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Analysis of forest cover changes in Nimbia Forest Reserve, Kaduna State, Nigeria using Geographic Information System and Remote Sensing techniques

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Abstract: Nimbia Forest Reserve is witnessing degradation due to anthropogenic activities such as Farming, Illegal felling and fuel wood extraction just like many other forest reserves in Nigeria. On the other hand, the management has failed to provide enough manpower to guard against anthropogenic activities and the few ones available were not receiving better remuneration. Other problems faced by the forest are that trimming is done on time and cleared lands were not replanted. These and many other reasons leading to overexploitation, increase rate of deforestation, modification of the forest structure, reduced income to government and increased unemployment. This study examines the use of GIS and Remote Sensing in mapping Land Cover in Nimbia Forest Reserve between 1986 and 2010 so as to detect the changes that may have taken place in this status between these periods. Subsequently, an attempt was made at projecting the observed land cover in the next 21 years. The result obtained show that some features will be lost to other features and possible reasons for that were evaluated. Suggestions were therefore made at the end of the work on ways to use the information as contained therein optimally.

Keywords: Landcover Change, Forest, Geographic Information System, Remote Sensing, Landsat Satellite Imagery

1. Introduction

Forests over history have value to the world's human population and their value is by each day increasing as people still use forest for shelter, fuel wood and provision of food for themselves. According to Misir (1997), beside raw material for wood processing industry that forest provides, it also provides habitat for wildlife, reserves for water and soil conservation, oxygen and food chain. However, our forest is facing so many problems. Most of the world's vegetation is in a constant state of flux at a variety of spatial and temporal scale, deforestation of our tropical forest is a result of many pressures (Lambin,1996). As people try to meet their daily needs, they are subjecting forest, woodland and grassland to the highest rate of change (Pomery, 2004). Also as noted by Tudunwada (2012), our forest today is faced with all sorts of anthropogenic activities, such as, illegal felling of trees for firewood and roofing, illegal cultivation and conversion of parts of the forest for residential use by nomads.

In a world with an increasing population and also increased pressure on our natural and man-made forest resources, there is a greater demand for up-to-date and accurate spatial information. Geographic Information System (GIS) and Remote Sensing (RS) are now providing new tools for advanced ecosystem management. Lunette (1999) stated that; the use of RS and GIS techniques allows the extent of change in our vegetation to be easily analyzed. Vegetation change detection is useful in land use and land cover changes, wildlife extinction and rate of deforestation.

Afforestation effect and other cumulative changes through spatial and temporal analysis techniques. Therefore, attempt will be made in this study to map out the status of Nimbia Forest Reserve between 1986 to 2010 with a view to detecting the change that has taken place and also predict possible changes that might take place in this status in the next 30 years using GIS and RS data.

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 *Gmelina arborea* stands. The purpose was to raise a logging plantation that could serve as a source of employment to the youths 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 of the nonchalant attitude of the management and illegal poaching currently going on in the forest. Some of the problems being faced by the forest are: logging of premature stands without replacing since 1991, inadequate manpower at the forest camp to guard the forest against illegal activities such as: illegal felling, setting bush fire, cultivation and encroachment of other land uses such as residential and agriculture. Regenerated trees were left unattended due to shortage of manpower to handle the trimming. Similarly, most of the workers were employed on casual basis receiving poor remuneration, thus, this encourages them to franchise the harvested plots for farming to nearby villagers instead of replanting and they also connive with illegal fellers to obtain timbers in exchange for money.

1.1. Aim and Objectives

The aim of this study is to use multi-temporal Landsat imageries for the past 24 years (1986-2010) to determine the spatio-temporal dynamics of the changes in Nimbia Forest Reserve.

The following specific objectives will be pursued in order to achieve the aim of the study is to:

i. To generate land cover maps of the forest structures for the period 1986, 1998 and 2010.
ii. To determine the magnitude and percentage change of the forest cover that occurred over the study periods.
iii. To forecast the future forest cover of the study area.

1.2. The Study Area

1.2.1. Geographical Location and Extent

Nimbia Forest Reserve is located in the Southern Guinea Savanna Zone of Nigeria. It lies between longitudes 8º30' and 8º35'E and latitudes 9º 29' and 9º 31'N (see figure 1.1) 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).

1.2.2. History of the Plantation

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 13ºc and 37ºc 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 rain. The altitude of Nimbia Forest Reserve contributes to the lower temperatures experienced. Its minimum temperatures are as low as 12.9ºc and 11ºc while the maximum temperature for the hottest month (March) is 25ºc.The highest humidity value of the reserve is obtained in July and August when the rainfall is heaviest (Ayuba, 2006).

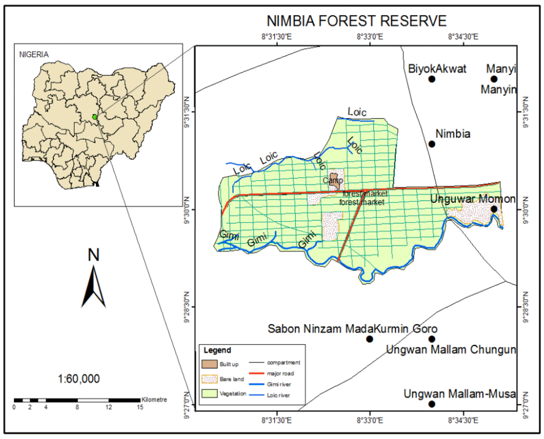

Figure 1.1. *The Study Area.*

2. Materials and Method

The data used for studying Nimbia forest spatio-temporal land cover change include three historical landsat satellite images covering Nimbia forest for the past 24 years (1986-2010).The images of 1986, 1998 and 2010 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 17th and 18th November 1986 and 1998 respectively, while the other Landsat ETM was captured on 21st December 2010 all using WRS 2 path/row 188/53 .

Spot-5 imagery was acquired from Regional Centre for Training in Aerospace Surveys, Ile Ife, Nigeria (RECTAS) 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 Figure 1.1. 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 Ayuba, (2006) 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 (Dewan, 2009).

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	21/12/2010
Spot-5	10 m	1,2,3		2010

Source: Field Survey 2010

The Global Positioning System (GPS) has developed into an efficient GIS data technology, which allows for users to compile their own data sets directly from the field as part of the 'ground truthing'. In this study, point data was collected using GPS at different points in the field. This is done whenever the GPS fully acquired connection from the satellite at the selected point.

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 assessment of land use and land cover was done by adopting a classification scheme for the Landsat images for years 1986, 1998 and 2010 and carrying out a Supervised classification (Maximum likelihood) based on ancillary data and other information obtained from the field and literature sources.

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.

Table 2. *Land cover classification scheme.*

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.

Four main methods of data analysis were adopted in this study, namely:

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 to produce 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 2010. 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 2010 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.

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

(Zubair, 2006).

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 immediate 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. 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

3. Results and Discussion

3.1. 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 2010.The Forest is categorized by four land cover features namely: 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 1, 2 and 3 for the land cover changes 1986, 1998 and 2010 respectively.

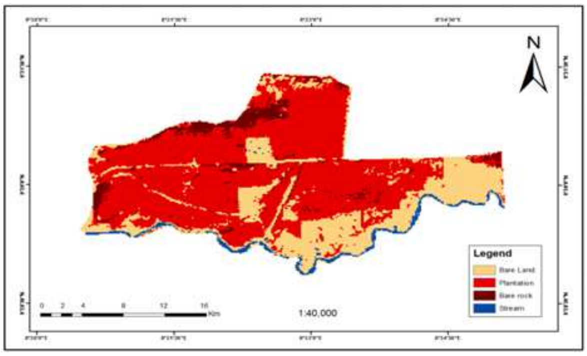

Fig 1. *Land cover of the study area 1986.*

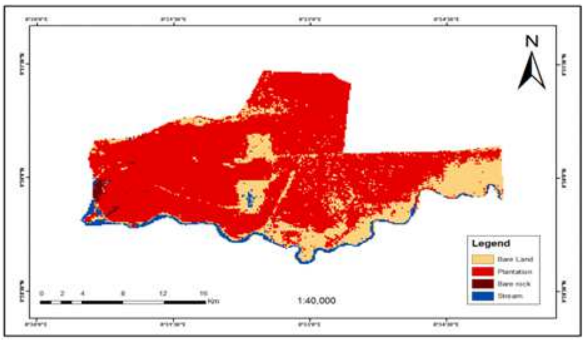

Fig 2. *Land cover of the study area 1998.*

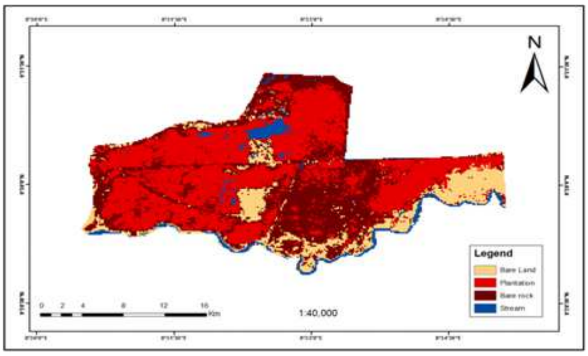

Fig 3. *Land cover of the study area 2010.*

3.2. 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, indicates the land use land cover classes in year 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 1986-2010.*

Land cover type	Are in 1986		Are in 1998		Are in 2010	
	(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
Steam	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

Source: Field Survey 2010

Table 4. *Land Use Land Cover Change: Magnitude and Percentage change.*

Activity Types	Area covered (Ha)			Difference (Ha)	Difference (Ha)	Increase/Decrease%	Increase/Decrease%
	1986	1998	2010	1986-1998	1998-2010	1986-1998	1998-2010
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

Source: Field Survey 2010

The data 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 flows toward the plantation. The strength of the water movement encroaches 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 rocks and some other categories of rocks. The vegetation grown might have covered most part of the rock in 1998. It also appeared in 2010 rock reflectance increased. This is as a result of bush fires that engulf the forest every year, which has really affected the reflectance of the plantation that leads it to drop from 75.59% in 1998 to 48.66% in 2010. 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.

Figure 4 and 5 are representation of the table above. The green bars (right side) indicate the gain per class in hectares, while the left side define the loss of each class.

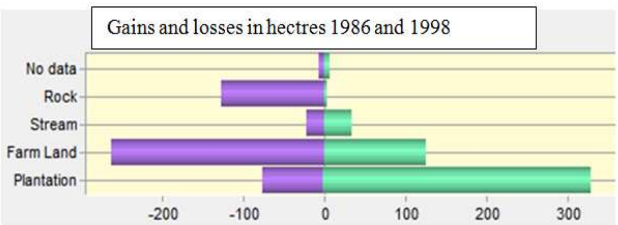

Figure 4. *Gains and losses in hectares 1986-1998.*

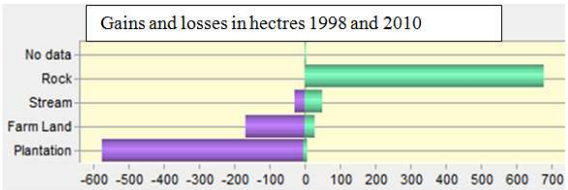

Figure 5. *Gains and Losses in Hectares 1998-2010.*

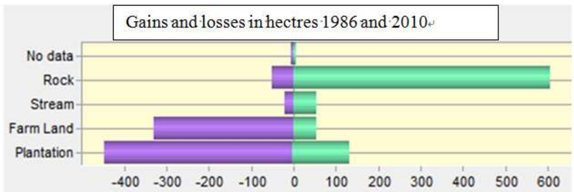

Figure 6. *Gains and Losses in Hectares 1986-2010.*

3.3. Accuracy Assessment of the Image

Evaluation of classification results is an important process in satellite image classification procedure. In doing so confusion/error matrices were used. It is the most commonly employed approach for evaluating per-pixel classification (Weng, 2007).

Landsat TM image (1986) was classified into six classes. It indicated an excellent overall classification (98.55%). In classifying the second Landsat TM image (1998), an overall accuracy (92.75%) was achieved. The third Landsat ETM image (2010) an overall accuracy (84.5%) was achieved. The worst result and that may be attributed to the reflectance of burnt area that appeared to be rock and the loss of reflectance from some part of the plantation affected by the fire. The higher accuracy was achieved due to the utilization of more ancillary data in collecting training samples for classification and the season of the image during the process of classification. In general, there was evidence for both systematic commission and omission errors resulting from the classifier side as incorrectly commits pixel of the class being sought to other classes as well when some class on the ground were misidentified as another class by the classifier.

Table 5. *Error (confusion) matrix for Landsat 5 TM (17/11/1986)*

Classified Data	Reference data				
	Plantation	Farm land	Strea m	Bare Rock	Total
Plantation	489	0	0	0	489
Farm land	1	156	3	0	160
Stream	0	4	79	0	83
Bare Rock	2	0	0	37	39
Total	492	160	82	37	771

Source: Field Survey 2010

Accuracy statistics for Table 5		
Class name	**producer's Accuracy**	**user's Accuracy**
Plantation	99.390%	100%
Farm land	97.500%	97.5%
Stream	96.341%	95.18%
Bare rock	100%	94.87%
Overall Accuracy=98.555%		

Table 6. *Error (confusion) matrix for Landsat 5 TM (18/11/1998)*

Classified Data	Reference data				
	Plantati on	Farm land	Strea m	Bare Rock	Total
Plantation	1556	3	0	0	1559
Farm land	53	141	0	0	194
Stream	0	3	33	0	36
Bare Rock	0	0	0	11	11
Total	1609	147	33	11	1800

Accuracy statistics for Table 6		
Class name	**producer's Accuracy**	**user's Accuracy**
Plantation	96.706%	99.807%
Farm land	95.918%	72.680%
Water body	100%	91.666%
Rock	100%	100%
Overall Accuracy=92.749%		

Table 7. *Error (confusion) matrix for Landsat 5 TM (21/12/2010)*

Classified Data	Reference data				
	Plantation	Farm land	Stream	Bare Rock	Total
Plantation	979	1	1	1	982
Farm land	0	117	2	0	119
Stream	0	4	20	0	26
Bare Rock	96	0	1	5	108
Total	1075	160	24	6	1235

Accuracy statistics for Table 7		
Class name	**producer's Accuracy**	**user's Accuracy**
Plantation	91.070%	99.694%
Farm land	73.125%	98.319%
Water body	83.333%	76.923%
Rock	83.333%	4.630%
Overall Accuracy=84.497%		

3.4. 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 4 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 2010 has an NDVI of 0.38 to -0.25.

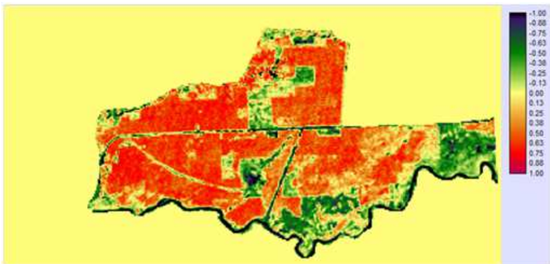

Fig 4. *NDVI Result for Landsat-TM 1986 of the study area.*

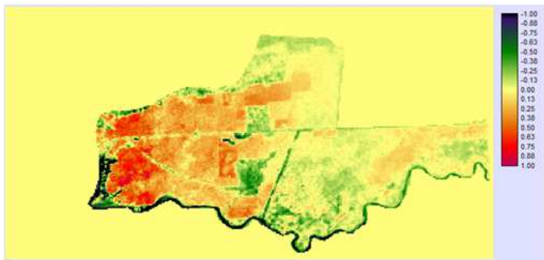

Fig 5. *NDVI Result for Landsat-TM 1998 of the study area.*

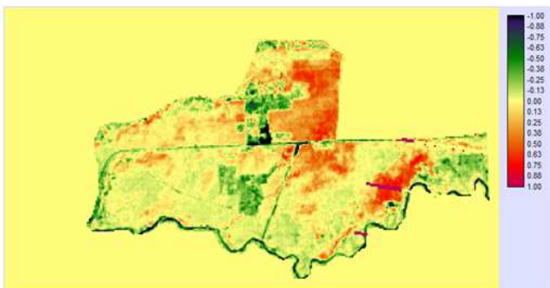

Fig 6. *NDVI Result for Landsat-TM 2010 of the study area*

3.5. Land Use Land Cover Projection for 2037

3.5.1. 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.

Table 8. *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

3.6. Markov Operation

This is simply an operation in which the future state of a system can be modeled purely on the basis of the immediate 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 (2010) 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. Twelve years was used for both numbers of periods.

Table 9. *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 and figure 7 below shows the statistic of land use land cover projection for 2037. Comparing the percentage representations of this table and that of table 8, 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.

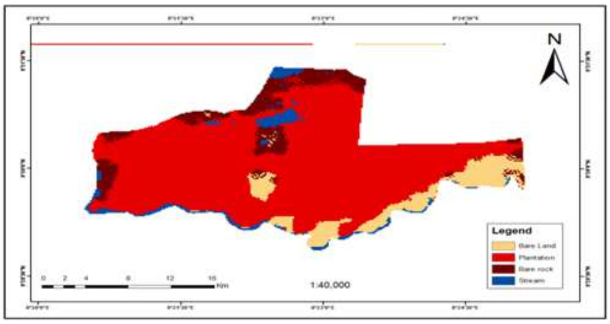

Fig 7. *image showing landcover projection for 2037.*

4. Conclusion and Recommendation

The 1986, 1998TM and 2010ETM Satellite remote sensing data were used to identify, classify, assess and interpret Nimbia Forest Reserve for the year 1986, 1998 and 2010 respectively. A GIS database of land use / land cover categories and their changes within 24 years (1986-2010) was generated and analyzed. The result shows that; in general the forest plantation was retreating due to several anthropogenic 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 forestplantation 'rebirth' and rejuvenation will bring to use the type of forest reserve we envisaged. In order to reducethe effects of deforestation in 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.
v. Trees should be allowed meet required maturity before felling.
vi. 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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