ASSESSMENT OF VEGETATION COVER DYNAMICS IN THE KPASHIMI FOREST RESERVE, NIGER STATE, NIGERIA

By

Jibrin, A.

Department of Geography, Ahmadu Bello University, Zaria, Nigeria
abdullahi717@hotmail.com

ABSTRACT

Changes in the vegetation cover of the Kpashimi Forest Reserve, was assessed over 20 years period (1987-2007). The study made use of satellite imageries TM, SPOT, ETM+, and NIGERIASAT-1 of 1987, 1994, 2001 and 2007 respectively. Arc GIS 9.2 and ERDAS Imagine 8.3 softwares were used for image processing and quantification of landscape transformation processes. Four land cover maps were produced for the four dates-1987, 1994, 2001 and 2007. Ground truth was conducted against the 2007 classified map and based on the derived confusion matrix, the Kappa coefficient is 0.73 while the overall accuracy is 0.77. The findings revealed a significant shrinking in the Savanna woodland and Riparian forest, with a corresponding expansion in Degraded forest, Bare surface and Scrubland classes. The Average annual rate of change of Bare surface is +2.0%; Scrubland is +2.6%; Degraded Forest is +2.4%; Savannah woodland is -2.8%; Riparian Forest is -2.1% while Grassland recorded +10.3%. The observed spatio-temporal variation of the respective vegetation communities over the period of study was found to be statistically significant with chi-square value of 43.75 at P< 0.01. The study indicates that the landscape structure of the forest reserve has undergone significant change over the 21 years period of study and the resulting landscape mosaic vary in shape, size, arrangement and structure. Based on the findings of this study, it is recommended that Kpashimi forest reserve requires more effective conservation measures in order to mitigate the far reaching ecological consequences of vegetation changes.

Key words: Remote Sensing, Deforestation, Degradation, Vegetation dynamics

INTRODUCTION

Vegetation cover dynamic is a widespread and accelerating process, mainly driven by anthropogenic activities and natural phenomena, which in turn drive changes that impact ecosystems (Chen, 2002). Quantifying the spatial and temporal dynamics of vegetation cover in terrestrial ecosystems is critical to our understanding of regional patterns of plant communities (Ahmad, 1986). Remote sensing techniques enable speedy, accurate and objective interpretation of the multispectral data received from remote sensing satellites (Green, Kempka and Lackey, 1994). The remotely sensed data, with its high correlations between spectral bands and vegetative parameters, make it a reliable source for large area aboveground growing stock volume and biomass estimation, especially in areas of difficult access (Lillesand and Kiefer, 2004). Consequently, the demands for reliable surveying methods that are verifiable, spatially and temporally specific, covering large areas at acceptable cost allude to the importance of remote sensing techniques in vegetation cover studies (Ahmad, 1986). It is thus clear that remotely sensed data, in conjunction with geographic information systems (GIS), has been widely applied and is recognized as a powerful and effective tool in detecting vegetation cover dynamics.

Forest landscapes are unique environments with valuable natural resources. They have particular spatial configuration, and perform a wide variety of productive, protective and aesthetic functions (Forman, 1997; Thomas and Sheldon, 2001; and World Resource Institute- WRI, 2005). However, forest ecosystems are delicate, interrelated and vulnerable to change through time, either due to environmental factors (Lamb, 2001) or anthropogenic pressures (Osborne *et al.*, 2001). To this effect, there has been a growing concern by environmental scientists worldover over the negative consequences of forest degradation (Luo, 2006), and this has induced awareness of the importance of identifying, surveying, delineating, monitoring and reporting globally and locally important ecosystems (International Union for Conservation of Nature- IUCN, 1994). The importance of information on vegetation cover dynamics at national and local scales for use in decision making process and rational planning cannot be over emphasized.

The importance of investigating land cover dynamics as a baseline requirement for sustainable management of natural resources has been highlighted by many researchers involved in global change studies (Martens and Lambin, 2000; Serneels, 2001; Chen, 2002; and Jensen and Gregoria, 2002). These scientists have argued that a more focused management intervention requires information on the rates and the impacts of land cover change as well as the distribution of these changes in space and over time. Monitoring changes in the forest cover and structure through time is important for planning and management (Zimble *et al.*, 2003; Jibrin and Jaiyeoba, 2013). The ability to measure forest and monitor changes in forested areas at regular intervals is also important because of the role forests play in the global carbon cycle; in global climatic trends and in providing species habitats (Woodwell *et al.*, 1984). Although understanding forest change is important worldwide, it is especially important in the tropics where land use transformation is occurring very rapidly and where timely ground data are scarce.

There is widespread concern that savanna woodland ecosystems with unique and valuable biodiversity resources are being lost (Rennolls and Laumonier, 2000; Jibrin, 2009) as a result of both natural and anthropogenic disturbances and mismanagement (O’Connor, 2005). They are rapidly undergoing severe large-scale changes, through harvesting, burning or conversion to other land use and cover types (Millenium Ecosystem Assessment-MEA, 2005). Consequently, the identification and better understanding of the dynamics of woodland community types, patterns of and quantitative properties of their changes is important to the conservation and sustainable management of these woodlands (Jibrin, *et al.*, 2013). Kpashimi Forest Reserve in Niger state (Nigeria) corresponds to category VI of the IUCN protected area management classification (IUCN 1994). That is, protected area managed mainly for the sustainable use of natural ecosystem. However, despite the vulnerability of the forest reserve to changes, there has been little or no quantitative data on the spatio-temporal changes in the vegetation cover of the reserve (Jibrin, 2013).

This study is based on the conceptual framework of complex environmental interactions (MEA, 2005), which emphasize that variation in vegetation is the product of complex and great number of interacting environmental variables. Hence, the composition and structure of any given vegetation community reflects the interaction between its component members and their environment through time. Consequently, any natural or man induced changes will definitely result in corresponding minor or major changes in the affected vegetation community. Sustainable management of natural resources requires knowledge about ecosystems at temporal and spatial scales (Bradshaw and Fortin, 2000). To understand how land use/land cover change affect and interact with global earth system, information is needed on what change occur, where and when they occur, the rate at which they occur, and the physical and social forces that drive those changes (Lambin, 1997).

The aim of the study is to assess the spatio-temporal dynamics of the vegetation cover of the Kpashimi forest reserve in Niger State. The specific objectives were to: produce vegetation cover maps of the study area for the years 1987,1994, 2001, and 2007, quantify spatial variation in the area coverage of vegetation communities the Kpashimi forest reserve for the years 1987,1994, 2001, and 2007, and identify the pattern of vegetation cover changes of the Kpashimi forest reserve between 1987 and 2007. The research null hypothesis (Ho) for the study states that: The spatio-temporal change in the vegetation cover of Kpashimi forest reserve between 1987 and 2007 is insignificant.

STUDY AREA

Kpashimi Forest Reserve is located between latitude 8^o 40**’** to 8^o 52**’** North and 6^o 39**’** to 6^o 49**’** East covering approximately 213.101 kilometres square (Figure 1). The study area lies within the tropical hinterland (tropical rainy climate with dry season) climatic belt of Nigeria; characterised by alternating wet and dry season coded as ‘Aw’ by Koppen’s classification. The mean annual rainfall is about 1,400 mm with mean annual temperature of about 28^oC (Ojo, 1977). The geology of the study area is made up of cretaceous sedimentary rocks underlain by the Precambrian basement complex rocks (FORMECU, 1994). The topography is gently undulating, sloping generally towards different directions in different locations. Soils in the study area based on the CCTA (Commission de Cooperation Technique en Afrique) classification system belong to *ferruginous tropical soils.* In some depressional areas, and valley bottom positions *hydromorphic* soils are found; while those around the inselbergs and other residual hills, and at the bed of rivers, are *weakly developed* (Areola, 1978; Jaiyeoba and Essoka, 2006). The study area lies within the southern Guinea savannah zone classified as woodland savannah vegetation with the understory dominated by annual grasses (Keay, 1953; Jaiyeoba and Essoka, 2006).

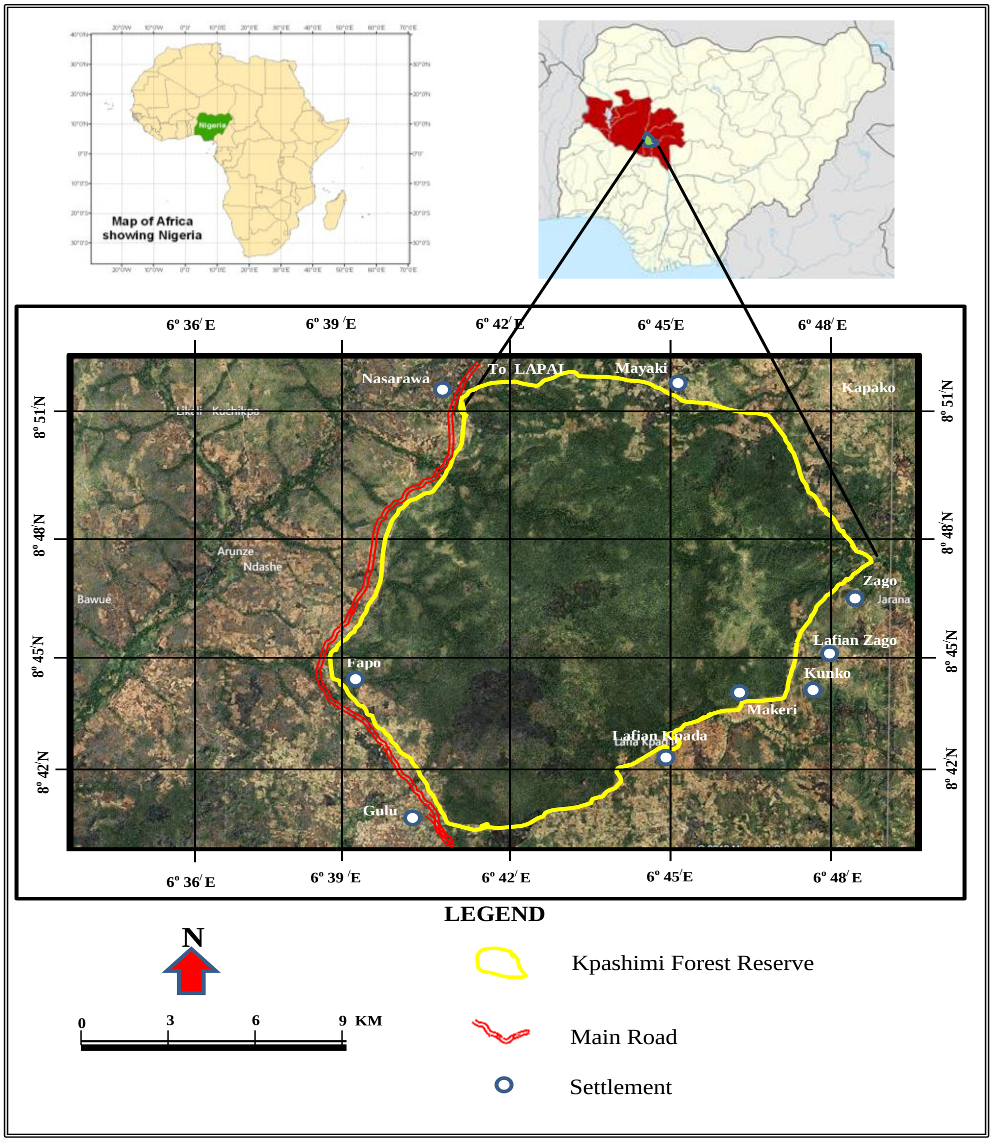

Fig. 1: Study area

MATERIALS AND METHODS

The study made use of four satellite imageries TM, SPOT, ETM+, and NIGERIASAT-1 of 1987, 1994, 2001 and 2007 respectively acquired during the reconnaissance survey in August, 2008. Using Erdas Imagine version 9.2, the images were rectified, and transformed. Geocoding was performed using second-degree polynomial function by rotation, scale, skew and offset adjustment. Thus the images were georeferenced using the UTM map projection (Zone 32 N) World Geodetic System, 1984 datum (WGS 84) coordinates system. Image enhancement was done by selection and stacking of band 4, 3, and 2 for TM, and ETM+ and bands 3, 2, and 1 for SPOT XS and NIGERIASAT-1. This aided in eliminating redundant information due to inter band correlation and better described the vegetation biophysical characteristics derived from

Visible, Near Infrared, and Mid Infrared portions of the Electro Magnetic Spectrum (Lillesand *et al*, 2006).

The imageries were imported in to the Arc GIS software, and the vegetation cover classes were identified. Eight pixels were randomly selected (by stratified sampling) from each of the vegetation classes; and their coordinates recorded totaling 48 sampling units. Based on the coordinates generated, ground data on plant community characteristics was collected from the field; for training area definition and signature generation. Thereafter, the respective images were classified using Maximum Likelihood Classification algorithm by the extraction of Normalized Difference Vegetation Index (NDVI) based on supervised classification. To evaluate the accuracy of the classification, a validation training dataset comprising of 48 sampling points were used for classification accuracy assessment. Thereafter, an error matrix was generated (see Table 1). The calculated accuracies were as follows: Producer's Accuracy (0.77); User's Accuracy (0.78); Kappa Coefficient (0.73); and Overall Accuracy (0.77). Post classification change detection was then carried out based on the four imageries pixels per area coverage. In order to test the hypothesis raised, Chi square statistic was applied for testing the observed variation in the area coverage of the vegetation communities over the period of study.

Table 1: An Error Matrix for Nigeriasat-1 2007 Image Derived Vegetation Cover Map

VEGETATION COVER CLASSES	BS	GL	SL	DF	SW	RF	TOTAL (N)	USER'S ACCURACY
Bare surface (**BS**)	7	0	0	0	0	0	7	1.0
Grassland (**GL**)	1	7	1	0	0	0	9	0.78
Scrubland (**SL**)	0	1	6	2	0	0	9	0.67
Degraded Forest (**DF**)	0	0	0	4	3	0	7	0.57
Savana woodland(**SW**)	0	0	1	2	5	0	8	0.63
Riparian Forest (**RF**)	0	0	0	0	0	8	8	1.0
TOTAL (N)	8	8	8	8	8	8	48	
PRODUCER'S ACCURACY	0.88	0.88	0.75	0.5	0.63	1.0		

RESULTS AND DISCUSSION

Vegetation Cover Maps

The vegetation cover maps derived from the multi-temporal satellite images acquired from four dates (1987, 1994, 2001, and 2007) presented in Fig. 2 shows the spatial variability in the vegetation cover of the study area. The vegetation cover maps presented in figure 2 show that there is a noticeable variation in the spatial coverage of the respective vegetation communities. The 1987 vegetation cover map shows that area coverage for Savanna woodland was prominent, followed by Degraded forest and Riparian forest. This indicates the initial point of the period under study; when though there was incidence of vegetation degradation, the Savanna woodland was predominant in spatial coverage compared to other vegetation communities. The1994 vegetation cover map reveals that there was comparatively less area coverage of Savanna woodland and more of Degraded forest. Bare surface began to appear at the forest edges. This suggests an increasing incidence of deforestation and forest degradation.

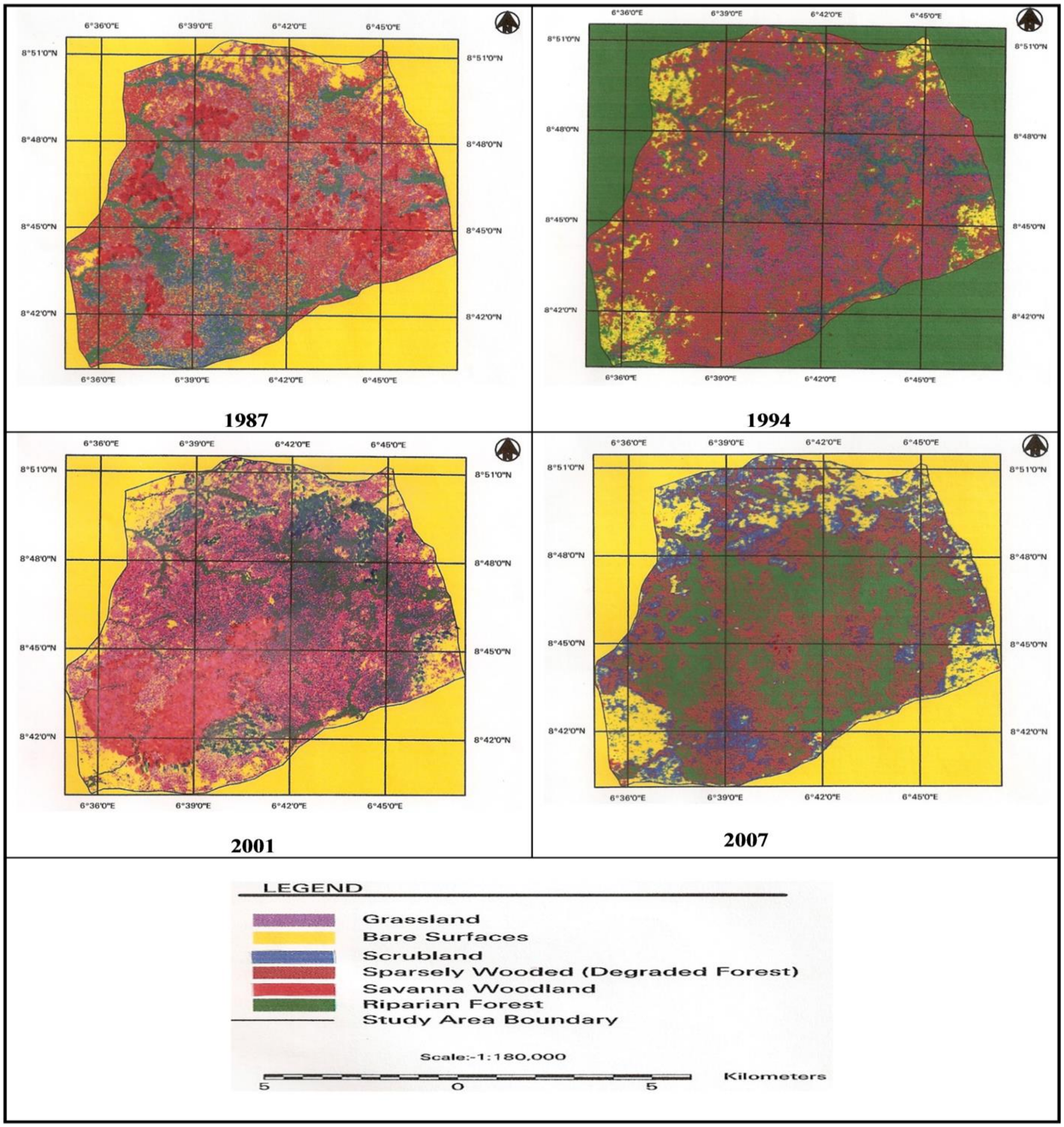

Fig. 2: Vegetation cover maps of Kpashimi forest reserve for 1987, 1994, 2001, and 2007

Subsequently in 2001, the vegetation cover maps presented in Fig. 2 show the Degraded forest vegetation seem to be more prominent than other vegetation communities; followed by Scrubland and Grassland. It is also observable that the Bare surface seems to be advancing inward from the outer perimeter of the reserve. This equally suggests increasing forest degradation; as vegetation communities with dense vegetation cover seem to be giving way to other less dense vegetation cover such as Bare surface, Degraded forest, Grassland and Scrubland. In 2007 vegetation cover map, the area coverage of the Bare surface, Degraded forest and Scrubland are more prominent. The Savanna woodland interspersed with degraded forest is hardly noticed. It is also important to note that in 2007, the vegetation cover shows more fragmentation into various mosaics.

Spatial Variation in the Area Coverage of Vegetation Communities

The estimation of area coverage by the plant communities yielded the results shown in Table 2.

Table 2: Area Coverage of the Vegetation Communities over the Examined Period

VEGETATION COMMUNITIES	1987		1994		2001		2007	
	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Bare surface	2311.78	*10*	2441.36	*10.6*	2888.8	*12.5*	3237.84	*14*
Grassland	2247.18	*9.7*	3787.73	*16.4*	4753.58	*20.6*	2623.48	*11.3*
Scrubland	2467.03	*10.7*	2115.23	*9.1*	2075.35	*9*	2971.76	*12.8*
Degraded Forest	5032.32	*21.8*	6007.11	*26*	7356.85	*31.8*	7480.38	*32.4*
Savanna Woodland	7930.3	*34.3*	6266.58	*27.1*	3845.02	*16.6*	4148.28	*18*
Riparian Forest	3132.44	*13.5*	2503.04	*10.8*	2201.45	*9.5*	2659.31	*11.5*
TOTAL	23121.05	*100*	23121.05	*100*	23121.05	*100*	23121.05	*100*

The table indicates that in 1987, Savanna woodland constitutes 34% of the vegetation cover but eventually decreased persistently to 18% in 2007. On the other hand, Degraded forest increased persistently from 21.8% in 1987 to 32.4% in 2007. It is also evident that while the area coverage of Bare surface, Degraded forest and Scrubland are on the increase, that of the Savanna woodland and Riparian Forest were on the decline. Chi-square was applied to the data set in order to determine the level of significant changes in the area coverage of the vegetation communities all together, the result show a chi-square value of 43.75 which is significant at $P < 0.01$ with table value of 30.58. Thus, the change in vegetation cover over the period under study is statistically significant, and consequently, the null hypothesis for the study is hereby rejected.

The Trend of Vegetation Cover Change

It is evident in Table 3 that Grassland recorded the highest average rate of change of +10.3% per annum Savanna woodland is next by -2.8% followed by Scrubland, +2.6%; Degraded forest, +2.4%, Riparian forest, -2.1, and Bare surface, +2.0%. The general trend suggests that the various vegetation units are changing at the rate of not less than 2.0% annually. The trend of change in the respective vegetation communities is also illustrated in Figure 3.

Table 3: Rate of Change in Area Coverage of Vegetation Communities

PLANT COMM-UNITIES	CHANGE BETWEEN 1987 AND 1994		CHANGE BETWEEN 1994 AND 2001		CHANGE BETWEEN 2001 AND 2007		AVERAGE RATE OF CHANGE	
	AREA (ha)	%	AREA (ha)	%	AREA (ha)	%	AREA (ha/year)	%
Bare Surface	+129.58	*5.6*	+447.44	*18.3*	+349.04	*12*	46.3	*+2.0*
Grassland	+1540.55	*68.5*	+965.85	*25.5*	-2130.1	*44.8*	231.8	*+10.3*
Scrubland	-351.8	*14.3*	-39.88	*1.9*	+896.41	*43.2*	64.4	*+2.6*
Degraded Forest	+974.79	*19.4*	+1349.7	*22.5*	+123.53	*1.7*	122.4	*+2.4*
Savannah Woodland	-1663.72	*30*	-2421.56	*38.6*	+303.29	*7.9*	219.4	*-2.8*
Riparian Forest	-629.4	*20*	-301.59	*12*	+457.86	*20.8*	66.1	*-2.1*

NOTE: Positive (+) indicates increase, Negative (-) indicates decrease

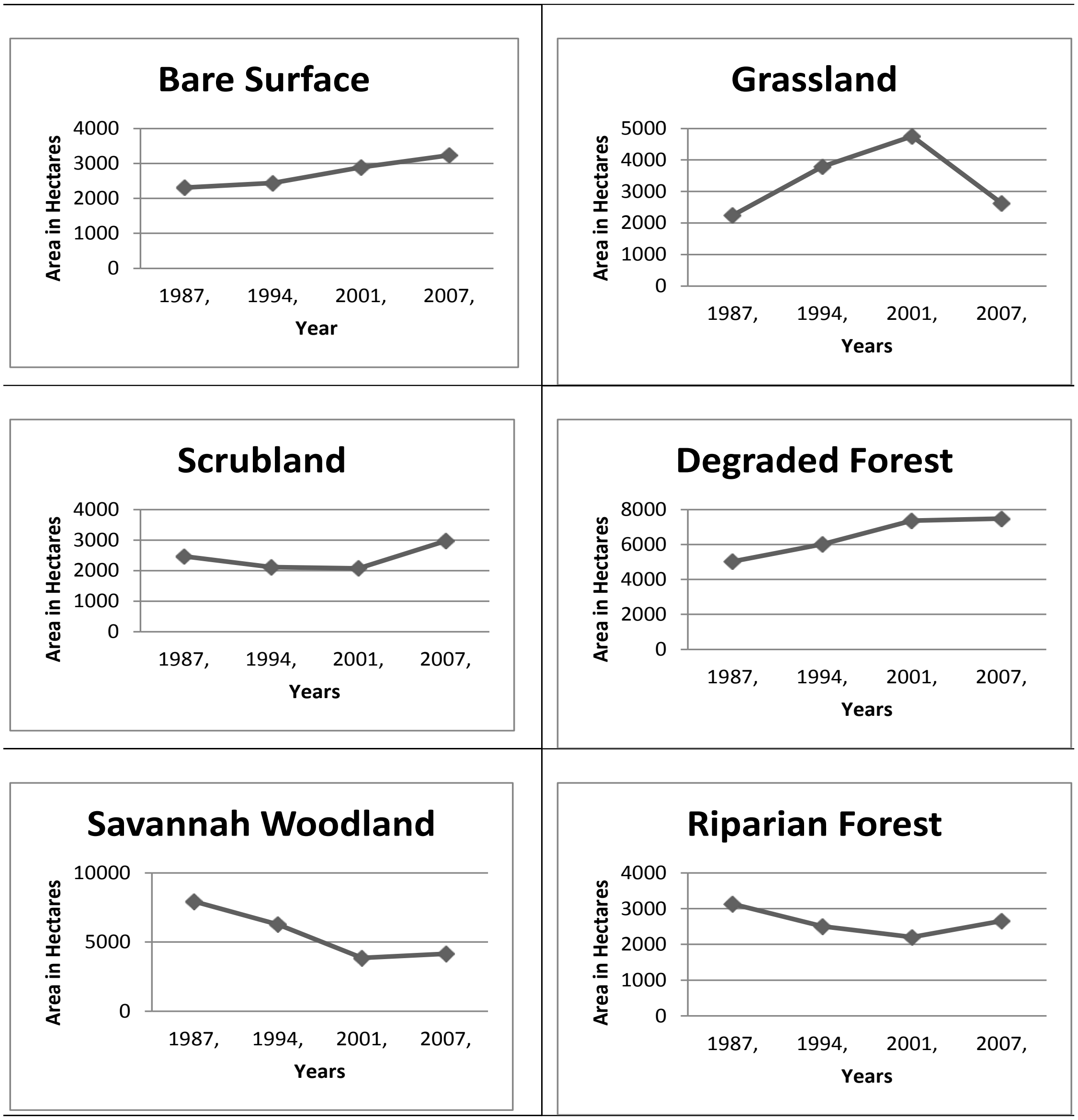

Fig. 3: Trend of change in the respective vegetation communities

The net changes over the twenty years period under study shows that by expansion, Degraded forest records the highest change of 48.6% followed by bare surface 40.0%. Conversely, by reduction, Savanna woodland recorded the highest change by 47.7%, followed by Riparian forest 15.1% (see Fig. 5). Findings in this study is in line with that of Salami and Akinyede (2006), which reported a 59.4 and 24.5% decline of these cover types in the south western part of Nigeria, between 1986 and 2004. Similarly, it can be related to the findings of Akinyemi (2005), which reported a 49.1% decrease of agro-forestry/secondary regrowth in the south western part of Nigeria between 1986 and 2002. In contrast, in their study of the pattern of changes in a part of tropical rainforest of south-western Nigeria, between 1986 and 2002, Mengistu and Salami (2007) revealed that the area under derived savanna and high forest declined by 71.9 and 8%, respectively, while those under shrub land/farmland complex and settlement/bare surface registered a net gain of 413.6 and 192.4%, respectively. Based on this analysis it is obvious that in spatial context, while Degraded forest, Bare surface and Scrubland had more expansion between 1987 and 2001, Savanna woodland and Riparian forest experienced more shrinking.

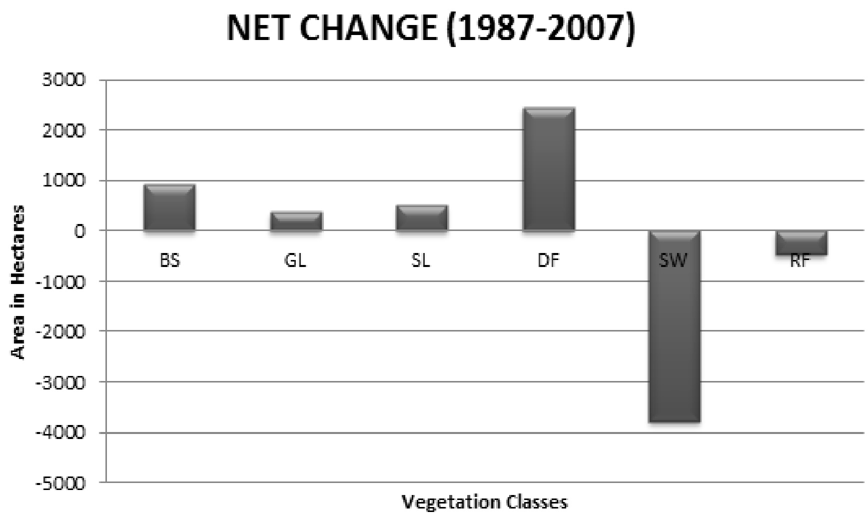

Fig. 4: Net Change between 1987 and 2007

In line with the findings highlighted in the foregoing paragraphs, several authors such as Hecht and Cockburn (1989), Myers (1984), Office of Technology Assessment (1984), Rippetto and Gillis (1988), National Research Council (1993) and Millenium Ecosystem Assessment (2005) argued that forest loss and degradation are driven by a combination of economic, political and institutional factors. Observed threats to structural characteristics of the vegetation cover of the forest reserve include farming, grazing, illegal logging, bush meat hunting, bush burning, collection of Non Timber Forest Products (NTFPs) and encroachment of settlements. The observed underlying causes include poverty, business, ignorance and corruption on the one hand and climate change on the other. In general, the landscape of the forest reserve has been influenced significantly by anthropogenic disturbances and the resulting landscape vegetation cover is a mixture of natural and human managed mosaics that vary in shape, size, structure and arrangement.

CONCLUSION

The spatio-temporal pattern of change observed is that the landscape structure of the forest reserve has significantly changed due to the shrinking in the proportion of the Savanna woodland and Riparian forest with a corresponding expansion in the Scrubland, Degraded forest and Bare surface. Thus the transformation of some parts of Savanna woodland and Riparian forest in to other vegetation classes is responsible for the observable alteration in the shape, pattern, and size of vegetation communities. The general trend in the rate of change is that each of the vegetation classes experienced an annual rate of change of not less than 2 percent. Specifically, an annual average rate of change for Bare surface is +2.0%; Scrubland is +2.6%; Degraded Forest is +2.4%; Savannah woodland is -2.8%; Riparian Forest is -2.1%; while Grassland recorded +10.3 % . Conclusively, the study indicates that the landscape structure of the forest reserve has undergone significant change over the 21 years period of study and the resulting landscape mosaic vary in shape, size, arrangement and structure. This study provides an initial basis for monitoring vegetation cover change which is an important factor to consider in the design of an environmental decision framework. It is equally important to point out that further studies over a longer period are necessary for better understanding of the relationship between changes in landscape structure, human impact and climate change. Use of satellite imageries of higher resolutions is also recommended for further studies.

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