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# ANALYSIS OF PATTERN AND EXTENT OF DEFORESTATION IN AKURE FOREST RESERVE, ONDO STATE, NIGERIA

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**Abstract**

Forest Reserves in Southwestern Nigeria have been threatened by urbanization and anthropogenic activities and the rate of deforestation is not known. This study examined the vegetation characteristics of Akure Forest Reserve using optical remote sensing data. It also assessed the changing pattern in the forest reserve between 1986 and 2017. Global Navigation Satellite System (GNSS) receiver was used to capture the location of the prominent settlements that surrounded the Forest Reserve in order to evaluate their effects on the forest. Landsat TM 1986, Landsat ETM+ 2002 and Landsat OLI_TIRS 2017 with 30m resolution were classified to assess the spatio-temporal changing pattern of the forest reserve. The results showed different composition of vegetation, which include undisturbed forest, secondary regrowth and farmlands. The study further revealed that in 1986, 2002 and 2017, undisturbed forest constituted 63.3%, 32.4% and 32.1% of the entire land area respectively, while secondary regrowth occupied 8.3% in 1986, 9.5% in 2002 and 15.6% in 2017. The farmlands had erratic growth between 1986 and 2017. It was 16.9% in 1986, 22.1% in 2002 and 17.5% in 2017. The bare ground exhibited inconsistency in the coverage. In 1986 the areal extent was 11.5%, when it increased to 36% in 2002 and decreased to 31.9% in 2017. In conclusion, the study revealed the extent of forest depletion at Akure Forest Reserve and it is therefore important that the residents, the government and the researchers show major concern about some of the critical factors to human beings that are responsible for forest depletion.

**Keywords:** Landsat, deforestation, image classification, Akure Forest Reserve, land use

## INTRODUCTION

Establishment of forests began in Nigeria in 1897 with the creation of Woods and Forests for the Colony and Protectorates of Lagos, a year earlier, in 1896 (Schoneveld, 2014). The first forest reserve was created in 1899 under the colonial master, which arose issues of land tenure (Adeyoju, 1975). The Colonial government's initial interest in creating protected areas was to ensure a continuous supply of timbers and other forest resources to the indigenous industries. In the 1900s, the first ever protected area was Olokemeji Reserve and it commenced near Ibadan under the Western State then in 1956. Having seen the benefits derived from the forest, this metamorphosed to the high demand for the establishment of more protected areas (Onokerhoraye, 1985). Spenceley (2015) gave an estimation of 200,000 protected areas in the world, which covered around 15% of the world's land and around 2.8% of the oceans and Nigeria has 960 constituted protected areas which covered a total land area of 10,752,702 hectares representing about 10% of the total land area of 997,936 hectares (Oyebo, 2006). These Protected Areas were subdivided into six categories. It comprised of 1 Strict Nature Reserve, 1 Community forest, 23 Game Reserves, 925 Forest Reserves, 8 National Parks, and 2 Wild Life Sanctuary (FOSA, 2000).

Forests are essential renewable natural resources that have a significant role in preserving environment and serving as home for all forms of life (Singh et al., 2002; Boyd and Danson, 2005). The Food and Agriculture Organization (FAO) in 1989 pronounced it as home to 300 million people around the world and also contributed to 1.2 billion people living in extreme poverty with women accounting for 70%. FAO (2001) and Singh et al. (2006) described forest as a plant community where the predominant of trees and other woody vegetation with a tree canopy covered more than 10% and area of more than 0.5 ha.

The forests of today have evolved over millions of years. It had been profoundly shaped drastically by swings between warm and cold climates all over the world FAO (2012). The news of last great ice age is ended about 10,000 years ago leaving forests on nearly 6 billion hectares, about 45 percent of the Earth's land area. During the last 10,000 years, cycles of changing climate and temperature had continued to influence the world's forests, while human activities had also increased (FAO, 2012). Fenning and Gershenzon (2002) reported that thirty percent of the Earth's land surface area (3.9 billion hectares) forest covers had been depleted from the original forest cover estimated to be six billion hectares while FAO (2010) put current forests cover at about 4 billion hectares, about 31 percent of the Earth's land surface; and over a period of 5,000 years, the cumulative loss of forest land worldwide is estimated at 1.8 billion hectares – an average net loss of 360,000 hectares per year (Williams, 2002). These patterns also applied to other developing countries in the tropics and sub-tropics. For instance, the East African region lost about 10% of its forest cover to deforestation between 1990 and 2000, with Uganda recording the highest rate (FAO, 2003). In the humid tropical rainforest region of Cameroon, about 200,000 hectares of forest was reported to be degraded annually due to high rate of exploitation (FAO, 2003). And always being an issue of disagreements that it was difficult to make a reliable estimate of the world total forest and local forests, since it depends on the different criteria used to define them then no accuracy measured or consensus in which forest to be measured currently.

In Nigeria, natural forest covered a total land area of 349,278 $km^2$ or approximately 35% of the country's total land mass of 997,936 $km^2$ (Nweze, 2002). But about 60% of the country's forests disappeared between 1850 and 1960 (Morakinyo, 1991). In 1980 alone, forest depleted from 14.9 million hectares to 10.1 million hectares and in 1990 to 1996, it further decreased geometrically to 9.5 million hectares (Federal Department of Forestry, 1997). On the average, it decreased at the rate of 0.4 million hectares per year but the rate of reforestation was put at 0.032 million hectares per year. The forest reserve has also been facing the same effect of this predicament from onset. In Ondo State, 107.36 $km^2$ of forest in Ore-Township has been converted to casual land (Adetayo, 2015). Donald (2004) worked on the rich tropical rainforests in many parts of the humid tropics, and the forest disappearing has been attributed to logging and agricultural expansion activities. Butler (2005) stated that Nigeria has the world's highest rate of deforestation of primary forests, with NEST (1991) documented that at least about (30,000 ha) of forest and natural vegetation were lost annually in Nigeria and this implied that Nigeria has lost 55.7% of its primary forest to logging, subsistence agriculture, collection of fuel wood and other agents between 2000 and 2005 (FAO, 2005). In an attempt to satisfy both local and international need for forest products and the continuous increase in rural population, forest resources exploitation in this ecosystem is carried out in uncontrolled and unsustainable manners (Onyekwelu et al., 2010). FAO (2005) listed Nigeria as one of the developing countries with very high rate of deforestation and this rate was estimated to be 3% which was not usually consistent. All other woodlands, apart from the constituted areas are regarded as free areas (Adekunle et al., 2013). Both constituted areas and non-constituted areas are almost exhausted for being leading producer of cocoa and timber respectively (Oke and Odebiyi, 2007). However, deforestation had been a major concern for the ministries, government, private individuals, Non-Governmental Organizations (NGOs) and researchers. In an attempt to curb indiscriminate felling of trees or general destruction of forests, Forest Reserves were gazetted across the State. Despite this, Forest reserves continued to shrink in size and area due to pressure mounted from growing populations. In this study satellite images (Landsat TM 1986, Landsat 2002 ETM+ and Landsat 2017 OLI_TIRS) of 30m resolution had been classified to forest vegetal characteristics of Akure Forest Reserve from optical remote sensors and spatial pattern changes were also assessed the in the forest reserve between 1986, 2002 and 2017.

Deforestation conceptual framework: concerning the deforestation in developing countries, an attempt is made to formulate an integrated theoretical framework of the deforestation and forest transition and sustainability theory among others (Yaoqi, 2000). The forecasts and policy suggestions to be presented are argued to be relevant. To analyze deforestation, it is necessary to understand its different causes and sources and adopt a standard for dealing with menace. An approach can be devised to guide the process of identification and analysis of deforestation. A decision point approach was adopted to facilitate this process as shown in (Fig. 1). The framework further

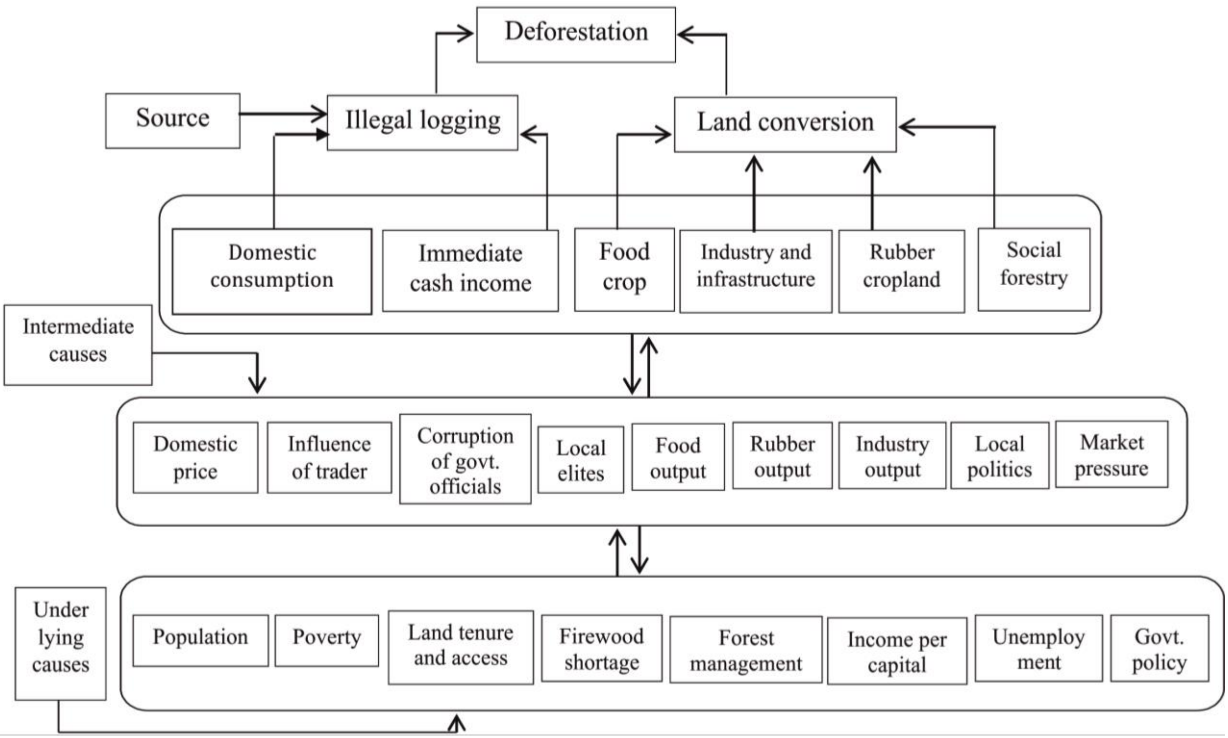


*Fig.1* Decision point approach for identification source and causes of deforestation

addresses the identification and classification of different sources and causes of deforestation. It made it necessary to link the analysis to a methodology for the estimation of the extent of potentials of deforestation. The first step was to apportion the deforestation leakage to the different baseline drivers and agents, as they may change with time and space. For example, if the baseline driver was deforestation, but there are two key baseline agents, subsistence farmers and commercial cattle ranchers, the extent to which each contributes to potential leakage may differ over the project lifetime (Louise et al., 2003). The study is therefore examining forest vegetation characteristics at Akure forest reserve from optical remote sensing, assessing the spatial changes in forest between 1986 and 2017, and compare the efficiency of optical remote sensing and normalized difference vegetation index. The factors mapped include land conversion and illegal logging which actually led to the extent of the total area at present status, what are the major anthropogenic activities involved, how much was the levels of encroachment and what was resuscitate steps towards the forest.

## STUDY AREA

Akure forest reserve is geographically located in a humid rainforest zone of Akure South Local government area of Ondo State, Nigeria (Fig. 2). It lies between latitudes$7^{o}16'$ and $7^{o}18'$ N of the Equator and longitudes $5^{o}$ $9'$ and $5^{o}11'$E of the Greenwich Meridian. It was constituted as a reserve in 1936 and the total land area covered is 69.93 $km^{2.}$ Politically, it lies in Ondo State in Southwestern Nigeria and shares border with Osun State in the Northeast, surrounded by five Local Government Areas in Ondo State namely: Ile Oluji, Oke-Igbo, Ifedore, Akure South, Idanre and Ondo East. Adetula (2002) estimated 11.73% (8.2 $km^2$) cleared for cocoa farming and other food crops, Fuwape et al. (2001) documented the *Gmelina arborea* covered (721.40 $m^3$ and *Nauclea diderrichii spp* (265.18 $m^3$) respectively, Oke (2012) worked on family *Sterculiaceae* including the species counted for 53% of the total tree canopies in the forest, Adejoba et al. (2014) identified hard species as *Strombosi apustulata*, *Celtismild breadi*, *Myrianthus arborea*, *or Khayasene galensis and Triplochitons cleroxylon*. Key informants interviewed according to the work of Owusu (2018) affirmed that the loss of vegetation in the city creates livability concerns relating to ecosystem functioning, temperature rise and air quality. He therefore recommended that decision makers should address three critical concerns of resilience, sustainability and livability. The relief pattern is low lying, elevation ranges from 216m to 504m and gently undulating in southern part while the northern part is hilly rock outcrops occurring at close intervals. The underlying rock is crystalline and gneiss. It is slightly neutral; pH of 6.7–7.3 and sandy-loam in nature. The dry season lasts from November to March while the wet season commences from April and ends in October with the highest rainfall records between July and August (Akinseye, 2010), Average daily temperature ranges between $21^{0}$C and $29^{0}$C almost throughout the year (Adejoba et al., 2014). The mean annual rainfall varies from 2000 mm in southern area to 1500 mm in northern area with relative humidity of 80–85% annually experienced in south-west (NiMET, 2016). Aponmu and Owena Yoruba speaking communities owned the forest, though, it also had minor settlements surrounding the forest. They include Ipogun, Kajola/ Aponmu, Kajola, Ago Petesi, Akika Camp, Owena Town, Ibutitan/Ilaro Camp, Elemo Igbara Oke Camp and Owena Water new Dam.

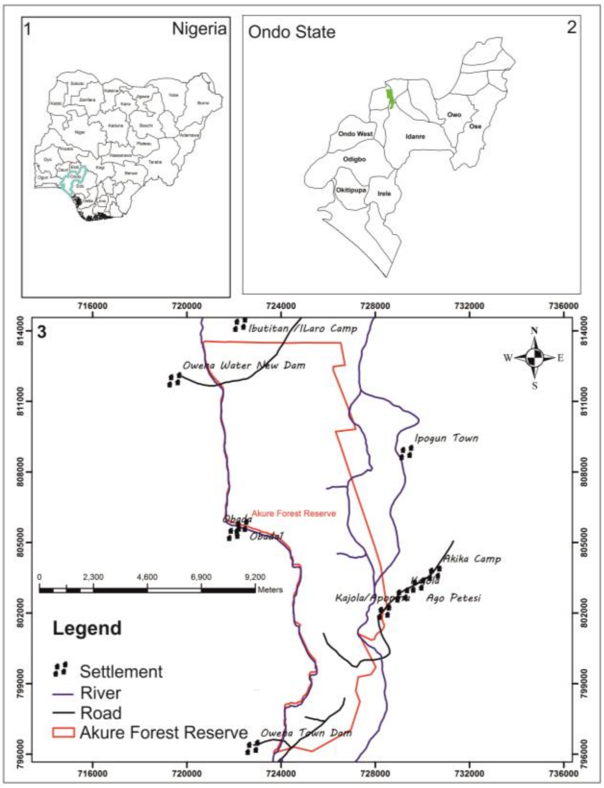


*Fig. 2* Overview of Akure Forest Reserve

## DATA

Spatial coordinates of prominent settlements in the Akure Forest Reserve (AFR) were captured as points with Garmin eTrex20 Global Positioning System (GPS) device. Topographic map (1:250,000) was sourced from the Office of Surveyor-General of the Federation (OSGOF), Abuja. The map was scanned through A0 scanner. The map was georeferenced with grid coordinates on the map through ArcGIS 10.3 and it was used to exact boundary of Akure forest reserve and other important features in the forest reserve such as, the road networks that are within the forest for accessibility was updated via open street map. The river network in the study area was extracted because the two major rivers flow through the forest forming the forest reserve boundary and the root means square error was 0.5 for the spatial accuracy. The survey plan (1:5000) was sourced from the Ministry of Natural Resources, Alagbaka, Akure, Ondo State. The plan was scanned using an A4 flatbed scanner. It was imported into the computer and georeferenced with grid coordinates on the survey plan using ArcGIS 10.3. Boundary was also extracted which was more accurate than the one from Topographical map and it was used for boundary extent and images subset as well. The existing topographical map and survey plan were referred as the base maps in the study. Landsat, a U.S developed series of platforms operated by Earth Observation Satellite Company (EOSAT) are the most common satellite systems for large area data acquisition. The satellites sensors offer broad area of coverage, and for instance Thematic Mapper (TM) sensor covers 165 x 180 km with temporal resolution of 16 days, six bands with spatial resolution of 30 m (blue, 0.45 to 0.52 µ m; green, 0.52 to 0.60 µm; red, 0.63 to 0.69 µm; near infrared, 0.76 to 0.90, µm; mid infrared, 1.55 to 1.75 µm; and mid infrared, 2.08 to 2.35 µm) and one band with spatial resolution of 120m (thermal infrared, 10.4 12.5 µm). Landsat Enhanced Thematic Mapper Plus (ETM+) sensor covers 170-183 km with temporal resolution of 16 days, bands 1-5 and 7 contain spatial resolution of 30meter. The resolution for Band 8 (panchromatic) is 15 meters (blue, 0.45-0.52 µm; green, 0.52-0.60 µm; red, 0.63-0.69 µm; near infrared, 0.7-0.90, µm; shortwave infrared (SWIR) (1) 1.55-1.75 µm; Thermal, 10.40-12.50 µm; Shortwave Infrared (SWIR) (2) 2.09-2.35 µm and Panchromatic band has a spatial resolution of 15 meter (0.52-0.90 µm). Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) sensor covers 170 x 183 km temporal resolution of 16 days. It consists of nine spectral bands with a spatial resolution of 30 meters, for bands 1 to 7 and 9. The ultra-blue band 1 is useful for coastal and aerosol studies. Band 9 is useful for cirrus cloud detection. The resolution for band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures, Ultra Blue (coastal/aerosol 0.435-0.451µm; blue 0.452-0.512µm; green 0.533-0.590 µm; red 0.636-0.673 µm; near Infrared (NIR) 0.851 - 0.879µm; Shortwave Infrared (SWIR) (1)1.566-1.651 30µm; shortwave Infrared (SWIR) (2) 2.107-2.294µm; Panchromatic 0.503-0.676 µm; Cirrus 1.363-1.384 µm; thermal Infrared (TIRS) (1) 10.60-11.19 µm; and Thermal Infrared (TIRS) (2) 11.50-12.51µm. (Both systems are in Sun synchronous orbits so the satellite passes over the same area of the earth at the same solar time in each temporal cycle. The Landsat TM 1986, Landsat 2002 ETM+ and Landsat 2017 OLI-TIRS of 30m resolution and each was captured in June. The land use/ cover classification systems were adopted for the study. The land use/cover product is classified into five land cover classes; undisturbed forest, farmland, secondary regrowth, bare ground and water body. The study used Landsat data to carry out change evaluation of forest vegetation characteristics and assessed the spatial pattern changes in the forest reserve between 1986, 2002 and 2017. Table 1 describes merely the secondary data with their parameters which include satellite data and existing data of Topographical map and survey plan used.

*Table 1* Parameter of the datasets for the study

| S/N | Data Type | Acquisi-tion date | Swath (km) | Path/Row | Spat. res. (m) |
|---|---|---|---|---|---|
| 1 | Landsat TM | 19/6/1986 | 185 | 190/55 | 30 |
| 2 | Landsat ETM+ | 19/6/2002 | 185 | 190/55 | 30 |
| 3 | Landsat OLI/TIRS | 20/6/2017 | 185 | 190/55 | 30 |
| 4 | Topographical map | 6/6/1986 | - | - | 1:250,000 |
| 5 | Survey plan | 15/12/2009 | - | - | 1:5000 |

## METHODOLOGY

The methodology was summarized in the workflow of the data processing (Fig. 3). Data analyses, compilation and raster statistics were generated in both Erdas Imagine and ArcGIS 10.3. Statistical analysis and investigation of possible trends were carried in Microsoft Excel as well. Pre-processing of satellite data was required and Normalized Difference Vegetation Index (NDVI) was also engaged and analyzed for the study. Satellite data was sourced through Path 190/Row 055 and downloaded from Global Land Cover Facilities (GLCF), United States Geological Survey (USGS) in digital format into the computer via earth explorer window and then it was imported into Erdas Imagine 9.2 version through classic viewer.

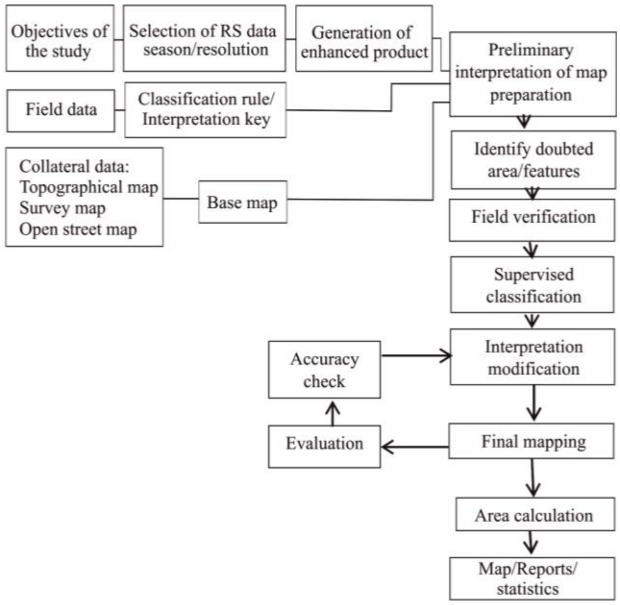


*Fig. 3* Workflow of data processing

The images noise was filtered through radiometric enhancement as shown in (Fig. 4). The visual image interpretation and digital image processing combined with aid of creating layer stacking from the images the useful Landsat manual guide was used to produce natural colour for the satellite data and sub-map creation of raster data was done from the boundary extracted survey plan. The pre-processing of layer-stacking were carried out intensively for proper accountability of Ortho-rectification of the satellite images. The image was then processed in Erdas Imagine software. The satellite image of each band was stacked. Then, from the stacked satellite image the study area image was extracted by masking in ArcGIS 10.3 software. Supervised classification was used and where the user develops the spectral signatures of known categories to extract phenomena by assigning each pixel in the image to the cover type to which its signature is most comparable. It is of interesting to know that area of interest (AOI) which also known as training classes were used to represent a particular class.

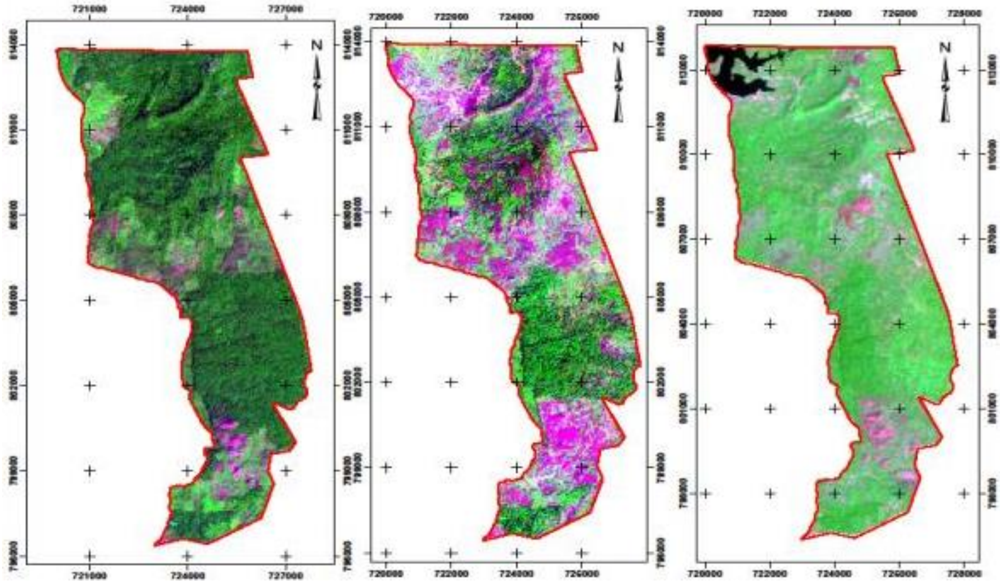

*Fig. 4* Enhanced Landsat imageries1986,2002 and 2017 RGB: 321, 753 and 654

Basically it follows the operational order of: defining of training sites, extraction of signatures and classification of the image (Supervised classification) then during the supervised classification process, the entire Signature editor was selected and it was used on the classification process. The pattern of land use type, ground truthing and personal experience were considered as the 3 major advantages to analyze the remotely sensed data. The classes were defined by the difference in their physical attribute and characteristics by considering the option of maximum of likelihood method which possessed the capability of taking care of similar features in the study area. The ground truthing was also employed by blowing up the image pixel and obtained the coordinates and pre-loaded these coordinate on the GPS device for the verification of the features in the study area in (Fig 5).

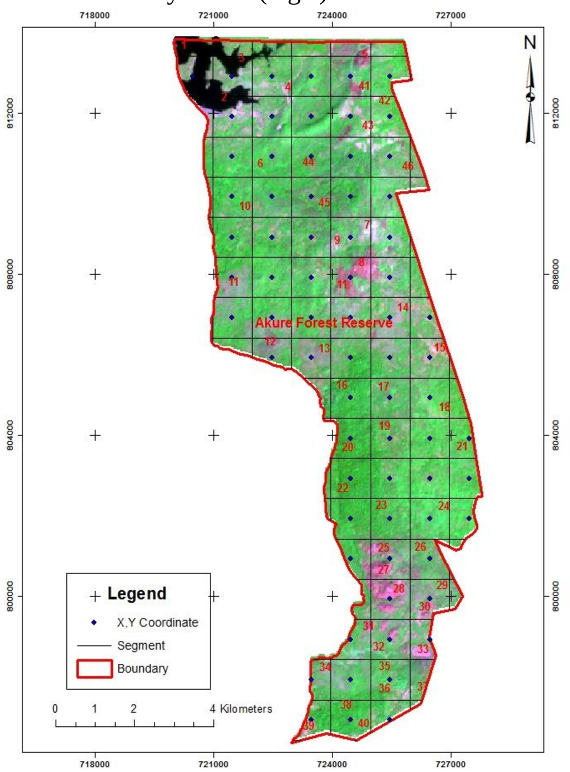


*Fig. 5* Area frame sampling of Akure Forest Reserve RGB: 654

It was conducted based on area frame sampling where the basic unit referred as segment. It was carried out in early march 2017. A systematic random sampling method was adopted for collecting sample points of samples segment. Systematic random sampling enabled the samples be distributed evenly to all parts of the study. The size of sample segment is 1 km by 1 km and sample size is 0.5 km by 0.5km. A total of 47 segments were selected and 71 sampling points were collected, where each sample has two samplings and it further enhanced the authentication of the forest and it was subdivided into equal portions. The second approach is to calculate of the Normalized Differenced Vegetation Index (NDVI). This index is the difference of the near infrared (NIR) and the red band divided by their sum (NDVI = NIR-RED/NIR+RED) which usually revealed areas that have high reflectance in the near infrared. Data post-processing which included checking pixel reliability and separability, producer, users, omission error, commission error and overall accuracy were also adopted for the analyses. Accuracy assessment reflects the real difference between classification and the reference data from the mapper by considering the rows (classes as mapped) and columns (classes as found in the field) and this has become more important than ever (Congalton, 1991). In our study the results of the percentage accuracy of the producers and users for each class names, reference total, classified total and number of pixels corrected and with their overall accuracy were described for 1986, 2002 and 2017. Remotely-sensed spectral data is a continuous form of data where digital numbers (dn) represent the reflected energy in each band (spectral region). The focus of image classification is to assign each cell or picture element (pixel) of the satellite digital data into an appropriate thematic category in a process called "discrete classification." The most common data clustering algorithm used was maximum likelihood and Other types of data clustering algorithms. The decision rules for the supervised classification process are multi-level:non-parametric and parametric. For parametric signatures, it comprises of: maximum likelihood, Mahalanobis distance and minimum distance. Parametric Rule was used and it defines classified pixels that fall into the overlap region where pixel is tested against the overlapping signatures only and whenever it reveals that neither of these signatures is parametric, then the pixel be given unclassified. But then, if only one of the signatures is parametric, then the pixel is automatically assigned to that signature's class. The maximum likelihood decision rule is based on the probability that a pixel belongs to a particular class. It assumes that these probabilities are equal for all classes, and that the input bands have normal distributions and it had capability of taken care of all similar phenomena.

Land use depictions become strong option to this study. It arranges human conceptualization of true picture of the reality i.e. how the view of reality usually being represented in a simplified manner that still satisfy the information requirement for study at hand without being distorted. Here are the basic entities used in the Land use classification schemes are described as follow: Undisturbed Forest describes deep dark green tree with which includes with other trees of similar spectral signatures and it is usually computed and represented in polygon; Bare ground includes Lands with exposed soil, sand or rocks, and never has more than 10% vegetated cover at any time of the year; Secondary regrowth describes light green tree with spectral response; Water Body describes Lakes, reservoirs, stream, rivers, and swamps and Farmland describes as tree crops and enclaves found within the forest. Therefore, the quality control of the pixels was verified on the land use and all were found above the average. The analyzed spatial change assessment was generated and it was used to compare the areas covered for the study. Meanwhile, time series of NDVI generation was subjected to the health status of the forest and also taking the average index over the complete study area, by allowing the comparison between years to examine.

The Normalized Difference Vegetation Index (NDVI) had been known for its capability of monitor the health of the vegetation. Both red and near infrared bands was adopted for this analysis This model has been extensively used to monitor drought, monitor and predict agricultural products, assist in predicting hazard fire zone and map desert encroachment (Lillesand et al., 2004). The model formula was given below mathematically by Rouse et al. (1974).

$$NDVI = \frac{P_{NIR - P_{RED}}}{P_{NIR + P_{RED}}} \qquad (1)$$

Pettorelli et al. (2005a) explained the concept behind NDVI that for vegetated surface, red (*P*RED) and near infrared (*P*NIR) wavelengths are characterized by high and low absorption respectively. The index output value range the greenness from -1 and 1 Negative values shows the presence of cloud water and snow while zero values form basis for rock and bare soil, moderate values such as 0.2 to 0.3 represents the shrub and grassland while high values such as 0.6 to 1.0 indicate the temperate and Tropical rainforest in accordance with work done by (Lillesand, 2004). In 1986, it was revealed in Figure 6 that -0.4 to 0.4 indicates the presence of water body, rock and the scattered tropical forest in the forest. In 2002, it revealed -0.4 to 0.08 which shows that the scattered tropical forests are no longer seen again as seen before. In 2017, it ranged from -0.4 to 0.3 which shows the presence of water, rock formation, tree canopies and the tropical forest recovered little from the shocked of consumers. The overall result indicated that there were moderate shrubs and grassland, fewer temperate and tropical rainforest in the reserve.

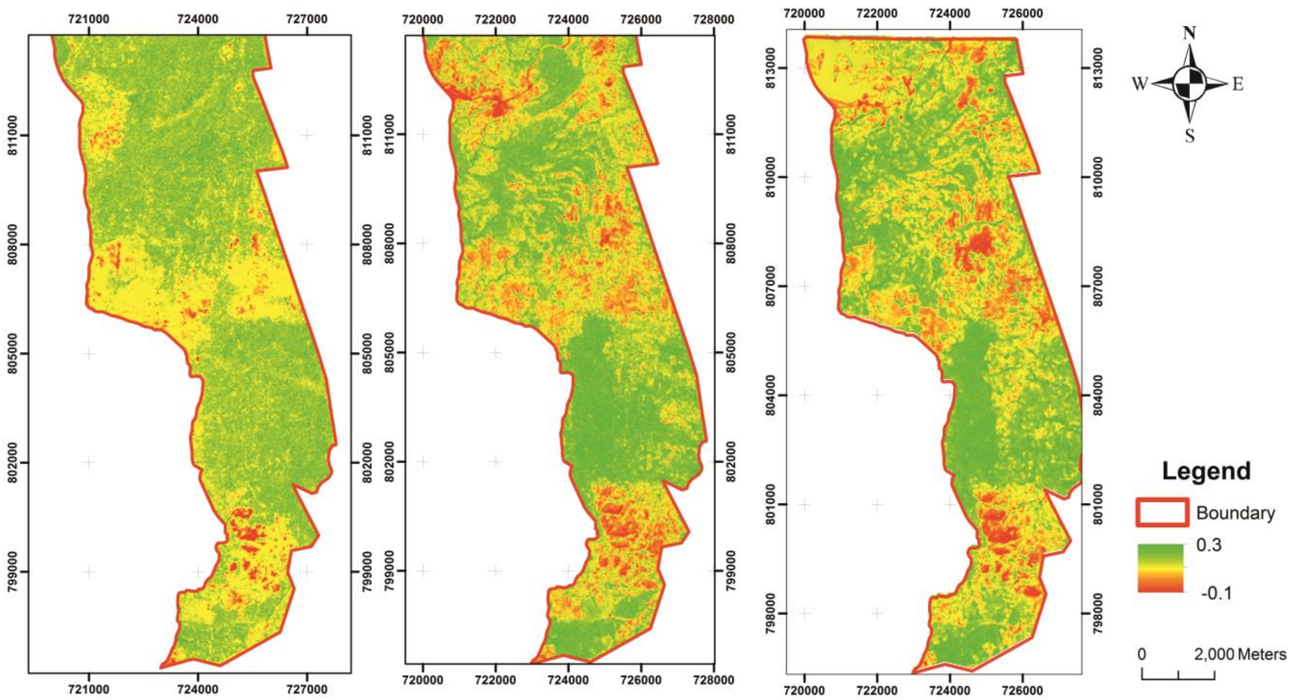


*Fig 6* Normalized Difference Vegetation Index of 1986, 2002 and 2017

## RESULTS

The entire study area covered 69.93 km$^2$ which was tuned to about 7139.8 hectares of forest land. The undisturbed forest was characterized as deep dark green tree in 1986 represents the total area of 4520.7 hectares (63.3%) of the whole study area, Bare ground covered, 818.1 hectare (11.5%), Farmland occupied 1209.9 hectares (16.9%), Secondary regrowth forest covered 590.9 hectares (8.3%) and water body as well covered the tune of 207.900 hectares which represents 2.9 % of the forest. These were so even before the forest was constituted as a reserve in 1936. In 2002, bare ground was increased by covering 2573 hectares represents (36 %) as against (11.5%) of 1986, Farmland increased by1575.3 hectares (22.1%) as against 16.9%, Secondary regrowth increased by 590.993 hectares (9.5%) against 8.3%, Undisturbed forest decreased gradually to 2311.3 hectares (32.4%) as against 63.3% increased previously. In 2017, bare ground represented 2274.4 hectares (31.9%) reduced by 4.1% in five year of the study, the Farmland also covered 1249.470 hectares (17.5%), undisturbed forest decreased further to 2289.900 hectares (32.1%), Secondary regrowth covered 1118.070 hectares (15.6%), while water body covered 207.900 hectares (2.9 %) emerges openly due to human factors being seen all over places in Table 2 and that summarized patterns of land use in details for 1986, 2002 and 2017. Figure 7 quantified amount of alterations influenced by the humans. While making compare of 1986, 2002 and 2016 land use change, it were discovered that the deleption around Obada,Owena and Ibutitan/Ilaro camp induced by the influence of human factors due to direct access. Vegetation was more seen in 1986 but unlike 2002 and 2017. Water body was not also revealed in the data of 1986 and 2002 but there the indication of riparian forest was seen on satellite image. Owena river that formed the bases of natural boundary of the forest was dredged for the purpose of dam construction. It was resulted into emergency of water body revealed on the image of 2017.

Figure 8 presents the proportion of land use categories of 1986, 2002 and 2017 in distinct multiple charts. It is vital to compare between green cover areas and areas are subjected to changes in proportions since it answered to when, how or

*Table 2* Compositions of land use of Akure Forest Reserve in 1986, 2002 and 2017

| Land use classes | Landsat TM 1986 | | Landsat ETM+ 2002 | | % change 1986-2002 | Landsat OLI 2017 | | % change 2002-2017 |
|---|---|---|---|---|---|---|---|---|
| | Area [ha] | Area [%] | Area [ha] | Area [%] | | Area [ha] | Area [%] | |
| Undisturbed Forest | 4520.7 | 63.3 | 2311.3 | 32.4 | -30.9 | 2289.9 | 32.1 | -0.3 |
| Farmland | 1209.9 | 16.9 | 1575.3 | 22.1 | 5.2 | 1249.4 | 17.5 | -4.6 |
| Bare Ground | 818.1 | 11.5 | 2573.0 | 36 | 24.5 | 2274.4 | 31.9 | -4.1 |
| Secondary Regrowth | 590.9 | 8.3 | 679.9 | 9.5 | 1.2 | 1118.0 | 15.6 | 6.1 |
| Waterbody | - | - | - | - | - | 207.90 | 2.9 | 2.9 |
| Total | 7139.8 | 100 | 7139.8 | 100 | 0 | 7139.8 | 100 | 0 |

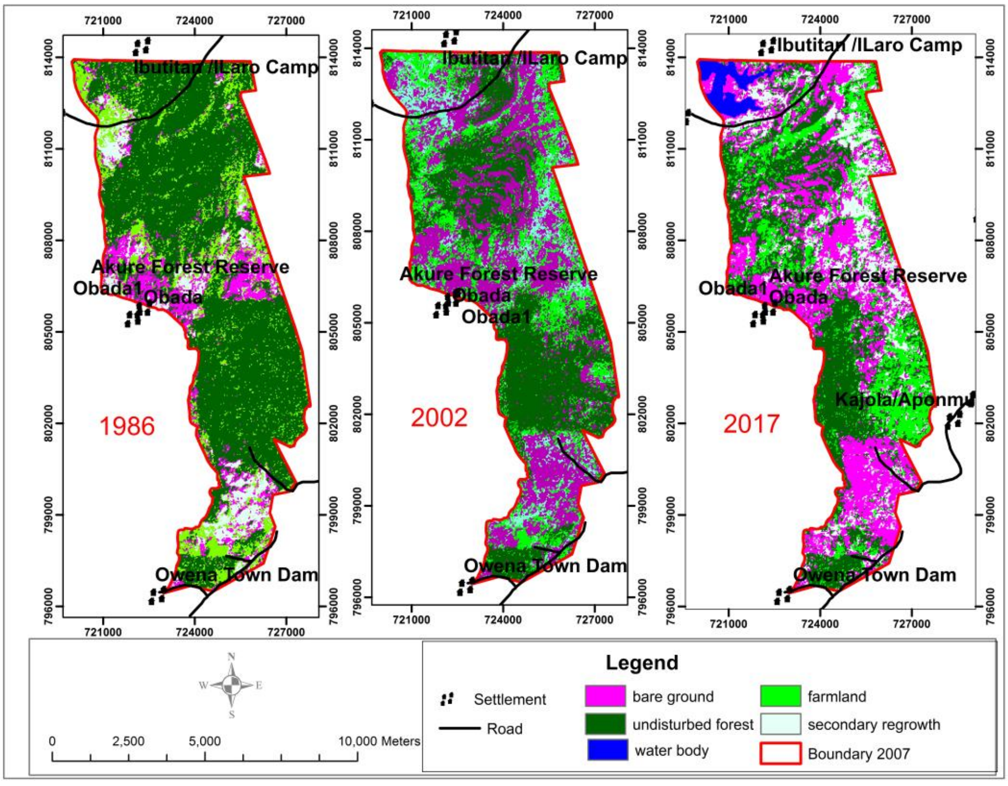


*Fig. 7* Patterns of land use in 1986, 2002 and 2017

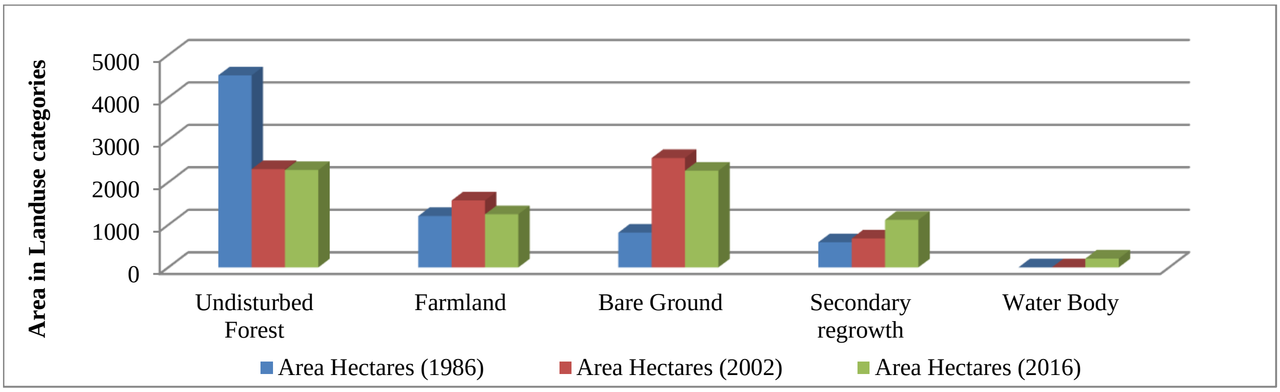


*Fig 8* Proportion of land use categories in 1986, 2002, and 2017

why the forest had changed from time without numbers. In 1986, 63.3% of the area was considered as vegetated areas, this decreased to 32.4% in 2002, and it was almost half of undisturbed forest had been altered over a period of sixteen years which was hugged. In fifteen years later, it was reduced to 32.1%, the reduction accounted for variation of 0.3% in 2017 which was no pronounced as it were in 1986 to 2002. The reduction is not significant as results of interference by the concerned authority of the forest in 2017. Farmland in 1986 was computed as 16.9%, it increased 22.1%, in 2002, in 2017, it was 17.5% which decreased by 4.6%. Bare ground in 1986 was 11.5%, in 2002, it significantly inclined to 36%, in 2017, it was 31.9%, in 1986, Secondary regrowth tends to increase from 8.3% - 9.5% for the period of sixteen years and later increased to 15.6% in 2017. This increased showed that there was interference of the concerned authority along the line to improve the forest by reintroducing seedlings to the settlers found around the forest. At emergence of water body, it accounted for 2.9% of the total area of the study.

The rate at which undisturbed forest reduced in forest between 1986 and 2002 was shown vividly in Table 2. It decreased by about 3.1% per annum and reached the peak around the year 2002. By this year, the forest area had recorded roughly at about 30.9% of the forest that was left under undisturbed forest. Between 2002 and 2017 the rate of vegetation reduction was close to negligible. It was as low as 0.3% which suggests that there were very little open forests to be altered and converted to other land uses. The farmland reduction in 2002 drastically as results of cocoa and banana plantations people around the forest had been practicing in the area. In 2017, also it shows that there was conversion of 4.6% which implies there conversion of more forest than in 1986, but slightly drops from the figures recorded in 2002. Large conversion of forest into other land uses, including bare ground has significant implications, which could be best explained by its settlers round the forest. In 2002, it was 36% of the total forest which had doubled up of what actually recorded in 1986. In 2017, the increased drop by 4.1% in fifteen years later. Secondary regrowth tends to improve by the initiate being put place by concerned authority for the period of last sixteen years. The water body emerges due to alteration of the river that formed the boundary for the forest. The study also focuses on the option of integrated ground truthing measured to authenticate the reality on the ground. Accuracy assessment reflects the real difference between classification and the reference data from the mapper by considering the rows (classes as mapped) and columns (classes as found in the field) and these had become more important than ever as it shown in Tables 3, 4 and 5. Reference data believes to be accurate and it reflects the true land use. It had a sources which include, ground truth, higher resolution satellite images and maps derived from aerial photo interpretation while number correct denote software correction after classification. The overall accuracy of the classified image compares how each of the pixels classified versus the actual land cover conditions obtained from their corresponding ground truth data and it considers all off-diagonals together as classification failures.

*Table 3* Accuracy assessment pattern of 1986

| Class Name | Reference Total | Classified Total | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| Undisturbed forest | 173 | 194 | 159 | 91.91% | 81.96% |
| Farmland | 54 | 38 | 37 | 68.52% | 97.37% |
| Bare ground | 44 | 30 | 28 | 63.64% | 93.33% |
| Secondary regrowth | 26 | 14 | 13 | 50.00% | 92.86% |
| Total | 297 | 276 | 237 | | |

*Overall Classification Accuracy (86.72%) * Overall Kappa Statistics (0.804)

*Table 4* Accuracy assessment pattern of 2002

| Class Name | Reference Total | Classified Total | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| Undisturbed forest | 18 | 39 | 16 | 88.89% | 41.03% |
| Farmland | 21 | 10 | 6 | 28.57% | 60.00% |
| Bare ground | 65 | 63 | 51 | 78.46% | 80.95% |
| Secondary regrowth | 30 | 12 | 10 | 33.33% | 83.33% |
| Total | 134 | 124 | 83 | | |

* Overall Classification Accuracy (77.34%) *Overall Kappa Statistics (0.675)

*Table 5* Accuracy assessment pattern of 2017

| Class Name | Reference Total | Classified Total | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| Undisturbed forest | 54 | 45 | 40 | 74.07% | 88.89% |
| Farmland | 37 | 25 | 21 | 56.76% | 84.00% |
| Bare ground | 67 | 46 | 36 | 53.73% | 78.26% |
| Secondary regrowth | 15 | 15 | 11 | 73.33% | 73.33% |
| Water | 9 | 2 | 2 | 22.22% | 100.00% |
| Total | 182 | 133 | 110 | | |

*Overall Classification Accuracy (71.05%) *Overall Kappa Statistics (0.675)

This further expressed some of human and environment factors which have contributed to the forest depletion. The factors concern includes the rising of logging, the frequency and severity of water over bank which sometimes falls most of tall trees because it was rivers the formed the natural boundary of the forest, cattle herders and fire. Although, these were views being seen during the data acquisition and they merely facts to reckon with Table 6 presents the trend of various land use for 1986, 2002 and 2017 as it shown below and it was explained further by displaying the rate change (%) in the two investigated periods (1986-2002 and 2002-2017).

*Table 6* Rate change (%) in the two investigated periods (1986-2002 and 2002-2017)

| Land use | Rate of change (%) 1986-2002 | Rate of change (%) 2002-2017 |
|---|---|---|
| Undisturbed Forest | -30.9 | -0.3 |
| Farmland | +5.2 | -4.6 |
| Bare Ground | +24.5 | -4.1 |
| Secondary regrowth | +1.2 | +6.1 |
| Water Body | - | +2.9 |

## DISCUSSION

The important concepts of forest cannot be overemphasized because it was spatially distributed across the surface of the earth and by offering the potential values to the dynamism of local, regional and global ecosystem processes. It needs to be protected, monitored for conservation and sustainable management at all time. Mostly, Forests are important globally for provision of fibers to meet human needs, from local uses such as cooking fuel through to industrial utilization for construction materials. Although, land use has been extensively analyzed by the researchers in the past through the aid of satellite data and they had been achieved greatly. In this study, it has been proven, that the supervised classification of multi temporal satellite images were more effective tool to quantify and detect changes/alteration of environment which were shown in Figure 7. However, it indicated that bare ground, farmland and secondary regrowth in the area have increased tremendously, to possibly support population growth of the surrounding settlements or influx of loggers often coming from the cities. With this evidence, one can actually submit that most of undisturbed forest had been converted to bare ground and farmland since it is obvious that undisturbed forest was at pace of reduction yearly and it was equally shown on the image while the secondary regrowth is gaining its popular expansion as well as others. NDVI is useful for checking the health of the reserve and to compliment the various categories of the spatial change patterns derived from the Landsat. Additionally, it is also important to adopt ground truthing approach as it was shown in Figure 5 to authenticate the exact feature on the ground as it is against the final classification for clarification and this was a little bit difficult but it was later successful. It was extensively discussed in Tables 2, 3and 4 describe the accuracy of classified image which had been proven important and that serves as of authenticity for any image used (Aronoff, 1958). The post classification required since the final accuracy of image depends on the accuracy of the independently classified images (Yuan et al., 2005). This was done by using the accuracy assessment module in Erdas Imagine. The results in Table 6 tend more than enough to permit its use for further analysis. Another way of identifying change within the study area is by using the Kappa Index of Agreement (KIA) which ranges from -1 to 1 and study findings were 0.8047 (in 1986 image), 0.6753(in 2002 image) and 0.6138 (in 2017 image) and the results supported the statement attributed by Congalton and Green (1999) that overall change occurred by chance, then K equals zero (K= 0). That means changes have taken place in both classified data. Most often conversion of the reserve to farmland had improved their quality life and behavioural pattern of the dwellers in the settlements by making their ends from the forest because they have known for cocoa farming as their major occupation especially those dwellers in the suburb. And to the authority, it contributes to the sustainable development of ecosystems and provision of ecological range and social benefits had been deeply threatened due to the quest of getting resources out of the forest. It is expected that the authority concerns control the abundance and biodiversity of the forest and take the responsibility by ensure protection and others.

## CONCLUSION

Forest vegetation characteristics and spatial pattern changes in the Akure Forest Reserve between 1986, 2002 and 2017 were successfully observed by obtaining Landsat images. The data analysis shows that forest has lost almost all the vegetation cover. It's just leaving about 32.1% of undisturbed forest as at 2017 while other land uses are increased yearly. The critical part of the reserve loss occurred between 1986 and 2002. These indicate that the spatial distribution pattern of bare ground had increased geometrically due to interferences of the settlers that surrounded the reserve and farmland also increased due the conversion of forest to cocoa plantations. Consequently, the reserve had been threatened due to anthropogenic activities of man while the vegetation of secondary regrowth, farmland, and bare ground began to increase and the vegetation being known within the reserve which characterized by hard species noticed no more. Interestingly, the period was characterized by conversions including farmland and among others. This study recommends that for Akure forest authority to address problems relating to conversions of forest there is the need to take critical look at the forest policies plans and its implementation which can provide quick answered to some of intermediate and underlay causes of forest conversion. The past three decades saw that there is a shift to revitalize some of our forest from the hands of loggers and others. This pattern had been helpful and it must be focused on it if forest in Akure needs sustainability. However, it's erroneous difficult in achieving these recommendations in conceptual frame work due to changes in policy most often.

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