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Monitoring Vegetation Change using NDVI Analysis and Image Differencing from Lands at imagery in North-Eastern Nigeria, 1975 – 2016

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Abstract

This study demonstrates the use of Normalized Difference Vegetation Index (NDVI) and image differencing to detect vegetation change for 41 yearsby applying Landsat imagery in North-Eastern Nigeria. NDVI images were produced from Landsat classified vegetation maps which were also produced through supervised classification techniques and maximum likelihood algorithm, and image differencing were produced from NDVI images, thereafter, change areas in hectares and percentage of vegetation change were all recorded. The study reveals that from 1975 to 1987 decreased is 6.41%, some decreased 48.11%, unchanged 0.11%, some increased 42.61% and increased is 2.76% respectively. And between 2003 and 2016decreasedis 1.09%, some decrease 1.43%, unchanged 0.00%, some increase 6.10% and increased is 91.38%.Based on these results, there were no much places on the natural environment which were not altered byhuman activities.However, the rate of vegetation is currently increasing in the region, as evident from the NDVI image of 2016.

Keywords: *NDVI image, Landsat, vegetation change, image differencing*

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I. Introduction

Normalized Difference Vegetation Index (NDVI) is one of the suitable techniques of monitoring vegetation change. The indices of vegetation are the product of multispectral data, which are determined by the differences in reflectance, transmittance and absorption of energy by the green plant in the near infrared and the red bands. These measure the green plant vigour and also exposed the patterns of vegetation distribution as well as the physiological conditions of the plant (Fung & Siu, 2000). NDVI is the mathematical combination of individual bands specifically (RED) visible light Band 3 and near infrared (NIR) Band 4, it is derived from Advanced Very High-Resolution Radiometer (AVHRR) imageries. Permitting 1 km^2 spatial scale land characterization moderately high spectral resolution, and it is used to indicate the presence and condition of vegetation, the pixel value ranges from -1.0 to +1.0. The positive values of NDVI indicate green plant surface, the reflectance of the red part of the spectrum reduces when solar radiation is absorbed mostly by chlorophyll, furthermore, the reflectance of NIR portion is produced by green leaf mesophyll structure (Weiss *et al.*, 2004). Spectral decomposition and NDVI techniques were essential tools for estimating the abundance of vegetation cover (Elmore *et al.*, 2000).

NDVI is applied in remote sensing to measure vegetation vigour, biomass and collect information through multispectral image, it eventually differentiates green plant among other surfaces due to presence of chlorophyll, and absorbs red light and reflects to the near-infrared (Al-doski, 2013). The heterogeneity in surface confused NDVI interpretation, the low reflectance resulting from scanty vegetation particularly in the semi-arid environment can increase uncertainties in the analysis of NDVI image, green plant canopy in semi-arid and arid areas do not reach full coverage. Making NDVI useful to the temporal influence of soil moisture and soil in gaps between green plants(William, 2006).The method of image differencing is among the extensively used in detecting change. Is, however, applied to a large geographical study area. This approach allows images of the same place captured at a different time to be subtracted pixel by pixel; it is *based* on the grey scale used to show the degree of change between two images (Xu *et al.,* 2009).

The concerns in vegetation cover change and that on land use management in both rural and urban land cover dominate the agenda of sustainable development programmes. However, this scenario is more pronounced in developing countries around the world. Therefore, spatial and temporal changes of river basin ecosystems have led to the intricate interactions of land cover change drivers, these are among the key issues of concern in this contemporary world (Ozah *et al.,* 2012).The drivers of vegetation cover change and pattern of change in the northern part of Nigeria might be ascribed to severe human activities, such as overgrazing, bush burning, farming, construction of roads and wood cutting (Mayomi, 2009). The natural ecosystems had experienced a notable modification particularly in the developing tropical countries, and these changes are a consequence of prolonged activities of human that have led to degradation of natural land resources, it, however, poses a severe problem for the environment (Santos *et al.,* 2008). Lake Basins in northern Nigeria experienced intensive drought situations in the 1970s and 1980s as a consequence of extensive and severe activities of human on the natural environment which have resulted to the reduction in water levels mostly in the lakes and rivers which are surrounding the north-eastern region. Drought condition and exploitation of water has led to a substantial change in land use/land cover and management of water resources in the past five decades (Babamaaji& Lee, 2013).

II. Study area

Lake Alau, the area under investigation, is located at latitude 11^0 4′ N & 12^0 5′ N and longitude 13^0 5′ E & 13^0 20′ E. in Konduga Local Government Area (LGA) of Borno State north-eastern geopolitical region of Nigeria. The reservoir has an area of about 50 km^2 and has a storage capacity of 112 million cubic metres. However, the construction work of the dam was completed in 1988. River *Gombole* and river *Yedzaram* are among the prominent rivers that drained into Lake Alau, both of which take their sources from the mountainous regions such as *Mandara* Mountain and *Hudu* hills from the eastern part of the country (Babagana*et al.,* 2015).

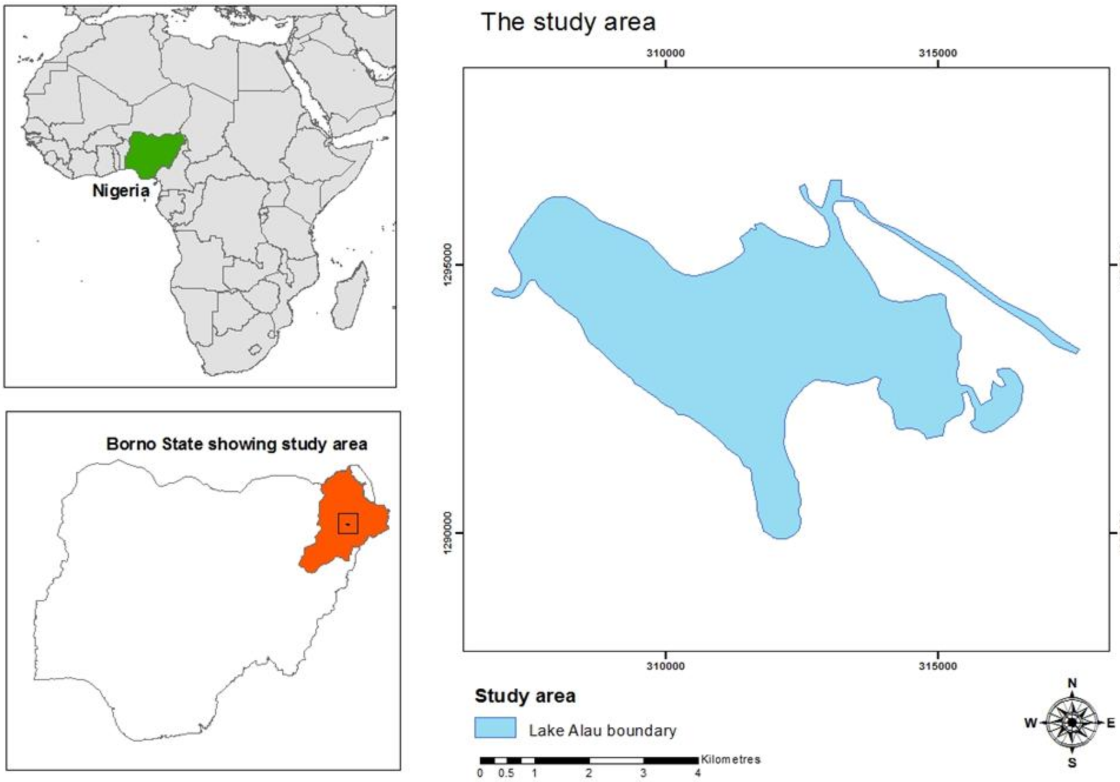

Figure 1: *Map of the study area, illustrating the region and Lake Boundary*

Lake Alau is within the vast open plain, developed on the young sedimentary rock of Chad formation. It flat terrain is relatively sloping towards the Lake Chad with average relief ranging from 300m to 600m. The most prominent river catchments include Bama Beach Ridge (BBR), river *Ngadda*, its tributary and *Ngaddabul* drains Maiduguri and environs (Daura *et al.,* 2012).

The area under investigation fall into the Sudan savannah climatic region, and it is characterised by four distinctive seasons, these include cold dry from December to February, hot dry from March to May, raining season comes between June to September and transitional period humid dry between September to November. However, temperature ranges from 15^0 C to 48^0 C annually. The most noticeable vegetation found in the area is drought resistant trees (xerophytes), such as Baobab tree (*Adansonia digitata),* Neem tree (*Azadirachta indica*) and Desert date (*Balanite Egyptica)* (Daura, 2001). The occupation of people in the study area is predominantly small scale farming. The major food crops cultivated includes millet, wheat, rice cowpea, sorghum, maize, sweet potatoes and cassava. Vegetables harvested include onion, tomatoes, pepper, okra and spinach. Trading and fishing are among the lucrative sources of livelihood (Shettima, 2000).

III. Materials and Methods

This study uses Landsat satellite imageries that were available from an open source, United State Geological Survey (USGS) through Earth Explorer in Landsat archive. Four different satellite images were downloaded and used for detecting a change in land cover in the study area. The Landsat images are covering the period from 1975 to 2016 which is 41 years.These Landsat sensors include Landsat 2 Multispectral Scanner (MSS) image for 1975. Thereafter, the MSS imagepixel size was resampled to 30 metres in order to enable direct comparison with the otherthree dates 30 metres resolution.Landsat 5 Thematic Mapper (TM) image for 1987, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) image for 2003 and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) image for 2016.

These images were those that are captured from a particular period that is month of March to avoid seasonality effects mainly raining season.These selected images were checked visually to make sure they are free from atmospheric interference for example cloud cover (Table 1).

Table 1: Data set attributes of the satellite imagery used for the classification of land cove

Sensor Identifier	Path	Row	Spatial Resolution (m)	Num. of Bands	Date Acquired	Source
L2 MSS	199	52	60	3,2,1	07/03/1975	earthexplorer.usgs.gov
L5 TM	185	51	30	4,3,2	20/03/1987	earthexplorer.usgs.gov
L7 ETM+	185	52	30	4,3,2	24/03/2003	earthexplorer.usgs.gov
L8 OLI	185	52	30	5,4,3	03/03/2016	earthexplorer.usgs.gov

3.1 NDVI and Image Differencing Calculation

The dataset used in this study were Landsat multispectral raster imageries. ERDAS Imagine 2015was employed to process them by using supervised classification tool and a parametric rule of maximum likelihood classifier algorithms to produce the thematic map of the different land cover types of the study area.The mathematical combination of Visible light (VIS) bands and the Near-infrared (NIR) band is used to detect the presence and condition of green vegetation, known as the NDVI (Weiss *et al.,* 2004). It is then calculated from images by using the following formula (Garrigues *et al.,*2007)

$$NDVI = \frac{NIR - red}{NIR + red}$$

To detect vegetation change, NDVI, image differencing technique was performed. This process allows for computing and comparing NDVI image of two different dates to assess the changes that had occurred. All pixel values were enhanced through histogram equalization to modify and also give equal chance range from 0-255 for two images. This procedure was followed to produce NDVI and differencing images(Cakir*et al.*, 2006). Thus, NDVI 1975 image was subtracted from the NDVI 1987 image and NDVI 2003 was subtracted from NDVI 2016.

To assess the changed areas from the differencing image, the technique uses a threshold centred on image differencing histogram. Therefore, the significant changes were distributed on the individual pixels. Where pixels showing increased were classified and given green colour, decreasedwere also clustered with red, unchanged is black colour. Finally, maps were created between 1975 and 2016 (Bruce & Hilbert, 2004).

3.2 Change detection

Change detection is the technique applied to figure out the changes that have taken place over time. The calculation not only identifies changes that had occurred but also includes all the pixels that have changed. This process was adopted in this study to give a comprehensive tabulation of the changes detected between two images. The statistics of the analysis primarily focuses on the pixel sums, where the area of each class was obtained, and the percentage is calculated by the total amount of changes and then multiplied by one hundred.

IV. Results

The pattern of vegetation change for the period of study is demonstrated in Figure 2, NDVI image for 1975. show the condition of vegetation cover in that period, there was a relatively slight increase in vegetation cover despite the prolonged drought condition experienced in the last decade.(Figure 3) illustrated vegetation cover condition in 1987, there was little vegetation cover experienced in that year. (Figure 4) Displayed the condition of vegetation cover in 2003. However, there was very little vegetation cover within the time limit that is vegetation had loss in great number. (Figure 5) Show vegetation cover condition in 2016. There was very high vegetation cover during this period compared to the other epochs, and that means there was continues gained in vegetation cover.

The change detection analysisinformation is illustrated in (Table 2), the areas of the changes are obtained in hectares (Ha) per square kilometres and also the percentage of change are calculated.Therefore, the results reveal that between 1975 and 1987 6.41% decreased, 48.11% some decrease, 0.11% unchanged, 42.61% some increase, 2.76%increased and total area was 76877.8 (Ha). The results of change detection from 2003 to 2016 reveals that there was 1.09% decreased, 1.43% some decrease, 0.00% unchanged, 6.10% some increase and 91.38% increased. Hence, the total land area was 76836.76 (Ha).

Table 2: Change Detectionanalysis of vegetation cover including Area and Percentage on (NDVI image differencing) from 1975 – 1987 and 2003 – 2016.

	1975 – 1987	
Class Name	**Area (Ha)**	**Percentage (%)**
Decreased	4931.1	6.41
Some Decrease	36985.7	48.11
Unchanged	82.62	0.11
Some increase	32750.6	42.61
Increased	2127.78	2.76
Total	76877.8	100 %
	2003 – 2016	
Decreased	833.36	1.09
Some Decrease	1102.93	1.43
Unchanged	0.02	0.00
Some increase	4684.45	6.10
Increased	70216	91.38
Total	76836.76	100 %

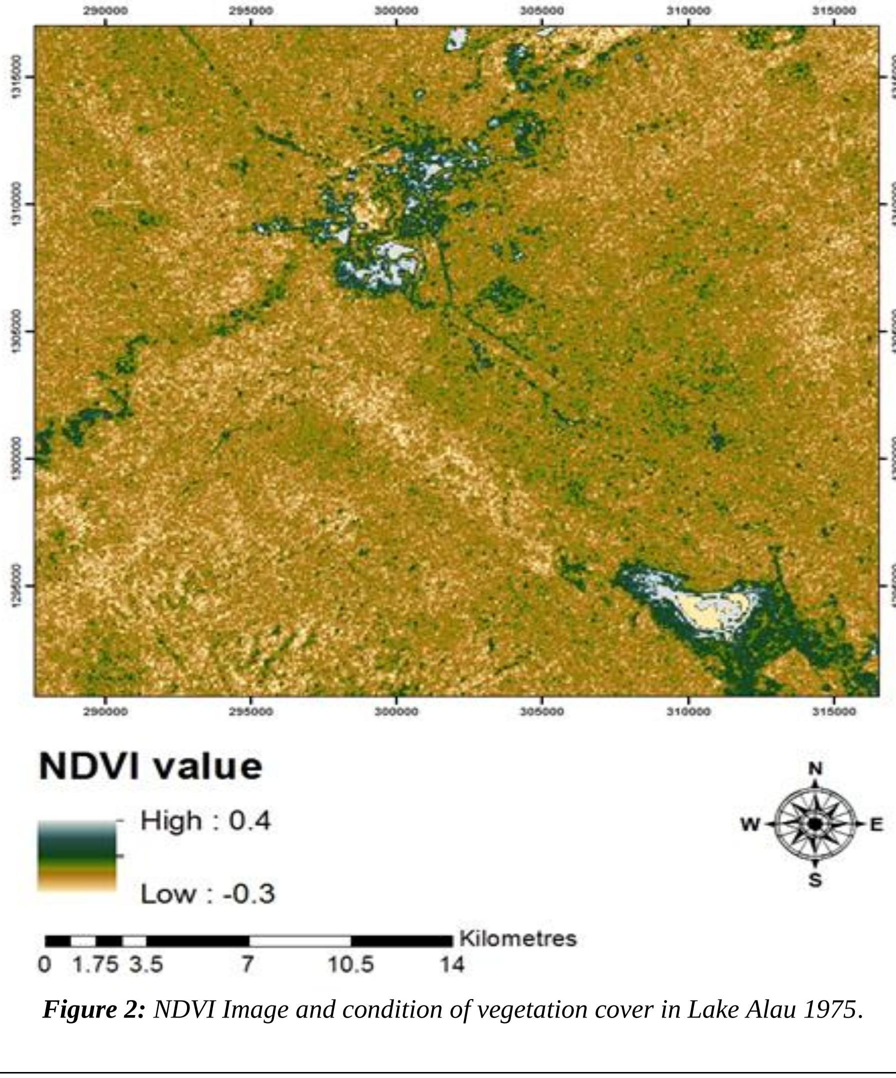

Figure 2: *NDVI Image and condition of vegetation cover in Lake Alau 1975.*

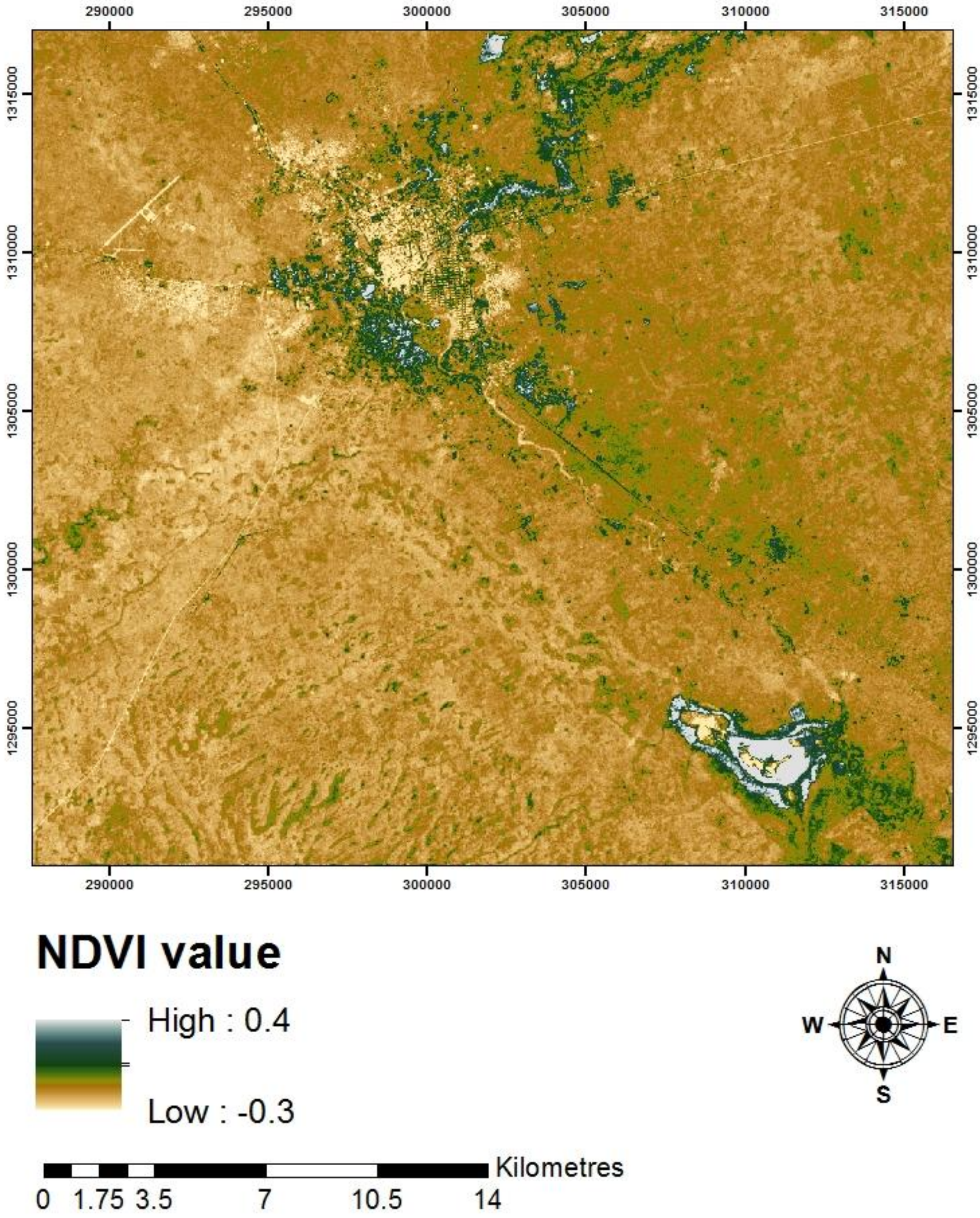

Figure 3: *NDVI Image and condition of vegetation cover in Lake Alau 1987.*

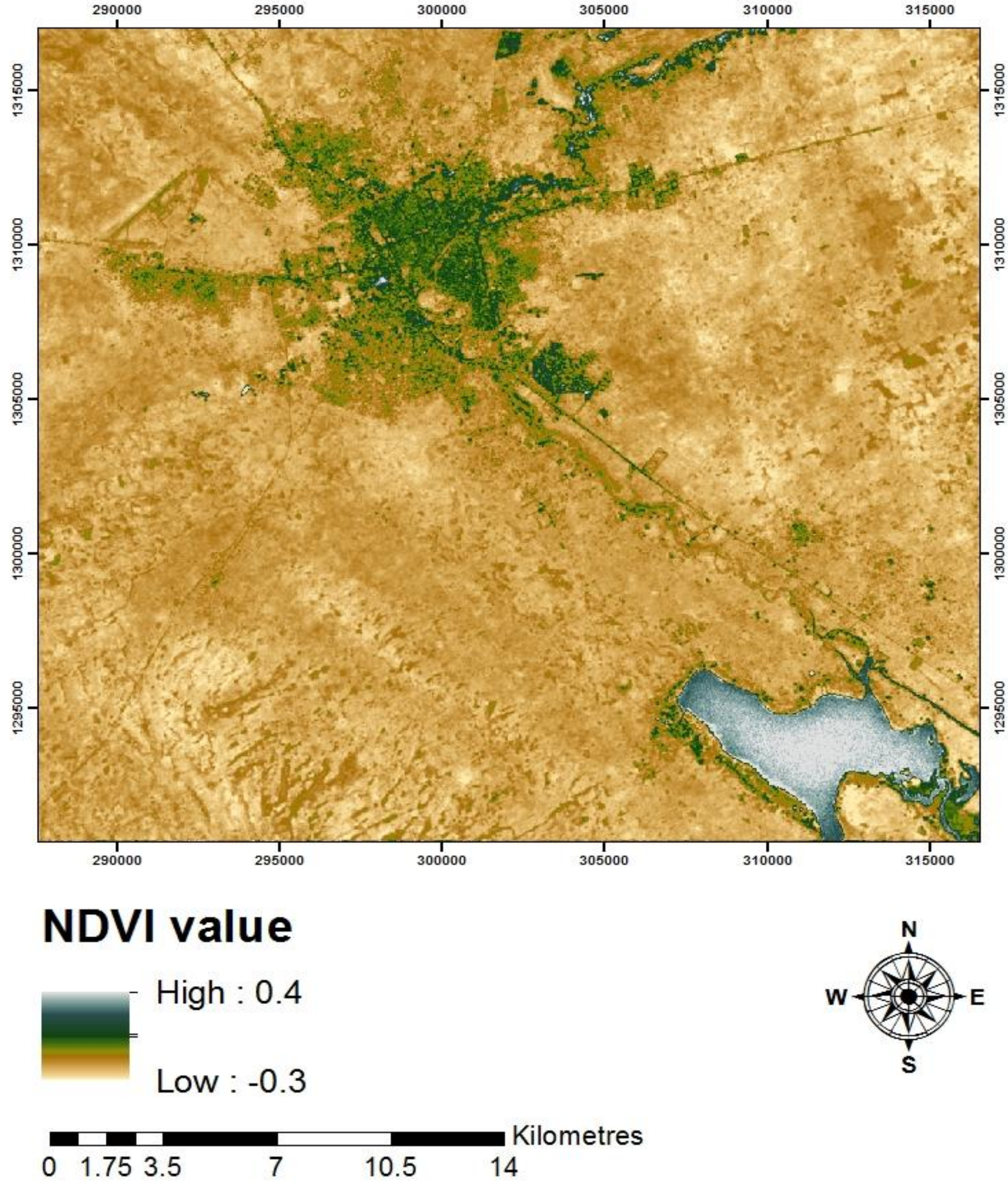

Figure 4: *NDVI Image and condition of vegetation cover in Lake Alau 2003.*

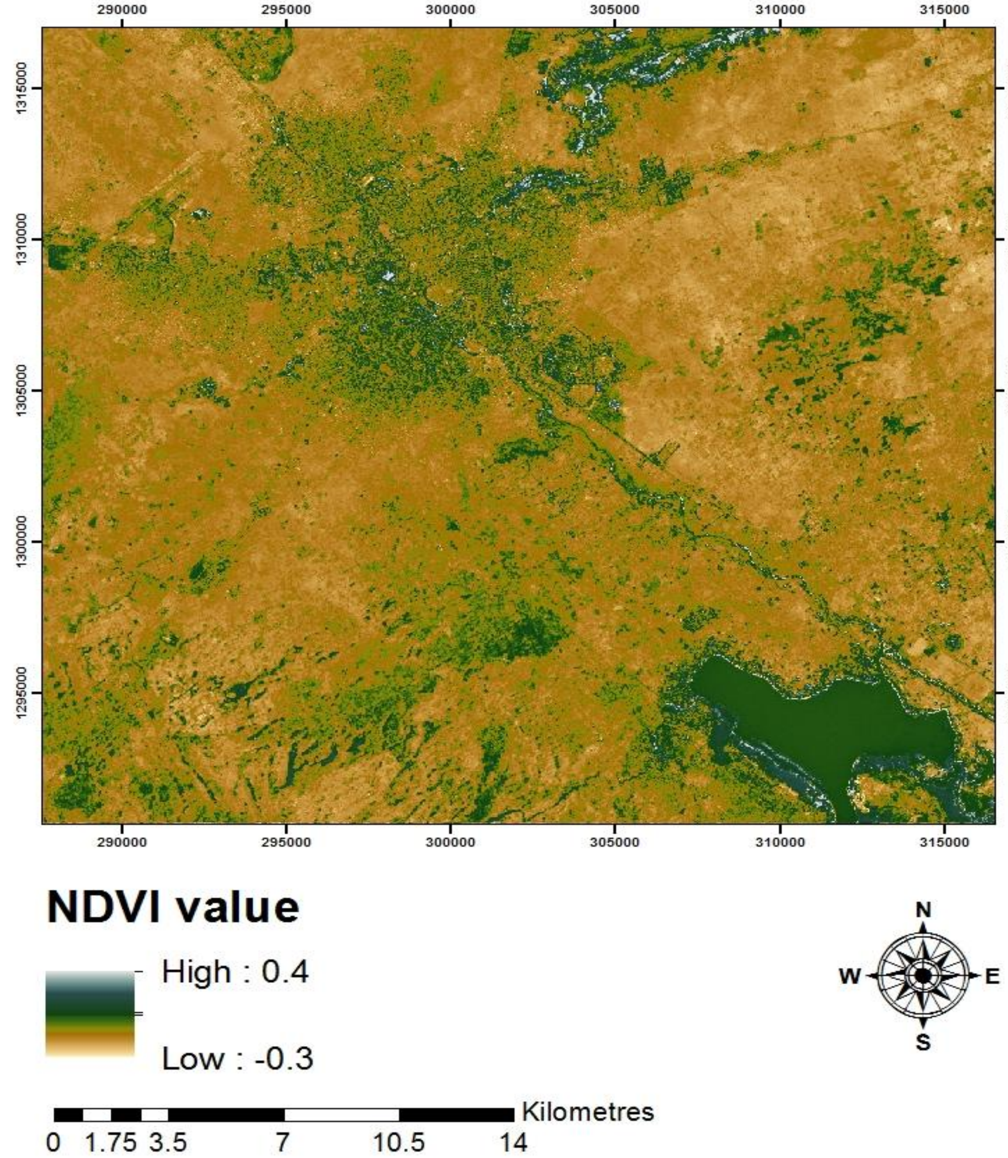

Figure 5: *NDVI Image and condition of vegetation cover in Lake Alau 2016.*

V. Discussion

5.1 Change Detection analysis of vegetation cover including Area and Percentage on NDVI image and image differencing from 1975 – 1987 and 2003 – 2016.

The changes detected from NDVI image and image differencing between 1975 and 1987 (Table 2) have shown that, the class decreased has an area of 4931.1Ha,at the same time is 6.41% that means there were decreased in vegetation cover within the period. The second is some decrease whichis 36985.7 Ha (48.11%)it has the highest percentage of change within the period, that shows that there were changes in almost all the land cover types found within the study region. Unchanged 82.62 Ha (0.11%)this indicates that there were only few areas which were not altered by human activities less than one percentage. Some increase is 32750.6 Ha (42.61%), there are changes all over the places due to severe human actions that led the increased to be 2127.78 Ha (2.76%)this observation was also noted by (Mayomi, 2009).

The vegetation change detected between 2003 and 2016 from the NDVI image differencing (Table 2) revealed that decreased is 833.36 Ha (1.09%) and some decrease is 1102.93 Ha (1.43%)that shows significant loss in vegetation cover as a result of the modifications which can be linked to climate driven as noted by (Lambin, 2003). From the image differencing the unchanged has 0.02 Ha (0.00%) that revealed how severe the level of alterations on the natural environment is, there was no place which is not altered probably due to agriculture activities and urban expansion this scenario is also noticed by (Olokeogun*et al.,* 2014). Some increase is 4684.45 Ha (6.10%) and increased is 76836.76Ha (91.38%) this possesses the largest land mass and highest percentage of change (Figure 4) have shown that, however, this is attributed to deforestation for the purpose of fuelwood and climate invariability that lead to great loss of vegetation cover in the region(Odihi, 2003).

5.2 NDVI and trend of change in vegetation cover (1975-2016)

Despite the severe drought condition experienced in the 1970s, there was relatively stable vegetation cover in 1975 within the study region. (Figure 2) The result revealed this scenario. Additionally, this phenomenon may be associated with the low population density that consequently led to less anthropogenic such as farming, deforestation, overgrazing, urbanization and much more on the natural ecosystem this investigation is also corroborated by previous studies as noted by (Ikusemoran, 2010). The trend of vegetation cover started declining in 1987 (Figure 3) revealed the situation. Naibbi*et al.,*(2014) reported a similar scenario and ascribed the changes to cutting of trees for the purpose of fuelwood (deforestation) and change in rainfall pattern as these are among the primary drivers of vegetation change in the study area. Government policies have contributed in controlling loss of vegetation cover for example in 1987 Borno State government during the military regime has promulgated decree to promote afforestation and stop felling of trees (Edict No. 7 of 1986) as noted by (Borno State Nigeria Gazette, 1987). However, the study period as stated earlier was selected purely to be in the month of March that was to avoid seasonality particularly raining season, this decision has indeed helped in revealing and understanding the actual trend of vegetation cover in the region which is not possible in raining period all over the places would be green.

Due to the change in government and policies in 2003, there was very little vegetation cover in the region compared to the previous years (Figure 4) has conspicuously shown the result, this might be associated to, or caused by deforestation (Santos *et al.,* 2008). Deforestation for the purpose of fuelwood in north-eastern Nigeria has led to the loss of vegetation cover due to lack of substantive and efficient substitute of cooking energy (electricity, cooking gas and kerosene) for the average citizen. Therefore, fuelwood business happened to be highly lucrative (Odihi, 2003).

The 2016 NDVI result revealed that there was an increase in vegetation cover in the study area (Figure 5) have shown that. Perhaps this vegetation growth could be linked to increasing and availability of rainfall that recharged ground water and increased soil moisture content in the entire Sahelian region of Africa as confirm by many similar studies in the region. (Huber *et al.,* 2011) noted that rainfall availability induced significant increase in trends of vegetation cover and this consequently increased soil moisture content which also contributed to greenness. It is, however, suspected that the driver of positive vegetation change was the availability of water, this assertion was claimed by (Anyamba& Tucker, 2005), the greening pattern in Sahelian climate tally with the rainfall trend. The recent increase in greenness observed over the African Sahel region has been interpreted as a reclamation from the severe long-term drought that was experienced in the 1970s as confirmed by previous findings, (Herrmann *et al.,* 2005) claimed that widespread positive trend of vegetation cover was observed.

Bégué*et al.,* (2011*)* reported the recent continuous greening in the Sahelian vegetation cover was influenced by the annual rainfall season over the years. The Sahel region of Africa has experienced an increase in rainfall over the last decade. Therefore, this has stimulated the increasing vegetation cover trend (Olsson *et al.,* 2005). Hence, this study revealed that there was increase in vegetation cover as a result of increasing rainfall pattern in the study area. However, NDVI analysis has often been used in many studies to assess the trend of vegetation cover as well as crop yield; this claim was noted by (Fung & Siu, 2000; Al-doski, 2013).

VI. Conclusion

This study adopted the use of remote sensing data (Landsat imagery) integrated with GIS tools to monitor vegetation cover change in Lake Alau (1975-2016) by using supervised classification technique through maximum likelihood algorithm.NDVI image and image differencing techniqueswere the major instruments used in the detection of vegetation changeover time in the study area. Area of change and percentage of change of the different classes were all taken from the image differencing.The study revealed that some significant changes occurred during the study period. The class decreased was 4931.1 Ha (6.41%) between 1975 and 1987 but dropped 833.36 Ha (1.09%) between 2003 and 2016. The class increased was 2127.78 Ha (2.76%) between 1975 and 1987 but it rises to 70216 Ha (91.38%) between 2003 and 2016. This is indicative of the significant changes that had occurred during the years. However, there are some signs of vegetation increase currently taking place as a result of abundance of rainfall and soil moisture as shown in (figure 5) the NDVI image of 2016.

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