Vegetation Dynamics in A Semi-Arid Area of Yobe State, Nigeria

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Abstract

The study assesses vegetation dynamics in a semi-arid area of Yobe State in Nigeria between 1972 and 2005. Vegetation index differencing method of change detection was used in identifying changes in vegetation cover of the study area. In this study, creation of NDVI and image differencing were carry-out using IDRISI Taiga version 16.05. The areas of change in the difference images were identified by statistical techniques of 'thresholding' using a range of 'Mean ± 3SD'. The results show that vegetation cover in the area has reduced between 1972 and 2005 from 18403.39 to 10046.80 hectares respectively. The study clearly demonstrates that human activities are main culprit responsible for vegetation degradation in the area. Hence, for any vegetation restoration project to succeed in the area and indeed in any arid environment, the communities residing in the vicinity of the project should be incorporated into the project from start to finish.

Keywords: NDVI, Image Differencing, Change Detection, Thresholding, Remote sensing, Vegetation Dynamics.

Introduction

Globally, environmental degradation is contemporarily a major issue. This is due to several centuries of poor management of the earth's resources, and the growing pressure associated with rapid population growth. The natural dimension of degradation in arid environment is mostly due to the occurrence of drought which greatly contributes to destruction of plants and animal resources. Degradation is most felt in the fragile environment of arid regions of the world (UNEP, 2008; FME, 2008) because of the limited moisture and low resilience of the ecosystem to disturbance. In the absence of vegetation, rain water is mainly disposed as runoff, infiltration is minimal. This further constrains the growth and productivity of plants. Even long-lived plants; trees, shrubs and other perennials that would normally survive years of droughts eventually find survival an insurmountable challenge. A reduction in plant cover also results in lowering the quantity of humus in the soil, and plant productivity drops further (Adesina, 2008). Analysis of vegetation and detection of changes in vegetation pattern are keys to natural resources assessment, monitoring and management. This study therefore assesses vegetation dynamics in an arid environment of Yobe State using vegetation index differencing techniques of change detection between 1972 and 2005.

According to Lu, et al., (2004), timely and accurate change detection of Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989). Timely and accurate change detection of Earth's surface features provides the foundation for better understanding of the relationships and interactions between human and natural phenomena so as to better manage and effectively use resources. In general, change detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the phenomenon. The advantages of repetitive data acquisition, its synoptic view, and digital format makes remotely sensed data suitable for computer processing. Remotely sensed data such as Landsat imageries have become a major data source for different change detection applications during the past decades (LU, et al., 2004).

Change detection of vegetal cover has been studied in different locations of the world to assess the extent and rate of vegetation change (Washington-Allen, 1997; Mas, 1999; Elmore, et al. 2000; Pu, et al. 2008). Washington-Allen et al. (1997) used image differentiation change detection techniques to study the ecological effects of drought on vegetation resources of subsistence agropastoral communities on the Bolivian Altiplano. They also observed the trend in vegetation cover from 1972-1987 using satellite-derived Transformed Normalized Difference Vegetation Index (TNDVI) as a surrogate for vegetation cover, or standing crop. In another study Elmore et al., (2000) used spectral mixture analysis and the Normalized Difference Vegetation Index (NDVI) to determine vegetation abundance from a semi-arid area. In this study, vegetation index differencing technique of change detection was applied on Normalized Difference Vegetation Index (NDVI) to map and assess the pattern of vegetation dynamics in the study area between 1972 and 2005.

Remote sensing is a ready tool for vegetation studies. This is because green vegetation has a distinct interaction with energy in the visible and near infrared regions of the electromagnetic spectrum. In the visible region, plant pigments (chlorophyll) cause strong absorption of energy, primarily for the purpose of photosynthesis. The absorption peaks at the red and blue area of the visible spectrum, thus, leading to the characteristic green appearance of most leaves. In the near infrared, however, a very different interaction occurs. Energy in this region is not used in photosynthesis, and it is strongly scattered by the internal structure of leaves, leading to a very high apparent reflectance in the near infrared. It is this variation between visible and infrared regions of the electromagnetic spectrum that has been used in remote sensing to develop quantitative indices of vegetation condition. Remote sensing is the technique of acquiring information without direct contact with the object. It consists of the interaction of measurements of electromagnetic energy reflected from or emitted by a target from a vantage point that is distance from the target. Understanding and interpretation of electromagnetic energy that the earth surface reflects or emits enable the earth observation by remote sensing.

Remotely sensed images are acquired from different region of the electromagnetic spectrum which ranges from ultra violet to radio waves. The ones frequently used in remote sensing are from visible to the thermal infrared spectrum. Landsat TM, and Landsat ETM+ images are the commonly used remotely sensed imageries that span from the visible to the thermal infrared region of the electromagnetic spectrum. The different spectral signatures of the earth surface materials have allow application in different fields of environmental studies like vegetation, soil, hydrology and geology. Remote sensing and GIS have provided tools for advanced ecosystem management. The acquisition of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional, and global scales over time; such data also provide a link between intensive, localized ecological research for conservation and management of biological diversity. Geoinformation which embraces the technology of remote sensing, global positioning systems (GPS) and geographic information systems (GIS) has been used in various studies in the earth sciences to explain the process taking place on the earth surface.

The study Area

The study was conducted in North-western part of Yobe State where the Nguru/Hadeja wetland is located. The area lies between latitude 12^0 $38^/$ N and 13^0 $13^/$ N, and longitude 10^0 $07^/$ E and 11^0 $02^/$ E. It is part of the Sahelian region of Nigeria where desertification is threatening the ecology and livelihood of the inhabitants of the area (UNESCO, 2000; UNDP, 2009; Orounye, 2009). Yobe State is bordered to the North by Niger republic, to the East by Borno State, to the West by Jigawa and Bauchi States and to the South by Gombe and Borno States. Yobe State has a land area of 47,153sq.km and a population of 2.7 million. The study area (Figure 1) like other parts of the dry savanna has clearly defined wet and dry season largely determined by the properties and movement of the Inter-Tropical Discontinuity (ITD).

Temperatures are generally high throughout the year, though there is significant variability. The highest air temperatures are normally in April before the onset of the rains and the minimum in December during the harmattan season. The area has a mean maximum temperature of 40.6^0 C and a mean minimum temperature of 12.8^0C (Oguntoyinbo, 1983).

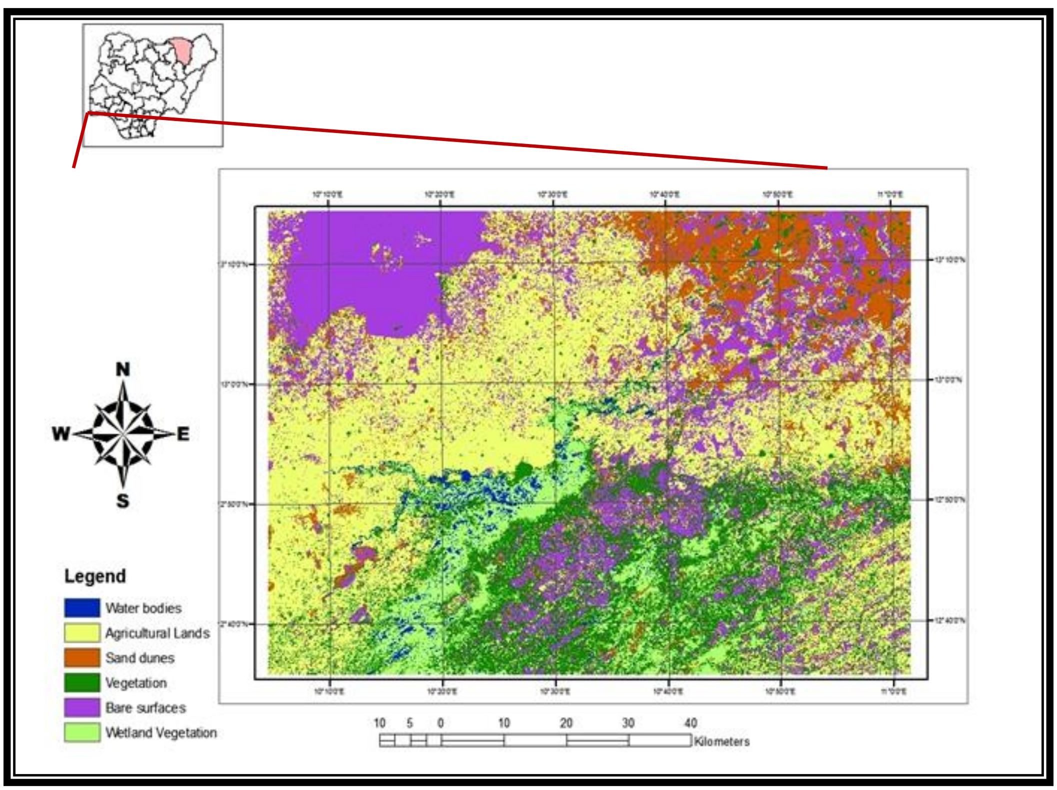


Figure 1: The study Area

The movement of the ITD controls the durations and amounts of rainfall received in most parts of West Africa including the study area. The area usually receives between 230- 640 mm of rainfall lasting for only three to four months (Oruonye, 2009). Since the last century, there have been more frequent droughts than what historical records indicate. Notable events are the droughts of 1913-14, 1931-32, 1942-43, 1972-73, and 1983-84 (Odekule, *et al*., 2008). This trend has contributed to the near disappearance of the Lake Chad which is located on the northeast of the study area and both are within the same region (Dami, 2008).

Materials and methods

Satellite Imagery

Medium resolution satellite images (Landsat MSS, TM and ETM+) of the study area were acquired for analysis. Four sets of the satellite images were acquired to cover the study period, that is, 1972 – 2005. The images taken in the same season of the year were used for the change analysis in order to reduce seasonal variation in vegetation cover. This is in line with Pu et al.'s, (2008) suggestion that for any meaningful assessment of vegetation change with remote sensing techniques, images to be used for analysis should be acquired at about the same time of the year in order to reduce vegetation phenological differences. This method of selecting images for change detection is referred to as "anniversary dates" or within "anniversary windows" (Lu, et al., 2004; Mas, 1999; Singh, 1989). Four sets of the Landsat images were acquired from Global Land Cover Facility website (http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp) and Earth Resources Observation and Science Center (EROS). Table 1 shows detail characteristics of the images used for the image analysis. IDRISI Taiga version 6.05 and ArcMap 9.3 were the software used for image processing and visualization.

Table 1: Spatial and Spectral Characteristics of LandSat (MSS, TM and ETM+)

Spatial Resolution			Spectral Resolution		Date of Acquisition	
Band	**MSS**		**MSS**		**MSS**	
1 (Green)	80 m		0.5-0.6 µm		04/11/1972	
2 (Red)	80 m		0.6-0.7 µm			
3 (Near IR)	80 m		0.7-0.8 µm			
4 (Near IR)	80 m		0.8-1.1 µm			
	TM	**ETM+**	**TM**	**ETM+**	**TM**	**ETM+**
1 (Blue)	30 m	30 m	0.45-0.52 µm	0.45-0.52 µm	09/10/1986	06/11/2000
2 (Green)	30 m	30 m	0.52-0.60 µm	0.53-0.61 µm		06/11/2005
3 (Red)	30 m	30 m	0.63-0.69 µm	0.63-0.69 µm		
4 (Near IR)	30 m	30 m	0.76-0.90 µm	0.78-0.90 µm		
5 (Middle IR)	30 m	30 m	1.55-1.75 µm	1.55-1.75 µm		
6 (Thermal IR)	120 m	60 m	10.4-12.5 µm	10.4-12.5 µm		
7 (Middle IR)	30 m	30 m	2.08-2.35µm	2.09-2.35 µm		
8 (Panchromatic)		15 m		0.52-0.90 µm		

Source: USGS Website

Image processing

Area of interest for this study was first extracted from the complete scene using the WINDOW facility in IDRISI Taiga. The extracted areas of interest were geometrically and radiometrically corrected. Geometric correction was done using the RESAMPLE method in order to co-register the images for further analysis. It is necessary for the images to have the same row and column in order for the pixels to properly align. Furthermore, the images were radiometrically corrected to reduce the impact of atmospheric attenuation. The dark object subtraction was used in the radiometric correction. Figure 2 shows the flowchart of the procedures followed for the image analysis.

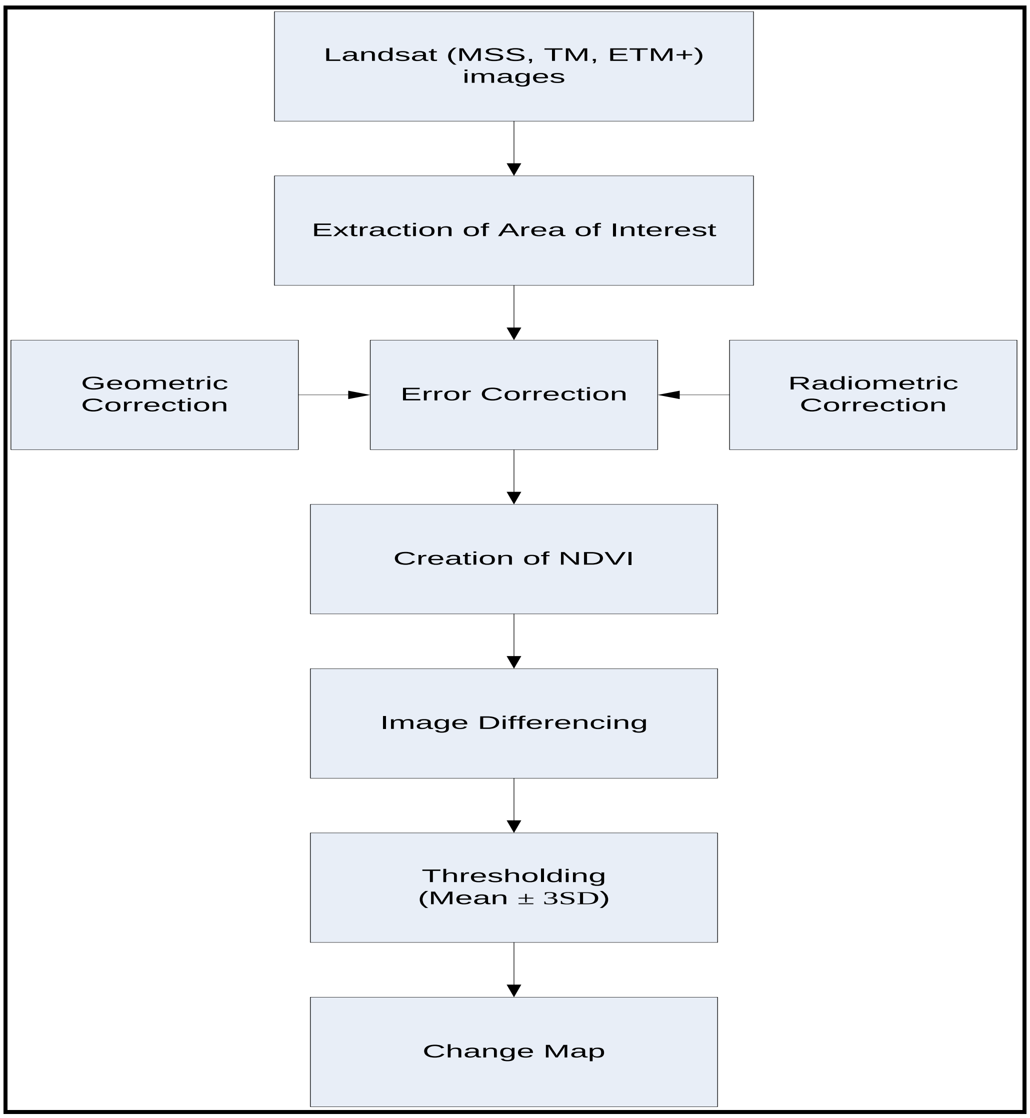


Figure 2: Flowchart of methodology

Creation of Vegetation Index

On the corrected satellite images, Normalized Difference Vegetation Index (NDVI) was calculated to determine vegetation dynamics in the area between 1972 and 2005. IDRISI Taiga software was used in creating the NDVI images.

NDVI is expressed as the difference between the NIR and Red bands normalized by the sum of those bands.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

This is the most commonly used vegetation index as it retains the ability to minimize topographic effects while producing a linear measurement scale and also divisions by zero errors are significantly reduced. Furthermore, the measurement scale has the desirable property ranging from -1 to +1 with 0 and negative values representing non-vegetated surfaces while positive values represent vegetation cover.

Image Regression Differencing

Image regression differencing techniques of change detection was used in analysing vegetation dynamics for this study area. Before carrying out image regression, the different images acquired at different dates were co-registered into the same coordinate as suggested by some authors (Washinton-Allen, et al., 1998; Pu, *et al.*, 2008). The images were regressed in order to reduce errors that may be introduced due to differences in sensors and dates. Regressing the images before change detection has the ability of correcting radiometric distortions as a result of satellite sensor differences, sensor error and atmospheric attenuations. The earlier image is used as independent variable while the later image as dependent variable in a regression line. Intercept and the slope of the regression are used to adjust the earlier image in order to have comparable characteristics with later image. The equation for adjusting the earlier image is given below:

Adjusted Image = (earlier image*slope) + intercept ----------------------- (2)

After adjusting the earlier image, differencing of the images were carried out to get a difference image which was used in 'thresholding' to get the final change image. This is in order to avoid the confusion associated with identifying areas of change (decrease or increase) in a difference image, (Eastman, 2009; Wojtek, 2007). With 'threshold', one can establish a lower and upper limit to a normal variation beyond which it is considered that true change has occurred. Histogram was used to establish the threshold limits of the normal variation. A normal distribution has a bell-shaped curve with a single peak and symmetrical tails that fall off in a convex fashion on either side (Figure 2). In a normal distribution, the standard deviation (SD) measures the characteristic dispersion of values away from the mean (Wojtek, 2007). Therefore, values that were within plus or minus 3SD from the mean are areas where change is not expected to take place (Eastman, 2009). This implies that any values beyond the -3SD or +3SD values mentioned above are considered as change in the difference image. The range (mean - 3SD and mean + 3SD) chosen for this study means that there is 99 percent probability that change has occurred in the areas indicated.

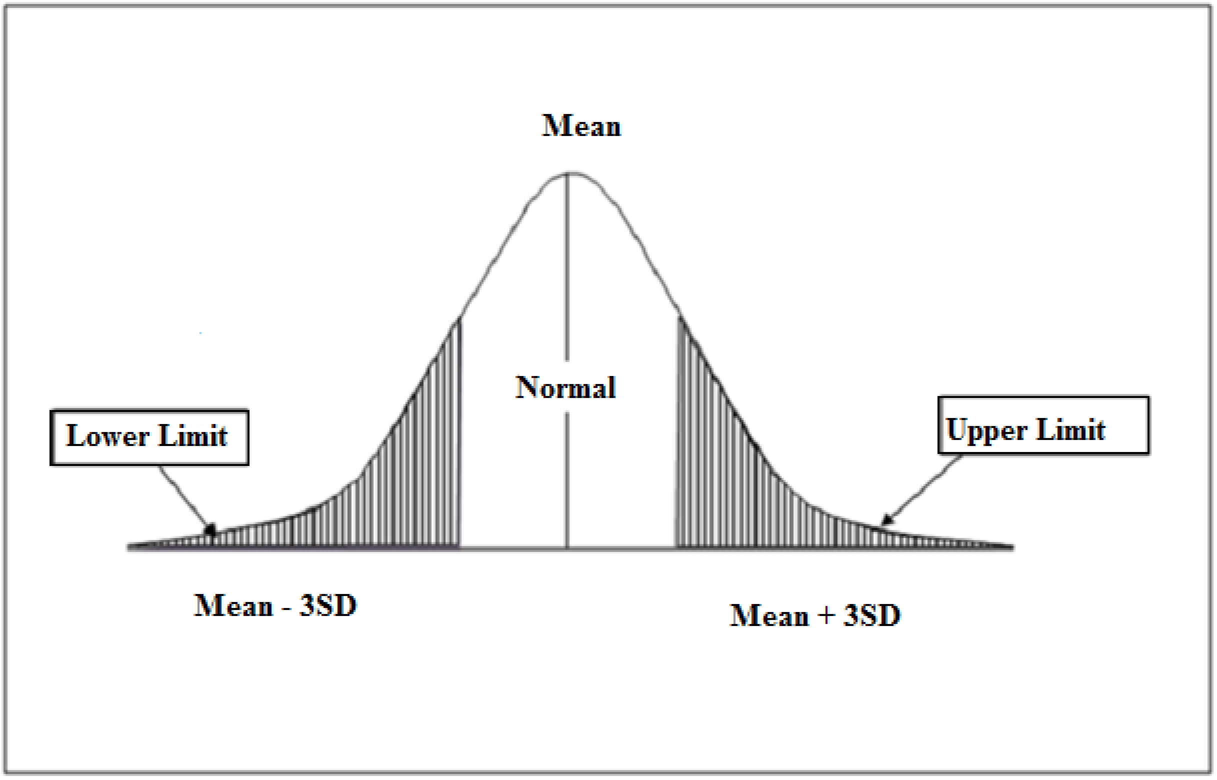


Figure 2: Illustration of the Thresholds used in the Analysis

Results and Discussions

The result from the image regression differencing of NDVI were reclassified into 3 classes; 0 (no change), 1 (decrease in vegetation cover) and 2 (increase in vegetation cover). The results of vegetation change between 1972 and 1986 are presented in Figure 3, and Table 2. Figures 2a, b, and c show graphic representation of the changes in a map form. From the maps, areas of "No Change" are presented with grey colour, areas of increase in vegetation cover with green while areas of decrease with yellow. The maps show that there was a decrease in vegetation between 1972 and 2005. The decrease in vegetation may be attributed to increase in population of the region as the population was reported to be increasing at a rate of 3 percent per annum. The majority of the people living in the area depend on subsistence agriculture for their survival. This therefore, entails that increase in population will eventually mean increase in activities that contributes to decrease in vegetation. Examples of such activities include; farming, grazing and wood extraction. The study shows that the pattern of vegetation cover in the area follows the shape of the wetland. This is due to the availability of water around the wetland as water is one of the major limiting factors to vegetation development in the arid environment.

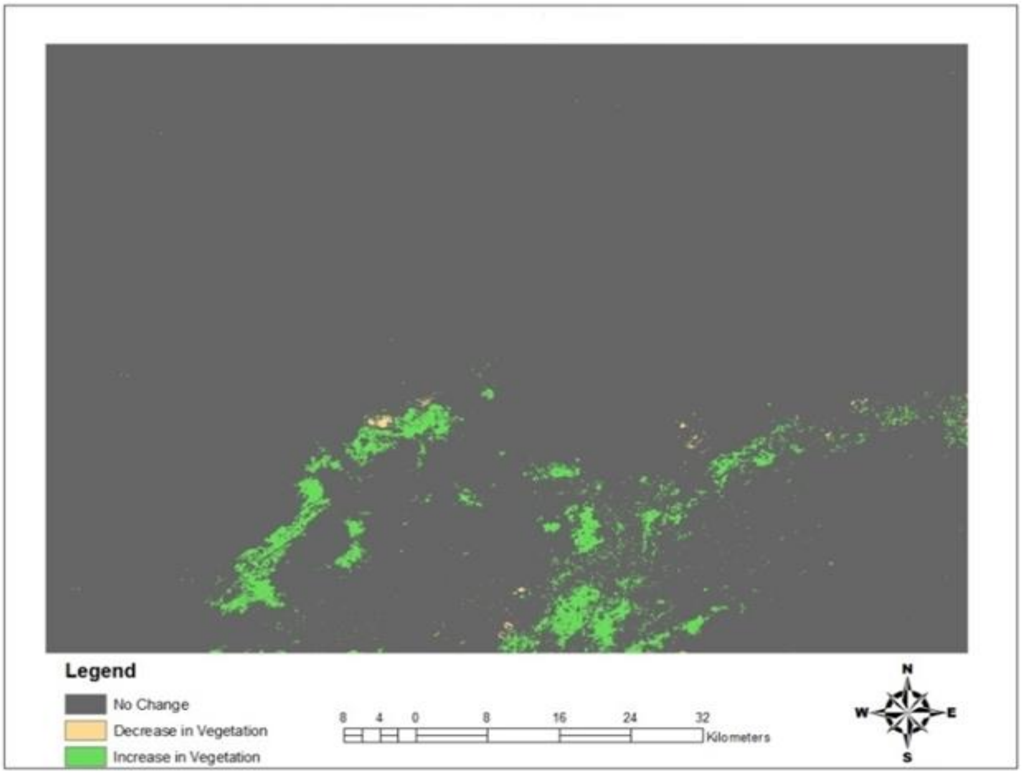


Figure 2a: Vegetation Difference between 1972 and 1986

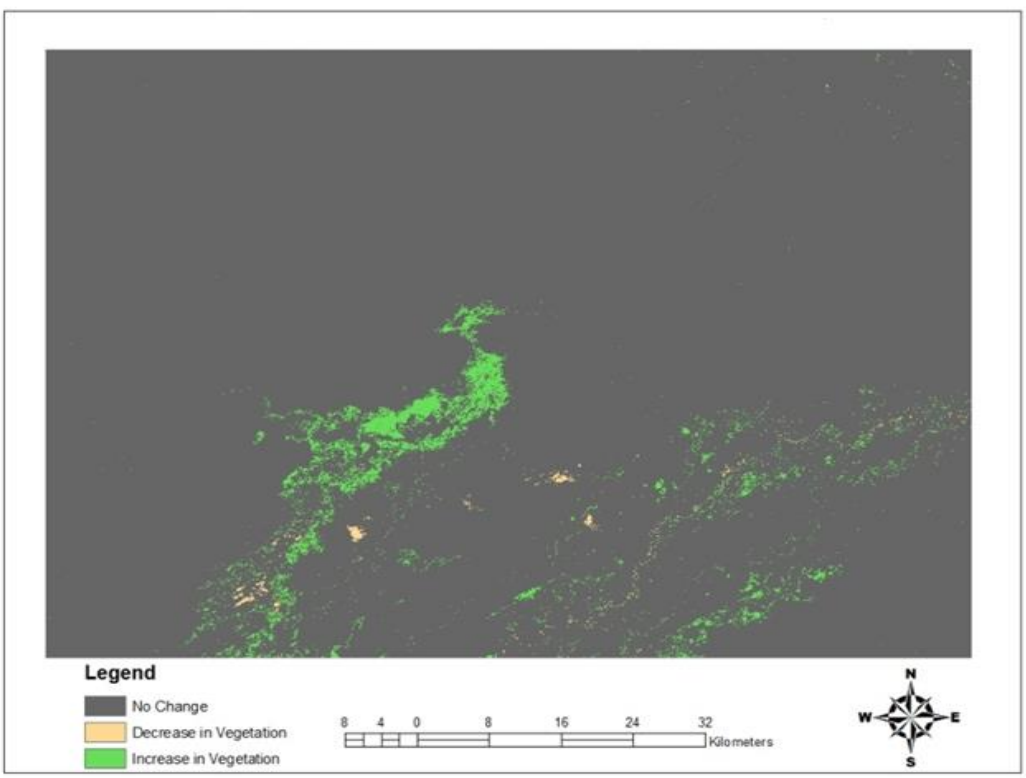


Figure 2b: Vegetation Difference between 1986 and 2000

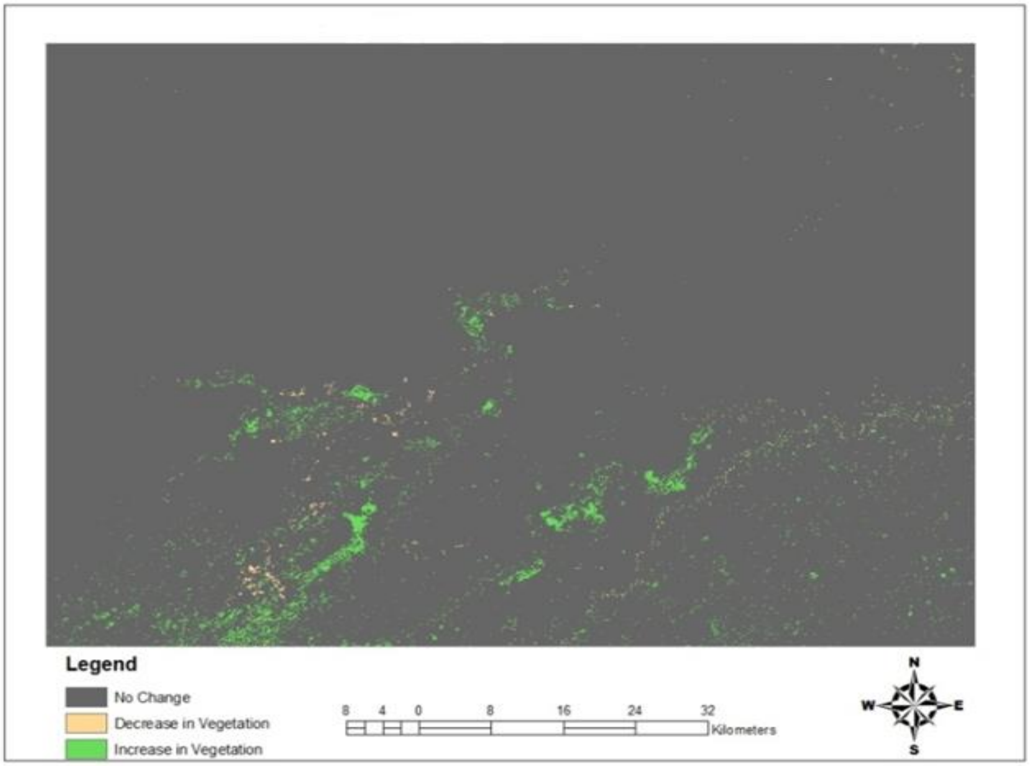
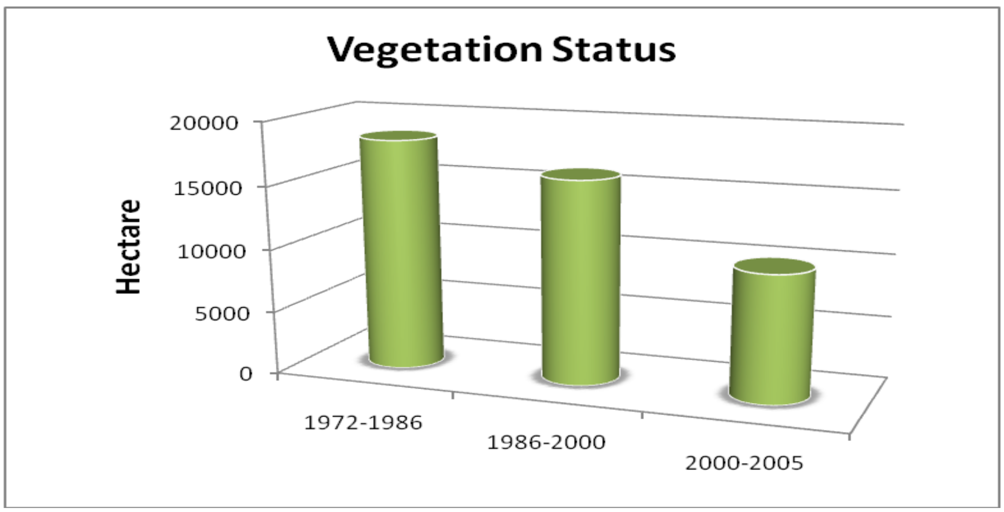


Figure 2c: Vegetation Difference between 2000 and 2005

The result on Table 2 shows the sizes of classes on the vegetation difference images. It reveals that the area of ‘No change’, ‘Decrease’, and ‘Increase’ in vegetation cover between 1972 and 1986 are 714813.95, 559.97 and 18403.39 respectively. Furthermore, the classes on the vegetation difference image between 1986 and 2000 are 716291.03 hectares for area of ‘No change’, 1360.36 hectares for area of ‘Decrease’ and 16125.92 hectares for area of ‘Increase’ while between 2000 and 2005 are 722200.07, 1530.44, and 10046.80 hectares for areas of ‘No change’, ‘Decrease’ and ‘Increase’ in vegetation cover respectively. This clearly reveals that vegetation in the area is decreasing as shown in figure 3. The result of the study is in disagreement with the findings of Anyamba and Tucker, (2005) which reported that vegetation in the area is increasing. Their conclusions were based on the high correlation they got between rainfall and vegetation in the Sahel region. However, the use of coarse spatial resolution satellite image in their study and also the large coverage of their study area might have cancelled some of the salient changes that might have occurred due to human activities. This study clearly demonstrates that human activities play a major role in determining the status of vegetation cover in the area. Therefore, it implies that for any conservation project to succeed in the region, the communities in the vicinity of the project should be involved in all the phases of the project because of their contribution in shaping the land cover features.

Table 2: Vegetation change between 1972 and 2005

Year	Area measured in Hectare		
	No change (0)	**Decrease (1)**	**Increase (2)**
1972-1986	714813.95	559.97	18403.39
1986-2000	716291.03	1360.36	16125.92
2000-2005	722200.07	1530.44	10046.80



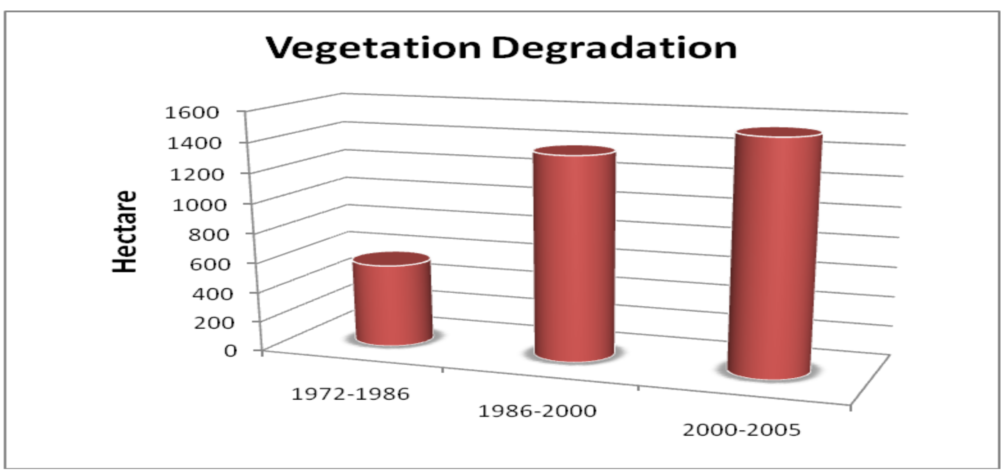


Figure 3: Vegetation Change between 1972 and 2005

Conclusion

Vegetation as a very important component of the ecosystem provides many functions and services which are vital in the sustenance of life in the biosphere. In the contemporary global challenges of climate change, biodiversity loss and land degradation especially in the arid zones, the importance of vegetation study cannot be neglected. This is because of its role in ameliorating the impact of the aforementioned challenges. Continuous vegetation degradation due to unsustainable human activities and droughts in arid environment has further aggravated the problem which calls for concerted efforts to salvage the situation. In arid and semi-arid zones of Nigeria, desertification is a major ecological problem threatening the survival of communities. Hence, huge resources have gone into reforestation projects in order to check the menace of desertification in these zones; however, the projects are bedeviled by failures. This may be attributable to lack of involvement of communities in the reforestation projects located in their vicinity. This study revealed that human activities has greater role to play in changing vegetation cover of an arid environment at a local scale as it showed a consistent decrease in vegetation cover over the years under study. Therefore, the study recommends better management of the dwindling vegetal resources in the area through efforts at protecting the resources from further degradation. The government and non-governmental organization concern with environmental matters should create an avenue where information can be easily disseminated to the people living in arid environment on importance of conservation to the environment and their own wellbeing.

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