Detection of Human-Induced Land Cover Changes in Nimbia Forest Reserve, Kaduna State, Nigeria

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Abstract
Nimbia Forest Reserve was established in 1957 as a plantation site to increase the productivity and curb desertification of the semi-arid zone of the Northern Guinea Savannah of Nigeria. But human activities has been acknowledged as a vital factor militating against the realization of this noble objective. This study attempts the use of GIS and Remote Sensing in mapping land cover in the study area between 1986, 1998 and 2007 so as to detect the changes that may have taken place in the study area between these periods as a result of human activities. The study utilized data from field surveys, remote sensed data and geographical information system technique, four main methods of data analysis were adopted in this study namely calculation of the Area in hectares of the resulting land cover types for each study year and subsequently comparing the results, Markov Chain and Cellular Automata Analysis for predicting change, Overlay Operations and Maximum Likelihood Classification. Subsequently, an attempt was made at projecting the observed land cover changes. The result obtained showed that some features will be lost to other features and possible reasons for that were evaluated. Recommendation were put forward to help curb the problem.
Keywords: Land cover, Forest, Remote sensing, GIS, Human activities

Introduction

Illegal forest activities pose a significant threat to the sustainability of forest ecosystems, result in losses of government revenues, foster a vicious cycle of bad governance, and may contribute to increased poverty and social conflict. As such, they have received considerable attention from the international community, particularly in recent years(Tacconi, 2003). Anthropogenic or illegal forest activities include a broad array of legal violation that ranges from violating ownership and use rights to engaging in corrupt relationships. They also may span activities at all stages of the forest production chain, from the acquisition of authorizations, to planning, to harvesting and transport of raw material and finished products, to financial management. Illegal forest activities pose a significant threat to the sustainability of forest ecosystems, result in losses of government revenues, foster a vicious cycle of bad governance, and may contribute to increase poverty and social conflict (CIFOR, 2003).Changes in vegetation cover are related to anthropogenic activity and/or natural causes. In the absence of anthropogenic impacts and extreme natural events (fire, flood, etc.), vegetation cover is related directly to rainfall. Rainfall is one of the most important factors that affect vegetation productivity in a desert ecosystem. In semiarid areas, vegetative cover is related to the amount and timing of rainfall (Lazaro, 2001)Upon all the benefits forest gave to people yet, forest faced problems such as deforested areas, mismanaged forests, broken structure and health, nonguaranteed sustainability, decreased biodiversity, and destructed forest due to conversion to other land use such as agricultural and industrial development(Misir,1997).

Lambin(1996), states that most of the world's Vegetation is in a constant state of flux at a variety of spatial and temporal scales. These changes are driven by seasonal and interannual climate variations, long-term climate shifts vegetation succession, and human or natural disturbance.Forest ecosystems are being degraded and lost because of rapid population change and economic incentives that make forest conversion appear more profitable than forest conservation (David, 2001).

Some of our forest reserves in Nigeria as observed by Tudunwada (2012) are facing degradation from anthropogenic activities, particularly the Fulani herdsmen, Firewood poachers and hunters. He also noted that some of these forest reserves have insufficient numbers of personnel to look after the forest at the same time they were ill equipped and were badly remunerated.

Before the current Nimbia forest reserve was established there was a natural forest which was cleared in 1957and replaced by the government with exotic species mainly Teak (*Tectona grandis*) and a few *Gmelinaarborea* stands. The purpose was to raise a logging plantation that could serve as a source of employment to the youth of the area and a source of revenue to the government. Contrary to this, the Forest is facing some level of degradation as a result ofthe nonchalant attitude of the management and illegal poaching currently going on in the forest.

Aim and Objectives

The aim of this study is to use multi temporal Landsat imageries for the past 21 years (1986-2007) to determine the changes in Nimbia Forest Reserve. The following specific objectives will be pursued in order to achieve the aim of the study.

i. To generate land cover maps of the forest structures for the period 1986, 1998 and 2007.
ii. To determine the magnitude and percentage change of the forest cover that occur over the study periods.
iii. To forecast the future forest cover of the study area.

The Study Area

Nimbia Forest Reserve is located in the Southern Guinea Savanna Zone of Nigeria. It lies between longitudes 8^{0}30' and 8^{0}35'E and latitudes9^{0} 29' and 9^{0} 31'N (see figure 1) with an elevation of about 600m above sea level. The forest reserve is located in Jema'a Local Government Area of Kaduna State Seventy Kilometers South East of Jos along Jos – Kafanchan road. Nimbia Forest Reserve covers an area of about 2,282.4 hectares. It is long and narrow in shape, bounded on the South by Gimi River and on the North by the Lioc Stream(Obidike, 2011).

The natural vegetation was cleared in 1957, by the then Jema'a native Authority and replaced with mainly Teak (*Tectona grandis*) and few *gmelina arborea* stands. According to Howard (1963), the first trial plantation of teak started in 1957, and between 1958 and 1966, 98.42 hectares were planted with teak. The planting continued through the seventies with the last planting carried out in 1991.

Teak *(Tectona grandis Linn. F),* a native of tropical and subtropical India and South East Asia. It tolerates a relatively wide range of climatic condition in areas of rainfall ranging below 762mm to over 3,810mm per annum at between 13^{0}c and 37^{0}c respectively. Nimbia Forest Reserve is located within the Jema'a platform and is underlain predominately by igneous and metamorphic rocks. The position Nimbia with respect to its altitude (600 m above sea level) induces orographic (topographic) rain. The altitude of Nimbia Forest Reserve contributes to the lower temperatures experienced. Its minimum temperatures are as low as 12.9^{0}C and 11^{0}C while the maximum temperatures for the hottest month (March) is 25^{0}C.The highest humidity value of the reserve is obtained in July and August when the rainfall is heaviest (Ayuba, 2006).

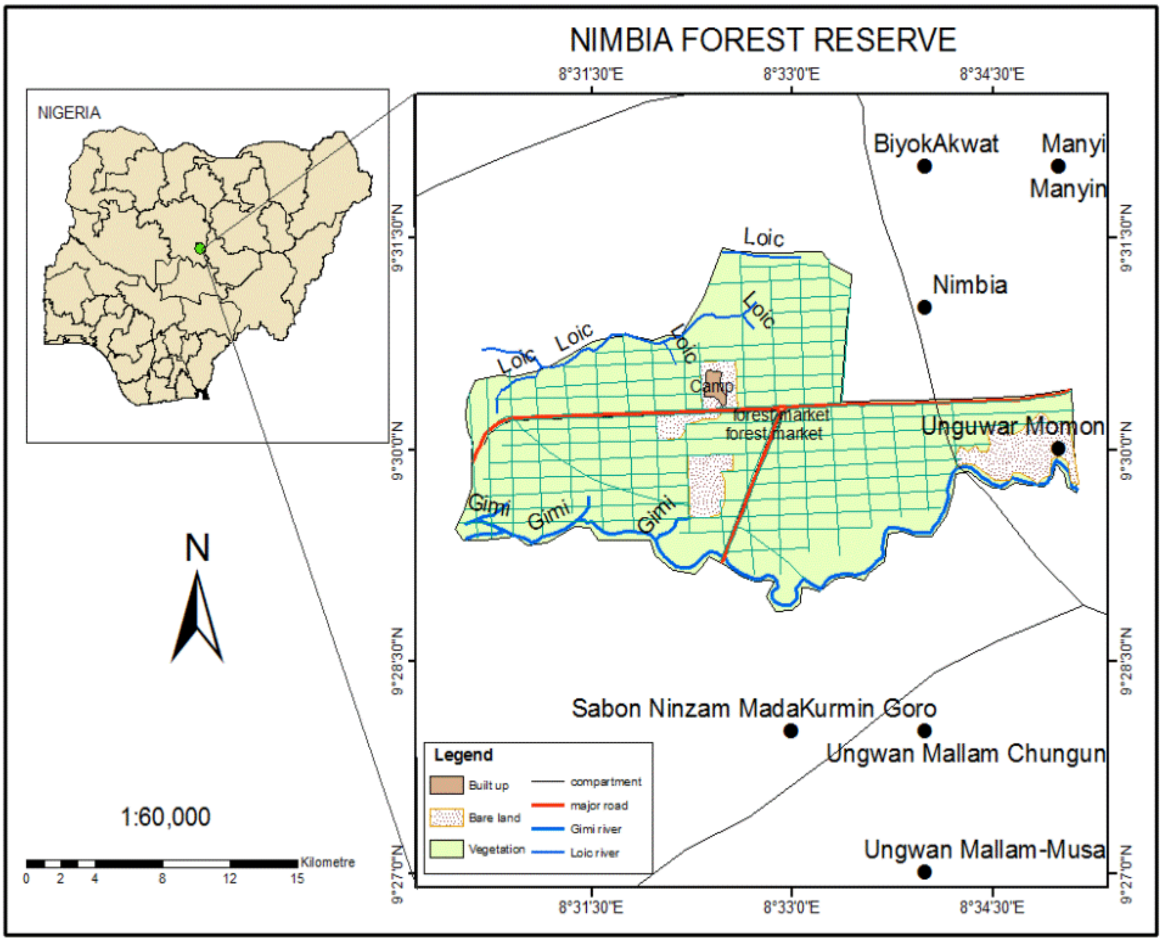

Figure1 Map of the Study Area

Materials and Methods

The data used for studying land cover changes in Nimbia forest include three historical landsat satellite images covering Nimbia forest for the past 21 years (1986-2007).The images of 1986, 1998 and 2007 with spatial resolution of 30m were obtained from Global Land Cover Facility (GLCF) an Earth Science Data Interface through the URL: http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp.These data sets were captured by Landsat-5 TM on 17 and 18 November 1986 and 1998 respectively, while the other Landsat ETM was captured on 21 December 2007 all using WRS 2 path/row 188/53 .

Spot-5 imagery was acquired from National Centre for Remote Sensing (NCSR) Jos and it was used as a reference data for classification accuracy assessment. It was also used to delineate the topographic map of the study area as shown in Figure1 and Table 1 shows the characteristics of the images used for this study. November 1986 and1998 scenes were selected because of reduced spectral separability and phonological stability as was noted by Hame, (1988) that for any meaningful change detection, summer and winter are the best seasons because of their phonological stability. Also, selecting the summer or the driest period of the year enhances spectral separability. However, the spectral separability is reduced as a result of excessive wetness prevailing during other period of the year (Burns, 1981).

Table 1: Attribute of the images use for the study

Data Type	Resolution	Spectral Bands	WRS: P/R	Date of Acquisition
Landsat TM	30m	1,2,3,4,5 and 7	188/054	17-11-1986
Landsat ETM	30m	1,2,3,4,5 and 7	188/054	18-11-1998
Landsat ETM	30m	1,2,3,4,5 and 7	188/054	21/12/2007
Spot-5	10 m	1,2,3		2007

The GPS has developed into an efficient GIS data technology, which allows for users to compiled their own data sets directly from the field as part of the 'ground truthing'(Cunningham, 1998). In this study, point data was collected using GPS at different points in the field (Appendix 1). This is done whenever the GPS fully acquired connection from the satellite at the selected point. The recorded points were used during training site creation and also reserve for accuracy assessment.

The acquired Landsat satellite imageries were individually imported into IDRISI Tiger environment by loading each layer at a time. Since the images were pre-georeferenced and orthorectified from the source, then, there was no need for that exercise again. Image window was performed using spatial analyst tool on a sub-scene from the full image on the basis of a frame covering the Forest. These pre-processing tasks allowed the satellite images for classification and extraction of land cover information.

The data processing in this study involves the use of a high resolution image to delineate the study area. This involves the creation of a database where relations/tables were created for: Plantation, Bare Land, Water Body and Bare Rock. Other data stored are the GPS points acquired during ground-truthing that was used for classification accuracy assessment.

The assessment of land use and land cover was done by adopting a classification scheme for the Landsat images for years 1986, 1998 and 2007 and carrying out a Supervised classification (Maximum likelihood) based on ancillary data and other information obtained from the field and literature sources. "An effective land use management planning is represented by a classification scheme as a necessary component".

Based on the knowledge acquired as result of reconnaissance survey with additional information from some staff of the forest reserve and information from previous researches in the study area, a classification scheme was developed for the study area after Anderson *et al* (1976).

Table 2: Land cover classification scheme (Anderson 1976).

Code	**Land use/Land cover categories**	**Description**
1	Plantation	Area predominately *Gmelina arborrea* and Teak(*Gmelina arborrea*).
2	Bare land	Area dominated by growing cropping field, Experiment plots and bare soils.
3	Stream	Stream and river channel.
4	Rock	Areas covered by basaltic boulders, escarpment, igneous and metamorphic rocks.

Methods of Data Analysis

Four main methods of data analysis were adopted in this study.

(i) Maximum Likelihood Classification

(ii) Calculation of the Area in hectares of the resulting land cover types for each study year and subsequently comparing the results.

(iii) Markov Chain and Cellular Automata Analysis for predicting change

(iv) Normalize Difference Vegetation Index (NDVI).

After all the necessary correction and making the images ready for classification, the bands 4,3,2 of the individual image were combined that produced a color composite for vegetation cover. Using linear enhancement module, the color composite was further enhanced. The Normalized Difference Vegetation Index (NDVI) was performed to detect areas prone to human activities. Vegetation health is estimated using NDVI and it also provides a means of monitoring changes in vegetation over time. Maximum likelihood technique and ground survey data were used to identify and classify the training sites using supervised classification. The classified images were then overlaid to determine the extent of change in the forest reserved. Image classification and interpretation was performed using IDRISI Tiger.

Using reference images (Spot-5), training samples were gathered from 30 points as signatures for each Landsat satellite images. These signatures were then used in a supervised classification method. Land use/land cover was mapped by means of visual interpretation of satellite images. The classification consists of four classes for each time period (Table 2). The major classes are; Plantation, Bare Land, Streams, and Bare Rock. From the supervised classification methods in IDRISI tiger, the Maximum Likelihood (ML) classification algorithm was used to produce the land cover maps. The maximum likelihood classification method uses a decision rule to evaluate each pixel. To be assigned to a particular class, a pixel must exhibit reflectance within this reflectance range for every band considered. The final land cover maps produced using these procedures enabled spatio-temporal change analysis and pattern through change maps and spatial metrics.

To achieve the second objective of this study, the study area was measured in hectares using IDRISI software by tabulating the result of the classified images obtained. The comparison of the land use/land cover statistics assisted in identifying the percentage change, trend and rate of change between 1986 and 2007. In achieving this, the first task was to develop a table showing the area in hectares and the percentage change for each year 1986, 1998 and 2007 measured against each land use/land cover type. Percentage change to determine the trend of change can then be calculated by dividing observed change by sum of changes multiplied by 100.

(Trend) Percentage change $= \frac{\text{Observe change}}{\text{Sum of change}} \times 100$

Predicting or projecting land cover change to a particular period is possible using Markov and cellular automata. These two algorithms are available in IDRISI. A Markovian process is one in which the future state of a system can be modeled purely on the basis of immediately preceding state. The Markov module analyzes a pair of land cover images and outputs a transition probability matrix, a transition area matrix, and a set of conditional probability images. The transition probability matrix is a text file that records the probability that each land cover category will change to every other category. The transition areas matrix is a text file that records the number of pixels that are expected to change from each land cover type to each other land cover type over the specified number of time unit. In both of these files, the rows represent the earlier land cover categories and the columns represent the later categories. The conditional probability images report the probability that each land cover type would be found at each pixel after the specified number of time unit. In addition to this process, Normalized Difference Vegetation Index (NDVI) was also applied to detect areas of vegetation cover decrease. This method has proved reliable in monitoring vegetation change. Vegetation differential absorbs visible incident solar radiant and reflects much of the infrared (NIR), data on vegetation biophysical characteristics can be derived from visible and NIR and MIR portions of the Electro Magnetic Spectrum (EMS). The NDVI approach is based on the fact that healthy vegetation has low reflectance in the visible portion of the EMS due to chlorophyll and other pigment absorption and has high reflectance by the mesophyll spongy tissue of green leaf (Campbell, 1981). NDVI can be calculated as a sensor system; its values range from -1 to +1. Healthy vegetation is represented by NDVI values between 0.1 and 1. Non vegetated surfaces such as water bodies yield negative values because of the electromagnetic absorption quality of water. Bare soil areas represent NDVI values which are closest to 0.

Results and Discussion

The objectives of this study forms the basis of all the analysis carried out in this chapter. The results are presented inform of maps, charts and statistical tables. They include the static, change and projected land cover of each class.

Land cover classification and mapping forest structures

A supervise classification using maximum likelihood algorithm was used for the three remotely sensed images and the result of the classification provides an overview of the major land cover features of Nimbia Forest Reserve for the year 1986, 1998 and 2007.The Forest is categorized by four land cover features as also identified are; plantation, Bare land, Stream, and Bare rock. These land use land cover classes were derived from images 1986, 1998, and 2007 for the study. The maps of the classified images was achieved and illustrated by figure 2, 3 and 4 for the land cover changes 1986, 1998 and 2007 respectively.

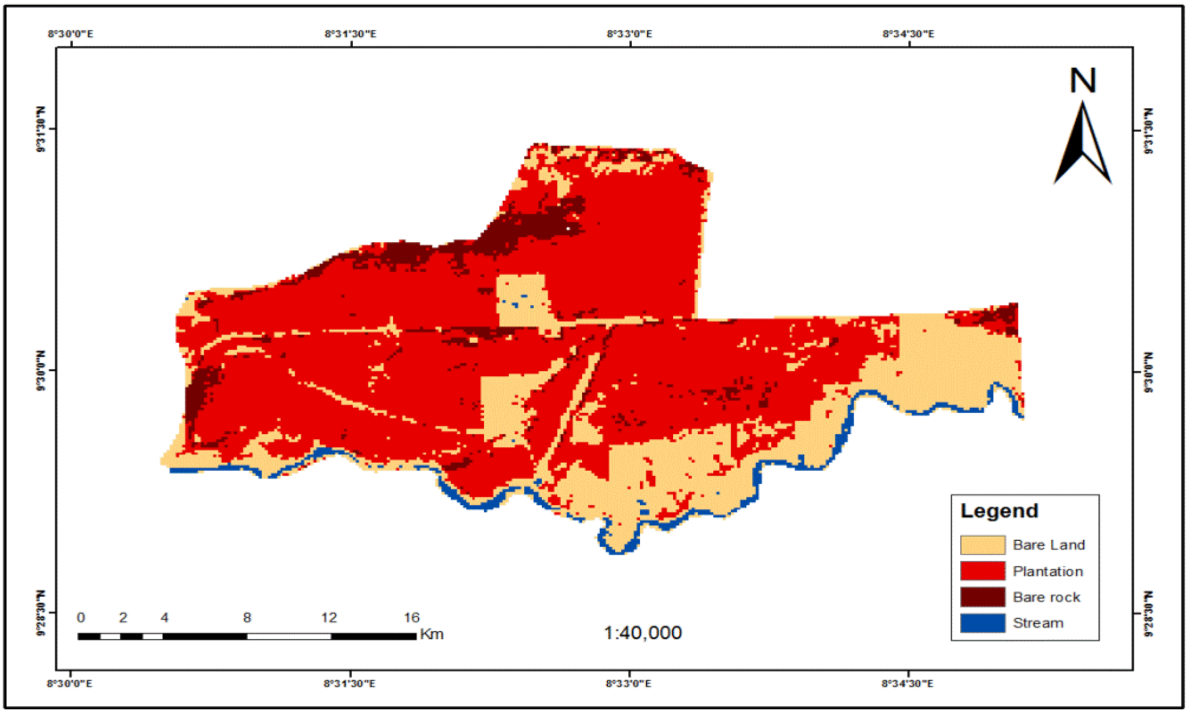

Figure 2 Land cover of the study area in 1986

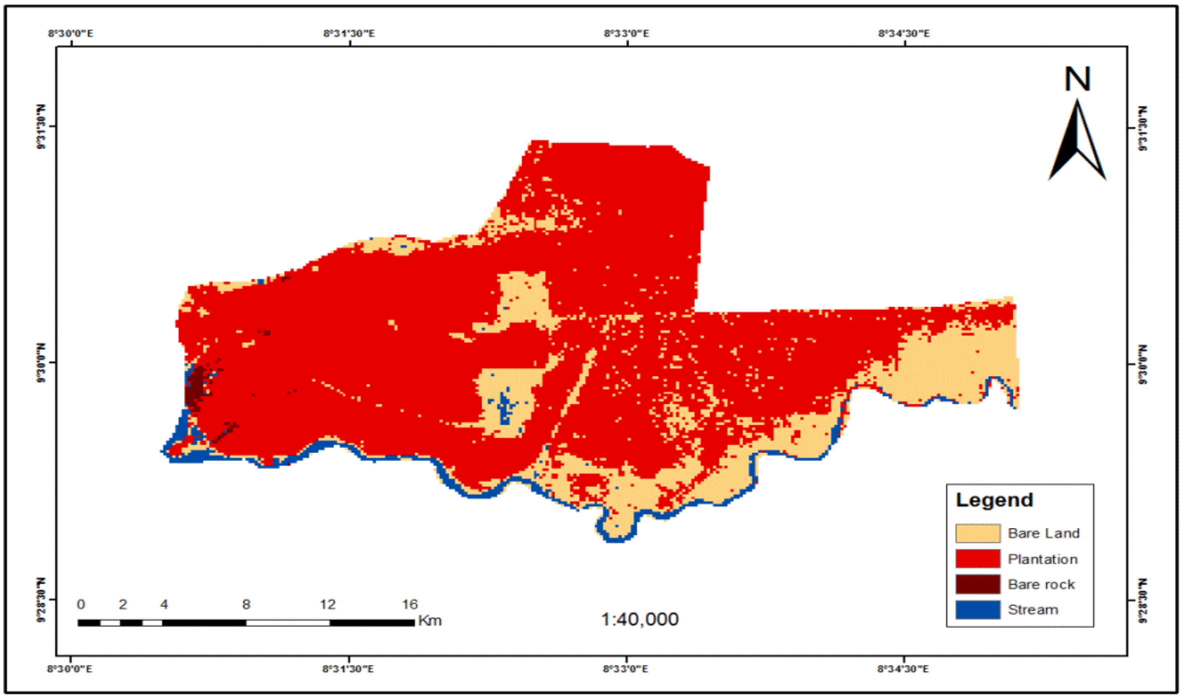

Figure 3 Land cover of the study area in 1998.

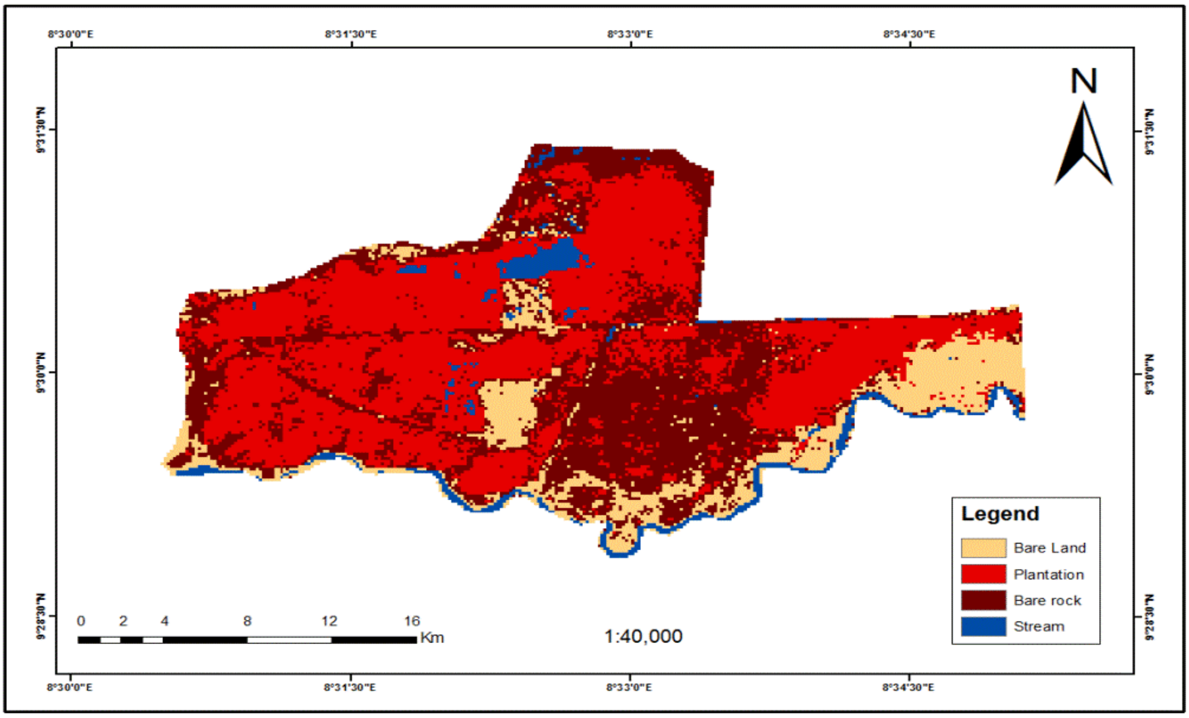

Figure 4 Land cover of the study area in 2007

Land use land cover distribution

The static land use land cover distribution for each year as derived from the image maps is presented in table 3 below.

The classification results shown in table 3, indicate the land use land cover classes in year 1986, 1998 and 2007 in the study area as; Plantation (63.51%, 75.59% and48.66%), Bare land (27.14%, 20.52% and 13.88%) Stream (2.85%, 3.36% and 4.43%) and Bare rock (6.51%, 0.53% and 33.03%), respectively.

Table 3 Size and proportion of land cover classes from 1986-2007

Land cover type	Area in 1986		Area in 1998		Area in 2007	
	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Plantation	1325.88	63.51	1577.97	75.59	1015.92	48.66
Bare Land	566.55	27.14	428.31	20.52	289.71	13.88
Stream	59.4	2.85	70.2	3.36	92.43	4.43
Bare rock	135.81	6.51	11.16	0.53	689.58	33.03
Total	**2087.64**	100	**2087.64**	100	**2087.64**	**100**

Table 4 Land Use Land Cover Change

Activity Types	Area covered (Ha)			Difference (Ha)	Difference (Ha)	Increase/ Decrease%	Increase/ Decrease%
	1986	**1998**	**2007**	**1986-1998**	**1998-2007**	**1986-1998**	**1998-2007**
Plantation	1325.88	1577.97	1015.92	252.09	-562.05	12.08	-26.92
Bare Land	566.55	428.31	289.71	-138.24	-138.60	-6.60	-6.64
Stream	58.95	70.20	92.43	11.25	22.23	0.54	1.06
Bare rock	135.81	11.16	689.58	-124.65	674.42	-5.98	32.31

The Figures in tables 3 and 4 above represent information about the static area of each land cover category of each study year. The increase in water body may be connected to the direction of the water waves of river Gimi which flow towards the plantation. The strength of the water movement encroach the plantation side. The type and nature of the rock in the study area allow outcrop of tree stands. The forest is underlain predominantly by igneous and metamorphic rock and some other categories of rocks. The vegetation grown might have covered most part of the rock in 1998. It also appeared in 2007 rock reflectance increased. This is as a result of bush fires that engulf the forest every year. The forest suffers bush fire around the period this image was captured. The burnt area eventually reflected no light which appears to have rock attribute. This has really affected the reflectance of the plantation that leads it to drop from 75.59% in 1998 to 48.66% in 2007. Another change is in bare land, this is due to a new development where a Forest Research Institute in Jos took over some of these bare lands and converts them to experimental plots.

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetative Index (NDVI) is a calculation, based on several spectral bands, of the photosynthetic output (amount of green stuff) in a pixel in a satellite image. It measures, in effect, the amount of green vegetation in an area. In this exercise, you will use MultiSpecs ability to create new channels in an image to display the NDVI for an image.

The NDVI for a pixel is calculated from the following formula:

$$NDVI = \frac{NIR - PAR}{NIR + PAR}$$

This formula yields a value that ranges from -1 (usually water) to +1 (strongest vegetative growth.) For this study NDVI calculation was performed using IDRISI NDVI algorithm to produce NDVI images for the three years.

From the maps obtained, figure 7 shows that, there was dense vegetation in 1986 with an NDVI range between 0.50 to 0.13.That means the forest was under good control with little or no any sort of anthropogenic activities.

In 1998, the NDVI result range from 0.5 to 0.25 shows that the vegetation index was very low. The last image of 2007 has an NDVI of 0.38 to -0.25.

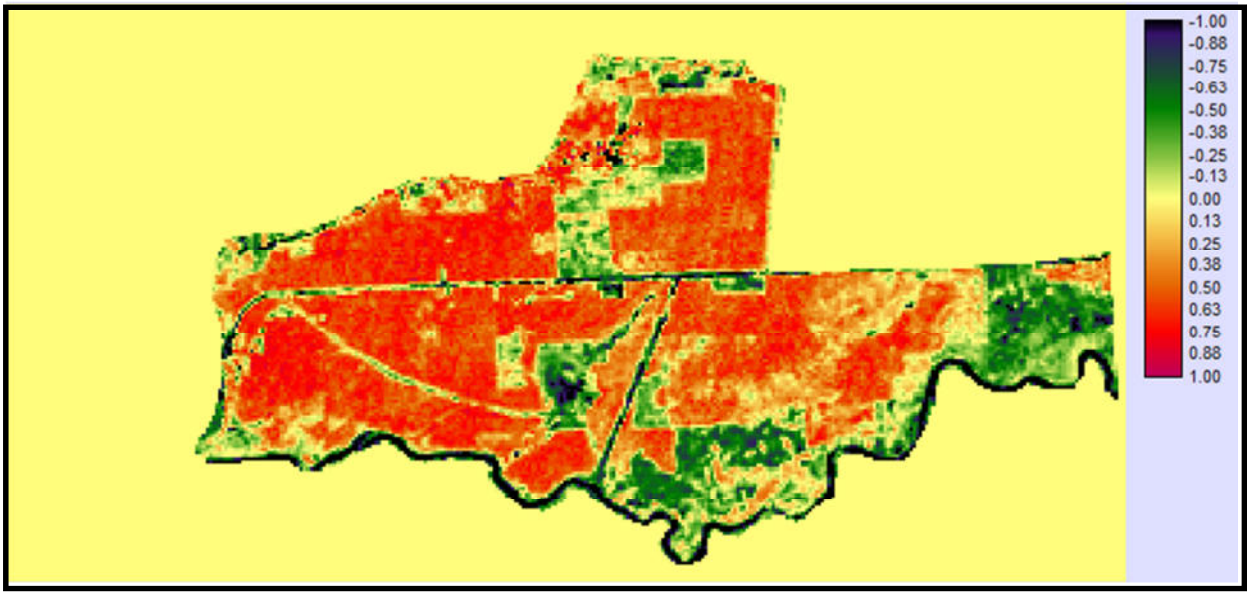

Figure 5 NDVI Result for Landsat-TM 1986 of the study area.

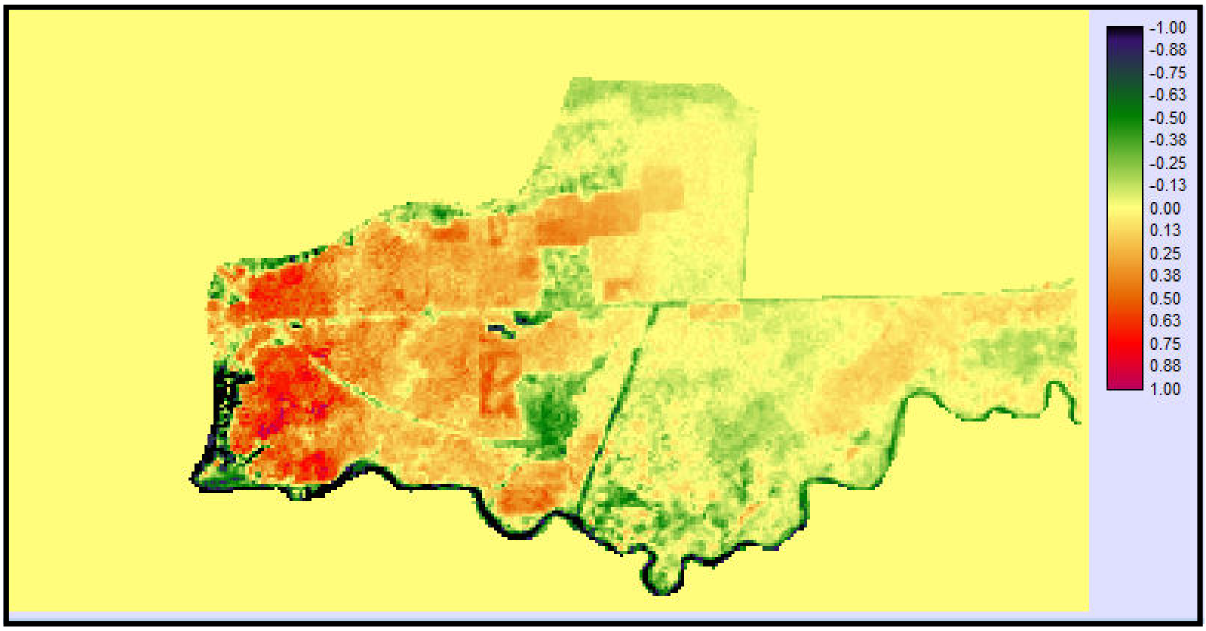

Figure 4.8 NDVI Result for Figure 6 Landsat-TM 1998 of the study area.

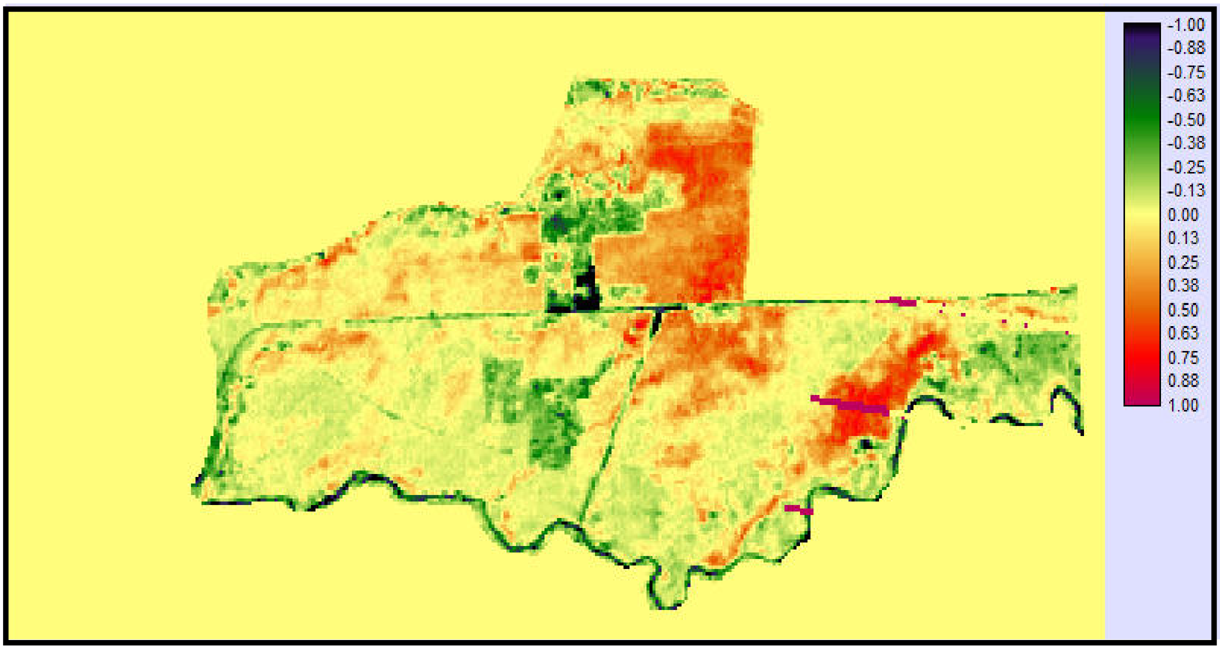

Figure 7 NDVI Result for Landsat 2007 of the study area.

Land use Land cover projection for 2037

Transition Probability Matrix

The transition probability matrix records the probability that each land cover category will change to the other category. This matrix is produced by the multiplication of each column in the transition probability matrix with the number of cells of corresponding land use in the later image. IDRISI markov algorithm was used in obtaining the result and also used for projecting changes in 2037.

Table5 Given: Probability of changing to:

Classes	Plantation	Bare Land	Stream	Bare Rock
Plantation	0.5700	0.0334	0. 3210	0.3628
Bare Land	0.2427	0.2817	0.0408	0.4267
Stream	0.0186	0.3144	0.5334	0.1146
Bare Rock	0.2958	0.1201	0.0410	0.5409

Markov Operation

This is simply an operation in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markov chain analysis described land use change from one period to another and uses this as the basis to project future change. The Markov module under change/time series analysis under GIS analysis of IDRISI was used. The first image (1986) as the earlier image and the second image (2007) as the latter image was inputted. The number of time period between the two images and the number of the projected year from the second image was also inputted. Ten years was used for both numbers of periods.

Table 6 Land cover change prediction for 2037

Land use Land cover classes		**Plantation**	**Bare Land**	**Water body**	**Bare Rock**
2037 Prediction	**Area in Hectares**	1585.26	**214.11**	**91.08**	**220.05**
	Area in Percentage	**75.113%**	**10.147%**	**4.316%**	**10.426%**

The table above shows the statistic of land use land cover projection for 2037. Comparing the percentage representations of this table and that of table 5, there exist similarities

In the observed distribution particularly in 1986-1998.There will be a gain in Plantation and a loss in bare land. This may be attributed to the intervention of an academic Forest institute that is converting bare land to an experiment plots. Likewise rock may be exposed at the Northern part of the forest.

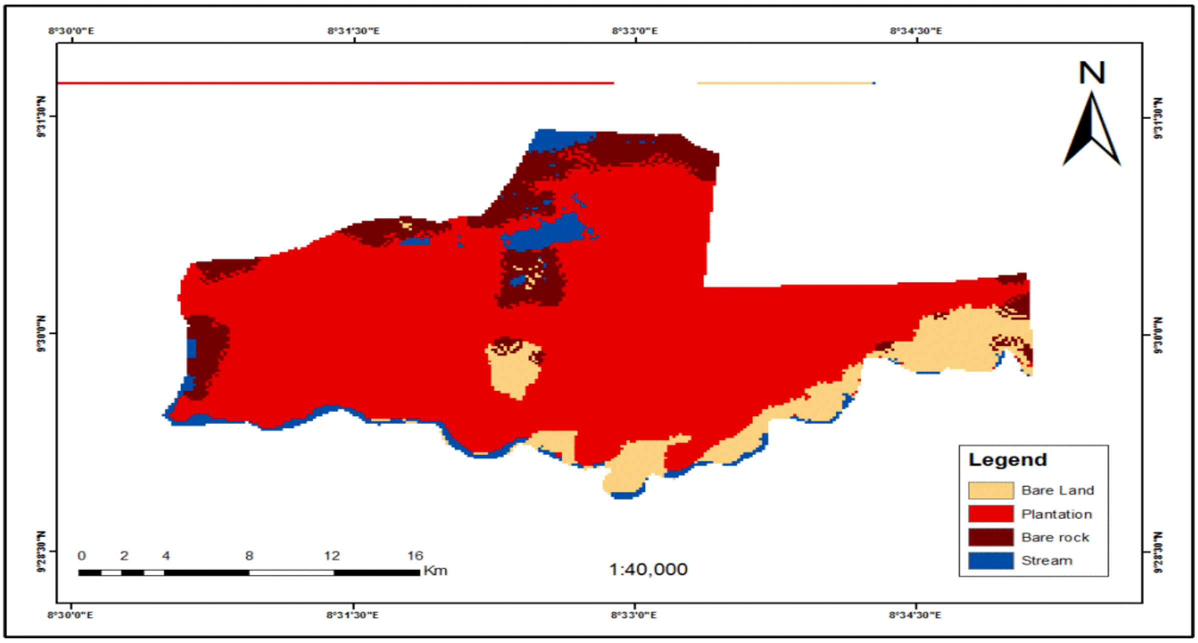

Figure 8 Projected Land Cover of Nimbia Forest Reserve for 2037

Conclusion and Recommendation

The 1986, 1998TM and 2007ETM Satellite remote sensing data were used to identify, classify, assess and interpret Nimbia Forest Reserve for the year 1986, 1998 and 2007 respectively. A GIS database of land use / land cover categories and their changes within 21 years (1986-2007) was generated and analyzed. The result shows that; in general the forest plantation was retreating due to severalanthropogenic activities of man such as illegal felling of wood, farming activities. The degradation can be attributed to the poor management of the forest.From this study, Landsat TM data are proved to be effective in mapping and monitoring the dynamics of land use / land cover of the study area.

Recommendations

Deforestation is not an unstoppable or irreversible process. Increased and concerted efforts in forest plantation 'rebirth' and rejuvenation will bring to use the type of forest reserve we envisaged. In order to reduce the effects of deforestation in Nimbia Forest Reserve the study offer the following recommendations:

i. Government by way of policy should be strict in preserving forest reserves from illegal occupation.
ii. The forest management should reclaim and replant every cleared surface within the forest.
iii. Employment of more personnel and provision of attractive remunerations to staff.
vi. Trees should be allowed meet required maturity before felling.
v. Lastly, the need to train the policy makers and resource managers on land use and land cover information through remote sensing and GIS. This will help in easily realizing where action should be taken and what kinds of intervention are needed

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APPENDIX 1: GPS points obtained from the study area.

S/**N**		lat		lon	class		Location
1		449609.5		1050818	2		Camp Office
2		450486.7		1050598	1		Beat 1 edge
3		451268.3		1050671	1		Beat 4 edge
4		450403.8		1050600	1		Beat 2 edge
5		449371.1		1050594	2		Compartment 3/4
7		449691.1		1048683	3		Gimi river
8		450138.9		1049726	2		Farm land
9		452976.5		1049842	3		River
10		449607.3		1049405	1		Compartment **edge**
11		449307		1049871	2		Bare land
12		451102.3		1052528	3		River
13		446505.3		1049906	4		Bare **rock**
14		448924.1		1051490	4		Bare rock
15		449633.6		1051727	2		Bare land
17		452778		1050317	1		Plantation
18		453009.7		1050327	1		Plantation
19		451317.8		1050327	2		T-junction
20		449359.6		1051146	2		camp **edge 1**
21		449802.6		1051146	2		camp edge 2
22		449851		1050619	2		camp edge 3
23		449385.1		1050603	2		camp edge 4
24		449061.5		1050497	1		Plantation
25		449338.6		1050492	1		Plantation
26		447852.7		1049694	2		Foot path
27		448937.6		1050868	1		Plantation
28		450488.9		1051566	1		Plantation
29		448819.7		1048673	2		River bank
30		450446.8		1050605	2		Bare land