



An assessment of the state of forest reserves in Southwestern Nigeria

R.O. Oyinloye¹, F.A. Adesina², and A.T. Salami³

¹ Regional Centre for Training in Aerospace Surveys, OAU Campus, Ile-Ife

² Department of Geography, Obafemi Awolowo University (OAU), Ile-Ife

³ Institute of Ecology and Environmental Studies, OAU, Ile-Ife

Abstract

It is a common knowledge that deforestation and land degradation have far reaching effects on the sustainability of natural resources and on the world's climate as well as the current unstable weather conditions being witnessed every year. The ability of the country to withstand the impacts of future climate change will likely be compromised if the forests and forest reserves continue to be degraded and eventually destroyed. The other phenomenon of southward movement of desertification, among other phenomena, is also worth being considered. This paper has carried out an assessment of the state of forest reserves in southwestern Nigeria over a period of three decades with a view to determining the rate of deforestation and demonstrating the crucial role of geoinformation production in forest reserve management. The techniques of Geoinformatics have been employed. The results of the study showed that the average annual rate of deforestation in southwestern Nigeria was 2.55% while the analyses showed that the forest reserves were on the verge of disappearing.

Keywords: Deforestation, Forest reserve, Monitoring, Remote sensing,
Tropical forest, Vegetation map

Introduction

Nigeria once had an extensive distribution of the tropical rainforest. Then it covered up to 45% of the country's landmass (WRI, 2003). Most of this is now lost to rapid population growth and urbanization as well as their associated demands. By 1995, the forest cover had reduced to 15% only and is expected to be currently less than 10% (Oyebo, 2006).

A major strategy adopted to ensure that the country's tropical forests are not completely lost has been the establishment of Forest Reserves in different parts of the country. Forest reserves are ecological sites set aside primarily for the conservation of flora and fauna. They are used to protect genetic diversity and enhance the production of forest products such as poles, sawlogs, pulp and paper, timber, leaves and herbs, among others (Isichei, 1995; Adesina, 2001). They help to preserve the genetic pool of the forest ecosystems (Salami *et al.*, 1999) and are important in the scientific studies of the tropical forests (Okali, 1991; Isichei, 1995). Although forest reserves are conceptually different from games reserves, in many instances, they also double as games reserves. Today, there are about 1,160 forest reserves in Nigeria (Oyebo, 2006).

The first forest reserves were established in 1899 in south-western and south-eastern Nigeria and in 1916 in the northern parts of the country after the amalgamation of the Northern and Southern protectorates in 1914 (Aminu-Kano and Marguba, 2002). Altogether, about 1.8 million hectares of land were under forest reserves in south-western Nigeria in 1959 (MANR, 1971). In 1961, a Forestry Technical Committee (FTC) was established to provide an opportunity for exchange of ideas among the Regional Chief Conservators of forests. The functions of this Committee were taken over by the National Forestry Development Committee established in 1970. Also, the Federal Department of Forestry was set up under the Federal Ministry of Agriculture and Natural Resources in 1970 to pursue the goals of forestry development in the country. Meanwhile, the then Western State had already inaugurated a Forestry Advisory Commission in October 1968 (MANR, 1971).

Throughout the country, the forest reserves themselves have been under increasing threats arising from the same factors that eliminated virtually all of the country's natural forests as well as those forests which supplied forest products have almost disappeared. Apart from the seemingly uncontrollable poaching of valuable timber resources from the reserves and the annual burning of the estates, farmers have continued to expand into the reserves (e.g. BSP, 1993a; Salami, 1995; Oyinloye 2008). In the forest areas, cash crops such as cocoa (*Theobroma cacao*), kola (*Cola acuminata* and *Cola nitida*), oil palm (*Elaeis guineensis*), citrus (*Citrus spp.*), plantain and

banana (*Musa* spp.) and cassava (*Manihot esculenta*) have replaced forests in the reserve (Okali and Onyeachusim, 1991).

There seems to be no controversy as to the general belief that forest areas are rapidly decreasing in Nigeria and many other tropical countries. However, there is no consensus opinion as to how the forests are decreasing and how long the remaining forests will last, going by the current trend of deforestation. Also, there exists no reliable data or information that can be used to strategically and sustainably manage the remaining forests. In Nigeria, for example, the often quoted rates of deforestation were based on intelligent guesses, mere estimates or surrogate data rather than empirical studies (Salami, 1999; Oyinloye, 2008). Therefore, the known rates of deforestation, whether globally, nationally or locally, are neither accurate nor consistent and thus unreliable. Again, this is as a result of overgeneralization of forest features on low resolution satellite images, the use of data from different sources, analogue techniques of data processing as well as computations based on the surrogate data. This paper used time series datasets from the same medium resolution satellite (Landsat) acquired within the dry season period and digitally processed all the datasets using the methods and techniques of Geoinformatics. It went further to demonstrate mapping of the reserves and their environs at scale 1:100 000, which is a non-existing vegetation map scale in the country.

The Study Area

The study area is southwestern Nigeria covering six States: Ekiti, Lagos, Ogun, Ondo, Osun and Oyo. In the study area, six forest reserves were purposively selected for this investigation because they all lie within the forest belt of southwestern Nigeria. Two were selected from each of Ogun, Ondo and Osun States, which have large areas of land committed to forest reserves. These reserves fall within the hot humid tropical climate, which support a wide diversity of life-forms (Richards, 1952). The reserves are Akure forest reserve, Aponmu Strict Nature Reserve (SNR), Ipetu/Ikeji, Oni, Ilaro and Omo forest reserves. The Akure and Aponmu are in Ondo State while Ipetu/Ikeji and Oni are located in Osun State. The Ilaro and Omo forest reserves are in Ogun State. These reserves have been sources of enormous economic benefits to the various States over the years (Okali and Onyeachusim, 1991) because of their rich wood and non-wood resources. The Akure, Aponmu, Ipetu/Ikeji and Oni forest reserves are within latitudes 07° 10' 06.29"N and 07° 30' 03.28"N, and longitudes 04° 42' 03.12"E and 05° 05' 08.78"E (an area of about 36.7km by 47.7km) while Ilaro forest reserve is within latitudes 06° 38' 51.36"N and 06° 57' 24.40"N, and

longitudes 02° 49' 06.12"E and 03° 10' 43.60"E (an area of about 34.2km by 39.9km). The Omo forest reserve is located within latitudes 06° 35' 09.90"N and 07° 06' 04.94"N, and longitudes 04° 04' 27.28"E and 04° 35' 22.16"E (an area of about 57km by 57km). Figure 1 shows the approximate locations of the forest reserves on the map of Nigeria.

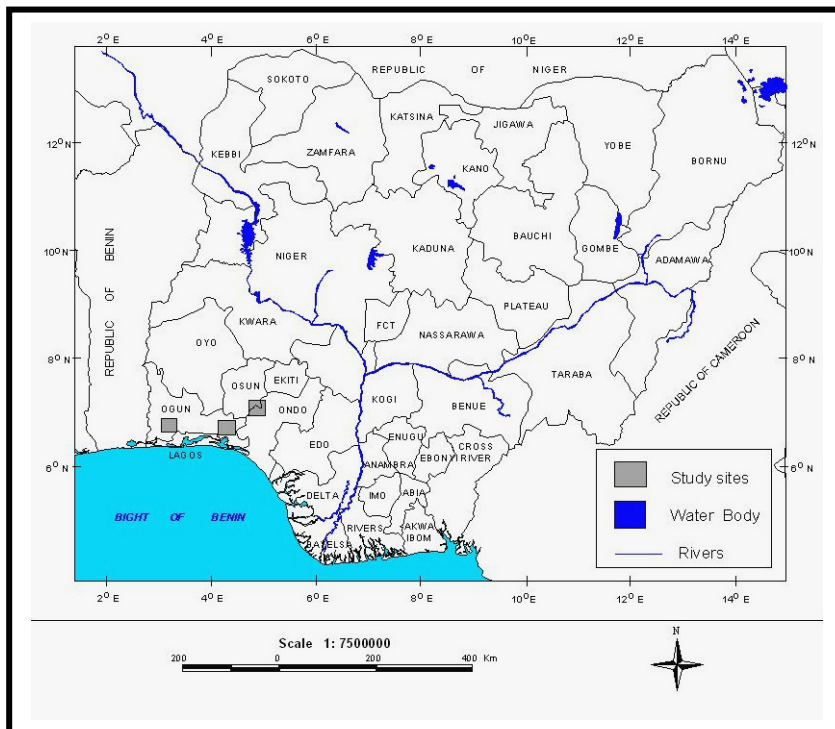


Figure 1: Map of Nigeria Showing the Study Sites in Southwestern Nigeria

Materials and Methods

Data Sources

The available satellite imageries for the study were those of 1972, 1984, 1986, 1991, 2000 and 2002. The details of the characteristics and applications of these Landsat images are (USGS and NOAA, 1984):

Band 1 (0.45 – 0.52 μ m) is the blue wavelength, which is used for water body penetration thereby making it applicable in coastal water mapping. It is also useful for soil and vegetation discrimination, forest type mapping and cultural feature detection.

Band 2 (0.52 – 0.60µm) is the green wavelength. It measures green reflectance peak of vegetation for vegetation discrimination and vigour assessment. The band is also useful for cultural detection.

Band 3 (0.63 – 0.69µm) is the red wavelength band. It senses chlorophyll absorption region thereby aiding in plant species differentiation. It is also useful for cultural feature detection.

Band 4 (0.76 – 0.90µm) is the near-infrared (NIR) wavelength, which is useful for determining vegetation types, vigour and biomass content. The band also aids water bodies delineation and soil moisture discrimination.

Band 5 (1.55 – 1.75µm) is the first of the two bands in the middle infrared (MIR) wavelength. It is indicative of vegetation moisture content and soil moisture. In the temperate region, it is useful for differentiation of snow from clouds.

Band 6 (10.4 – 12.5µm) is the far infrared (FIR) wavelength. This wavelength is also known as the thermal infrared (TIR). It is useful in vegetation stress analysis, soil moisture discrimination as well as thermal mapping applications.

Band 7 (2.08 – 2.35µm) is the second of the middle infrared wavelength. It is useful for discrimination of mineral and rock types. The band is also sensitive to vegetation moisture content. Table 1 shows the datasets used for the study.

Table 1: Some Characteristics of the Remote Sensing Data Used for the Study

Landsat Scene	Acquisition Date	Location on WRS	Dimensions (in Pixels)	Actual Spatial Resolution
MSS	07/11/1972	P204R055	3796 x 4204	56m x 79m
TM	18/12/1984	P191R055	6389 X 6939	28.5m x 28.5m
TM	17/12/1986	P190R055	7327 x 7757	28.5 m x 28.5m
TM	05/01/1991	P190R055	5965 x 6967	28.5 m x 28.5m
ETM ⁺	06/02/2000	P191R055	8525 x 7512	28.5m x 28.5m
ETM ⁺	03/01/2002	P190R055	7549 x 8707	28.5 m x 28.5m

All the datasets were obtained from the Regional Centre for Training in Aerospace Surveys (RECTAS), Obafemi Awolowo University (OAU) Campus, Ile-Ife. Some basic premises in the application of such multi-date remote sensing (satellite) data for change detection are that changes in

landcover characteristics necessarily result in changes in reflectance values and that changes in reflectance due to landcover characteristics should be larger than those due to other factors such as differences in satellite sensor conditions, atmospheric conditions, solar angle and soil moisture (Tokola *et al.*, 1999 and Sedano *et al.*, 2005).

Landsat datasets were used in this study for three main reasons:

- (i) They have proved highly suitable for vegetation studies as they are available in many channels including the infrared portion of the electromagnetic spectrum which is sensitive to vegetation. Landsat data can therefore be available as high quality images with little or no cloud cover;
- (ii) They gave a time series coverage of the study sites in dry seasons between 1972 and 2002; and
- (iii) The data sets guaranteed a reasonable level of data consistency being from the same satellite system.

Data Processing

The satellite datasets were processed using the ILWIS version 3.3 software package. The full scenes covering the study sites were each loaded onto the computer hard disk memory and converted to ILWIS format. They were respectively displayed and enhanced using the linear contrast stretching technique of the global contrast enhancement method. The spectral channels were combined to obtain false colour composite (FCC) and pseudo-natural colour (PNC) displays, among other multi-spectral combinations as described in Haack and Jampoler (1995). Except for the Landsat-TM data of 1991, all the other Landsat data sets were already geometrically corrected (auto-rectified) from source. The Landsat-TM of 1991 full scene was therefore georeferenced and geocoded (i.e., geometrically corrected in the adopted UTM map projection system on the WGS84 reference ellipsoid as with the other images) using eleven tie points identified on both TM 1986 full scene and TM 1991 full scene. The tie points, which were in geographic coordinates, were first converted to UTM space rectangular coordinates as required by the ILWIS software. A standard root mean square error (σ) of 0.550 pixel size was achieved. After the geometric correction, the TM 1991 full scene thus possessed high metrical qualities as with the other full scenes. This georeferencing helped to integrate and maintain consistency with data from external sources and will also help easy updating in future. After such correction, the images became super-imposable on themselves when printed out at the same scale. Thus all the images were of the same datum, the same map projection and in the same ground coordinate system. Thereafter, the extraction of the respective sub-scenes covering each of the study sites followed.

The enhanced sub-scenes covering each of the study sites were then subjected to the “supervised” classification procedure. Vegetation classification is widely accepted as an appropriate analytical technique for estimating changes in vegetation cover and quality of above-ground biomass. Such classification enables an appreciation of the details of physical and structural changes taking place within a vegetation unit such as forest reserve (Cannon *et al.*, 1988; Ikhuoria, 1993; ERGO, 1994; Salami, 1999). The supervised classification of the imageries was performed using the Maximum Likelihood algorithm that is based on the Gaussian normal distribution (Swain and Davis, 1978).

Vegetation components including normalized difference vegetation index (NDVI), ratio vegetation index (RVI), transformed vegetation index (TVI), enhanced vegetation index (EVI), weighted difference vegetation index (WDVI), moisture vegetation index (MVI), moisture stress index (MSI) and structural index (SI) were computed (Huete *et al.*, 1991; Chen *et al.*, 2005; Yemefack, 2005 and Beck *et al.*, 2006). The vegetation indices were computed to assess the vegetation in the forest reserves. This was followed by the computation of moisture content and stress of the vegetation. These indices were needed to monitor deforestation in the forest reserves.

The classification accuracy assessment was carried out using two approaches. The first approach relates thirty well distributed randomly sampled field points for each class of features to the corresponding pixels on the classification result for each of the image dates. The field sample points’ coordinates were obtained using GPS during ground truthing. For each class, the statistical index of validation (SIV), the cartographic index of validation (CIV) and the class purity (CP) were calculated using the following formulae:

$$\text{Statistical index of validation} = \frac{\text{number of pixels in class } C_i}{\text{number of pixels of theme } T_i \text{ on the terrain}} \quad (1)$$

$$\text{Cartographic index of validation} = \frac{\text{number of pixels correctly classified in class } C_i}{\text{number of pixels of theme } T_i \text{ on the terrain}} \quad (2)$$

$$\text{Class purity} = \frac{\text{number of pixels correctly classified in class } C_i}{\text{number of pixels of the class } C_i} \quad (3)$$

The second approach used was the evaluation of the validity of classification results when no ground truth data (i.e. actual terrain cover) is available. Here, the confusion matrix was computed in order to validate, reject or improve upon the classification results. These two approaches were carried out in this study.

Landuse/Landcover (LULC) in the Forest Reserves

Each of the satisfactorily classified sub-scenes for the different study sites was put in raster map form through on-screen digitizing of the categories of the landuse and landcover units covering each of the study sites using the ILWIS software. The respective landuse/landcover units were digitized and colour-coded. The digitized boundaries of these landuse and landcover units were then converted to vector form through the ***polygonization function*** of the digitizing environment of the software. Each unit was given a code name to distinguish the different LULC units.

While in the digitizing environment of the ILWIS software, the boundaries of each forest reserve were on-screen digitized in closed segments with the enhanced pseudo-natural colour display of the sub-scene at the background layer. Where a forest reserve had been fragmented, each fragment was on-screen digitized in a closed segment. At this stage, the digitizing was yet in raster format and had to be converted to vector format through the ***polygonization function*** of the software. The software computes the corresponding histogram in terms of the total number of pixels and the total surface area of the polygon to arrive at the surface area of each forest reserve.

The polygonized result was exported into ArcView software environment for map design and visualization. This process is the cartographic presentation of the polygonized landuse and landcover units in map form. The map design has to do with the design of the map frames, emplacement of graticules at regular intervals, the appropriate graphical scale at suitable intervals, colour codes for the themes, the legend and other marginal information. In visualization, the various components of each map were laid out. Different colours were used to portray the map features. In this operation, modern cartographic variables were used in depicting the mapped features. For instance, thematic context, differences in size, value (lightness) and colour were used to differentiate the features.

Results and Discussion

Table 2 summarises the landuse and landcover (LULC) types that characterize the study sites.

Figures 2 – 7 show the graphic plots of the different vegetation indices for the selected forest reserves over the time periods. They show that the vegetation richness of the forest reserves decreased significantly between 1972 and 1991. This is indicated in the changing trend from NDVI to EVI. The low values of the indices further indicated a decrease in the amount of tree cover between 1991 and 2002.

Table 2: Characteristics of the Landuse/Landcover in and around the Forest Reserves

Formation	Characteristics
Light Forests	Secondary forests and re-growths with small trees. Tree-like growths, climbers, etc.
Built-Up Area	Settlements which are places of human buildings with varying network of roads; could be medium-sized villages or a hut with only one road passing through.
Agro-forests	A complex of tree crops such as cocoa, kola, oil palm and orange with pockets of interspaces cultivated to food crops. There are scattered trees present.
Ridge Forests	High forests on ridges and fractured inselbergs
Forest Reserves	High forests in protected areas for conservation
Gallery Forests	Forests occurring along river courses. They may be evergreen, with considerable number of woody plants.
Exposed Rocks and Bare Lands	Inselbergs, bare rock outcrops, major or minor roads that are not paved.
Plantations	Exotic trees mainly <i>Tectona grandis</i> (teak) and <i>Gmelina arborea</i> (gmelina) with low brush undergrowths.
Shrubs/Arable Lands	Farmlands abandoned for a few years for soil recuperation in anticipation of another round of cultivation. They are made up of shrubs, herbaceous plants, seedlings and saplings that compete and grow together in an interlocked manner. They also include cultivated lands where crops like cassava, maize, yam, plantain and cocoyam are grown.
Burnt/Marshy Areas	Burnt bushes in preparation for cultivation and waterlogged areas with patches of dark soil rich in organic matter
Mangrove forests	Fresh water swamps of trees with airy roots near and along the coast
Water Bodies,	Open water bodies e.g. reservoir, river and stream

Source: Oyinloye (2008)

The WDVl on the graph is a region of change in the tree cover and the moisture content of the trees of the forest reserves. The increasing moisture content of the remaining vegetation of the forest reserves is indicated in the region between MVI5 and MVI7 over the period of study. This however is suggestive of high soil moisture rather than dense vegetation cover. Indeed as confirmed in the MSI5 to MSI7, the vegetation cover in the reserves had considerable moisture stress. The region SI5 to SI7 (the structural index) indicates that there are significant breaks (i.e., gaps) in the vegetation cover of the forest reserves. It is sufficient to state here that the behaviour of the vegetation indices graphs for the forest reserves depict the deforestation trend over the time periods. This is consistent with field observations.

Table 3 contains the summary of the classification accuracy assessment. The first approach was preferred to validate the classification accuracy simply due to its pragmatic nature. The accuracy given by the usual confusion matrix was generally lower. The lower accuracy was mainly due to some patches of cloud cover and time difference between the time the images were acquired and the time of ground truthing. The accuracy attained was therefore considered acceptable for thematic (vegetation) map preparation at the desired scale of 1: 100 000.

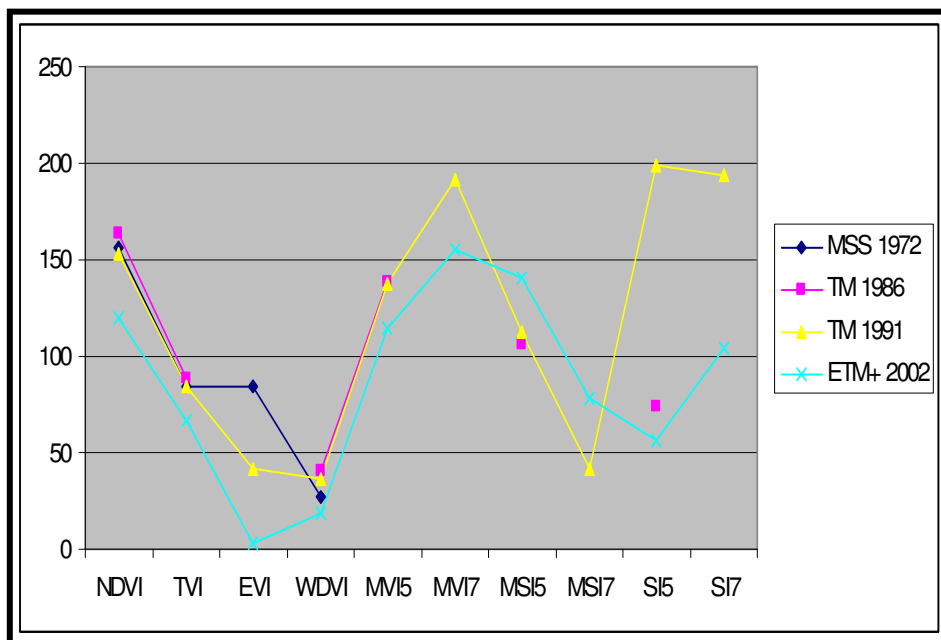


Figure 2: Average Values of Vegetation Indices for Akure Forest Reserve - 1972 to 2002

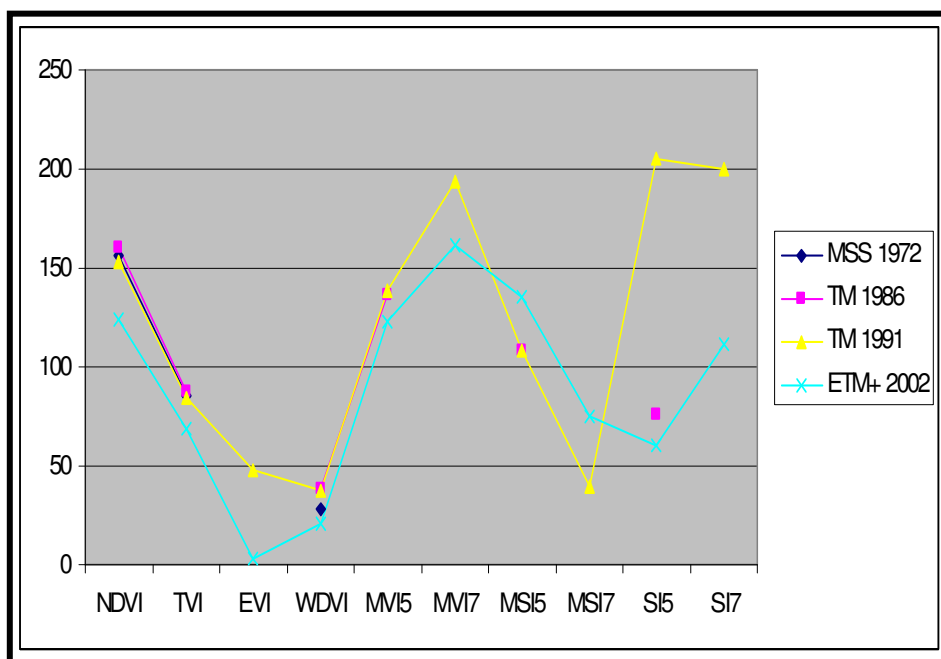


Figure 3: Average Values of Vegetation Indices for Aponmu SNR - 1972 to 2002

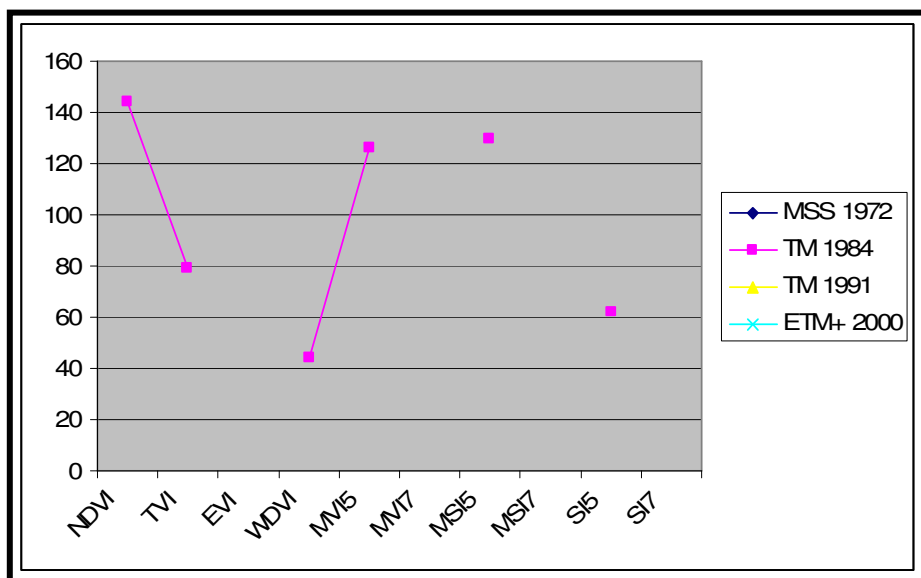


Figure 4: Average Values of Vegetation Indices for Ilaro Reserve - 1972 to 2000

(Note: there are no relevant channels for computing all the indices in the available images.)

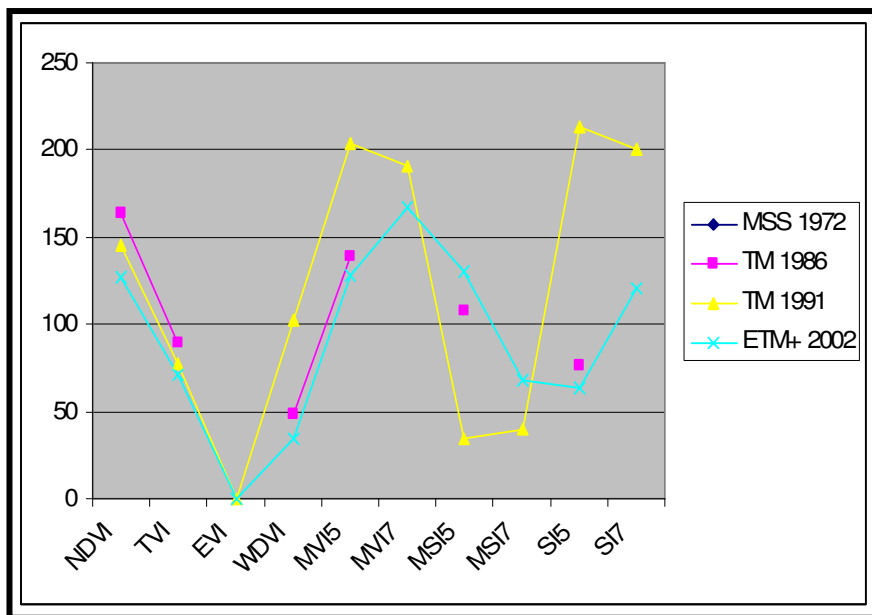


Figure 5: Average Values of Vegetation Indices for Ipetu/Ikeji Reserve - 1972 to 2002

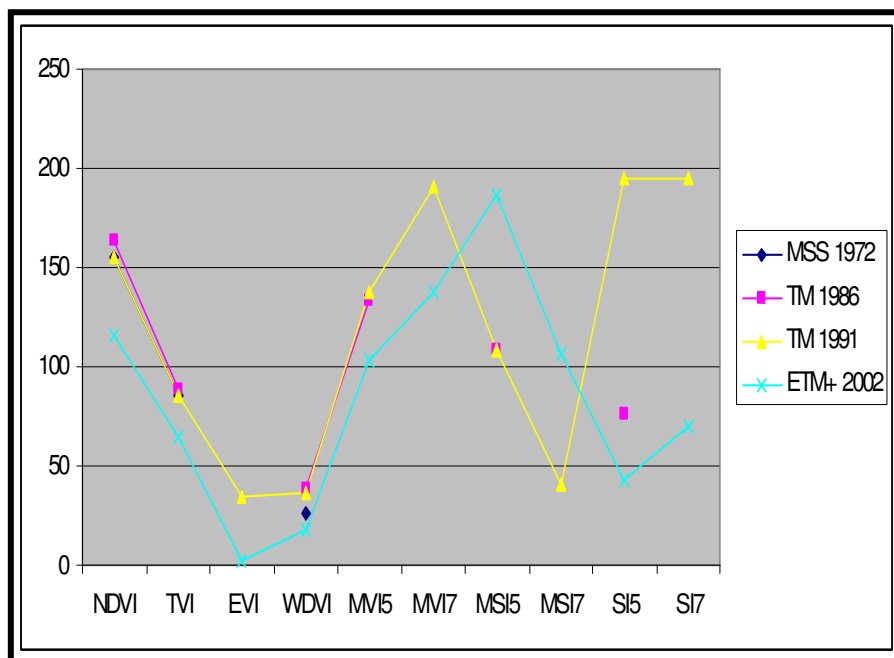


Figure 6: Average Values of Vegetation Indices for Omo Forest Reserve - 1972 to 2002

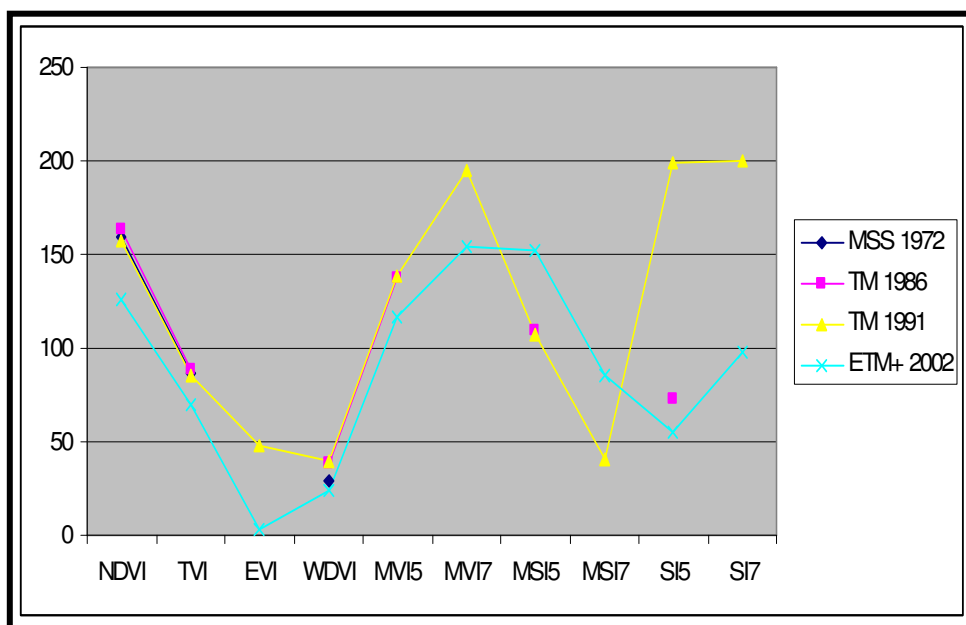


Figure 7: Average Values of Vegetation Indices for Oni Reserve - 1972 to 2002

Table 3: Assessment of Classification Accuracy

	1 st Approach	2 nd Approach
Landsat-Image Classification	Using Ground Truth Data (SIV, CIV and CP)	Using Confusion Matrix Alone
MSS 1972 Akure, Aponmu, etc.	0.57	0.75
TM 1984 Ilaro	0.85	0.64
TM 1986 Akure, Aponmu, etc.	0.83	0.66
TM 1986 Omo	0.83	0.62
TM 1991 Akure, Aponmu, etc.	0.81	0.68
ETM ⁺ 2000 Ilaro	0.90	0.66
ETM ⁺ 2002 Akure, Aponmu, etc.	0.79	0.62
ETM ⁺ 2002 Omo	0.78	0.54

SIV = Statistical Index of Validation (measure of reliability)

CIV = Cartographic Index of Validation (measure of accuracy)

CP = Class Purity (measure of purity, non-corruption or goodness of class)

Figures 8 to 11, for example, show the time series vegetation maps of Oni, Ipetu/Ikeji, Akure and Aponmu forest reserves and their immediate environs maps between 1972 and 2002. The trend of deforestation observable on these maps is similar in the case of Ilaro and Omo forest reserves (not included here due to space limitation).

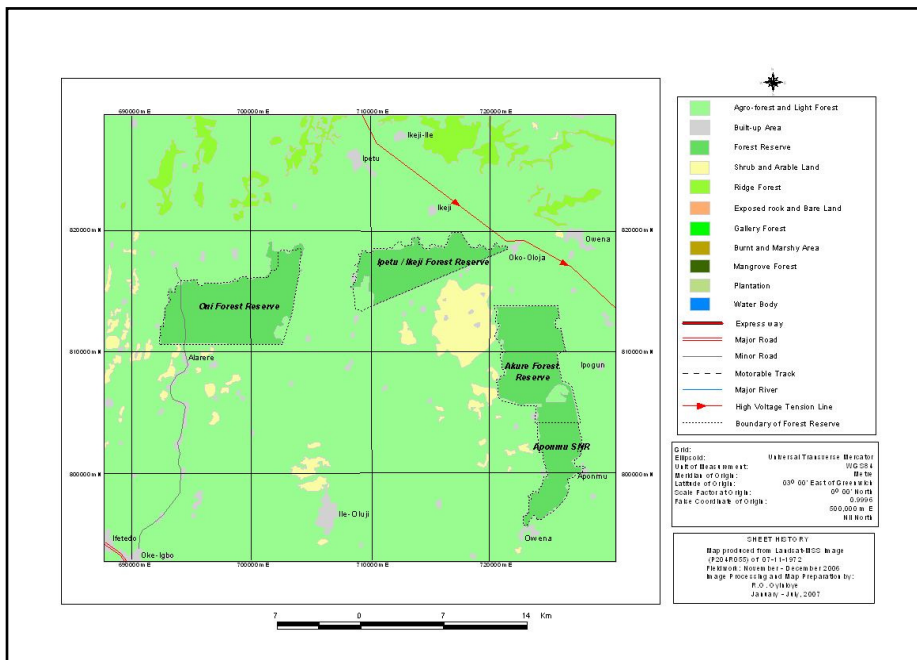


Figure 8: Vegetation Map of Akure, Aponmu, Ipetu/Ikeji and Oni Forest Reserves and Environs in 1972

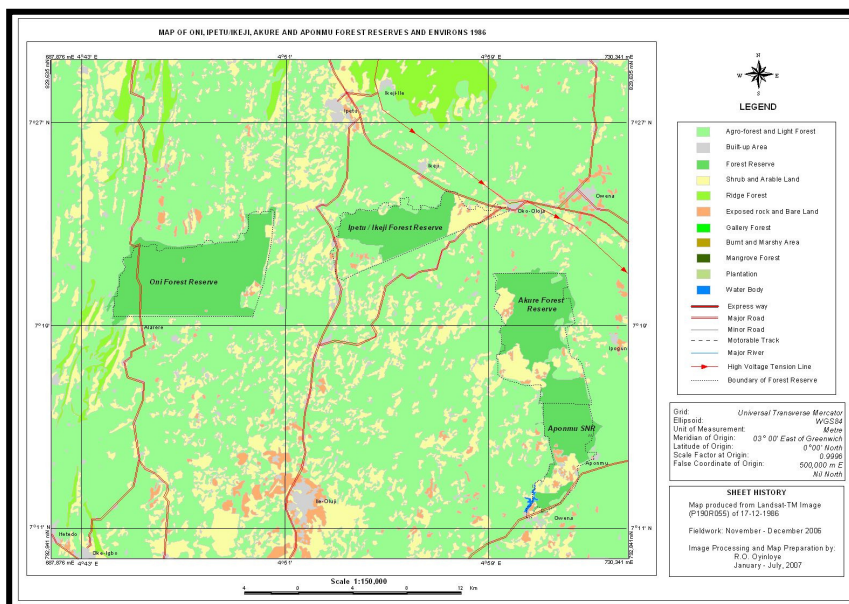


Figure 9:
Vegetation Map of Akure, Aponmu, Ipetu/Ikeji and Oni Forest Reserves
and Environs in 1986

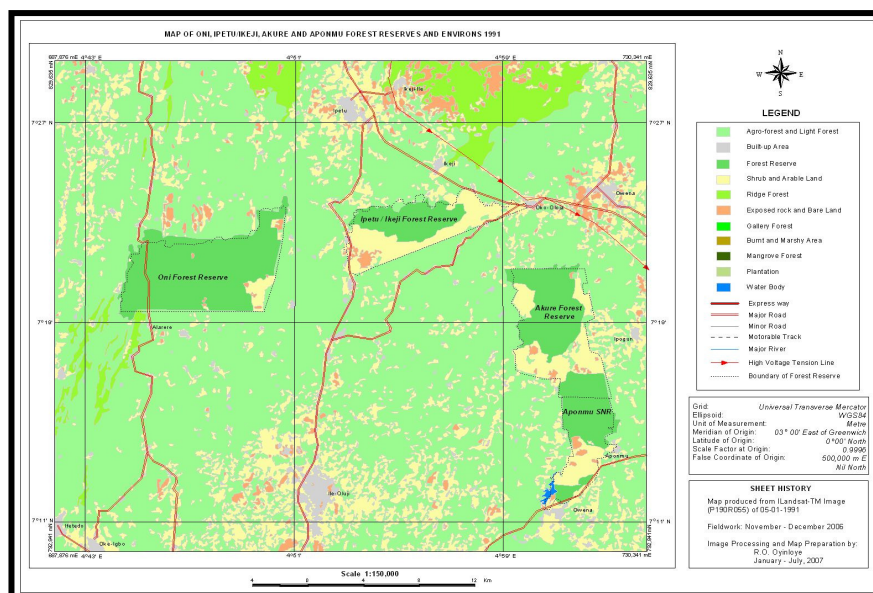


Figure10: Vegetation Map of Akure, Aponmu, Ipetu/Ikeji and Oni Forest Reserves and
Environs in 1991

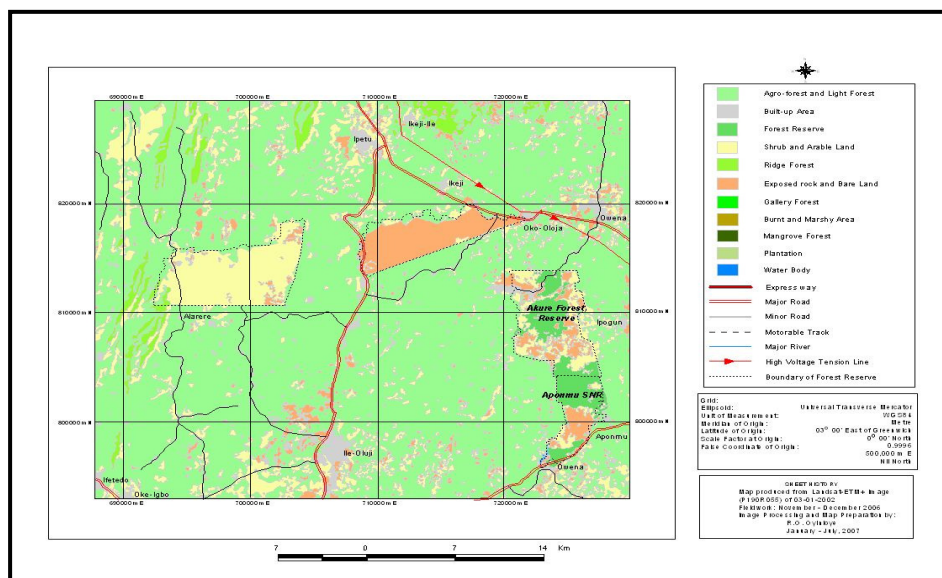


Figure 11: Vegetation Map of Akure, Aponmu, Ipetu/Ikeji and Oni Forest Reserves and Environs in 2002

Tables 4 and 5 provide a quantitative data on the changes in landuse/landcover of the forest reserves over the study period. Seven landuse categories were defined based on the data sets: Agro-forest/Light Forest, Built-up area, Exposed Rock/Bare Land, Forest Reserve, Shrub/Arable Land, Vegetated Ridge and Water body. In general, the landscape, between 1972 and 1986, showed some changes, with a decrease in the size of the forest in the reserves and an expansion of other landuse types such as the agro-forest/light forest, farmland and shrub/arable land. For example, from Table 6, the Akure reserve decreased to 69.9% of its 1972 size in 1986; 84.9% of its 1986 size in 1991 and 41.2% of its 1991 size in 2002. The trends in the other reserves as shown in the table are similar to that of the Akure reserve. The loss in Ilaro and Ipetu/Ikeji reserves appeared to have been rather too rapid until they were completely cleared and reduced to bare land in 2000 and 2002 respectively (Tables 4 and 5).

Table 4: Changes in the Areal Extent of Reserves from 1972 to 2002 and Projection to 2022

Forest Reserve	1972 Area (ha)	1986 Area (ha)	1991 Area (ha)	2002 Area (ha)	Rate of Deforestation (1972 – 2002)	2012 Projection (ha)	2022 Projection (ha)
Akure	4,756.00	3,323.91	2,821.42	1,163.64	2.52% p.a.	864.07	564.49
Aponmu	2,276.00	1,619.59	1,402.82	1,143.80	1.66% p.a.	953.93	764.06
Ipetu/Ikeji	3,490.00	2,191.64	1,178.08	Bare Land	2.21% p.a. (1972 – 1991)	Plantation	Plantation
Omo	132,000.00	95,651.99	68,900.00	49,855.45	2.07% p.a.	39,535.37	29,215.29
Oni	5,853.00	5,701.16	5,420.96	422.10	3.09% p.a.	409.06	161.24

Table 5: Surface Area Dynamics of Ilaro Forest Reserve from 1972 to 2000 and Projection to 2022

Forest Reserve	1972 Area (ha)	1984 Area (ha)	2000 Area (ha)	Rate of Deforestation (1972 – 1984)	2012 Projection (ha)	2022 Projection (ha)
Ilaro	4,844.00	2,681.33	Bare Land	3.72% p.a.	Plantation	Plantation

Computed Overall Average Rate of Deforestation for the forest reserves is 2.55% p.a.

Nb: For computing the rate of deforestation, e.g. between 1972 and 2002, the formula used is:

$$r = [(Area_{2002} - Area_{1972}) * 100] / [(Area_{1972} * (2002 - 1972))] \% \text{ p.a}$$

Table 6: Land Areas of Akure, Aponmu, Ipetu/Ikeji and Oni Reserves in 1986, 1991 and 2002

Forest Reserve	% age left 1972 – 1986	% age Left 1986 – 1991	% tage Left 1991 – 2002	% age Left 1972 – 2002
Akure	69.9%	84.9%	41.2%	24.5%
Aponmu	71.2%	86.6%	81.5%	50.3%
Ipetu/Ikeji	62.8%	53.8%	0.0%	0.00%
Oni	97.4%	95.1%	7.8%	7.2%

From the maps and Tables above, it is evident that the state of the forest reserves in southwestern Nigeria has declined over the years. The extents of the reserves have considerably reduced indicating a significant process of deforestation over the period of 30 years. For example, the Ipetu/Ikeji reserve that was almost intact in 1972 had been completely cleared and rendered bare in 2002. Field observation showed that the reserve area was converted to plantation of *Tectona grandis* in 2006/2007. In the same vein, Akure forest reserve had become fragmented into two parts resulting from farming while Aponmu strict nature reserve had a fairly homogeneous forest structure with well defined ecological units during the field observation. The trees were of varying heights and were at different stages of development but the crowns mimicked a mature forest stand. The ecological units did not show any regular pattern and the undergrowths were made up of climbers that hanged down from the tree tops. The Oni forest reserve, which was a distinctive ecological unit with full forest cover in 1972 had almost gone thirty years later. Most of the reserve was already converted to cocoa and food crop farms as observed during the field work. The physiognomic and floristic properties of Ilaro and Omo forest reserves were not significantly different. Between 1984 and 2000, Ilaro forest reserve witnessed a process of rapid degradation. The forest had entirely been replaced with plantations of *Tectona grandis* and *Gmelina arborea*. In the case of Omo forest reserve, there was a continued reduction in the physiognomy of the reserve's vegetal cover from 1986 to 2002. A major factor of change was the extensive plantations of *Tectona grandis* and *Gmelina arborea* within the reserve through a deliberate action of government.

Detailed field studies also showed that several new villages sprang up within and around all the forest reserves over the study period. The main factors of degradation in the forest reserves, in general, include establishment of farming settlements, farming, logging and fuelwood harvesting.

The implications of the deforestation are multifaceted. Nigeria may soon commence importing wood from 2050s to meet the demand for wood for construction and other purposes. This would have adverse impact on her economy. It is expected that the population of Nigeria would be over 200 million at this time. The pressure for more agricultural land would tremendously increase, the hydrological cycle would be more affected as smaller rivers and streams including some watersheds which were otherwise protected by forest would dry up, desertification would force its way close the coast, flood incidents would rise and more land area would become exposed to heat and serious erosion, increased carbon concentration in the atmosphere, full loss of habitat for fauna, climate change and associated outbreak of epidemics, to mention but a few of the associated disasters. In essence, the ecological, economic, protection as well as climate stability functions of forest will all be impaired. It should be noted that humans are the most endangered species to suffer the impacts.

Conclusion

Efficient assessment of landcover and the ability to monitor change are fundamental to sustainable forest reserve management, environmental protection, food security and successful humanitarian programmes. Forest policy formulators and forest reserve planners in the past did not have access to reliable and comparable land cover data. This paper has provided a lead-way for having such basic information. An assessment and monitoring of six forest reserves in south-western Nigeria have been carried out using time series Landsat datasets from 1972 to 2002. Ecological, economic and location factors were considered in purposively selecting the forest reserves. Geoinformatics methods and techniques were employed in the data processing using ILWIS and ArcView software packages. Vegetation analysis was carried out through the various computed vegetation indices. The computations and analyses of the results showed that the forest reserves are on the verge of disappearing. The computed average rate of deforestation of the reserves was 2.55% per annum. Vegetation maps of the six forest reserves have been prepared at scale 1:100 000 but four have been presented here due to space limitation.

References

- Adesina, F.A. (2001): Forestry sector response to global climate change: The African Challenge *Conflicts and Development Watch*, 2: pp 19-29
- Aminu-Kano, M. and Marguba, L.B. (2002): History of conservation in Nigeria. In Ezealor, A.U. (ed.) (2002) Critical sites for biodiversity conservation in Nigeria Nigerian Conservation Foundation 2002, Lekki Conservation Centre (LCC), Lagos, Nigeria, pp 3 – 11.
- Beck, P.S.A.; Atzberger, C.; Høgda, K.A.; Johansen, B. and Skidmore, A.K. (2006): Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI *Remote Sensing of Environment* 100, pp 321 – 334.
- BSP (Biodiversity Support Program) (1993a): *Central Africa global climate change and development: Overview* Corporate Press, Landover, Maryland, USA. 108 pp.
- Cannon, T.K; Ellefsen, R.A. and Craib, K.B. (1988): The application of remote sensing techniques to forest vegetation surveys in tropical areas and urban fringe land-use problems in Costa Rica Unpublished Monograph.
- Chen, X.; Vierling, L. and Deering D. (2005): A simple and effective radiometric correction method to improve landscape change detection across sensors and across time *Remote Sensing of Environment* 98, pp 63 – 79.
- ERGO (1994): Land-use change in Nigeria, 1976 – 1990 Environmental Research Group Oxford (ERGO) Ltd Federal Environmental Protection Agency (FEPA), Abuja, Nigeria. 29 pp.
- FAO (2001): Forest resources assessment 2000 Food and Agriculture Organisation, Rome, Italy.
- Haack, B. and Jampoler, S. (1995): Colour composite comparisons for agricultural assessments. *International Journal of Remote Sensing*, Vol. 16, No. 9, pp 1589 – 1598.
- Huete, A.R.; Chehbouni, J.Q.; Leeuwen, W. and Hua, G. (1991): Normalization of multidirectional Red and NIR reflectances with SAVI Proceedings of the 5th International Colloquium – Physical measurements and signatures in remote sensing. 14 – 18 January 1991. Courchevel, France. pp 419 – 422.
- Ikhuria, I.A. (1993): Vegetation and land-use changes in a rainforest ecosystem *Nigerian Journal of Remote Sensing*, 1: 73 – 82.
- Isichei, A.O. (1995): Omo biosphere reserve, current status, utilization of biological resources and sustainable management. Working paper No. 11, 1995, UNESCO (South-South Cooperation Programme), Paris, France.
- MANR (1971): Annual report of the western state forestry advisory commission 1st October, 1968 to 31st March, 1971 Ministry of agriculture and Natural Resources, Western State of Nigeria Official Document No. 4 of 1973. 18 pp.
- NEST (1992): *The challenge of sustainable development in Nigeria* Nigerian Environmental Study Action Team, Intec. Printers Ltd., Ibadan.
- Okali, D.U.U. (1991) Guidelines for selection of sites and species of conservation interest Report to Natural Resources Conservation Council, Abuja, Nigeria. Mimeograph

- Okali, D.U.U. and Onyeachusim, H.D. (1991): The ground flora and rain forest regeneration at Omo forest reserve, Nigeria. In Gómez-Pompa, A., Whitmore, T.C. and Hadley, M. (eds.) *Rain forest regeneration and management*. Man and The Biosphere Series, Volume 6. UNESCO, Paris and The Parthenon Publishing Group Limited. Carnforth, UK. pp 273 –283.
- Oyebo, M.A. (2006): History of forest management in Nigeria from 19th century to date Paper presented at the International Stakeholders Workshop on Geo-Information System-Based Forest Monitoring (GEOFORMIN) in Nigeria held at the National University Commission (NUC) Auditorium, Maitama District, Abuja, between 27th – 30th March 2006.
- Oyinloye, R.O. (2008): *A geoinformation-based model for assessing and monitoring forest reserves in southwestern Nigeria* Unpublished P.hD Thesis. Department of Geography, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. 337 pp.
- Richards, P.W. (1952): *The tropical rain forest: An ecological study* Book 1. The Syndics of the Cambridge University Press, London. 450 pp.
- Salami, A.T. (1995): *Structural changes in vegetal cover in Ife and Ede regions of southwestern Nigeria between 1963 and 1993*. Unpublished Ph.D. Thesis, Department of Geography, Obafemi Awolowo University, Ile-Ife. 186 pp.
- Salami, A.T. (1999): Vegetation dynamics on the fringes of lowland humid tropical rainforest of southwestern Nigeria – An assessment of environmental change with air photos and Landsat-TM *International Journal of Remote Sensing*, Vol. 20, No. 6, pp 1169 – 1181.
- Sedano, F.; Gong, P. and Ferrão, M. (2005): Land cover assessment with MODIS imagery in southern African Miombo ecosystems *Remote Sensing of Environment* 98, pp 429 – 441.
- Swain, P.H. and Davis, S.M. (1978): *Remote sensing: The quantitative approach* McGraw-Hill Book Company, New York. 396 pp.
- Tokola, T.; Löfman, S. and Erkkilä, A. (1999): Relative calibration of multi-temporal Landsat data for forest cover change detection *Remote Sensing of Environment* 68, pp 1–11.
- USGS and NOAA (1984): *Landsat-4 data users handbook* NASA, Maryland, USA.
- WRI (2003): World Resources Institute report – 2003.
- Yemefack, M. (2005): *Modelling and monitoring soil and land–use dynamics within shifting agricultural landscape mosaic systems in Southern Cameroon* Doctoral Dissertation. ITC Dissertation 121, ITC, Enschede and Utrecht University, The Netherlands. 194 pp.