Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.3, 2016

Application of Delta Classification Algorithm in Land Cover Change Detection in a Semi-Arid Environment of Northern Nigeria

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Abstract
This study attempts to reveal Land use /land cover changes (LULCC) using multi-temporal and multi spectral satellite images in a semi-arid environment of northern Nigeria. Three separate Landsat satellite images for 1986, 1996 and 2001 were employed in this research. The study utilized Delta classification algorithm. The three images were separately classified before change in land use/land cover (LULC) was detected. Out of the seven detected LULC types in the study area, Scrubland, Woodland, and Riparian vegetation decreased while scattered cultivation, Settlement /built-up areas, Reservoir/water body and bare sand surface/rock out crops increased over spatial and temporal scales. Similarly, seven change scenario patterns were identified manifesting various patterns of change in the study area. The research revealed a gradual deforestation from grassland into agriculture, settlements/built-up areas and bare sand surfaces over the spatial and temporal scales. More researches are required that monitor and assess the trends of LULCC in this ecologically fragile environment.

1.0 Introduction

Rapid Population growth affects environmental resource base through increased demand for food, fodder, water and arable land (Federal Department of Forestry, 2001). Of all the environmental components, vegetation cover suffers the most alarming and rapid anthropogenic effects. This manifests in various ways. As high potential land becomes less available in the face of rapid population increase, production activities, particularly agriculture, extend into open grasslands or forest thereby permanently converting the landscape from hitherto previous cover (FAO, 2005). Nigeria was once covered by extensive and luxurious vegetation varying from humid tropical forests in the south to savannah grasslands in the north, much of which has been removed in the course of various human activities such as crop cultivation, urbanisation and other forms of production and development activities (FDF, 2001). Out of this, forest reserves cover about 10% of the national territory, mostly of the savannah woodland type. Between 1981 and 1985, deforestation, being a fundamental land cover change, was estimated at an average rate of 400,000 ha (3.48%), per annum; while between 1986 to 1990, deforestation increased at an estimated average rate of 3.57%, including the loss of some forest reserves (FDF, 1998). By the year 2005, Food and Agricultural Organisation (FAO), had concluded that if deforestation rate persisted, the remaining forest area in the country would disappear by the year 2020. Understanding this phenomenon mandated the need for assessing the status of land use/land cover change (LULCC) over spatial and temporal scales most especially in this marginally and fragile Sudan savannah ecosystem.

Efforts to detect changes in LULC started with mapping of earth's surface features from space using either manned or unmanned platforms (Slater, et al., 2000; Eltahir, et al., 2009). Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Yamamoto, et al., 2001). Timely and accurate change detection of earth's surface features in the face of the current tempo of resources production and consumption deserves to be a major research and policy priorities particularly in marginal areas of the semi-arid region which are naturally characterised by delicately balanced ecosystem (Gadzama, 1991; FAO, 2005).

Change detection involves the application of multi-temporal datasets to quantitatively analyse the spatial and temporal effects of the phenomenon (Rogan, et al., 2002; Stefano, et al., 2003). Because of the advantages of repetitive data acquisition, its synoptic view, and digital format suitable for computer processing, remotely sensed data such as Thematic Mapper (TM), Satellite Probatoire d'Observation de la Terre (SPOT), radar and Advanced Very High Resolution Radiometer (AVHRR), have become some major data sources for different change detection applications particularly LULC change (Tucker, et al., 1986; Stow, et al., 1990; Sunar, 1998; Woocock, et al., 2001; Laura, et al., 2005). Important as it may seem, change detection research is an active topic and continues to grow in order to match the tempo of LULC transformations and other application fields. However, efforts to accurately detect changes in LULC must provide information about area and rate of change, spatial and temporal distribution of change types, change pattern/trajectories of land cover types and accuracy assessment of change detection results (Zomer, et al., 2001; Yamamoto, et al., 2001; Suzanchi, et al., 2006). Delta classification algorithm commonly referred to as "post-classification comparison", where images belonging to different dates are classified and labelled separately. Later, the classification results are compared directly and the change areas are extracted (Suzanchi, et al., 2006). Separate classification of two images minimises the problem of radiometric and geometric normalisation for sensor differences between two dates (Suzanchi, 2006). Unfortunately, the errors in the individual classification of each image are reflected in the final change detection (Yuan, et. al, 1998). By properly coding the classification results, a complete matrix of change as well as change classes can be defined and obtained. This method is the most widely used digital change detection algorithms, because of its straightforwardness and easy to implement (Sunar, 1998). However, accuracy of this method is totally dependent on the accuracy of the initial classifications of the base dataset.

2.0 Methodology

2.1 Study Area

The study area is located in the Sudan savannah region of northern Nigeria, precisely in the central parts of Katsina state covering a landmass of about 2,377.38 km^2 approximately (or about 9.8%) of the entire state, (Figure.2.1). The area stretched between longitude 7^0 18''E to 7^0 55''E and latitude 12^0 28''N to 12^0 47''N. The area, rectangular in shape (69.230km^2 X 34.340km^2), is situated about 10 km away south of Katsina city. Administratively, the study area comprised of parts of Batsari, Batagarawa, Bindawa, Charanchi, Dutsimma, Kankia, Kurfi, Mani and Rimi local Government areas. The area is predominantly underlain by crystalline rocks of Basement Complex origin. Lithologically, it consists largely of coarse, purple and mottled feldspatic grits. Maximum day temperature of about 38^{0}C in the months of March, April and May are common and the minimum temperature is about 22^{0}C in the months of December and January. Rain fall duration rarely exceeds 190 days with single peak maxima in August. The area has an average rainfall of about 700mm. The study area lies within Sudan Savannah vegetation zone associated with a greater proportion of open trees (woodland) including perennial short grasses. Common species in this area belong to xerophytes groups with varying degree of adaptability to water deficiency.

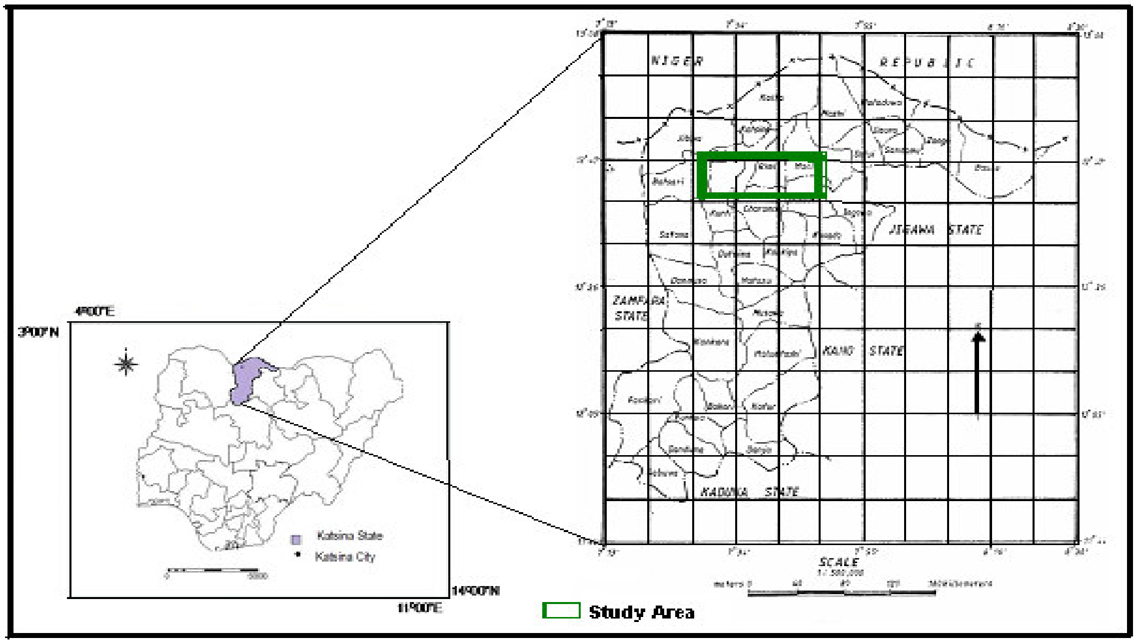

Figure 2.1: Location of the study Area

The 2006 population census revealed that Katsina state as a whole had a total population of 5,801,584 and a projected figure of 6, 489, 069 for the year 2011. Similarly, the study area had an estimated population of about 1, 276, 940 of the state's population in 2006 and a projected figure of 1, 428, 255 for the year 2011 representing about 22% (N.P.C., 2006).

2.2 Materials and Methods

This study was carried out using Landsat TM image for 1986, ETM image for 1996, ETM$^+$ image for 2011 with 189/051 as path and row. Other materials employed include topographical maps, GPS (Standard Garmin GPS 78^s), Idrisi Taiga and ILWIS 3.3 Academic GIS Software for land use/land cover (LULC) change detection and analysis.

2.2.1 Image Pre-Processing and Analysis

The image scenes were georeferenced to a UTM Zone 32N WGS 1984 projection, Ellipsoid (Clarke 1880), and Datum (Minna-Nigeria) using the 'Create' New coordinate system procedure on the Ilwis Operation List. The study area was subset from a complete scene after these images were orthorectified in Idrisi Taiga GIS software. The Landsat images were corrected geometrically within the using deriving GCPs from the topographical maps of the subset area. Radiometric correction was performed using the Chavez's Cos (t) model (Eastman, 2009), and image calibration was done for multi-date image comparison (Chen and Rao, 2008). The subset images were resampled and enhanced for maximum spectral distinction using Histogram equalization in Idrisi Taiga.

2.2.2 Digital Image Classification

The study utilizes the supervised image Classification procedure using maximum likelihood classifier in ILWIS 3.3 Academic software. False colour composites were developed for the three images using only four out of the seven respective bands 4 (NIR), 3 (Red) and 2 (Green) and 1 (Blue). The developed composites were used to classify all the three images separately for 1986, 1996 and 2011 before any change was detected subsequently in a post-classification approach. Ground truth exercise using a hand-held Garmin GPS 78^{s} was carried out throughout the study area at the beginning and during classification exercise. Coordinates of the various training sites were sampled and later compared and verified with image coordinates for most of the LULC classes. In this way, classes of pixels with similar spectral values were defined and assigned class names where the spectral values of those pixels were similar enough to a training class. Thus a classification scheme was adopted from the National Land use/land cover Project of the National Centre for Remote Sensing (LULCP/NCRS., 2008) and came up with seven individual classes for this study (Table 2.1).

Table 2.1 Land use/Land cover Classification Scheme

S/N	LULC Category	Definition
1	Reservoir/Water body	Natural man-made stagnant water body usually created by damming streams.
2	Riparian Vegetation	Forests adjacent /along water courses characterised by dense canopy cover.
3	Rock outcrop/Bare sand surface	Exposed rock out crop with little or no vegetation and bare sand surface along river beds.
4	Scattered Cultivation	Small scale subsistence farming usually of house hold or arable crops.
5	Scrubland	Dominantly shrubs with scattered trees and sub dominant grass component.
6	Settlements/Built-up areas	Densely populated cities and towns including both smaller urban centres, large scale nucleated settlements and villages without social amenities.
7	Woodland	Dominantly trees of open canopies and shrubs with sub dominant grass component.

Source: Ground Truth and Field Validation, 2011

2.2.3 Digital Change Detection and Analysis

Delta classification comparison of LULC statistics was utilized in detecting for changes as well as quantitative analysis of the various LULC categories in the study area. The statistics for each of the LULC classes was obtained from the classification of the images for each date (1986, 1996 and 2011) separately. The LULC statistics were copied and exported to Microsoft Excel window for computations of areal extent of each LULC type, based on which extent of change, annual rate and percentage of change in LULC among the three different data sets as well as the pattern of changes (positive or negative) in each LULC type for 1986 and 1996, 1996 and 2011, as well as between 1986 and 2011 were statistically estimated and compared.

2.2.4 Accuracy Assessment and Field Validation

Ground Truth data (Training sites) comprises the Ground Control Points (GCPs) and site description of the sampled locations for image classification and classification accuracy assessment. Information on the number and class distribution of GCPs to be collected for supervised image classification is not clear from the literature. What appears important is the accuracy of classification which is a function of the number of GCPs used for training. A useful rule of thumb is 30*n (n = number of bands) (Janssen and Gorte, 2004). Thus, in this study, the rule was applied and sampling was done using stratified random technique on the latest LUC map of 2011. Accuracy of the classification exercise was measured by analysing both *commission* and *omission* errors that were supposed to have occurred during image classification. It was assessed for each land use/land cover type separately using an accuracy index (AI) that incorporated both omission and commission error into a single summary value: $AI = ((n-o-c)/n) \times 100$.

3 RESULTS AND DISCUSSION

3.1 Land use/land cover Distributions

Consequent upon classification of the three satellite imageries of the study area at the selected time intervals (1986, 1996 and 2011), spatial and temporal distributions of static LULC was generated. These statistics were later compared to detect changes in LULC across the study area. Table 3.1 provides data on spatial and temporal distributions of LULC statistics in the study area from which changes were detected among the three data sets. Generally, it could be seen from table 3.1 that while significant increases were noticed in some LULC types, there were also substantial decreases in others over the twenty five year period. Out of the seven LULC types considered in this research, three were noticed to have continually decreased while the remaining four manifested some increases over spatial and temporal scales. The three LULC types that maintained a consistent decrease include scrubland, woodland and riparian vegetation in this order, while those that maintained consistent increase were the scattered cultivation, settlement/built-up areas, bare sand surface/rock out crop and water bodies/reservoirs respectively.

Table 3.1: Land use/Land cover distribution for 1986, 1996 and 2011 in the study area

S/N.	Land use/land cover types	1986		1996		2011	
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Reservoir/Water body	4.87	0.2	7.62	0.3	8.68	0.4
2	Riparian vegetation	113.77	4.8	85.99	3.6	39.63	1.7
3	Rock out crop/Bare sand surface	89.98	3.8	128.77	5.4	158.60	6.7
4	Scattered cultivation	723..60	30.4	1175.61	49.4	1650.59	69.4
5	Scrubland	1120.40	47.1	695.70	29.3	276.25	11.6
6	Settlement/Built-up areas	69.95	2.9	107.76	4.5	171.73	7.2
7	Woodland	254.81	10.7	175.93	7.4	71.90	3.0
Total		**2,377.38**	**100%**	**2,377.38**	**100%**	**2,377.38**	**100%**

Source: Generated from classified satellite images of the study area, 2011

3.1.1 Land Use/Land Cover Distribution in 1986

1986 serves as the base year for this research on which all research findings related to spatial and temporal distributions and change detection were generated. Figure 3.1 and table 3.2 indicate LULC distribution in the study area as at 1986. During that year, the predominant LULC type in the study area was scrubland covering an estimated land area of about 1120.40km^2 or about (47.1%). This was followed by scattered cultivation which approximately occupied an estimated land area of about 723.60km^2 representing (30.4%). The other predominant LULC type in 1986 was the Woodland covering an estimated land area of about 254.81 km^2 (or 10.7%) of the study area. Beside this, Riparian vegetation cover was the next predominant cover type in 1986 covering an estimated land area of about 113.77 km^2 representing about 4.8% of the study area. This was followed by Bare sand surface/Rock out crop, settlement/Built-up areas and Reservoir/Water body with estimated areas of 89.98 km^2 (or 3.8%), 69.95 km^2 (or 2.9%) and 4.87 km^2 (or 0.2%) respectively.

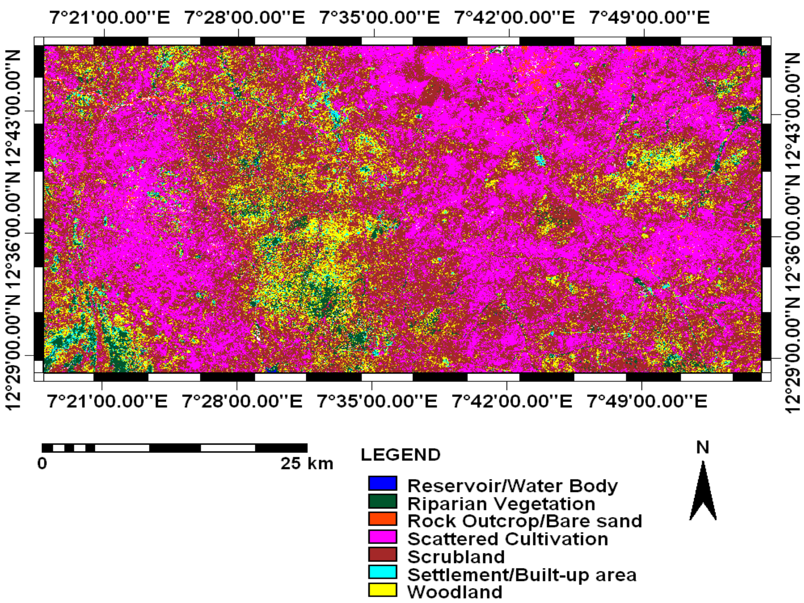

Figure 3.1: Land Use/Land Cover Distributions in 1986

3.1.2: Land Use/Land Cover Distribution in 1996

1996 served as the year of second data set in this research. Predominant LULC type in 1996 was scattered cultivation with an estimated land area of 1175.61km^2 representing about (49.4%) of the study area. This was followed by scrubland which covered an estimated land area of about 695.70 km^2 (or 29.3%). Subsequently, Woodland, Rock outcrop/Bare sand surface and Settlement/Built-up area followed suite in this order with estimated land covers of about 175km^2 (or 7.4%), 128km^2 (or 5.4 %), and 107km^2 representing (4.5%) respectively. This indicated an appreciable increase in population due to migration from within and outside Nigeria nine years after the creation of the state. Katsina state being the “Home of hospitality” witnessed large scale transfer of civil servants, movements of indigenes, non indigenes and foreigners for various reasons into the state which resulted into rapid population growth.

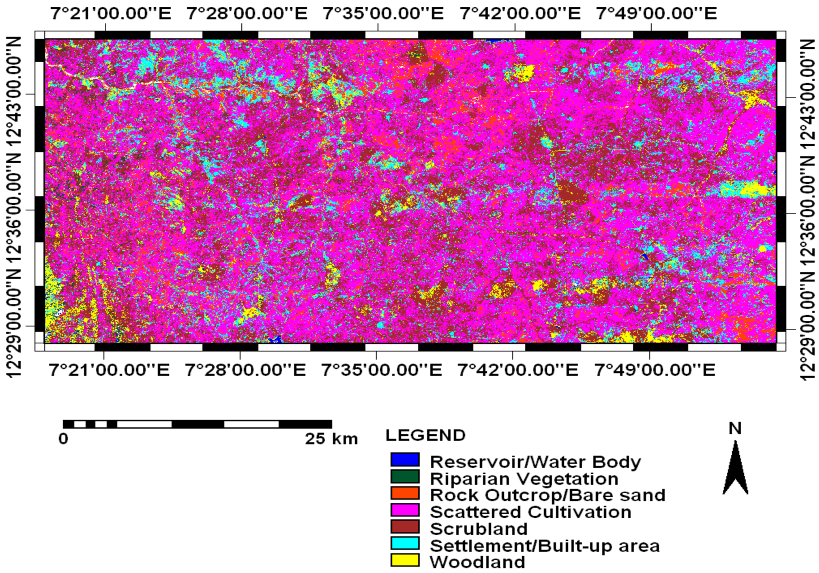

Figure 3.2: Land Use/Land Cover Distributions in 1996

3.1.3: Land Use/Land Cover Distribution in 2011

Figure 3.3 and Table 3.1 revealed that scattered cultivation was the predominant LULC type covering an estimated land area of about 1650.59 km^2 (or 69.4%) of the total land area as at 2011 as against 723.60 km^2 (or 30.4%) in 1986 and 1175.61 km^2 (or 49.4%) in 1996. It could be seen from this between 1986 to 1996 and 1996 to 2011, scattered cultivation increased by about 19% and 20% respectively. Overall increase in scattered cultivation between 1986 and 2011 stood at about 69.4%. This was followed by scrubland, settlement/built-up areas and Bare sand surface/Rock out crop with estimated areas of about 276.25 km^2 (or 11.6%), 171.73 km^2 (or 7.2%) and 158.60km^2 (or 6.7%) respectively.

The state as a whole had witnessed tremendous socio-economic and infrastructural development. In 2004, the Katsina state Government created additional 30 development areas enjoying almost the same status with existing 34 local government areas. This also promoted expansion and growth of infrastructure across the state which subsequently promoted substantial changes in LULC pattern, as many additional roads of various categories, hospitals, dams and bridges, schools, markets, viewing stations etc were constructed across the state. This specifically led to the development of new settlements as well as rapid urbanization of existing ones across the state.

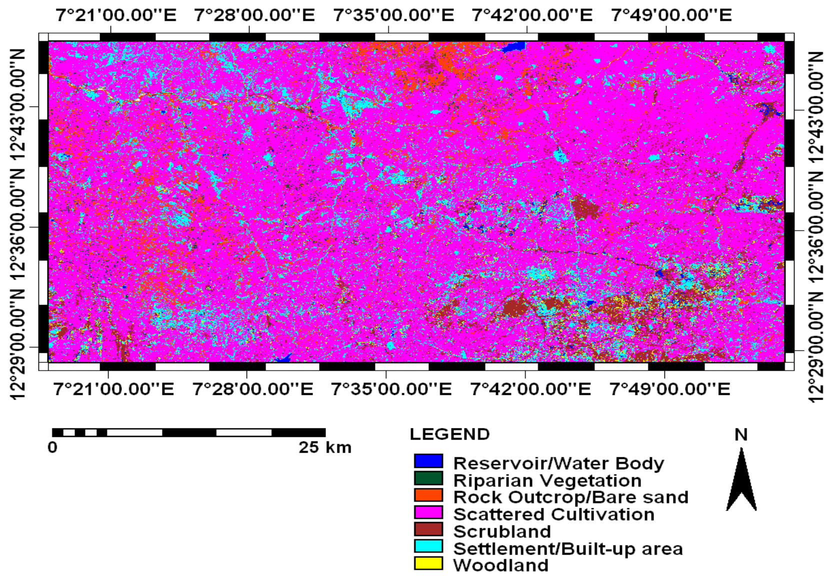

Figure 3.3: Land use/Land cover Distribution in 2011

3.1.4 Rates and extent of changes in LULC in the study area

3.1.4.1 1986 to 1996 Period

Variable annual rates of change in LULC types were noticed in the study area during this period. It could be noticed from table 3.2 that scattered cultivation and scrubland had the highest annual rate of change within this period having 45.201 km^2 and 42.770 km^2 respectively. Similarly, it could be deduced from the table that Water body, Bare sand surface/Rock out crop, Scattered cultivation and Settlement/Built-up areas had increased over the ten year period by 2.75km, 29.79km, 452.01 km^2, and 37.81 km^2 with annual rates of 0.275 km^2, 2.979 km^2, 45.201 km^2, and 3.781 km^2 respectively. Riparian vegetation, Scrubland, and Woodland had decreased by 27.78 km^2, 427.70 km^2, and 78.86 km^2 with annual rates of 2.778 km^2, 42.770 km^2 and 7.886 km^2 over the ten year period respectively. The case of increase in bare sand surface /Rock out crop could be attributed to increasing desertification/intensification of aridity, drought as a result of high variable rainfall condition, and excessive human activities such as over grazing, and widespread infrastructural development activities across the state.

Table 3.2: Land use/Land cover Status and Change Statistics (1986-1996)

LULC Types	1986 (Km^2)	1996 (Km^2)	Extent of Change (Km^2)	Annual Rate of Change (Km^2)	% of Change
Reservoir/W. Body	4.87	7.62	+2.75	0.275	56.5
Riparian Vegetation	113.77	85.99	-27.78	2.778	24.4
Rock out crop/ Bare Sand surface	89.98	128.77	+29.79	2.979	33.1
Scattered Cultivation	723.60	1175.61	+452.01	45.201	62.5
Scrubland	1120.40	695.70	-427.70	42.770	37.9
Settlements/ Built-up areas	69.95	107.76	+37.81	3.781	54.1
Woodland	254.81	175.93	-78.86	7.886	31.0

NB + Indicate increase – Indicate decrease

3.1.4.2 1996 to 2011 Period

During this period, mixed changes and rates were evident. It is evident from table 3.3 that scattered cultivation exhibited greater change in terms of extent, rate and percentage within this period. It increased from 1175.61 km^2 in 1996 to about 1650.59 km^2 in 2011, gaining about 477.98 km^2 in spatial extent estimated at 31.87 km^2 annual rate of increase over this ten year period. Similarly, Settlement/Built-up areas manifested increase from about 107.76 km^2 in 1996 to about 171.73 km^2 in 2011 gaining about 63.97 km^2 at 4.27 km^2 annual rate. Conversely, Scrubland manifested alarming decrease rate from 695.70 km^2 in1996 to 276.25 km^2 in 2011, losing about 419.45 km^2 of areal extent at an estimated annual rate of 27.96 km^2 over the ten year period. Woodland cover also manifested alarming decline from 175.93 km^2 in 1996 to about 71.90 km^2 losing about 104.03 km^2 of areal extent at an annual rate of 6.94 km^2 over the ten year period.

Table 3.3: Land use/Land Cover Status and Change Statistics (1996-2011)

Land use/ Land cover Types	1996 (Km^2)	2011 (Km^2)	Extent of Change (Km^2)	Annual Rate of Change (Km^2)	% of Change
Reservoir/W. Body	7.62	8.68	+1.06	0.07	13.9
Riparian Vegetation	85.99	39.63	-46.36	3.09	53.9
Rock out crop/Bare Sand surface	128.77	158.60	+29.83	1.99	23.2
Scattered Cultivation	1175.61	1650.59	+477.98	31.87	40.4
Scrubland	695.70	276.25	-419.45	27.96	60.3
Settlements/ Built-up areas	107.76	171.73	+63.97	4.27	59.4
Woodland	175.93	71.90	-104.03	6.94	59.1

NB: + Indicate increase; – Indicate decrease

3.1. 4.3 1986 to 2011 Period

This summarizes the entire research period (about 25years). The spatial and temporal changes over this period could be deduced from figure 5.4 and table 5.4. During this period, about four land use/land cover types exhibited positive increases in spatial extent. Prominent among these include Scattered cultivation which was estimated at 723.60 km^2 in 1986, but rose to about 1650.59 km^2 in 2011, gaining an estimated area of about 926.99 km^2 (128.1%). This was followed by Settlement/Built-up areas which also exhibited tremendous increase from 69.95 km^2 in 1986 to 171.73 km^2 gaining an estimated area of about 101.78 km^2 (145.5%). Bare sand surface also exhibited increase over this period from 89.98 km^2 in 1986 to 158.60 km^2 in 2011 with estimated spatial extent of about 68.62 km^2 representing about 76.26%. This largely represents area lost due to increasing desertification in addition to numerous rock out crops that dotted the study area. Reservoir/Water body also exhibited substantial increase from 4.87 km^2 in 1986 to about 8.68 km^2 in 2011. This could be attributed to widespread construction of earth dams across the state to meet with portable water demand.

Table 3.4 Land use/Land cover Status and Change Statistics (1986-2011)

Land use/Land cover Types	**1986 (Km^2)**	**2011 (Km^2)**	**Extent of Change (Km^2)**	**Annual Rate of Change (Km^2)**	**% of Change**
Reservoir/W. Body	4.87	8.68	+3.81	0.15	78.23
Riparian Vegetation	113.77	39.63	-74.14	2.97	65.16
Rock out crop/Bare Sand surface	89.98	158.60	+68.62	2.75	76.26
Scattered Cultivation	723.60	1650.59	+926.99	37.08	128.10
Scrubland	1120.40	276.25	-844.15	33.77	75.34
Settlements/ Built-up area	69.95	171.73	+101.78	4.07	145.50
Woodland	254.81	71.90	-182.91	7.32	71.78

NB: + Indicate increase; **–** Indicate decrease

3.2 Development of Change Scenario patterns in the study area

In order to explore the pattern of LULC change in the study area vividly, seven specific changed areas were identified and subset from the three data sets creating seven change scenario patterns. Table 3.5 provides summary of change scenarios and composition of changes from one LULC to another.

Table 3.5 Summary of Change Scenarios Identified in the study area

Change Scenario	**Types of change (From-To)**	**Lat Long. Coordinates**	
		Nothings	**Eastings**
1	Scrubland to Scattered Cultivation	12^0 38' 55.91'N'- 12^0 41'18.93''N	7^0 42'58.06''E - 7^0 45'44.66''E
2	Woodland to Settlement/Built-up areas	12^0 34'43.42''N - 12^0 38'03.64''N	7^0 31'14.89''E - 7^0 35'49.58''E
3	Riparian Veg. to Scattered Cultivation	12^0 27'56.96''N - 12^0 32'48.81''N	7^0 17'59.95''E - 7^0 22'53.91''E
4	Woodland to Bare sand surface	12^0 42'18.06''N - 12^0 46'52.47''N	7^0 37'23.88''E - 7^0 43'48.31''E
5	Scrubland to Bare sand surface	12^0 43'27.34''N - 12^0 46'00.02''N	7^0 36'22.76''E - 7^0 39'51.98''E
6	Woodland to Scattered Cultivation	12^{0}39'03.64''N - 12^{0}42' 24.36 N	7^0 48' 01.43''E - 7^0 52' 33.11''E
7	Scrubland to Settlement/Built-up areas	12^0 28'30.90''N - 12^0 31'50.93''N	7^0 43'53.89''E - 7^0 48'20.19''E

NB: LatLong: Latitude and longitude

3.2.1 Change Scenario One (Scrubland to Scattered Cultivation)

The Federal Department of Forestry (F. D. F., 1993) and the Land use/land cover project of the National Centre for Remote Sensing (LULCP/NCRS., 2008), Jos, defined a scrubland as predominantly shrubs cover with scattered trees and sub dominant grass component. An area located on longitude (12^{0}38' 55.91''N - 12^0 41'18.93''N) and latitude (7^0 42'58.06''E - 7^{0}45'44.66''E) in all the three datasets was selected to demonstrate a gradual transformation in LULC from scrubland to scattered cultivation. The first subset was derived from the 1986 classified image that indicated a thick scrubland cover around the reference area. A gradual change could however be observed in the subsequent image (1996) due to emergence and expansion of some settlements and built-up areas that were not in existence in the previous subset image of 1986. The emergence and expansion of such settlements could vividly be seen in the subsequent image of 2011. This situation could have led to the widespread conversion of scrubland into farmlands for cultivation and possibly grazing activities due to growth in the surrounding population in 2011. Scrubland being comprised of shrubs and grasses provides ample source of animals' feed and fuel wood for the surrounding populations. The conspicuous disappearance of scrubland cover into scattered cultivation could probably be attributed to rampant fuel wood extraction around the area as well as expansion of farmlands by the rapidly growing rural and semi-urban populations as could be seen from the 2011 subset image.

3.2.2 Change Scenario Two (Woodland to Settlement/Built-up Areas)

An area in the south western part of the study area located on longitude ($12^0$34'43.42''N -$12^0$38'03.64''N) and latitude ($7^0$31'14.8"E - $7^0$35'49.58''E) was selected to demonstrate a gradual transformation in LULC from Woodland cover to settlements/built-up areas. The first subset represented an area covered predominantly by woodland and riparian vegetation in the 1986 classified satellite image. By 1996, the subset of the same portion indicated a somewhat total disappearance from a hitherto woodland cover to some few settlements and bare surfaces or rock outcrops probably attributed mainly to farmlands expansions and settlements development by surrounding populations. The same portion of the 2011 classified satellite image indicated a complete transformation from woodland to settlement/built-up areas of various sizes and scattered cultivation. This transformation could most probably be as a result of the emergence and growth of settlements around the area, as it is situated at the tail edge of the 'Rugu' forest Reserve' and few Kilometers away from the famous Zobe dam. Moreover, the area was a stronghold of the Fulani herdsmen. This was coupled with the fact that numerous infrastructural development projects were introduced in the area over the study period.

3.2.3 Change Scenario Three (Riparian vegetation to scattered cultivation)

According to the F. D. F., (1993) and LULCP/NCRS (2008), riparian vegetation connotes a forest cover adjacent or along water courses characterized by dense tree canopy. An area located southwest of the study area on longitude ($12^0$27'56.96''N--$12^0$32'48.81''N) and latitude ($7^0$17'59.95''E--$7^0$22'53.91''E) was selected to demonstrate specific LULC transformation from Riparian vegetation cover to scattered cultivation. The first subset image represents a portion of an area from the 1986 classified image that was covered by riparian vegetation. The presence of this cover was due largely to the various tributaries that flow into Zobe dam. This area was bordered to the west by 'Rugu forest reserve' and to the south by Zobe dam. On the north-eastern part, the area was bordered by some inselbergs located in parts of Safana, Batsari and Dutsin-ma local government areas. On this subset image, riparian vegetation cover was represented by green colour along some river channels that probably flow into Zobe dam to the south. The second subset represents the same portion in the 1996 classified image depicting losses and gains in some predominant LULC. In this epoch, changes could be noticed in the hitherto predominant cover. Some changes could be noticed into woodland and scattered cultivation. This could probably be attributed to deforestation that has affected the wider forest reserve as well as other human activities such as irrigation in the surrounding dam area. The same subset of the area in the classified image of 2011 depicted remarkable LULC transformation into scattered cultivation as exemplified by some emerging settlements around central and western parts of the subset. Due to influx of people into the area for irrigation activities, the remaining vegetation cover has almost been wiped out for the thriving agricultural activities.

3.2.4 Change Scenario Four (Woodland to Bare sand surface)

By the definition of the FDF, 1993 and LULC/NCRS., 2008, woodland cover comprises of dominantly trees of open canopies and shrubs with sub dominant grass components, while bare sand surface or rock outcrop refer to exposed rock outcrop with little or no vegetation and bare sand surface along seasonal river beds or bare sand dunes. In order to demonstrate LULC conversion from Woodland cover to bare sand surface, an area in the extreme northern part of the study area on the main Katsina-Kano highway was selected. This area was located on longitude ($12^0$42'18.06''N - $12^0$46'52.47''N) and latitude ($7^0$37'23.88''E - $7^0$43'48.31''E). In the baseline image (i.e.1986), the area was covered by scrubland that transformed into woodland cover in the 1996 image. On the 1986 subset image, there were not many settlements or built-up areas until when agricultural farm site was established in a small linear settlement called Eka in the present Charanchi local government area In order to set up demonstration farms in the area, scrubland was cleared and trees of open canopy were planted around demonstration farmlands. This could be seen on the 1996 subset image identified by the yellow colour.

On the 2011 subset image, the entire woodland area has disappeared due possibly to the growth and expansion of Eka settlement and other neighbouring settlements. Similarly, it was discovered while ground truthing the area that a woodland cover that existed on the eastern part of the Katsina-Kano highway at Eka village was cleared in 2008 leaving the vacant land. Numerous farmlands have been established in a hitherto scrubland and woodland covers.

3.2.5 Change Scenario Five: Scrubland to Bare sand surface

The FDF, 1993 and the LULC/NCRS, Jos, 2008, defined a scrubland as dominantly shrubs cover with scattered trees and sub-dominant grass component. An area in the extreme north western part of the study area located on longitude ($12^0$43'27.34''N-$12^0$46'00.02''N) and latitude ($7^0$36'22.76''E-$7^0$39'51.98''E) was subset in order to demonstrate a gradual conversion from scrubland cover to bare sand surface. On the 1986 subset image, two parcels of scrublands could be observed both to the north and south of the area. There were very few settlements or built-up areas on this subset as at that time. However, a sub set of the same area from the 1996 classified satellite image indicates a gradual change into scattered cultivation and bare sand surface due to growths in both settlements and populations around the area. Some settlements emerged right around the scrubland cover area that could have probably been responsible for the scrubland cover degradation first into scattered cultivation and bare sand surface in the subsequent years. These settlements grew and continued to expand by the years, thereby translating on the landscape through loss of the hitherto predominant scrubland cover of the area. More of these changes could be seen from a subset of the same area in the 2011 classified satellite image. By this year, the area under reference had already transformed into bare sand surface as depicted by some red portions around the area due probably to increased development pressure as a result of improved access from previously remote rural areas as well as fuel wood supply to the growing populations.

3.2.6 Change Scenario Six: Woodland to Scattered cultivation

An area in the north central part of the study area located on longitude ($12^0$39'03.64''N-$12^0$42'24.36''N) and latitude ($7^0$48'01.43''E - $7^0$52'33.11''E) was used to demonstrate LULC conversion from woodland cover to scattered cultivation. In this scenario, the first subset represents an area covered by woodland as at 1986. The area had little human or natural intervention as could be seen from the subset. There were very few infrastructural development projects or settlements around the reference area. However, a close observation of the next subset image of the same area in 1996 revealed emergence of some rural and semi urban settlements connected by network of roads across the area. This points to the fact that woodland cover had transformed into scattered cultivation due most probably to increased development pressure as a result of improved road network and growth of some rural and semi-urban settlements around the area. As a result of this, large scale conversion from woodland to scattered cultivation could be seen on the subset of the same area from 2011 classified satellite image. On this subset, a total conversion from woodland into scattered cultivation as exemplified by settlements or built-up areas surrounded by large expands of farmlands all over the subset area was observed which was confirmed through field checks and validation across most of the area.

3.2.7 Change Scenario Seven: Scrubland to Settlement/Built-up areas

An area in the central parts of the study area located on longitude ($12^0$28'30.90''N -$12^0$31'50.93''N) and latitude ($7^0$36'53.89''E - $7^0$48'29.19''E) was subset to demonstrate a gradual degradation from scrubland cover into settlements or built-up areas. The first subset of the area from the 1986 classified image indicated predominance of scrubland cover across the area under review. The predominant cover had manifested little or no pressure as could be seen on the subset. The subsequent subset of the same area from the classified image of 1996 manifested some level of development pressure as indicated by some road improvements that traversed the area leading to development and growth of some rural and semi-urban settlements across the area under review. These settlements attracted increased government projects in terms of feeder roads, earth dam, schools tarred roads, hospitals, mosques, viewing centres, markets etc; which altogether translated on the landscape of the area. Thus, the subset of the same area from the classified image of 2011 had manifested large scale growth in human settlements and built-up areas ranging from farmsteads to neighbourhoods, villages, towns up to local government headquarters. Some of these settlements or built-up areas around the central parts of the subset represent a closed-settled Fulani farmsteads and rural areas. The scrubland cover served as source for fuel wood for the teeming populations mostly children and as grazing ground for their animals; a situation that rapidly facilitated deforestation of scrubland cover into settlements and scattered cultivation.

4.0 CONCLUSION AND RECOMMENDATIONS

The study revealed that:

i. There were conspicuous changes in the LULC across the study area between 1986 and 2010 as shown by the three classified satellite images;

ii. Overall spatial and temporal changes in LULC in the study area revealed a steady and gradual deforestation into agriculture, settlement/built-up areas and bare sand surfaces;

iii. Between 1986 and 2011, riparian vegetation, scrubland and woodland decreased by 27.78 km^2 (or 24.4%), 427.70 km^2 (or 37.9%) and 78.86 km^2 (or 31.0) respectively, while reservoir/water body, bare sand surface/rock out crop, scattered cultivation and settlement/built-up areas manifested significant increases by 2.75 km^2 (or 56.6%), 29.79 km^2 (or 33.1%), 452.01 km^2 (or 62.5%) and 37.81 km^2 (or 54.1%) respectively.

iv. The study discovered about seven (7) change scenario patterns across the study area viz:
1) Scrubland changes to Scattered Cultivation
2) Woodland changes to Settlement/Built-up areas
3) Riparian Vegetation changes to Scattered Cultivation
4) Woodland changes to Bare sand surface
5) Scrubland changes to Bare sand surface
6) Woodland changes to Scattered Cultivation
7) Scrubland changes to Settlement/Built-up areas

In spite of its usefulness in providing essential spatial information for environmental assessment, change detection processes still remain an active research topic and new techniques continue to be developed with various levels of accuracies. This makes it difficult to have an optimum method to implement accurate change detection for a specific research purpose or study area. Application of multi-sensor data will become increasingly important in future change detection research, and thus more advanced change detection techniques are needed.

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Plate 1: Conversion of Scrubland to Scattered cultivation

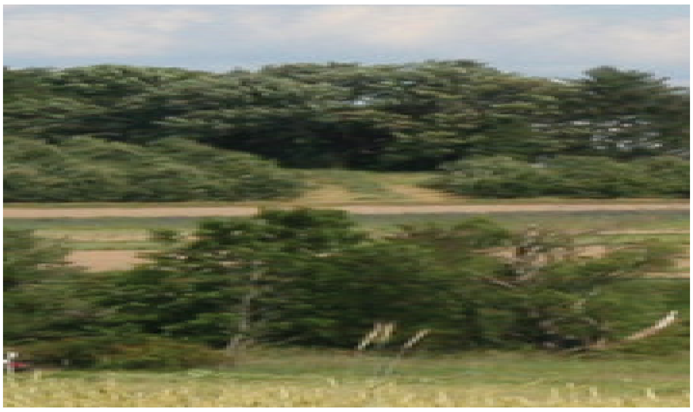

Plate 2: Woodland degraded by a road project in the study area

Plate 3a: Conversion of Riparian vegetation to cultivation

Plate 3b: Conversion of Woodland to Bare sand surface

Plate 4: Conversion of Scrubland to Bare sand surface

Plate 5: Conversion of Woodland to Scattered Cultivation

Plate 6: Conversion of Scrubland to Settlement/Built-up areas