NDVI THRESHOLD CLASSIFICATION AND CHANGE DETECTION OF VEGETATION COVER AT THE FALGORE GAME RESERVE IN KANO STATE, NIGERIA

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Abstract

Vegetation cover types of Falgore game reserve (FGR) in Kano, Nigeria, a watershed protective cover, were classified and their temporal changes were retrieved using Landsat TM/ETM and ASTER data for 1986, 1998, 2000 and 2005. Prior to classification, the near- anniversary images were all corrected for geometric disorder, registered to a common map projection and atmospherically corrected. The threshold NDVI classification analysis revealed five different woodland vegetation cover types including dense, moderate, open, very open, and sparse woodland. Vegetation cover types revealed significant spatio-temporal changes for all the image years assessed. There was a general decrease in vegetation cover signifying a trend of degradation of the ecosystem with a greening trend in some pockets within the reserve. The observed changes indicate a net loss of 54% and net gain of 11%, while 34% of the area have not changed. A bi-plot of rainfall-NDVI relationship shows a slight increase in rainfall and a negative trend in NDVI suggesting anthropogenic lead factors as likely explanatory variables in operation.

Key words: *Falgore, Nigeria, Remote sensing, land cover change, NDVI, vegetation dynamics.*

1. Introduction

Human activities affect the dynamics of ecosystems (especially natural vegetation cover) and other earth systems. For instance, the modification of vegetation cover, with a predominant clearing of natural vegetation may have long term impact on sustainable food production, freshwater and forest resources, the climate and human welfare (Foley *et al..,* 2007). Riruwai (2006) observes evidence of human encroachment into the Falgore game reserve that is the focus of the current study. It, therefore, follows that adequate monitoring of the ecosystem is essential to maintain the necessary conditions for providing ecosystem services and for human development. Hence, documenting changes occurring in vegetation cover at periodic intervals is vital to providing important information about the stability of that natural ecosystem (vegetation) and whether significant changes are taking place there or not (Jensen, 2000).

Remote sensing (RS) techniques have been identified to provide a viable source of data from which updated land cover information can be extracted efficiently in order to inventorise and monitor ecosystem changes (Houghton, 1991; Roy *et al.,* 1991; Mas, 1999; Rao *et al.,* 1999; Munyati, 2000; Vasconcelos *et al.,* 2002; Yelwa, 2005 and Potter *et al.,* 2007). This study assesses the spatio-temporal changes in vegetation cover in the Falgore Game Reserve, Kano State, Nigeria using different remote sensing change detection techniques.

Deforestation in all its ramifications has been identified as one major cause of vegetation/forest cover change in addition to climate change (Mortimore, 2002; Maconachie, 2004; 2007). Changes in vegetation cover at the micro scale, is the concern of this study; the Falgore Game Reserve (FGR) in Kano State is an example of a protected forest within the tropical drylands of Nigeria. The reserve serves as a watershed for river Kano; it is also an important source of water to Tiga Lake that effectively controls one of the two major feeders of the Hadejia river system.

An attempt to protect the Tiga lake (meant for storing water) saw the upgrading of the protection level of the reserve from hitherto forest reserve status to its current status of a game reserve (see IUCN, 2004 for guideline on protection levels). Although no precise estimates of deforestation exist for the FGR, Riruwai (2006) and Badamasi and Yelwa (2010) have observed large patches of bare surface within the reserve, suggesting potential threat to the reserve.

Vegetation cover is an obvious part of land cover. Land cover undergoes changes due to natural or man-made causes over time. Change detection has become a major application of remotely sensed data because of repetitive coverage at short intervals and consistent image quality (Mas, 1999). Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Lu *et. al.,* 2004). This involves the use of multi-temporal satellite data sets to discriminate areas of land cover change between dates of imaging (Singh, 1989; Lillesand and Kiefer, 2000) and involve data acquired by the sensors having same (or similar) characteristics. The basic premise in using remote sensing data for change detection is that changes in land cover result in changes in radiance values and changes in radiance due to land cover change are large with respect to radiance change caused by others factors such as differences in atmospheric conditions, differences in soil moisture and differences in sun angles (Mas, 1999; Jensen, 2005). Changes in vegetation reflectance are a useful basis to judge the relative success of protected area management. Hence, vegetation cover managed in time one can be compared to vegetal cover managed at different time, after adjusting for unplanned or uncontrollable variations.

Despite its protected status, rural communities living around the reserve have been encroaching into the reserve owing to ineffective management by the authorities overseeing the game reserve and partly owing to the shift in rural household economy and population pressure and overall alienation from such natural resource. Poaching, illegal grazing, over-fishing (including use of chemical poisons), illegal mining and bush fires have been identified as major threats to the conservation of the FGR (Riruwai, 2006; BirdLife International, 2007). For instance, BirdLife International (2007) has expressed fear that unchecked deforestation of the Falgore reserve could accelerate the siltation rate in the Tiga Lake thereby reducing its lifespan. This would certainly have profound effect on the forest cover conditions.

Several studies (for example Salami, 1999; Salami and Balogun, 2004; Salami, 2006) have identified deforestation as the major cause of vegetation cover change and have mapped and quantified the degree of changes. Relatively few researches covering northern Nigeria using remote sensing tools have concentrated on vast areas (Mashi, 1998; Herrmann *et al.,* 2005; Yelwa, 2008). Arguably, few studies (Uchua, 1999; Eniolorunda, 2010; Dakata and Yelwa, 2012) have been conducted in the drylands of Nigeria and none has been conducted in any protected area such as FGR in the literature. Adequate information is, therefore, required since a dearth of data exists in designing appropriate biodiversity and forest management practices in this part of the country. Lu *et al.* (2004) have outlined that determining where, when and why natural ecosystem changes occur using an appropriate technique is a crucial scientific concern.

Therefore, understanding trends in land cover conversion or changes on local scales is a necessary requirement for making useful numerical predictions about other regional and global changes of similar situations (Potter *et al.,* 2007). Hence, this study assesses the spatio-temporal changes in vegetation cover of FGR from 1986 to 2005 using Post Classification Comparison (PCC) Technique.

2. Materials and methods

2.1 Study area

Falgore Game Reserve (92,000 ha), formerly Kogin Kano Forest Reserve, is located between longitudes 8° 30' and 8° 50' East and latitudes 10° 46' and 11°

20' North, some 110 km south of Kano on the Jos-Kano road (Figure 1). The northern boundary is formed by the artificial Lake Tiga which, when full, submerges the north-western tip of the reserve. To the south-east of Falgore lies Lame Burra Game Reserve (205,900 ha) in Bauchi State (BirdLife International, 2007).

The climate is tropical wet-and–dry type, coded *Aw* by W. Koppen (Iloeje, 1965). Rainfall is a very critical element in the area because of its deficiency during the dry season. In a normal year, the mean annual rainfall in FGR is estimated at 1000 mm and this value decreases northward to about 800 mm around Kano Metropolitan (Olofin, 1987).

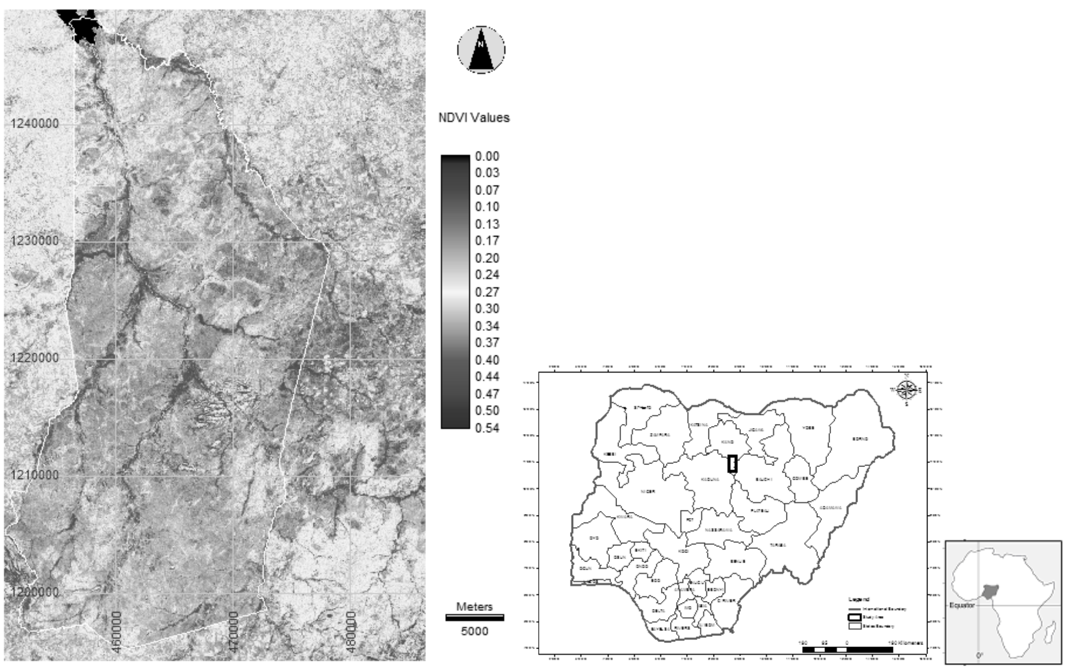


Figure 1   Falgore Game Reserve

The relief which influences the drainage is highly influenced by the geology; hence the area could be described under the following units: Highlands and the high plains. The highlands occupy a very small area to the south and southeast of the reserve where they constitute part of the foot slopes of the Jos Plateau. They are mostly younger granite, rising more than 1100 m above sea level. The elevation of their bases ranges between 700 m and 800 m. The highest peak is about 1230 m above sea level. The area is rocky in nature forming what is known as ring complexes (Olofin, 1987). The high plains dominate the relief units of the surface area and the elevation ranges between 650m to 800m. They are relatively areas of low relief usually less than 30 m. The area is drained by two major rivers systems: the Kano and the Basara systems.

The FGR is gallery forest with a high density tree species and high floristic variations found within the open Northern Guinea Savanna woodland vegetation type, though with elements of the Sudan Savanna in the northern tip. Examples include *Isoberlinia doka, Khaya senegalensis, Vitex doniana, Anogeissus leiocarpus, Tamarindus indica, Detarium microcarpum and Pterocarpus erinaceus* (BirdLife International, 2007).

The wildlife has been dwindling over time. According to a personal communication with a wildlife officer of the FGR, 9,751 and 15,223 wild and domesticated animals were reported in the 1970 and 1981 censuses respectively. However, by 1992 the number had decreased to 10,915 in the reserve. Frequent bush burning, lumbering and hunting were observed to be responsible for the decrease (personal communication with Mal Fagge, 2007).

2.2 Data

The software used for this study includes Idris Taiga, ENVI 4.7 and Microsoft Excel. The data used for this study are described in Table 1. Near-anniversary dry season (November-April) images with minimum cloud cover were used.

Table 1 Remotely sensed data used for the study

Images Used for the study	Path/row	Resolution	Date of acquisition	Format	Product Type (Cloud Cover %)
Landsat 5 TM[a] Band 1 -7	188/052	30m	19-12-1986	GEOTIFF	L1T (0%)
Landsat 5 TM[a] Band 1 -7	188/052	30m	18-11-1998	GEOTIFF	L1T (0%)
Landsat 7 ETM+[a] Band 1 -8	188/052	30	17-12-2000	GEOTIFF	L1T (0%)
ASTER Band 1-14[b]		15m	29-11-2005	HDF	AST_L1B (0%)
ASTER Band 1-14 [b]		15m	29-11-2005	HDF	AST_L1B (0%)

Note: TM = thematic mapper; ETM+ = enhanced thematic mapper plus; ASTER = Advanced Spaceborne Thermal Emission and Reflection Radiometer

Source: [a]Free from *http://glovis.usgs.gov*; [b]Purchased from *http://glovis.usgs.gov*

2.3 Data preprocessing

2.3.1 Geometric correction

The 2005 ASTER image (reference image) was geometrically corrected and projected to the Universal Transverse Mercator (UTM-N32) co-ordinate system by using an already rectified SPOT 5 satellite image of 4/05/2005 obtained from the National Space Research and Development Agency (NASRDA), Abuja. 18 ground control points (GCPs) were selected interactively from both images and an image to map geo-referencing was then used to rectify the ASTER image. Finally, an interactive image to image registration was performed to rectify the three Landsat images (1986, 1998 and 2000) using the 2005 ASTER. They were all resampled to 15x15 m pixels using nearest neighbour re-sampling and registered to base image for change detection.

2.3.2 Atmospheric correction and radiometric normalisation

To correct for atmospheric attenuation in the images the Cost model developed by Chavez (1996) was applied to all bands 3 and 4 of the Landsat series and bands 2 and 3 of the ASTER image representing the red and infra-red bands respectively to facilitate the generation of NDVI. The ASTER image was later used as the reference image. Using the technique of image normalisation (Du, *et al..*, 2002) the four Landsat series were then indirectly normalised for atmospheric absorption with the ASTER image as the reference image.

Radiometric normalization of the Images was achieved by applying regression equations to the 1986, 1990, 1998, and 2000 image data set to predict what a given brightness value (*BV*) would be if it had been acquired under the same conditions as the 2005 reference scene. These regression equations were developed by correlating the brightness of pseudo invariant features (PIFs) present in both the scene being normalised and the reference (2005) scene. A total of three reservoirs, Two rock outcrop (the surface of the selected rocky area was smooth and have not vegetation cover) and Two bare sites were used to normalise the 1986, 1990, 1998 and 2000 data. The Three PIFs were digitised, rasterised and converted into Boolean images (a value of 1 for the PIFs pixels and 0 for other areas). The Boolean image was then used as a mask image for regressing all the earlier images against the 2005 ASTER image.

2.4 Data analysis

2.4.1 Image Classification

Prior to change detection and image classification, a Normalised Difference vegetation Index (NDVI) image was generated. A simple threshold classification technique was then applied to the NDVI images of 1986, 1998, 2000 and 2005 using Idrisi Taiga. The best threshold used for classification is often chosen based on known ground data using sites of known change and stability. The threshold used was based on information from the ground data Standard deviation of 3σ, 2.5σ, 2σ, 1.8σ, 1.5σ and 1.2σ were tested on the images in relation to the ground data to define the most suitable threshold. The ≤ -1.3σ, -1.3σ to -0.7σ, -0.7σ to 0.7σ, 0.7σ to 1.3σ, ≥ 1.3σ was used after testing.

2.4.2 Change detection

Change detection involves an operation to identify and quantify the extent and the rate of change in land cover types in time. Having classified the images separately, PCC was employed to determine the trend of change in the area.

This was based on PCC of independently classified land cover maps of 1986, 1998, 2000 and 2005. The technique was based on pairwise comparison of two images using cross-classification. Cross-classification calculates the logical AND (within GIS environment) of all possible combinations of categories on two maps (Eastman *et al..,* 2007). This results in the output table from the logical AND operation of different image dates. This output is summarised with a cross-tabulation matrix: a table that records the number of raster cells that fall within each possible combination of classes on the two dates.

2.4.2 Change rate analysis

Change rates in vegetation cover type were analysed using the following formulae:

i. Change area = $D_2 - D_1$, where D_1 and D_2 are the area of the target vegetation cover type at the beginning (1986) and the end (2005) of the study period, respectively.
ii. % change = (change area / A) X 100, where A is the total area.
iii. Annual rate of change (ha/year) = (change area / T_i), where T_i is number of years between the beginning and the end of study period.
iv. % annual rate of change (%/year) = change area / (D_1 X T_i)

3. Results and Discussion

3.1 Geometric correction and radiometric normalisation

For the image to map geo-referencing of ASTER image, the result shows that a threshold of 0.00197was only obtained after deleting 10 GCPs out of the 18 GCPs earlier selected for the analysis. The remaining eight GCPs produced an acceptable root mean square error (RMSE) of 0.00197 indicating less than one metre error. The Landsat series (1986, 1998 and 2000) images yielded RMSEs of 0.496, 0.486 and 0.396 respectively using first order polynomial transformation method and nearest neighbour resampling algorithm for intensity interpolation of the brightness values (BV) and 15 x15 m pixel. It is important to note that the accuracy of geometric rectification can have a direct bearing on the accuracy of a subsequent radiometric normalisation. Table 2 presents the result of radiometric normalisation of the images used. Only PIFs with a linear co-efficient => 0.90 were considered appropriate for the analysis.

In this case, the results fulfilled the assumptions and all the models estimated by the regression procedure are significant at an α-level of 0.05. This showed that the PIFs co-efficients are really not good estimators.

Table 2: Image normalisation regression models developed for the FGR

Image normalised with the 29 Nov 2005 Aster reference image	Regression models	r^2 (%)
19 Dec 1986 TM	2005ASTER_2 = 0.110432 + 0.813615(TM_3 1986)	90.1
	2005ASTER_3 = 0.09636 + 1.006432(TM_4 1986)	93.2
18 Nov 1998 TM	2005ASTER_2 = 0.100110 + 0.704082(TM_3 1998)	94.1
	2005ASTER_3 = 0.121362 + 0.702687(TM_4 1998)	95.2
17 Dec 2000 ETM+	2005ASTER_2 = 0.087655 + 0.642297(TM_3 2000)	92.7
	2005ASTER_3 = 0.123989 + 0.669437(TM_4 2000)	94.9

a-level of 0.05. Note that the 1990 TM_3 Red band had a very low r^2 value; hence the 1990 dataset was dropped in the analysis.

Source: Authors' image analysis (2012)

3.2 Image classification

The NDVI images were all classified into six classes each. The classes include water body and five other vegetation classes which were designated in an increasing order of vegetation vigour. These are Dense vegetation (Dw), Moderate vegetation (Mw), Open woodland vegetation (Ow), Very open woodland vegetation (Vw) and Sparse woodland (Sw). Table 3 shows the threshold and the distribution of vegetation cover classes across the different images. The vegetation classification maps (Figure 2) clearly illustrate the spatial patterns of vegetation cover distribution within and around the reserve. The classified image of 1986 shows that the vegetation cover is dominated by Ow accounting for more than 52%, followed by Mw and Dw accounting for about 47% all together. Water and some minor intrusion of Vw and Sw cumulatively account for less than a per cent. This depicts the entire woodland to be relatively stable when compared against subsequent years. The pattern remains relatively similar for 1998 and 2000 classified images except for a slight decrease in the areal coverage of Dw and a counter increase in Ow and Vw in both respective years. However, the spatial pattern is entirely different in the classified 2005 image, which shows both Sw and Vw cumulatively accounting for about 28% of the areal coverage as against the earlier coverage of less than 0.2% in 1986. In addition, the Mw and Dw has decreased by more than 50% and 21% respectively within the same period (Figure 3).

This pattern and trend observed from 2000 to 2005 represents the worst degradation scenario across the period studied. It is important to note that the classified images were later used for extracting *"from-to"* vegetation class changes in the next section.

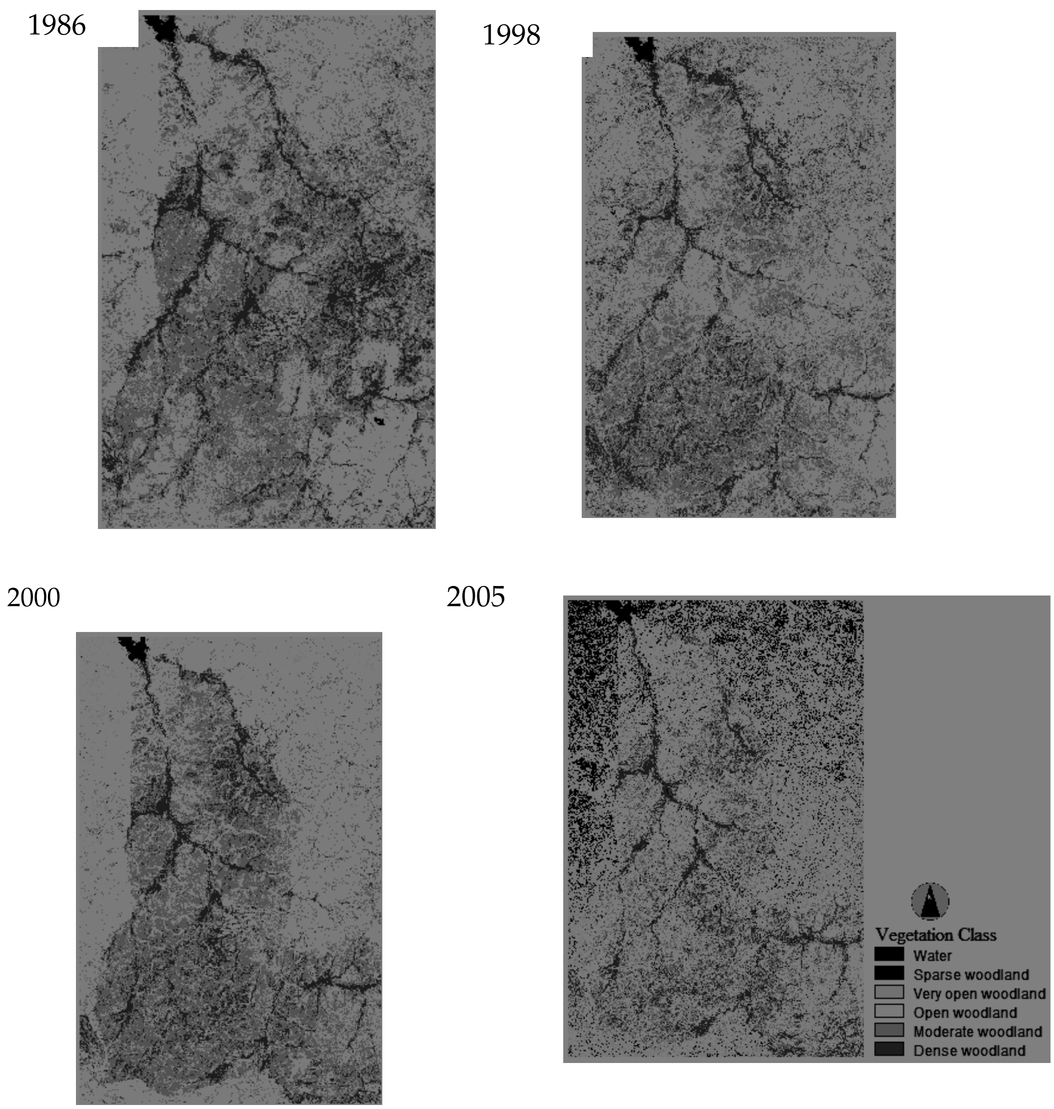


Figure 2: Distribution of vegetation classifications of 1986; 1998; 2000; and 2005.
Note that the same threshold class was used for all the NDVI images as indicated in Table 3.

Table 3: Class cover distribution classified by thresholds defined by histogram

Class cover	Thresholds† (NDVI values)	1986		1998		2000		2005	
		Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Water	[-0.175, 0.00001]	613.40	0.31	613.94	0.31	613.58	0.31	616.84	0.31
Sparse woodland	[0.00001, 0.1741]	83.32	0.04	230.06	0.12	13.32	0.01	21801.08	10.93
Very open woodland	[0.1741, 0.2179]	214.25	0.11	2191.55	1.10	1178.96	0.59	34857.92	17.47
Open woodland	[0.2179, 0.3201]	103823.98	52.03	110094.32	55.17	111507.32	55.88	93374.48	46.79
Moderate woodland	[0.3201, 0.3639]	72566.19	36.37	67159.04	33.66	67794.32	33.97	31442.51	15.76
Dense woodland	[0.3639, 0.671]	22244.29	11.15	19256.51	9.65	18437.92	9.24	17452.58	8.75

†The images were reclassified based on thresholds. Standard deviation of 3σ, 2.5σ, 2σ, 1.8σ, 1.5σ and 1.2σ were tested on the images in relation to the ground data to define the most suitable threshold. The ≤ -1.3σ, -1.3σ to -0.7σ, -0.7σ to 0.7σ, 0.7σ to 1.3σ, ≥ 1.3σ was used after testing

(a)

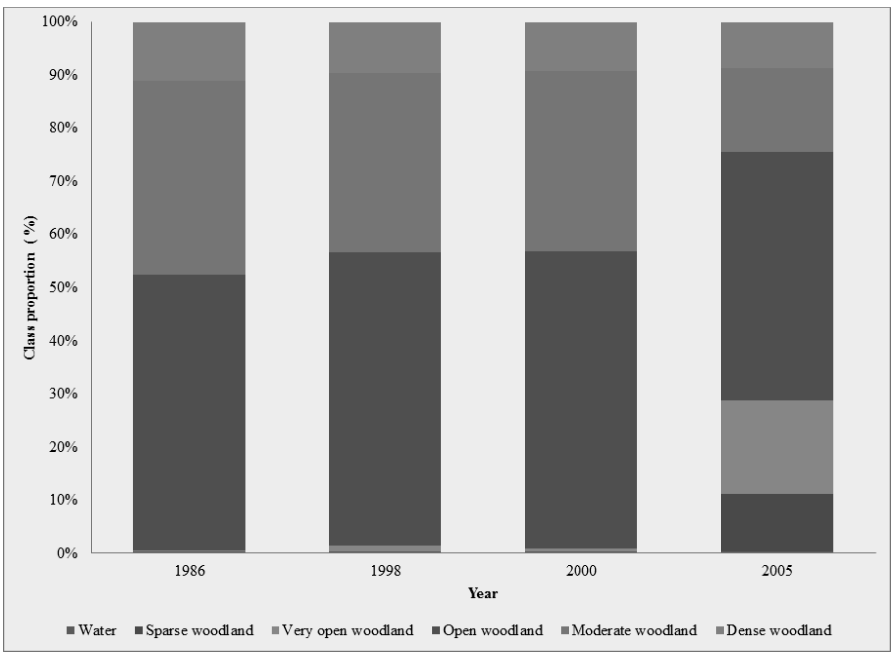
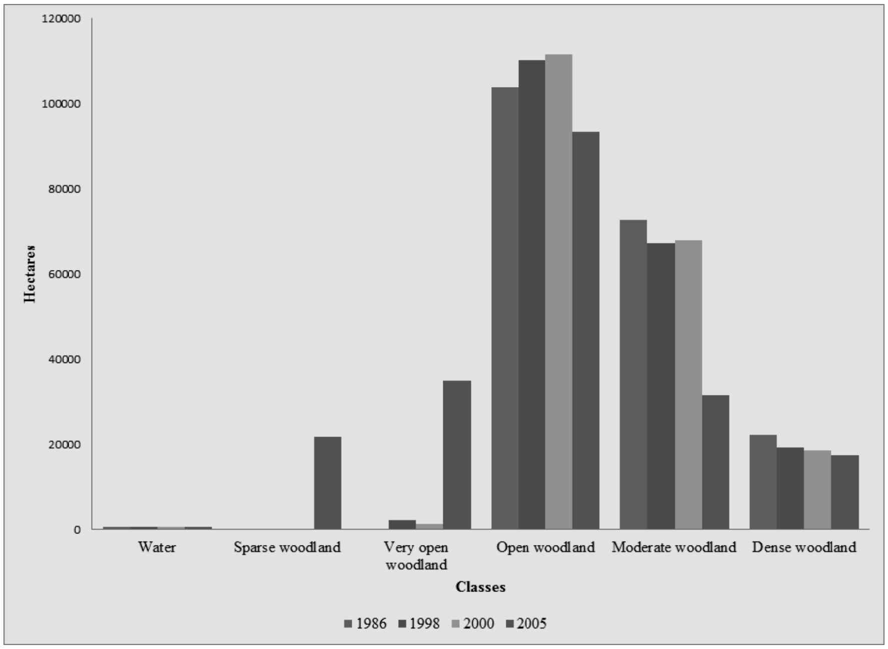


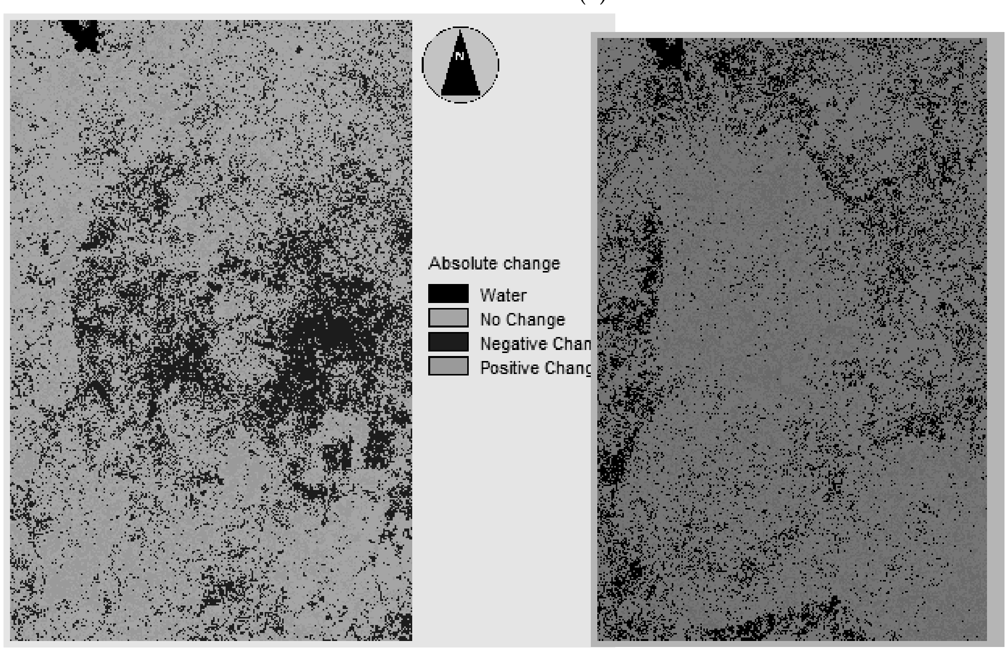
Figure 3: Distribution of vegetation covers classes from 1986 to 2005. (a) Percentage proportion of vegetation cover classes within the years



(b) Comparative distribution of each vegetation cover class across the years

1986-1998 | 1998-2000

(a) | (b)



2000-2005 1986-2005

(c) (d)

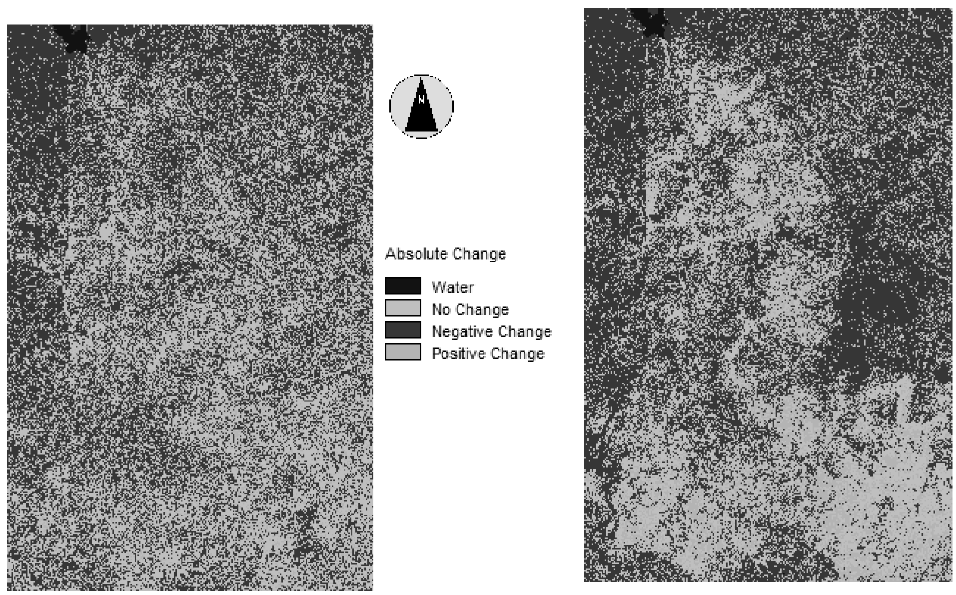


Figure 4: Absolute Change Categories (a) and (d) represents a long term changes for 13 years and 20 years respectively. While (b) and (c) depicts short term changes for 3 years and 6 years respectively.

4.3 Change detection

Figures 4 shows the spatial patterns of vegetation cover changes on a temporal scale, while the change matrices is detailed in Table 4 to 7. The most significant changed areas are found around areas adjoining the reserve boundary, especially the eastern part (areas around Gwamo where boundary dispute between Kano and Bauchi states has encourage over exploitation of vegetal resources) where a large area of Mw and Dw has progressively been degraded to Ow from 1986 to 2000, with a sudden degradation to Sw in 2005. In addition, the north-western and north-eastern part of the area has equally degraded from Ow to Sw from 1986 to 2005. The Mw class has generally been degraded across a large area, mainly at the fringes of the reserve. However, the southern part of reserve shows a different pattern. The Ow patches from 1986 have shown sign of recovery in 1998 and 2000

Table 4: Vegetation cover change matrix from 1986 to 1998 (ha)

1986	1998						
	Wt	Sw	Vw	Ow	Mw	Dw	Total
Wt	613.40	0.00	0.00	0.00	0.00	0.00	613.40
Sw	0.09	9.63	2.66	32.27	33.86	4.82	83.32
Vw	0.05	16.31	11.66	109.49	69.57	7.18	214.25
Ow	0.41	185.36	1993.64	70694.71	26792.80	4157.08	103823.98
Mw	0.00	14.65	146.48	33299.06	31604.65	7501.37	72566.19
Dw	0.00	4.12	37.13	5958.81	8658.16	7586.08	22244.29
Total	613.94	230.06	2191.55	110094.32	67159.04	19256.51	199545.41

Wt, water; Sw, sparse woodland; Vw, very open woodland; Ow, open woodland; Mw, moderate woodland; Dw, dense woodland.
Source: Authors' image analysis (2012)

Table 5: Vegetation cover change matrix from 1998 to 2000 (ha)

1998	2000						
	Wt	Sw	Vw	Ow	Mw	Dw	Total
Wt	613.40	0.50	0.05	0.00	0.00	0.00	613.94
Sw	0.14	9.99	124.29	88.81	4.16	2.68	230.06
Vw	0.05	1.85	334.73	1817.21	29.93	7.79	2191.55
Ow	0.00	0.99	692.53	84613.16	23788.24	999.41	110094.32
Mw	0.00	0.00	23.00	21302.19	37910.57	7923.29	67159.04
Dw	0.00	0.00	4.37	3685.95	6061.43	9504.77	19256.51
Total	613.58	13.32	1178.96	111507.32	67794.32	18437.92	199545.41

Wt, water; Sw, sparse woodland; Vw, very open woodland; Ow, open woodland; Mw, moderate woodland; Dw, dense woodland.
Source: Authors' image analysis (2012)

Table 6: Vegetation cover change matrix from 2000 to 2005 (ha)

2000	2005						
	Wt	Sw	Vw	Ow	Mw	Dw	Total
Wt	613.40	0.11	0.07	0.00	0.00	0.00	613.58
Sw	0.74	10.73	1.06	0.72	0.00	0.07	13.32
Vw	0.47	882.45	188.12	97.00	7.43	3.49	1178.96
Ow	2.14	20129.54	32119.97	52772.76	5115.74	1367.19	111507.32
Mw	0.09	673.47	2308.66	37061.98	20786.15	6963.98	67794.32
Dw	0.00	104.78	240.05	3442.03	5533.20	9117.86	18437.92
Total	616.84	21801.08	34857.92	93374.48	31442.51	17452.58	199545.41

Wt, water; Sw, sparse woodland; Vw, very open woodland; Ow, open woodland; Mw, moderate woodland; Dw, dense woodland.
Source: Authors' image analysis (2012)

Table 7: Vegetation cover change matrix from 1986 to 2005 (ha)

1986	2005						
	Wt	Sw	Vw	Ow	Mw	Dw	Total
Wt	613.395	0	0	0	0	0	613.395
Sw	0.315	7.47	3.4875	42.1425	19.44	10.4625	83.3175
Vw	0.18	25.4475	8.64	106.2675	48.6675	25.0425	214.245
Ow	2.7225	18134.7	23993.7	46544.67	11356.9	3791.25	103823.98
Mw	0.1125	3064.79	8703.32	38576.835	15287.49	6933.645	72566.19
Dw	0.1125	568.643	2148.77	8104.5675	4730.018	6692.175	22244.288
Total	616.8375	21801.1	34857.9	93374.483	31442.51	17452.58	199545.41

Wt, water; Sw, sparse woodland; Vw, very open woodland; Ow, open woodland; Mw, moderate woodland; Dw, dense woodland.

Source: Authors' image analysis (2012)

Table 8: Net Percentage Absolute Vegetation Cover Change from 1986 to 2005

Category of change	% Vegetation cover			
	1986-1998	1998-2000	2000-2005	1986-2005
No Change	55.08	66.34	41.53	34.35
Net gain	19.40	17.43	6.79	11.19
Net loss	25.21	15.92	51.36	54.15
Total	99.69	99.69	99.69	99.69

Note that the analysis excludes water class

Source: Authors' image analysis (2012)

The vegetation shows a relative stability from 1986 to 2000 with areas that have not really changed increasing from 55% in 1998 to 66% in 2000 (Table 8). The net gain slightly reduced within same period, while the net loss was on the decrease, indicating sign of vegetation restoration. Although the interval between 1998 and 2000 is a short term, it can still be argued that the rate of vegetation recovery was very high as against the duration of 13 years (1986-1998) which might have witnessed fluctuations in the vegetation cover. For instance, the net loss was about 25% between 1986 and 1998, and by 2000 this figure had reduced to nearly 16%. However, the structure of the vegetation had virtually changed by 2005. Evidence of high degradation is quite apparent looking at the net loss amounting to 51%, further indicating that this period (2000-2005) presented worse vegetation conditions than other periods studied; this signifies that between year 2000 and 2005 a lot of activities contributed to the loss in the cover. The most visible are the anthropogenic factors, including grazing and poaching. Similar developments were observed looking at the overall time frame studied from 1986 to 2005 (Figure 4).

It could be observed that the south and south eastern parts of the reserve show some level of consistence in greening with the exception of the period between 2000 and 2005 which accordingly reflects the worst change scenario of degradation. The reserve suffered some level of degradation especially around the central part and the eastern portion between 1986 and 1998 and recovered in 2000. However, since then, the trend toward degradation has spread and increases (Figure 4c).

4.4 Change rate

Table 9 shows the change analysis as extracted from the PCC change detection technique to appreciate the depth of changes that occurred in the study area within the period covered. The per cent change within the cover classes ranges between -20.6% and 17.4% over a period of 19 years. The overall change (which is the sum of all gains, loss and no change pixels) shows a per centage change of -12.6%, 26.2% and 13.5% for positive change (gain), negative change (loss) and no change cover types respectively.

As revealed from Table 3.8, there are variability in the per cent cover change and annual rate of change between the different cover classes. Sparse and Very open woodlands increased at a rate of +114304.0 ha/year (+1371.9%/year) and +182335.1 ha/year (+851.1%/year) respectively over a period of 19 years (i.e 1986-2005) assuming a linear increase. This rapid increase might be due to natural (rainfall) and a number of anthropogenic factors such as clear felling for agriculture, extraction of firewood and grazing. The Open, Moderate and Dense woodlands decreased consistently at a rate of -54997.3 ha/year (-0.5%/year), -216440.4 ha/year (-3.0%/year), and -25219.5 ha/year (-1.1%/year) respectively.

Table 9: Change area and the rate of change between 1986 and 2005

Type of cover	Change area (ha)	% change	Annual rate of change (ha/year)	% Annual rate of change (%/year)
Class cover change				
Water	-	-	-	-
Sparse woodland	21717.77	10.9	114304.0	1371.9
Very open woodland	34643.68	17.4	182335.1	851.1
Open woodland	-10449.50	-5.2	-54997.3	-0.5
Moderate woodland	-41123.68	-20.6	-216440.4	-3.0

Dense woodland	-4791.71	-2.4	-25219.5	-1.1
Overall change				
Positive change (net gain)	-25154.415	-12.6	-132391.7	-0.7
Negative change (net loss)	52182.427	26.2	274644.4	1.4
No change	-27031.095	-13.5	-142268.9	-0.7

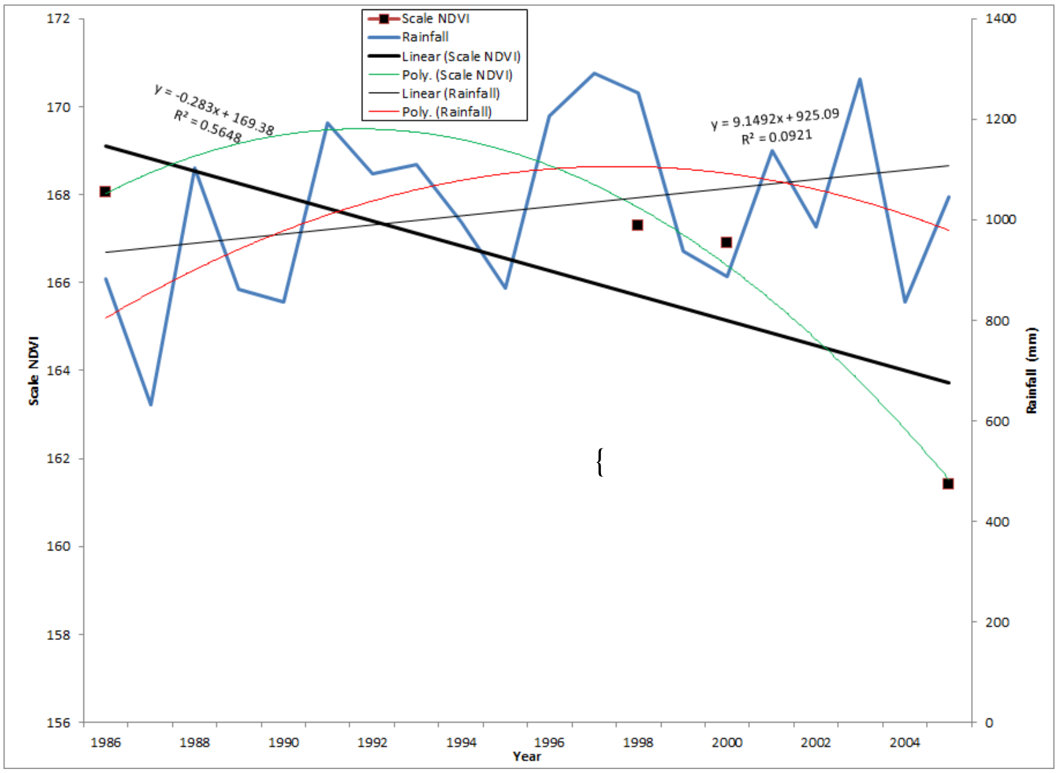
Note: the change rate was estimated from PCC result to see the per class cover change rate.
Source: Authors' image analysis (2012)

It is clear from Table 9 that the vegetation vigour is declining with an overall net gain and no change area decreasing at a rate of -13239.7 ha/year (-0.7%/year) and -142268.9 ha/year (-0.7%/year) respectively over an average period of 19 years (i.e. 1986/1998 and 2000/2005); while, the net loss area continue to increase at a rate of +274644.4 ha/year (+1.4%/year.

4. Discussions

It is not clear what could have been responsible for the observed pattern in vegetation cover changes. An examination of the relationship between NDVI and rainfall in Figure 5 visually indicates that there is an inverse relationship between mean annual rainfall and mean NDVI. While NDVI is experiencing a negative trend between 1986 and 2005, rainfall on the other hand shows an increasing trend. Thus, the picture painted in Figure 5 concurs with the observation of Herrmann *et al*. (2005), who investigated the temporal and spatial patterns of vegetation greenness and rainfall variability in the Sahel using a combination of remotely sensed indicators (the NDVI) and gridded satellite rainfall estimates for the period 1982-2003. Although according to their study, rainfall remains the dominant causative factor for an increase in vegetation greenness, they argued that human factors or what they refer to as the 'human signal' can also either trigger or inhibit vegetation greenness. While their study demonstrates that throughout the Sahel, there is no real recent evidence of large-scale anthropogenic land degradation, they argue that this does not mean that 'pockets' of degraded areas do not exist at local scales. From their data, they noted: 'Only parts of northern Nigeria and Sudan show areas where human impact hypothetically inhibited a greening trend in order of magnitude expected from the positive trend in rainfall conditions' (2005: 400). It remains unclear as to why vegetation greening has fallen behind what would be expected from the increase in rainfall in northern Nigeria, but Herrmann *et al.* (2005:400) suggest that one hypothetical explanation might be 'the neglect of good land use practices due to civil strife and conflict.' They concluded that more detail field work is needed at local level with the analysis of finer spatial satellite data, such as LANDSAT and MODIS imagery to examine the.

This study, therefore, provides a preliminary evidence that despite increasing trend in rainfall, vegetation cover has steadily decreased from 1986 – 2005. It will, therefore, be of immense value if other causative factors could be investigated including rainfall in spatial context.



To convert, scale NDVI = (NVDI+1)*127.5}. Note that the mean NDVI years used are 1986, 1998, 2000 and 2005.

Figure 5: The trend of mean annual rainfall and NDVI of the study area

The annual NDVI shows a general decreasing trend despite an increasing trend in annual rainfall (Figure 5). This might perhaps signal the need to examine the influence of human activities as one of the major causes of the observed trend. However, given

the complexity of the area the polynomial trend shows that both rainfall and NDVI are on the decrease though the intensities differ. This, therefore, requires further examination of the rainfall and NDVI relationship on a spatial basis, and perhaps if possible on a per pixel basis. The NDVI here was mathematically scaled from 0-255.

5. Conclusion

In this study, remote sensing classification and change detection methods was used to investigate vegetation cover changes. The rmse of geometric correction for all the images used range between 0.00197 and 0.49, while the r^2 for radiometric normalisation of the images were all >90% except for TM 1990 band 3 with 10%. Classification analysis using threshold on NDVI images indicated five vegetation cover classes (Dw, Mw, Ow, Vw and Sw) and one water body (Wt) class.

The post classification change analysis revealed a net change of 54% and 11% for vegetation loss and gain respectively from 1986 to 2005. The trend of mean annual rainfall shows a negative relationship suggesting human activities as causative factors. It is, therefore, concluded that changes have occurred in the study area particularly negative change and this requires adequate monitoring and sustainable forest management strategy that incorporated the local peoples need to ameliorate the trend. Efforts should be made toward assessing the anthropogenic factors

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