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Analysis of Change Detection of Birnin-Kudu Land Cover Using Image Classification and Vegetation Indices

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Abstract

The study utilizes Landsat-7 ETM+ based Normalized Differences Vegetation Index (NDVI) and Normalized Differences Water Index (NDWI) from 1972 to 2012 at the study area situated in Birnin Kudu, Jigawa state, in North-western Nigeria. The classified satellite data based NDVI of 1972, 1986, 2003 and 2012, including NDWI of 1986, 2003 and 2012 were used to determine land-cover change; vegetation and water body that have occurred in the study areas. This study attempts to use a comparative change detection analysis to produce the best way to quantify changes that has occurred in the study area with a lag time of 40 years (1972-2012) for NDVI and 26 years (1986-2012) for NDWI. The results of the classifications of NDVI and NDWI were displayed on satellite imagery, of which the percentage differences of change detected from variations of land cover/vegetation using NDVI of 1972-1986 is 15%, 1986-2003 is 40% and 2003-2012 is 11.6%. In the same vein, the result of percentage differences of change detected from variations of water bodies using NDWI of 1986-2003 is 0.03% and 2003-2012 is 1.5%. In the final analysis the change detected using NDVI for the period of 40 years (1972-2012) is 43.4%, while using NDWI for the periods of 26 years (1986-2012) is 1.47%. The study recommends periodic examination of land-use changes for determining various ecological and developmental consequences over time. The study area is of great environmental and economic importance having land cover rich in agricultural production and livestock grazing.

Keywords: Analysis, change detection, land-cover, image classification algorithms, NDVI, NDWI

1.0 Introduction

Land Cover (LC) identification and classification of landscape depends largely on a good knowledge of the area of study, which is usually acquired through thorough fieldworks and ground truthing exercises. There is a need for analyzing land-cover (Stuckens, et al. 2000) changes in order to have a comprehensive plan over the land-cover area for future planning towards sustainability. The use of land-cover change detection tools such as NDVI and NDWI vegetation indices, can help to discriminate different areas of land-cover changes that has occurred between different years in an imaging (Lillesand et al., 2004). Change detection using remote sensing techniques (Yang and Lo, 2002) that involves the comprehensive analysis of spatio-temporal (Stathakis and Kanellopoulos, 2008) as well as spectral characteristics of RS dataset so as to derive accurate information of a given changes in landscape (Singh, 1989). Jensen (1986) explains that, the theory of change detection is that the spectral value of cells from datasets covering the same landscape but of different epochs will differ if the physical characteristics have change overtime. Change detection techniques are many, for example image algebraic technique which include principal component analysis, tasseled cap transformation, image regression etc. there is also the multi-date composite technique, change vector analysis, and post-classification (Morisette, 1997) change detection techniques. Some techniques are mainly to detect the presence or absence of change variation (Currit, 2005). The classification of LC for a growing agricultural and grazing area like Birnin Kudu in Nigeria is most essential to its planning, land resource management, and agricultural development control and monitoring. For effective and sustainable land cover analysis, we suggested that the use of vegetation index NDVI and NDWI should be encouraged, which is adopted in this study.

1.1 The study Area

Birnin Kudu local Government Area of Jigawa State is situated in the north-western part of Nigeria between latitudes $11^0 00' 00''$ N to $13^0 00' 00''$ N and longitudes $8^0 00' 00''$ E to $10^0 15' 00''$ E. The state is bounded by Niger Republic to the north, Yobe State to the north-east, Kano State to the south-west and Katsina State to the north-west. The topography of the study area consists mostly of woodland savannah in the south and spatial vegetation in the north. The main occupations of the people who are mostly Hausa and Fulani are farming of cattle, goat and sheep rearing. The populations of Birnin-Kudu as at 2006 are 313,373 respectively (NBS, 2008). The climate is semi-arid, characterised by a long dry season and a short wet season with mean annual temperature of about 25 ℃, relative humidity ranges from 80% in August to 23% in between January and March. The total annual rainfall ranges from 600-1000mm.

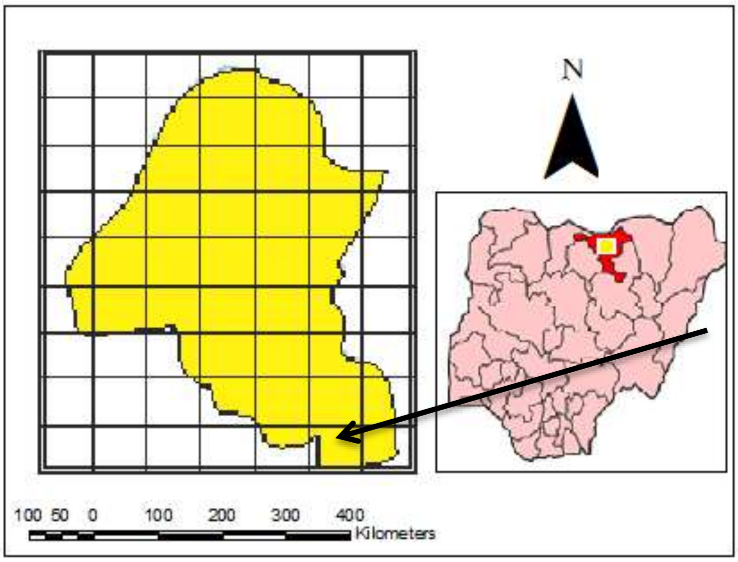

Figure 1. The map of the Study Area

1.2 Statement of Research Problem

It is obvious that, land cover management in the study area lack spatial content and control, therefore, there is the need to support with the available strategies through the introduction of innovative geospatial techniques such as NDVI and NDWI to enhance surveillance and response. The following research questions were advanced:

a) Can the change of land cover in a given area be fully understood or explained by the image classification algorithms and vegetation indices?
b) Can the level of propagation in land cover in a clustered settlement be adequately explained from remotely sensed data?
c) Is there any observed spatial-temporal change detection in the study areas?

1.3 Aim and Objectives

The aim of this research is to analysis detected change of land-cover in Birnin Kudu Area Council, Jigawa State using image classification algorithms and vegetation indices, Nigeria. To achieve the aims of this research, the following objectives will be executed:

a) Examine the performances of change detection in the study area
b) Analyses detected changes of land cover from 1972-2012
c) Develop a classification scheme for classifying land cover
d) Investigates the use of NDVI and NDWI for analyzing land cover change detection

2.0 Review of Remote Sensing Studies

Satellite remote sensing capability is to provide near or real-time consistent and promising data that covers large areas through orbiting satellites that have different wavelengths, look angles and resolution (Kwarteng, 1999). Also, the ability to obtain remote sensing data (Sabins, 1996) for vegetation land-cover studies plays major role in developing classification scheme (Lillesand et al., 2004). According to investigation carried out by Buiten and Clevers (1993), image classifications are the basis for many environmental and socioeconomic applications. Several attempts have been made in developing advanced classification methods towards improving accuracy in NDVI products (Pal and Mather, 2003; Stuckens et al., 2000; Aplin et al., 1999; Foody, 1996). But, due to some factors, for example, the nature of the landscape in the research area, selected RS data (Mitchell, 2005), and image-processing and classification approaches, classification of RS data into a thematic map remains a challenge (Lu and Weng, 2007). RS data vary in spatial, radiometric, spectral, and temporal resolutions (Salami and Balogun, 2006). In selecting RS data for classification, it is very vital to understand the characteristics of the data (Gilruth et al., 2002). There are studies that have reviewed the basic characteristic of RS data (Lefsky and Cohen, 2003: Althausen, 2002). When selecting RS data for classification, there is the need to put into consideration: According to Lu and Weng (2007), the users need to determine the nature of classification and the scale of the study area, thus affecting the selection of suitable spatial resolution of remotely sensed data. NDVI is a measure of the amount of green vegetation (Tucker, 1979). The index was derived from the red and near-infrared wavebands of Landsat1 MSS, Landsat 4 and 5 TM and Landsat7 ETM+ images using the following formula: NDVI = (near-infrared−red) / (near-infrared + red) (Tucker, 1979). To assess change in the water body, NDWI techniques was used to classify each image used separately, while the multi-date composite technique was used to assess and detect the presence or absence of change (Pal and Mather, 2003), atmospheric effects, solar illumination angle, sensor view angle and vegetation phenology between epochs since each image is classified separately (Chen, et al., 2005). The algebraic technique was combined with the later technique because of its simplicity in change detection especially with the use of Landsat images and several studies (Skakun et al., 2003,; Collins and Woodcock, 1996; Cohen and Spies, 1992) have employed and attested to its value. In order to obtain enough evidence of the level of change in a study area, NDVI and NDWI were calculated. These indexes were very vital to land cover studies (Lyon, et al., 1998) affirming that, NDVI technique for example, is least affected by topographic factors (Parodi and Prakash, 2004). In the work of Ngigi and Tateishi (2005), used mixed-unmix classifier to generate fraction images of two to eight spectral classes from Landsat-7 ETM+. They used unsupervised K-mean classification 3 on the original data of 28.5m resolution for ground truthing. The mix-unmix classifier was applied as dual classification method and compared with popular conventional hard and soft classifiers. Thanapura et al (2005) adopted unsupervised spectral classification approach in their study using 2.39m resolution Quick Bird Image. According to Tukur, et al. (2002) high resolution NDVI and NDWI can improve the efficiency and effectiveness of land cover extraction and a simple random sampling technique was adopted for the accuracy assessment.

3.0 Methods

The methods used are image pre-processing, geometric transformation and image classification.

3.1 Image pre-processing

To derive maximum benefits from satellite imagery, there is the need to reduce or eliminate errors embedded in the data due to sensor effects, atmospheric and illumination effects as well as misregistration. For the present research, both radiometric and geometric corrections were applied to the RS images used, including applied Landsat-7 ETM+ to obtain useful predictive parameters.

3.2 Geometric Transformation

The data was registered using control points that linked the Landsat imagery to some identified positions in the topographic/administrative maps. The reason for using the control points is to build a polynomial transformation that will change dataset to spatially correct location from its existing location**.** Because the study area is relatively plain and the continuous nature of the datasets used for the present research, first order or affine transformation and cubic convolution resampling method were adopted.

3.3 Image classification

The enhancement of 1972, 1986, 2003 and 2012 base data linked to Landsat 7 ETM+ image using ArcMap-10.1 for colour composite. This is to improve visualization as well as combining all the bands of the image into a single raster dataset but still have all the bands embedded. This is to ensure that the satellite image bands that will be used for colour composite have low correlation so as to reduce problem due to linearity. Each classification image map was used as input file name for the computation of the area using the GIS Analysis Module.

4.0 Results

4.1 Change Detection using Normalized Differences Vegetation Index (NDVI)

Figures 2, 3, 4 and 5 shows that Normalized Difference Vegetation Index (NDVI) can be classified into two based on their pixel values. The pixels in green with high and low values were classified as “high NDVI positive and low NDVI positive” and pixels in red with high and low value were classified as “high NDVI negative and low NDVI negative”, to establish the difference in land cover change detection (Lyon, et al., 1998) in the study area of 1972, 1986, 2003 and 2012 periods respectively. The Figure 2 indicates high NDVI positive value of 58.0% and low NDVI negative value of 42.0% in 1972 period. While, Figure 3 also shows low NDVI positive value of 43.0% and high NDVI negative value 0f 57.0% in 1986 period (Shalaby and Tateishi, 2007).

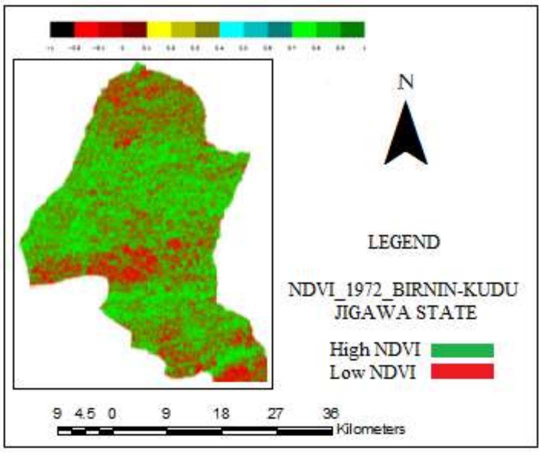

Figure 2.NDVI for the 1972 period

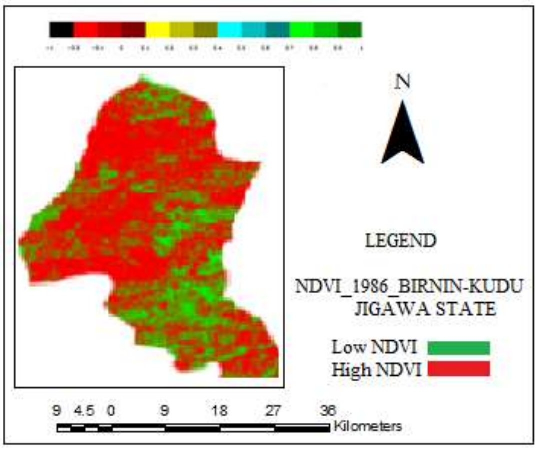

Figure 3.NDVI for the 1986 period

Figures 4 and 5shows spectral differences of land cover between 1972/1986 periods and 2003/2012 periods respectively, and further illustrates the spectral similarity of 2003 NDVI and 2012 NDVI. The Figure 4 indicates low NDVI positive value of 3.0% and high NDVI negative value of 97.0% as of 2003 period. While, Figure 5 also shows low NDVI positive value of 14.6.0% and high NDVI negative value 0f 85.4% in 2012 period (Lu and Weng, 2007).

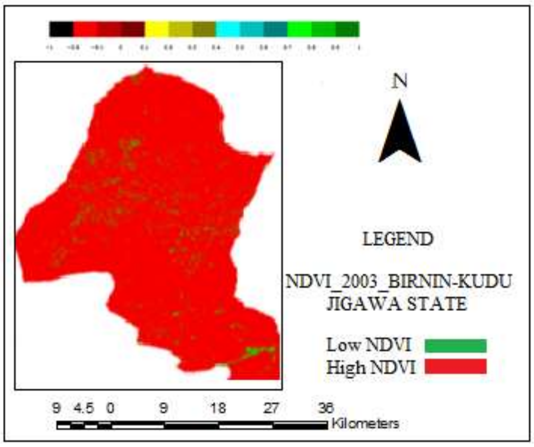

Figure 4. NDVI for the 2003 period

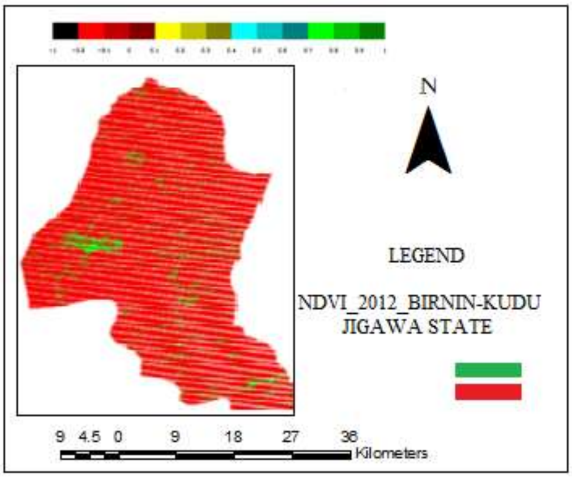

Figure 5. NDVI for the 2012 period

4.2 Change Detection using Normalized Differences Water Index (NDWI)

Figures 6, 7 and 8 shows a clear similarity of 1986 NDWI and 2003 NDWI, and further enumerates differences observed in 1986/2003 NDWI and 2012 NDWI respectively. The Figure 6 illustrates that in 1986, low NDWI positive value of 0.13% and high NDWI negative value of 99.87% are observed. While, Figure 7 also shows low NDWI positive value of 0.1% and high NDWI negative value 0f 99.9% in 2003 period (Price, et al., 2002).

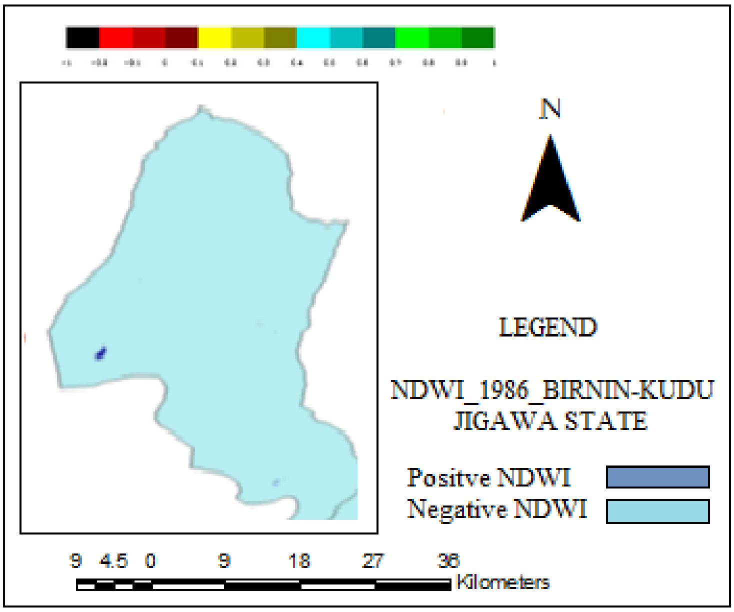

Figure 6. NDWI for the 1986 period

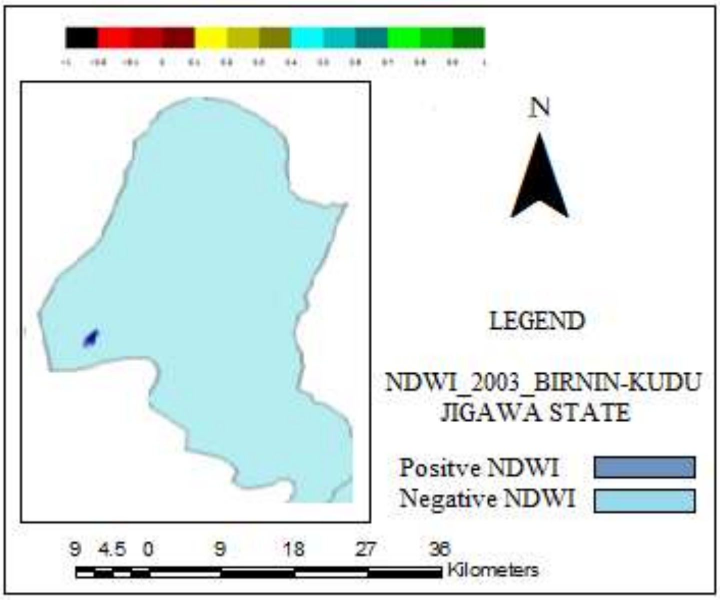

Figure 7. NDWI for the 2003 period

Figure 8 show a clear differences from that of 1986 NDWI and 2003 NDWI period, and indicates more robust in the NDWI value. The Figure 8 illustrates that the period 2012, records low NDWI positive value of 1.6% and high NDWI negative value of 98.4%.

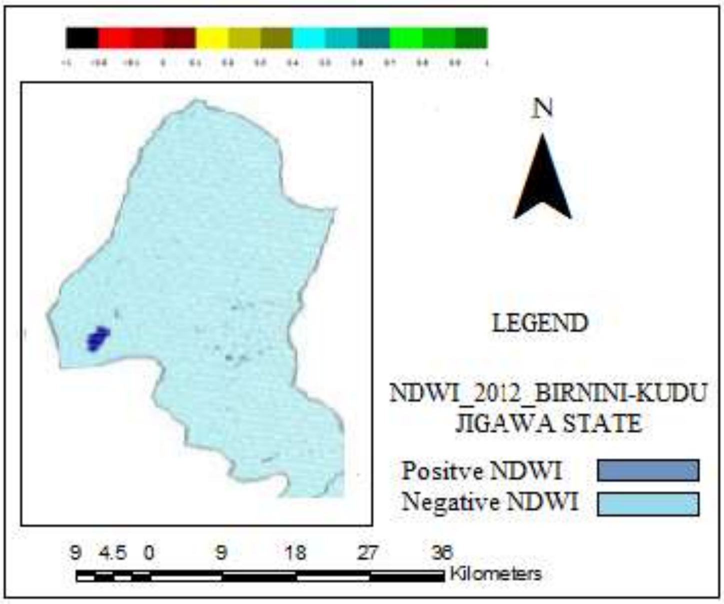

Figure 8. NDWI for the 2012 period

4.3 Discussion and Analysis of Results

A close examination on the final analysis shows the classified Figures 2 -8 in relation to the verification of the LC, put NDVI and NDWI as the most approximate method for discriminating land cover, hence used as the reference in this discussion. For the NDVI-positive, there are spectral disagreement of -15.0% between 1972 and 1986, -40.0% between1986 and 2003, 11.6% between 2003 and 2012, it implies that the spectral disagreement of 1972 and 1986 NDVI-positive is negligible. While, in the case of NDVI-negative, spectral disagreement of 15.0% between 1972 and 1986, 40.0% between 1986 and 2003, and -11.6% between 2003 and 2012 were recorded, meaning disagreement of 1972 and 1986 NDVI-negative indicates minimal, 1986 and 2003 NDVI-negative show appreciable value. However, spectral disagreement also exists in NDWI-positive that shows -0.2% between 1986 and 2003, 1.5% between 2003 and 2012 respectively, it implies that disagreement of 1986 and 2003 NDWI-positive is negligible, perhaps shows minimal disagreement in 2003 and 2012 NDWI-positive.

Whereby, NDWI-negative also shows a spectral disagreement of 0.03% between 1986 and 2003 NDWI-negative, -1.5% between 2003 and 2012 NDWI-negative respectively, meaning disagreement of 1986 and 2003, 2003 and 2012 NDWI-negative are negligible. Furthermore, a spectral classification agreement of 11.6% is recorded for 2003 and 2012 NDVI-negative. While the mean average of 0.88% (approximately 1) between 1986 and 2003 NDWI-positive and 2003 and 2012 NDWI-negative respectively that illustrates the presence of the same previously observed water body of the study area. Table 1 there is decrease in NDVI change detected in 1972 and 1986 of -15% NDVI-positive and 15% NDVI-negative respectively within the study period, for the period between year 1986 and 2003 (Table 2) which reveals a decrease of -40.0% NDVI-positive and 40.0% NDVI-negative. Accepts for the period between 2003 and 2012 (Table 3) that reveals an increase of 11.6% NDVI-positive. This may be as a result of afforestation program on-going in the area. The overall result shows that between 1972 and 2012 the rate of NDVI change is 43.4% (Table 4). The NDVI decrease indicates increase in bare surface.

Table 1. Percentage of NDVI change detection between 1972 and 1986

	NDVI 1972		NDVI 1986		Change Detected	
NDVI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDVI Positive	1350.3	58	993.1	43	-357.2	-15
NDVI Negative	970.3	42	1327.5	57	357.2	15
Total	2320.6	100	2320.6	100		

Table 2. Percentage of NDVI change detection between 1986 and 2003

	NDVI 1986		NDVI 2003		Change Detected	
NDVI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDVI Positive	993.1	43	62.3	3	-930.8	-40
NDVI Negative	1327.5	57	2258.3	97	930.8	40
Total	2320.6	100	2320.6	100		

Table 3. Percentage of NDVI change detection between2003 and 2012

	NDVI 2003		NDVI 2012		Change Detected	
NDVI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDVI Positive	62.3	3	262.7	14.6	200.4	11.6
NDVI Negative	2258.3	97	1539.7	85.4	-718.6	-11.6
Total	2320.6	100	1802.4	100		

Table 4. Percentage of NDVI change detection between 1972 and 2012

	NDVI 1972		NDVI 2012		Change Detected	
NDVI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDVI Positive	1350.3	58	262.7	14.6	-1087.6	-43.4
NDVI Negative	970.3	42	1539.7	85.4	569.4	43.4
Total	2320.6	100	1802.4	100		

Tables 5, 6 and 7shows that the margins of NDWI change for the period of study are almost the same. It illustrates that 1986 and 2003 the rate of change in the study area is -0.03% NDWI-positive and 0.03% NDWI-negative. While in 2003 and 2012 the rates of change were 1.5% NDWI-positive and -1.5 NDWI-negatives. Then, between 1986 and 2012 the total change recorded are 1.47 NDWI-positive and -1.47% NDWI-negative. This rate of change may be as a result of a similar factor.

Table 5. Percentage of NDWI change detection between 1986 and 2003

	NDWI 1986		NDWI 2003		Change Detected	
NDWI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDWI Positive	2.9	0.13	1.84	0.1	-1.06	-0.03
NDWI Negative	2317.7	99.87	2318.72	99.9	1.02	0.03
Total	2320.6	100	2320.6	100		

Table 6. Percentage of NDWI change detection between 2003 and 2012

	NDWI 2003		NDWI 2012		Change Detected	
NDWI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDWI Positive	1.84	0.1	30.3	1.6	28.46	1.5
NDWI Negative	2318.72	99.9	1812.7	98.4	-2220.32	-1.5
Total	2320.6	100	1843	100		

Table 7Percentage of NDWI change detection between 1986 and 2012

	NDWI 1986		NDWI 2012		Change Detected	
NDWI_ Category	Area (Km2)	Area (%)	Area (Km2)	Area (%)	Change (Km2)	Change (%)
NDWI Positive	2.9	0.13	30.3	1.6	27.1	1.47
NDWI Negative	2317.7	99.87	1812.7	98.4	-505	-1.47
Total	2320.6	100	1843	100		

Conclusions

Based on the geospatial techniques used in the research and the results of its applications, it can be concluded that NDVI and NDWI classification scheme is a suitable tool to support decision makers in managing land-use and land-cover efficiently. The research work derived datasets that will be used to assessing changes in land cover in the environment. The approach of using Remote Sensing and GIS techniques to derive the datasets is important most especially for the study area as all the existing data are dilapidated and many missing. The scientific and field assessment of Birnin Kudu Local Government Area using NDVI and NDWI reveals changes in the study area overtime. The NDVI results reveal that there are variations in land cover from 1972-2012, while the NDWI reveals that there are persistent variations in water bodies from 1986-2012. The rate of change in the NDVI is high as compare to changes detected in NDWI that shows very low variation. Using RS and GIS techniques to analyses the classification of land cover has proved to be effective and efficient. Conclusively, this study has demonstrated the efficiency of geospatial techniques in generating useful datasets and in monitoring change in a given environment.

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