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Spatial relationship between NDVI, EVI, SAVI and land cover change in the Lake Chad area from 1987 to 2017

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ABSTRACT

The interpretation and analysis of remotely sensed data for land cover change detection can be enhanced with the use of vegetation indices. This study used Landsat imageries to assess the relationship between the normalized difference vegetation index (NDVI), the enhanced vegetation index (EVI) the soil adjusted vegetation index (SAVI), and land cover changes in the Lake Chad area with a view to providing an informed perspective on changes within the lake's environment. The Landsat imageries were subjected to maximum likelihood classification to extract land cover and the VIs were calculated. The interim results show that between 1987 and 2017, built-up areas and bare lands increased by 174.69km^2 and 349.90km^2 respectively while vegetation increased by 2,290.10km^2. The water bodies reduced by 937.54km^2 during the period. The correlation coefficient between NDVI, EVI, and SAVI in 1987 and 2017 is strongly positive. These are interim results presented from an ongoing study. Further research can determine the pattern and trajectory of the observed changes in the Lake Chad area.

1. Introduction

The Sahelian region in Africa is experiencing unprecedented environmental changes in land cover and land quality (Lambin et al., 2001; Onyewotu et al., 2003). These changes over time are usually the accumulated impacts of both natural and anthropogenic interactions. The remote sensing technique of land cover analysis has proven to be one of the most sensitive tools for assessing the dynamics of these interactions, especially in an arid environment, where the ecosystems are considered fragile (Zhou et al., 2008; Humagain, 2012). The interpretation and analysis of remotely sensed data for land cover change detection can be enhanced with the use of Vegetation Indices (VIs).

The Normalized Difference Vegetation Index (NDVI) has found the widest applications because it is accurate, not computationally intensive, efficient and useful for agricultural land use mapping in tropical environments (Ali, 2009; Meera et al., 2015; Mushtaq and Asima, 2016; Marco, 2019; Alademomi et al., 2020). Similar to NDVI, the Enhanced Vegetation Index (EVI) can be used to quantify vegetation greenness. EVI corrects for some atmospheric conditions and canopy background noise and is more sensitive in areas with dense vegetation. In arid regions where vegetation cover is low, the Soil-Adjusted Vegetation Index (SAVI) is often used. SAVI minimizes soil brightness influences using a soil-brightness correction factor.

Several studies have been done on the monitoring of land cover changes in the Lake Chad region (e.g., Babamaaji and Lee, 2014; Ikusemoran et al., 2017; Hussaini et al., 2020; Nwilo et al., 2019; Nwilo et al., 2020). Generally, these previous studies and others have established several trends on the ongoing land cover changes in the Lake Chad area. However, there has been little focus on the link between land cover changes and vegetation indices in the Lake Chad area. This is required for a deeper understanding of the environmental and ecological changes occurring in the Lake Chad environment. In the present study, a comprehensive classification scheme is employed for mapping the land cover around the Lake. Also, the study assesses the relationship between the land cover changes and VIs.

2. Methods

The image processing workflow from the image preparation to the land cover classification was done with ENVI Classic 4.3 and Erdas Imagine 14 software.

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2.1. Study area

Lake Chad (shown in Figure 1) is a freshwater lake in the African Sahel (Isiorho et al., 1996). The lake is bordered by Cameroon, Niger, Nigeria and Chad. Its depth varies from 1.5 - 10.5m and it is about 215m above sea level, with apparently no outlet (FAO, 2009). A characteristic physiography of the lake, according to Babamaaji and Lee (2014), is a shallow ridge or 'great barrier', which extends between the northern and southern parts of the lake, approximately 40km wide. Within the lake area, numerous islands have developed trapping pockets of water in between. The area has continuous high temperature (except during the June to September wet season), strong solar radiation and low humidity that has contributed to the evaporation responsible for its shrinkage over the years (Odada et al., 2006; LCBC, 2015; Nagarajan et al., 2018). These continuous variations in climate among other factors affect the vegetation of the Lake Chad area which are majorly scrubs and grasses (Onamuti et al., 2017).

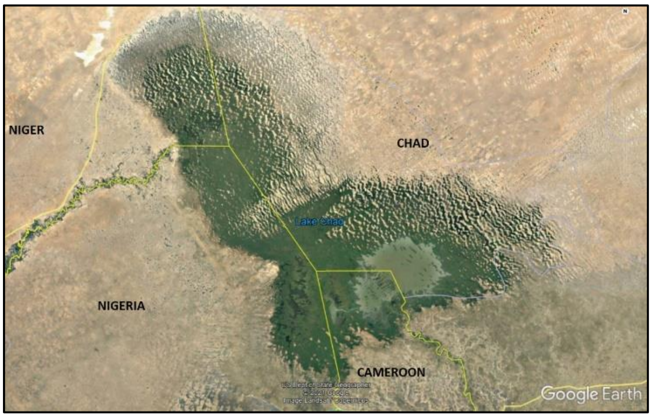

Figure 1. Imagery showing the location of Lake Chad (Source: Google Earth)

2.2. Datasets

Landsat satellite level 1 imageries covering the Lake Chad area at two epochs (1987 and 2017) were acquired to carry out image classification for this study. The level 2 NDVI, EVI, and SAVI image products for the same epochs were also downloaded for the study.

2.3. Data processing

To prepare the imageries for interpretation and classification, the imagery spectral bands were layer stacked and false color composites (FCCs) were created for each scene. The following band combinations were used to generate the FCCs: 1987 TM (4-3-2) and 2017 OLI (5-4-3). Afterwards, the scenes in each epoch were mosaicked together in Erdas Imagine. For the land cover classification, the mosaics were subsetted to the area covered. The maximum likelihood classification algorithm was used to classify the imagery into six classes: built-up area, bare land, sand dune, water body, vegetation, and soil.

The NDVI, SAVI, and EVI level 2 data were rescaled to actual index values by dividing the pixel values by 10000 to obtain index values between -1 and +1 for all the indices. The raster calculator on ArcMap Spatial Analyst tool was used for this operation.

3. Results

Figures 2 – 6 shows the results of the image classification and the processed vegetation indices. Table 1 shows the magnitde of areal changes between 1987 and 2017 while Table 2 shows the descriptive statistics of the VIs. Table 3 shows the correlation analysis between the VIs.

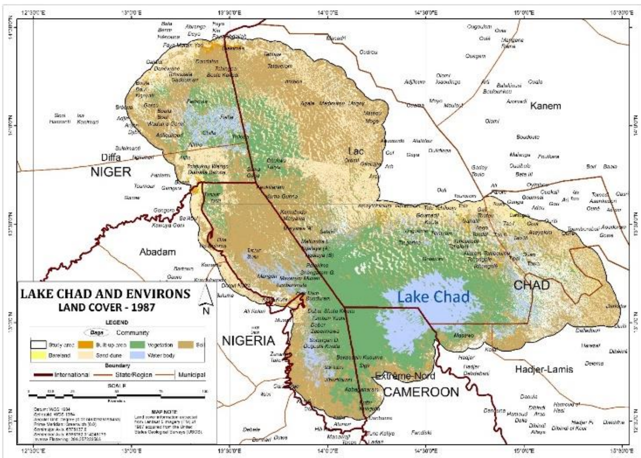

Figure 2. Land cover map of the Lake Chad area – 1987

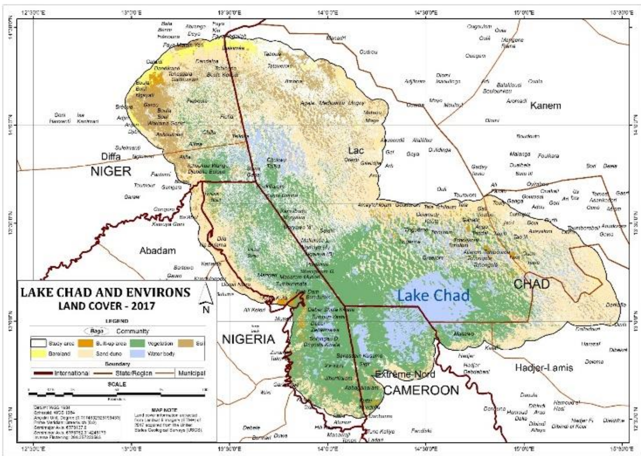

Figure 3. Land cover map of the Lake Chad area – 2017

Table 1. Magnitude of areal changes, 1987- 2017

Feature class	Magnitude of areal change (km^2)
Built-up area	+174.69
Bare land	+349.90
Sand dune	+1069.92
Soil	+4868.49
Vegetation	+2290.10
Water body	-937.54

Table 2. Descriptive Statistics of the Vegetation Indices

Parameter	Year	Min	Max	Mean	Std. dev
NDVI	1987	-0.68	0.85	0.22	0.22
	2017	-0.72	0.89	0.26	0.27
EVI	1987	-0.02	0.65	0.16	0.13
	2017	-0.21	0.78	0.18	0.14
SAVI	1987	-0.31	0.8	0.15	0.12
	2017	-0.23	0.68	0.18	0.14

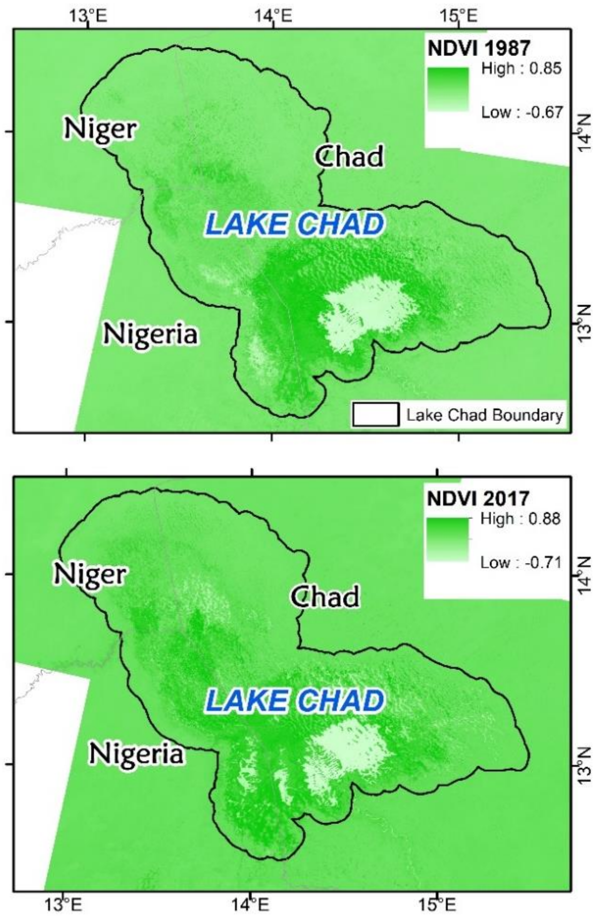

Figure 4. Normalised Difference Vegetation Index

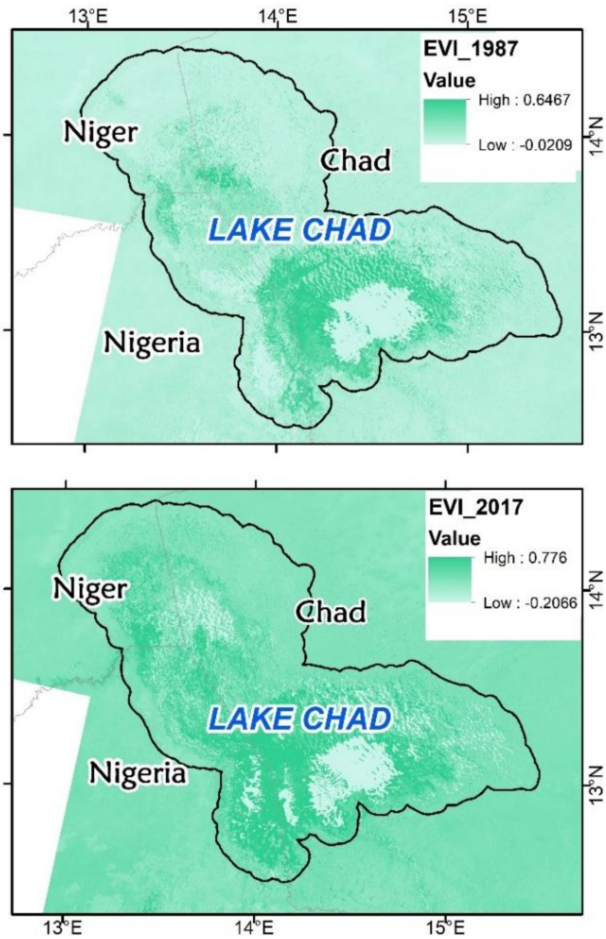

Figure 4. Enhanced Vegetation Index

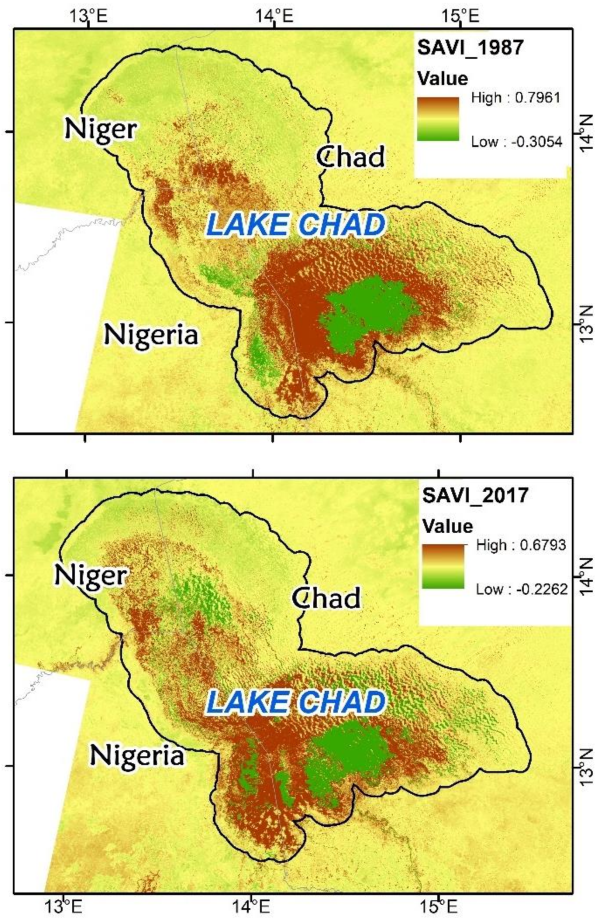

Figure 6. Soil Adjusted Vegetation Index

Table 3. Correlation coefficient (r) between the VIs

	NDVI 1987	NDVI 2017	EVI 1987	EVI 2017	SAVI 1987	SAVI 2017
NDVI 1987	1	0.57	0.95	0.51	0.97	0.52
NDVI 2017	0.57	1	0.45	0.95	0.48	0.96
EVI 1987	0.95	0.45	1	0.4	1	0.42
EVI 2017	0.51	0.95	0.4	1	0.43	1
SAVI 1987	0.97	0.48	1	0.43	1	0.44
SAVI 2017	0.52	0.96	0.42	1	0.44	1

4. DISCUSSION

Between 1987 and 2017, built-up areas and bare lands increased by 174.69km^2 and 349.90km^2 respectively while vegetation increased by 2290.10km^2. Also, there was a drastic reduction in surface water of about 937.54km^2. This alarming depletion translates to a staggering decrease in the surface area of the lake in a space of 30 years. The correlation coefficient between NDVI, EVI, and SAVI in 1987 and 2017 is positive. The highest is observed in SAVI-EVI for both years followed by NDVI-SAVI and NDVI-EVI respectively.

5. Conclusion

We have presented interim results from the ongoing study of the spatial relationship between NDVI, EVI, SAVI and land cover change in the Lake Chad area. In another paper, a comprehensive analysis and interpretation of the distribution of the VIs, and the interdependence between the VIs and land cover will be presented

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