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SPATIO-TEMPORAL MONITORING OF CHANGE IN VEGETATION OF POTISKUM AND NANGERE LOCAL GOVERNMENT AREAS OF YOBE STATE IN NIGERIA

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ABSTRACT

As vegetation serves several critical functions in the biosphere, this paper tends to monitor the changes of vegetation in potiskum and Nangere local government areas from 2003 to 2015 using the Normalized Difference Vegetation Index (NDVI). To achieve this, three Landsat data; Landsat 7 Enhanced Thematic Mapper (ETM+) data for April 2003 and April 2008 as well as Landsat 8 OLI April 2015 have been acquired from the US Geological Survey (USGS) Global Visualization Viewer. Image processing was carried out using ERDAS/IMAGINE 9.2 and Arc GIS version 10.4. The result of the NDVI In 2003 was found that the average NDVI is 0.14, having 0.59 as maximum, 0.03 as a minimum, and 0.02 as standard deviation respectively. Likewise, the standard deviation in 2008 and 2015 is 0.02, while in 2008 the maximum of NDVI was 0.43, 0.03 as a minimum and 0.13 as mean respectively. Also, 2015 exhibits 0.53 as maximum NDVI, 0.05 as minimum NDVI and 0.18 as mean. This was further correlated with Air Temperature and Rainfall data of the study area to examine their relationship. Moreover, the change in vegetation of the study area is manifested due to natural or artificial impact. It is therefore recommended that the application of remote sensing data should be involved for timely and cost-efective information in the monitoring of vegetation.

Keywords: GIS, NDVI, Remote Sensing, Vegetation.

I. INTRODUCTION

Vegetation includes all plants from evergreen forests to grassy meadows and cropland. It refers to the ground cover provided by plants and is by far the most abundant biotic element of the biosphere (North Carolina Climate office). Vegetation serves several critical functions in the biosphere at all possible spatial scales. For instance, it serves as a wildlife habitat and the energy source for the vast array of animal species on the planet (and, ultimately, to those that feed on these). It is also critically important to the world economy, particularly in the use of fossil fuels as an energy source, but also in the global production of food, wood, fuel, and other materials (Science daily).

Vegetation mapping presents valuable information for understanding the natural and man-made environments through quantifying vegetation cover from local to global scales at a given time or over a continuous period. It is critical to obtain current states of vegetation cover to initiate vegetation protection and restoration programs (Egbert et al. 2002; He et al. 2005). Strong preference has been given to acquire updated data on vegetation cover changes regularly or annually to better assess the environment and ecosystem (Knight et al. 2006).

Considering the importance of vegetation in the global landscape, more attention has to be paid to monitoring the change in vegetation in any region of the world. However, because of the vastness of the area covered by vegetation, a suitable and scientific method needs to be employed. Traditional methods (e.g. field surveys, literature reviews, map interpretation, and collateral and ancillary data analysis), however, are not effective to acquire vegetation covers because they are time-consuming, date lagged, and often too expensive. The technology of remote sensing offers a practical and economical means to study vegetation cover changes, especially over large areas (Langley et al. 2001; Nordberg and Evertson 2003). Because of the potential capacity for systematic observations at various scales, remote sensing technology extends possible data archives from the present time to over several decades back. For this advantage, enormous efforts have been made by researchers and application specialists to delineate vegetation cover from local scale to global scale by applying remote sensing imagery.

The study shows that the extent to which the vegetation covers around the town of Potiskum has been afected from 1978 to 2005.

The population increase can be seen to be partially responsible for the rapid decline of the vegetation as the growing population has increased demand for the construction of social amenities, new housing, and the associated increasing demand for farmland to supply the increased population needs (Naibbi et al., 2014). However, the situation of the increase in population can lead to a change in vegetation cover. This paper aimed to monitor the Spatio-temporal changes of the vegetation in the study area for the period 2003-2015, identify the changes in vegetation in the study area for the aforementioned time, and also evaluate the change of vegetation concerning air temperature and rainfall data of the study area.

II. MATERIALS AND METHOD

Study Area

The study area lies between 11˚ 30' – 12˚ 05'N, 10˚ 50' – 11˚ 20'E, the study area involves two administrative areas namely, Nangere Local Government Area and Potiskum Local Government Area, covering an area of 1,553.60 square kilometers. The topography within 3.2km of the study area contains only modest variations in elevation, with a maximum elevation change of 32m and an average elevation above sea level of 423m. Within 16km also contains only modest variations in elevation (100m). Within 80km contains only modest variations in elevation (332m). The study area is located in the Sudan Savanna zone of the seven (7) Nigerian ecological zones. It is covered by cropland, grassland, trees, and sparse vegetation, with seasonal variation in monthly rainfall. The rainy period of the year lasts for 6 months, from April to October, with a sliding 31-day rainfall of at least 12.7mm. The most rain falls during the 31 days centered around August 9, with an average total accumulation of 175.26mm.

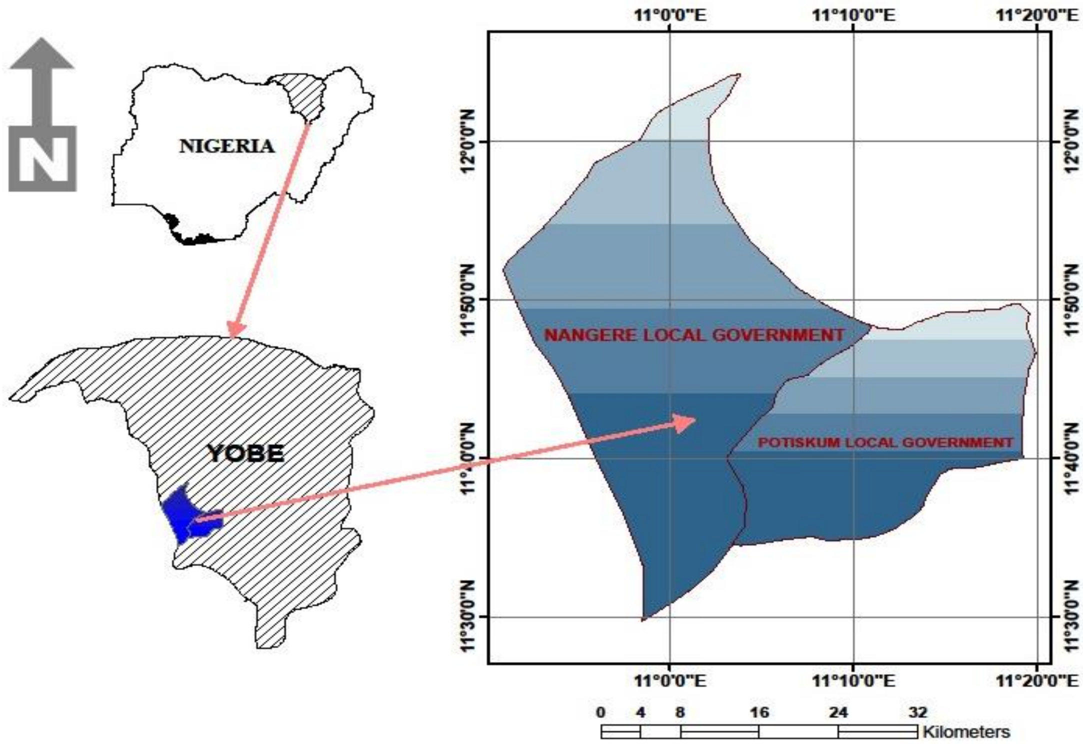

Fig 1: The study area

Data used

The data used in this research involves the satellite data and meteorological data (air temperature and rainfall data) of the study area.

Satellite Data

Landsat 7 Enhanced Thematic Mapper (ETM+) data for April 2003 and April 2008 as well as Landsat 8 OLI April 2015 have been acquired from the US Geological Survey (USGS) Global Visualization Viewer, and detail is given in Table 1. The Landsat ETM+ data resolution lies between 15m to 60m, while Landsat 8 OLI data resolution lies between 15m to 100m. The detailed information related to bands, wavelength, and resolution is given in Table 2

Table 1: Description of satellite data

Satellite Data	Sensor	Date of Acquisition	Path and Row	Number of Bands used	Spatial Resolution (m)
Landsat 7	ETM	2003/04/23	187/52	04	30 and 60
Landsat 7	ETM	2008/04/20	187/52	04	30 and 60
Landsat 8	OLI_TIRS	2015/04/16	187/52	04	30 and 100

Source: Landsat-8 data user handbook

Table 2: OLI and TIRS Spectral Bands Compared to ETM+ Spectral Bands

Landsat-7 ETM+ Bands (µm)			Landsat-8 OLI and TIRS Bands (µm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	100 m TIR-1	10.60 - 11.19	Band 10
			100 m TIR-2	11.50 - 12.51	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

Source: Landsat-8 data user handbook

Not all the bands were used, the bands used for the requirement of this research are stated below:

Landsat-7 ETM+ bands are Band 1, 2, 3, and 4. While Landsat-8 OLI and TIRS bands are Band 2, 3, 4, and 5

Air temperature and rainfall data

Table 3: Yearly Air Temperature and Rainfall Data

Year	Temperature (Max.)	Temperature (Min.)	Average	Rainfall (mm)
2003	34.9	20.2	27.6	707
2008	34.5	19.8	27.2	693.3
2015	34.5	20.7	27.6	701.6

Source: Nigerian Meteorological Agency, Potiskum, Yobe State, Nigeria

Hardware and software used

A 64-bit operating system Hp Laptop (4.00GB RAM) equipped with a 2.00GHz processor was used in this research. ERDAS/IMAGINE 9.2 image processing software and Arc GIS 10.4 were also used.

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Image pre-processing

This involves image extraction, image layer stack, and image subset.

Image extraction

The satellite data downloaded from USGS is in zip format, so for further process of the image, there is a need for the data to be extracted to produce separate layers from it.

Image layer Stack

Layer stacking is a process for combining multiple images into a single image. To do that the images should have the same extent (number of rows and number of columns), which means you will need to resample other bands which have diferent spatial resolutions to the target resolution. In other words, all images/bands should have the same spatial resolution to be able to perform layer stacking.

In this research, layer stacking of satellite data was carried out in ERDAS IMAGINE 9.2 through the "interpreter - utilities - layer stack channel" then the output and the input images were chosen in the "layer selection and stacking window". After the process, the output was the layer stacked image of the selected layers. The same process was conducted for the three sets of data (2003, 2008, and 2015).

Image Subset

A typical Landsat-7 scene covers an area of about 233.73km by 209.43km, while a Landsat-8 scene covers an area of about 226.83km by 231.63km. At times, it makes sense to cut out a subset of this larger image to simplify the analysis and focus on the portion of the scene that is of primary interest.

ArcGIS 10.4 was used to subset (extract) the study area through the following selections: "Catalog – Tool Boxes – System Tool Boxes – Spatial analyses tool boxes – Extraction – Extract by Mask" then the Input Raster, Feature Mask data (shapefile of the study area) and the output raster were chosen. The processed result was the subset (extracted) image of the study area. This process was carried out for 2003, 2008, and 2015 layer stacked images.

Image processing

Image processing is a method of performing some operations on the image, to get an enhanced image or to extract some useful information from it. It involves the following operations:

Atmospheric Correction of Images

Before the NDVI calculation, the Digital Number was converted into reflectance (Landsat8 Data User Handbook), the following equation was used to convert DN values to TOA reflectance

$\rho\lambda' M\rho Qcal + A\rho$ .... Equation (2.1)

Where,

$L\lambda'$ = TOA planetary reflectance, without correction for solar angle.

$M\rho$ = Band-specific multiplicative rescaling factor from the metadata

(REFLECTANCE _MULT _BAND _x, where x is the band number)

$A\rho$ = Band-specific additive rescaling factor from the metadata

(REFLECTANCE_ADD_BAND x, where x is the band number)

Qcal = Quantized and calibrated standard product pixel values (DN)

TOA reflectance with a correction for the sun angle is given a

$$\rho\lambda = \frac{\rho'}{\cos(\theta SZ)}] + \text{...............Equation (2.2)}$$

Where,

$\rho\lambda$ = TOA planetary reflectance

θSE = Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION)

θSZ = Local solar zenith angle; $\theta SZ = 90° - \theta SE$

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Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) is used to indicate and measure the live green vegetation from remote sensing satellite imagery. It can be calculated from the following formula (Ranagalage et al., 2017):

NIR−¿

NDVI= ……………………..Equation (2.3)

NIR+

Where Red (0.631-0.692 μm and 0.636-0.673 μm for landsat7 and 8 respectively) and NIR (0.772-0.898 μm and 0.851-0.879 μm for landsat7 and 8 respectively) stand for the spectral reflectance measurement acquired in the visible (red band) and near-infrared regions, respectively. NDVI values range from -1 to 1.

III. RESULTS AND DISCUSSION

NDVI maps for the three epochs are shown in Figures 2, 3, and 4 respectively. In 2003, the result was found that the average NDVI is 0.14, while 0.59 as maximum, 0.03 as a minimum, and 0.02 as the standard deviation respectively. Likewise, the standard deviation in 2008 and 2015 was 0.02, while in 2008, the maximum of NDVI is 0.43, 0.03 as a minimum, and 0.13 as mean of NDVI respectively. Also, 2015 exhibits 0.53 as maximum NDVI, 0.05 as minimum NDVI and 0.18 as mean. Figure 5 shows the spatial distribution of NDVI classes in percentage having five classes labeled as, <0.12 (barren areas of rock, sand, or snow), 0.12 – 0.20 (Sparsely shrub and grassland), 0.20 – 0.28 (shrub and grassland), 0.28 – 0.36 (less dense vegetation) and >0.36 (Dense Vegetation). The moderate (0.20 – 0.28) class is dominated by 2003 with about 75% area covered. There is a continuous increase in area covered by less dense vegetation (0.28 – 0.36) between 2003 and 2015.

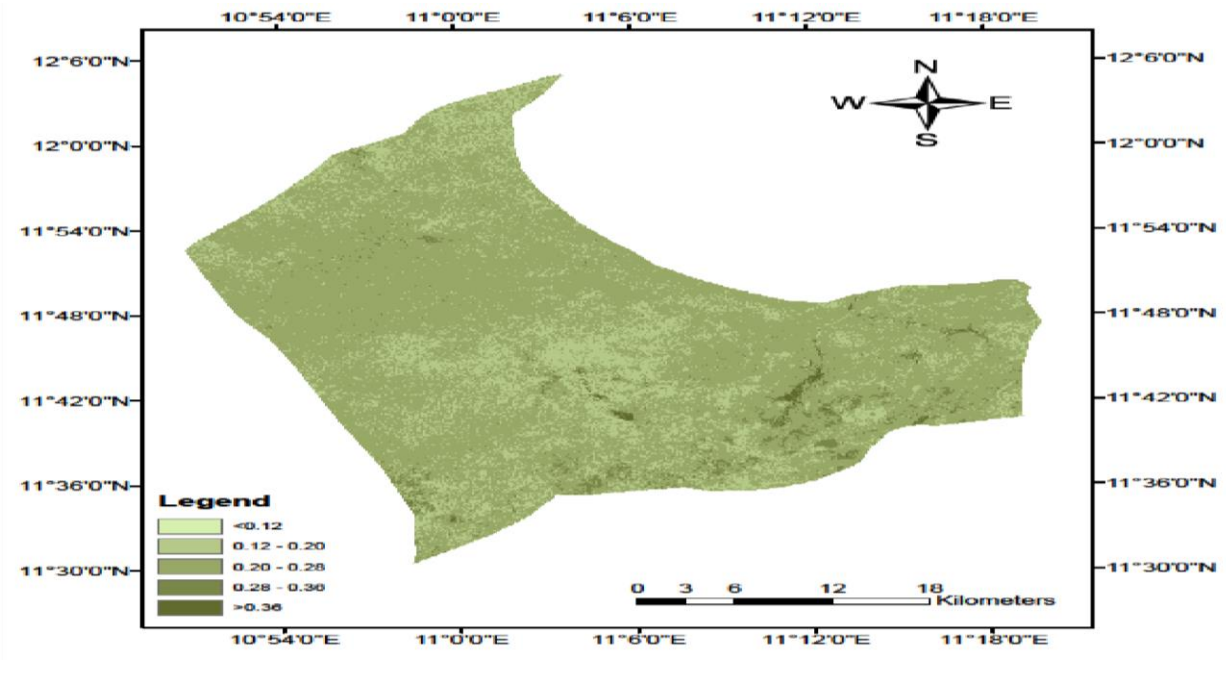

Fig 2: Classified NDVI for the year 2003

Source: Authors analysis

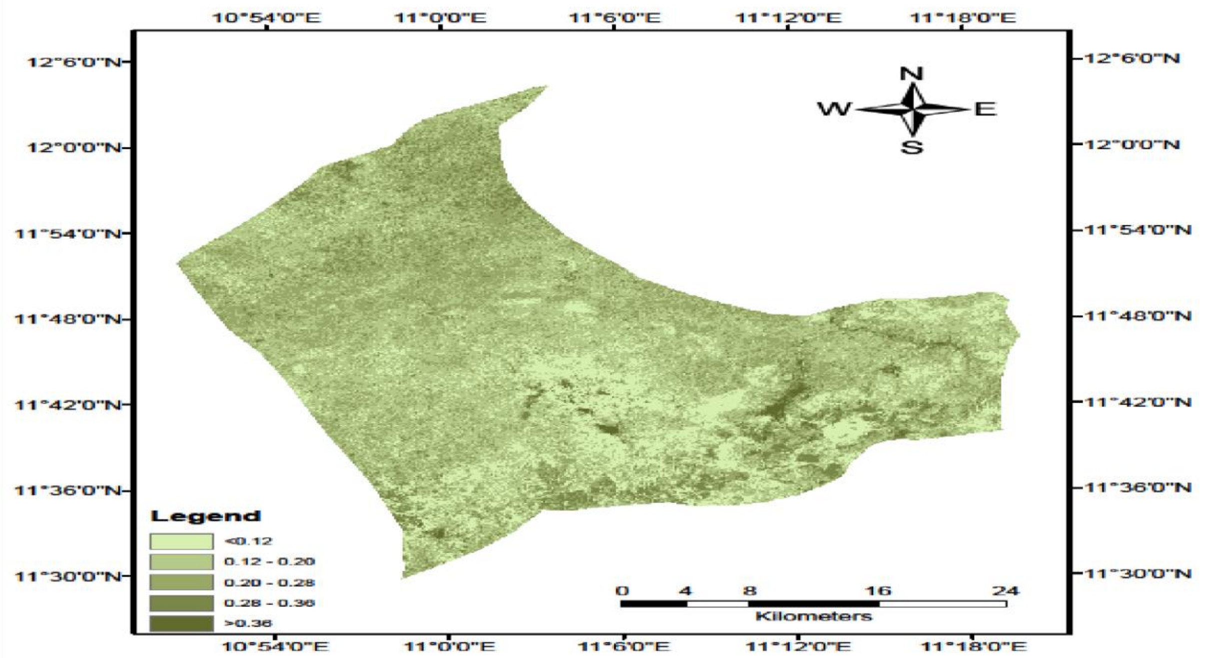

Fig 3: Classified NDVI for the year 2008

Source: Authors analysis

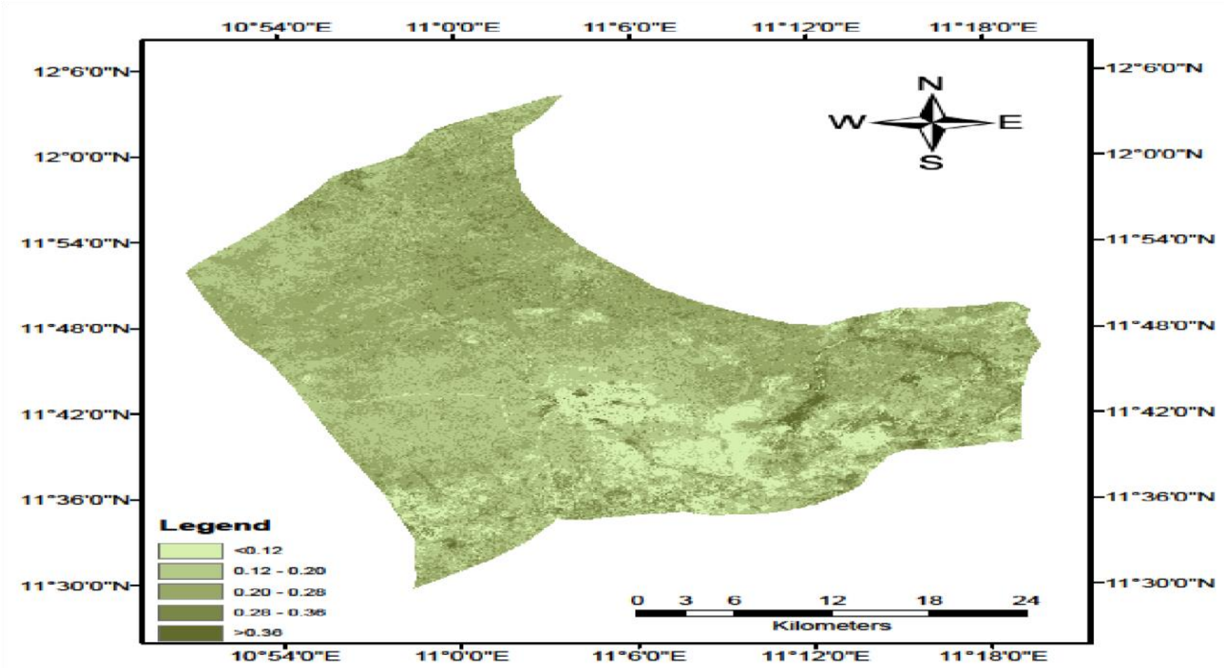

Fig 4: Classified NDVI for the year 2015

Source: Authors analysis

Table 4: Classified NDVI in Hectares and Percent for 2003, 2008 and 2015

Class	Area 2003		Area 2008		Area 2015	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
0.0-0.12	0	0	25797.4	16.7	13739.9	8.9
0.12-0.20	33790.5	21.9	69671.0	45.1	59339.1	38.4
0.20-0.28	115829.2	74.9	48659.4	31.5	69103.7	44.7

0.28-0.36	4562.3	2.9	9741.4	6.3	11710.4	7.6
>0.36	454.8	0.3	767.5	0.5	743.8	0.5
Total	154636.7	100	154636.7	100	154636.7	100

Source: Authors analysis

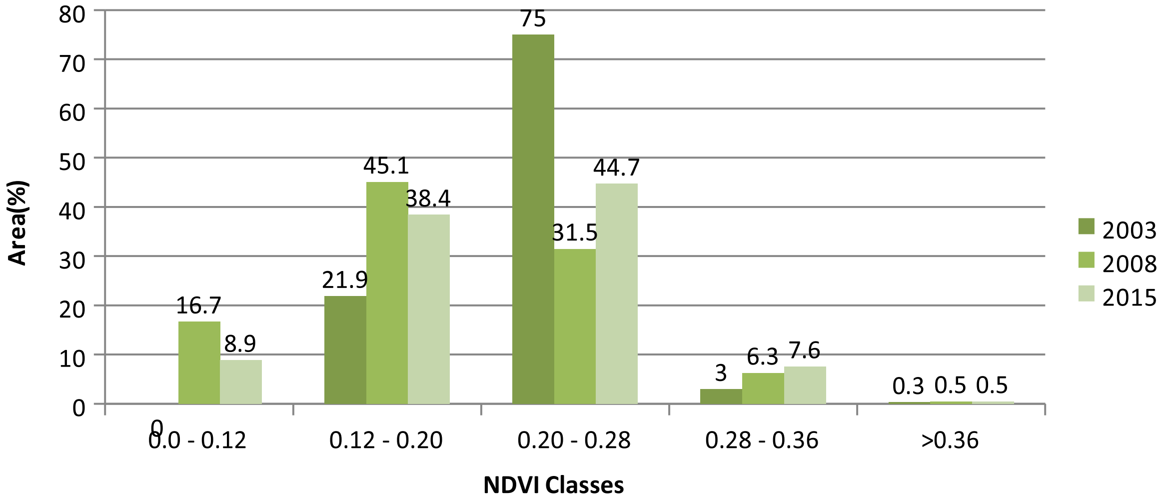

Fig 5: Statistics of NDVI area in percentage for 2003, 2008, and 2015 study year

Source: Authors analysis

Table 5: NDVI, Annual Rainfall and Air Temperature for 2003, 2008, and 2015 study years

Year	Mean NDVI	Mean Annual Temp. (°C)	Annual Rainfall (mm)
2003	0.14	27.6	707
2008	0.13	27.2	693
2015	0.18	27.6	702

Source: Authors analysis

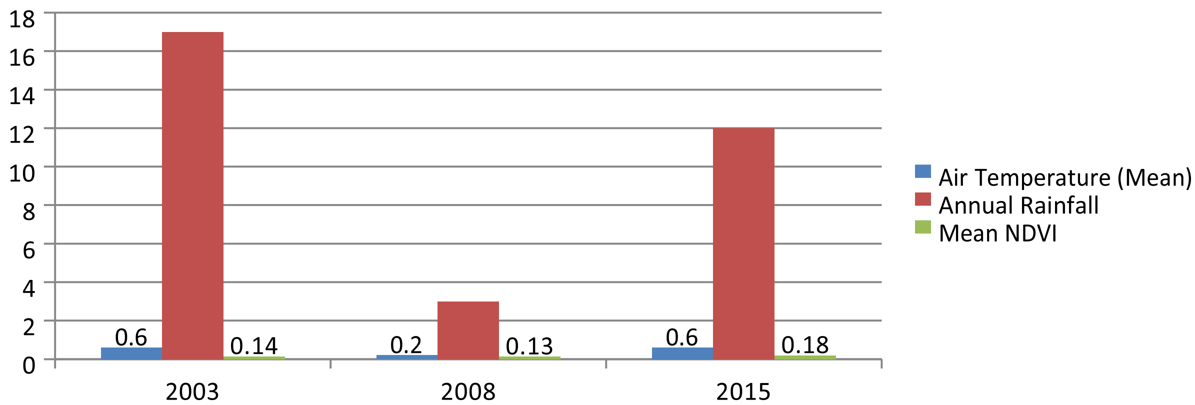

Fig 6: Correlation of NDVI, Annual Rainfall and Air Temperature for 2003, 2008, and 2015 study years

Source: Authors analysis

Considering the results indicated in Table 6, there is a correlation between the NDVI and annual rainfall for the study period because when there is more rainfall there is also an increase in NDVI which indicates an increase of vegetation cover in the area. On the other hand, the increase in rainfall and vegetation cover yields a decrease in the air temperature.

IV. CONCLUSION

This research applied the method of remote sensing and GIS to monitor the nature of vegetation and how the vegetation change over time based on the result of the classified NDVI concerning area covered; it shows that

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from the year 2003 to 2015, there was a continuous increase in almost all the classes. This indicates the increase in vegetation cover in the study area. In the light of the problems associated with change in vegetation of Potiskum and Nangere Local Government

Areas of Yobe State in Nigeria as revealed in this study; it therefore recommends that; the application of remote sensing data is highly recommended for timely and cost-efective information in the monitoring of vegetation, tree planting and landscaping should be encouraged by any relevant authority and individuals and cutting down trees and shrubs unnecessary should be stopped.

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