 below. The overall accuracy for year 1984, 2000, 2016 and 2021 were 92.1%, 89.3%, 85.9% and 83% respectively. The kappa statistic for year 1984, 2000, 2016 and 2021 was 89 %, 86%, 82% and 79%.

Table 6: 1984, 2000, 2016 and 2021 error matrix

	1984			2000			2016			2021		
LULC	UA	PA	OA	UA	PA	OA	UA	PA	OA	UA	PA	OA
Dense Forest	95	100		95	91		100	91		100	79	
Less Dense Forest	100	95		100	83		95	76		93	74	
Built-Ups	71	100	92	75	100	89	60	100	86	55	100	83
Bare Land	100	79		84	89		80	76		80	60	
Water Bodies	N.A	N.A		N.A	N.A		100	100		100	100	
Kappa statistic	89			86			82			79		

UA: User Accuracy, PA: Producer Accuracy, OA: Overall Accuracy, N.A: Not Available

DISCUSSION

Knowing the key consequences of unregulated use of the forest with a means of evaluating this high loss of forest cover, biodiversity reduction, decline of environmental quality and wetland destruction is by examining and understanding LULC. Analyzing land use has been extensively researched with the aid of acquiring satellite imagery data, processed and achieved greatly either using supervised or unsupervised classification method (Alo *et al*., 2020; Gbiri and Adeoye, 2019). For this study, a supervised method of image classification was adopted and used for analyzing changes in the LULC. The depletion and disappearance of the forest cover and reduction in the floristic components of the forest reserves are as a result of the alteration of the forest to other land use. This also agrees with the findings of Alo *et al*. (2020) that most forest reserves in this country experience a high rate of anthropogenic disturbances due to the increase in the human population. Increasing rate of Build-ups in the forest is a pointer to unregulated entry of people into the forest reserve. The reduction in dense forest from 1984 to 2021 in this study area was in agreement with Gbiri and Adeoye (2019) findings in Akure forest reserve where they observed that the undisturbed forest in 1986 was higher as compared to year 2002.

The rapid increase in less dense forests and continuous decrease in the dense forest is a pointer to the continuous movement of people into the forest for diverse agricultural activities. This was also in concord with Olayode (2019) findings in Osho Forest reserve, indicating a gradual decline in the natural forested area into farmland and plantation. Ojo *et al*. (2019) findings also noted that classification of Landsat imagery of year 2018 shows that, light vegetation occupies larger percentage of the land area. Chukwuka *et al*. (2020) in geospatial modelling of forest assessment in Ikere also reported that forested area decreases annually.

The increase in built-up area from 1984 to 2021 is inimical to the forest reserve. Alo *et al*.

(2020) in the dynamics of LULCC in Enugu State also observed an increase in the area occupied with built-up across the year examined. The presence of water bodies in the year 2016 and 2021 reduce dense forest which was not found in imageries of the year 1984 and 2000. However, to ascertained the reason for lack of water bodies in year 1984 and 2000 classification, a validation check was carried out by backdating Google Earth historical imagery and the possibility of canopy closure might have contributed to the result obtained for the two years. This was explained by the appearance of water body observed in 2008 and 2021 when the forest cover reduced and exposed the forest floor. The presence of water bodies observed in the two imageries (2016 and 2021) was in concord with Gbiri and Adeoye (2019) findings that the presence of water bodies was a result of dredged Owena River for dam construction.

The Normalize Difference Vegetation Index (NDVI) was used in comparing greenness levels of the spatial change patterns derived from the Landsat. The NDVI of 1984 images was higher compared to what was observed in the year 2000. However, the result obtained for this was in agreement with Singh *et al*., (2016) findings, where they observed a significant decrease in NDVI values across the year examined. Veritable evidence from this study highlighted the significant reduction in the area occupied by forests due to the role of humans in various LULC types particularly agricultural land use and built-up areas at the expense of forest land.

CONCLUSION AND RECOMMENDATIONS

Landsat images were used to successfully assess forest vegetation features and the pattern of spatial and temporal changes in the Akure forest reserve between the year 1984 to 2021. According to the result, the forest had lost almost all its vegetative cover within 37 years. The changing forests turning to less dense forests such as agricultural land, cocoa plantation and farmland is highly significant in the study area which will continue to increase if the rate of anthropogenic disturbances in the forest is not checked. The need for constant monitoring of the forest reserves should be put in place, this could be greatly achieved through the use of higher resolution satellite imagery and using Unmanned Aerial Vehicle to detect any unpermitted encroachment and disturbance to the ecosystems. In addition, the need for proper planning of the land use of this forest reserve must be of utmost priority by the government to checkmate the rate of forest loss by reviewing law and policy for proper monitoring of the forest. This study recommends quick intervention from authorities in charge to take their responsibility in addressing problems related to forest conversions and implementation of forest policy plans to provide quick resolutions to some of the daunting causes of forest conversion in the reserve.

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