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An Assessment of Desertification Trend in Sokoto State, Nigeria using Enhanced Vegetation Index (EVI) Imageries from AQUA-MODIS

Mohammad Hadi Ahmad[1], Shehu Suraju[2], Salihu Adama Yunusa[3], Labaran Mohammed Shuaibu[4], Aduojo Atakpa[5], Yusuf Danbaba[6], Isah Alhaji Isah[7], Okpara Richard Tobechi[8]
[1] *National Space Research and Development Agency (NASRDA), Advanced Space Technology Applications Laboratory (ASTAL), Kano*
[2, 3, 4, 5, 6, 7] *ASTAL, BUK, Kano*
[8] *Center for Basic Space Science*

Abstract: Extreme Northern part of Sokoto plains is vulnerable to desertification. Consequently, the zone has been designated as fragile due to issues related to desertification, drought, desert encroachment, aridity area among others. This have popularly been used to accentuate the fact that the zone is undergoing serious vegetation decline. This study is on the assessment of the trend of desertification in Sokoto state, Nigeria using monthly 250m resolution Enhanced Vegetation Index (EVI) imageries from AQUA-MODIS covering the period 1990 to 2009. The monthly composite imageries were initially recomposed into annual mean composites and finally into quasi-five year periods (1990-1994, 1995-1999, 2000-2004, and 2005-2009) within the Idrisi remote sensing and GIS software environment. Field observation was carried out using Global Positioning System (GPS) and digital camera to ascertain the status of some selected sites based on the analysis performed. Results from the analysis have shown different trends in vegetation decline from the different quasi-five year mean imageries. An overall picture from the time series (1990-2009) indicated that there was a fair downward trend in vegetation decrease. For a periodic monitoring of the status of desertification in this part of the country it was recommended that the AQUA-MODIS dataset with a fairly good spatial resolution and good repetitive coverage of the world should be utilized. The fact that the data is freely available makes it possible for monitoring the status of desertification in this era of climate change.
Keywords: Desertification, Vegetation, Trend, EVI, Remote Sensing and GIS

I. INTRODUCTION

Desertification is assumed to be a complex phenomenon requiring the knowledge of researchers in such disciplines as climatology, soil science, meteorology, hydrology, range science, agronomy, veterinary medicine, as well as geography. Other fields include political science, economics, anthropology and environmental planning. It has been defined in many different ways by researchers in these and other disciplines, as well as from many national and institutional perspectives, each emphasizing different aspects of the phenomenon. A review of the desertification literature shows a great diversity (and confusion) among definitions [1]. An analysis of the definitions of desertification could prove useful in developing an improved understanding of the phenomenon, of how it is viewed from different disciplines and countries (and bureaucratic units), and of whether progress in combating it has in fact been as slow as many observers suggest [2],[3].

Satellite remote sensing has become a common tool of investigation, prediction and forecast of environmental change and scenarios through the development of GIS-based models [4]. With the advent of new high spatial and spectral resolution satellite and aircraft imagery, new applications for precision mapping and accurate monitoring have become feasible. In this context "vegetation" is interpreted as an indicative measure of the character, attributes or dynamics at a site. It is also an indicator of change, which enables scholars to identify and evaluate desired quality standards and to outline remedial actions for maintaining or improving the quality of the environment. Any change in the indicator may show unacceptable levels of negative impact or stress, or conversely a positive impact or reduction in stress [5].

The dryland region of Africa is facing serious climate variability including, frequent droughts compounded by poorly managed land and water resources that have resulted in degradation of natural resources caused by climate change. Desertification poses serious challenge to food security, sustainable livelihoods and socio-economic development in the dryland communities [6].

Affected countries, including Nigeria, have been making efforts to reverse the situation by implementing projects and programmes such as Great Green Wall for the Sahara and Sahel Initiative (GGWSSI). Across most states of Northern Nigeria, especially those bordering the Sahara the environment has, within a generation turned from lush to arid-like zones such as Kebbi, Sokoto, Zamfara, Katsina, Kano, Jigawa, Yobe and Borno states.

However, according to previous desertification studies carried out by [7], [8], [9], [10], and [11]. [12] shows either they covered a section of Nigeria with or without climatic data or a combination of both but never covered Sokoto State.

Although [13] studied vegetation trend in Sokoto from 1982 to 1986 and their study utilized a coarse resolution imagery and the time span was limited to 1986. In view of this, the research will bridge the gap in terms of utilizing better spatial and temporal resolution data from MODIS.

II. THE STUDY AREA

Sokoto State, Nigeria lies between latitudes 13^0 05′N and 13^0 83′ N and longitudes of 5^0 15′E and 5^0 25′ E (Fig 1). The area covers a land area of approximately 27,825km^2 and a population of about 3,702, 676 [14]. Sokoto is a city located in the extreme northwest of Nigeria, near the confluence of the Sokoto River and the Rima River [10].

The climate of Sokoto State is tropical continental and is dominated by two opposing air masses, tropical maritime and tropical continental. The tropical maritime is moist and blows from the Atlantic, while the tropical continental air mass which is dry, blows from the Sahara desert [10]. The tropical maritime predominates during rainy season while the tropical continental air mass predominates during the dry season. Much of the rain in Sokoto State is being experienced between June and September in the north and from May to October in other parts. The annual rainfall is between 500mm in the north and 1000mm to the south [15]. With an annual average temperature of 28.3°C, Sokoto is one of the hottest cities in Nigeria. However, the maximum daytime temperatures are generally under 40°C most of the year, and the dryness makes the heat bearable [15].

Moreover, the State is characterized by two extreme temperatures relative to its tropical position namely, the hot and cold seasons. The highest temperature during the hot season is experienced in the months of March and April. Between November and February, there is the prevalence of harmattan, characterized by very cold temperatures and dust laden winds often accompanied by thick fog of alarming intensity.

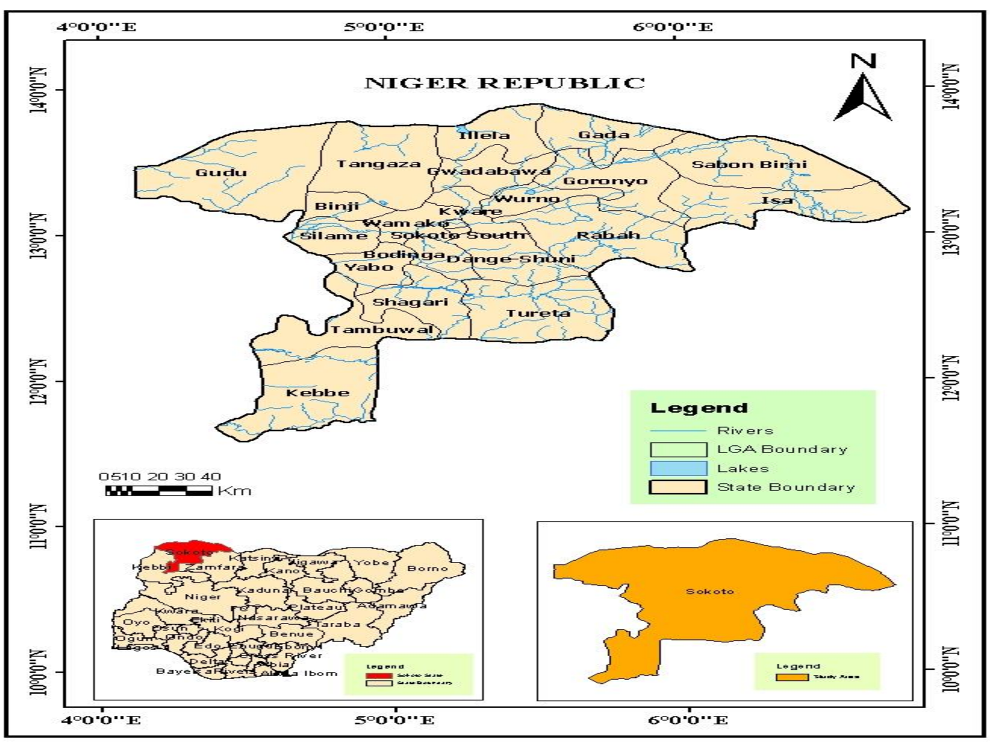

Figure 1. Map of the Study Area.
Source: Adapted and Modified from the Administrative Map of Sokoto Stata

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Sokoto State is drained by the Rima River and its tributaries, most of which rise in the south eastern part of the state and in the neighboring Kaduna State. While the Bunsuru and Gangere Rivers flow in a northerly direction, joining the Rima near Sabon Birni, the Sokoto, Zarnfara and Katsina tributaries, on the other hand, flow west wards to join the Rima [10].

The whole state lies within the Sudan Savannah. The vegetation belt is found in the north- west stretching from the Sokoto plains in the west, through the northern sections of the central highland. Ferruginous Tropical sandy soil with clayey subsoil are common, except along the flood plains of the river valleys where alluvial Hydromorphic soils predominate.

III. METHODOLOGY

The enhanced vegetation index (EVI) was developed as an alternative vegetation index to address some of the limitations of the NDVI. The EVI was specifically developed to:

A. Be more sensitive to changes in areas having high biomass (a serious shortcoming of NDVI),
B. Reduce the influence of atmospheric conditions on vegetation index values, and
C. Correction for canopy background signals.

EVI tends to be more sensitive to plant canopy differences like leaf area index (LAI), canopy structure, and plant phenology and stress than does NDVI which generally responds just to the amount of chlorophyll present. With the launch of the MODIS sensors, NASA adopted EVI as a standard MODIS product that is distributed by the USGS (see below).

EVI is calculated as

$$EVI = G \times \frac{(NIR - RED)}{(NIR + C1 \times RED - C2 \times Blue + L)}$$

Where NIR, RED, and BLUE are atmospherically-corrected (or partially atmospherically- corrected) surface reflectance, and C_1, C_2, and L are coefficients to correct for atmospheric condition (i.e., aerosol resistance). For the standard MODIS EVI product, L=1, C_1=6, and C_2=7.5.

EVI data from AQUA-MODIS satellite images of 1990-1994, 1995-1999, 2000-2004 and 2005-2009 were downloaded from http:ipdaac.usgs.gov as monthly synthesis set to derive EVI Statistics. MODIS EVI of 1990 to 1999 was received with a different projection to the one of 2000 to 2009.

The former has a projection of clabsha as a reference system, layer type is raster, data type byte, reference unit of kilometers (km), Minimum X Value of 1093.776001, Maximum X Value 8906.2236328, Minimum Y value 117.2200012, maximum Y Value 9882.7802737, Number of Rows is 1280 and a Number of columns is 1024 with a unit distance of 1 in contrast to 2000 to 2009 images that was obtained with a reference system of Lat long, and a reference unit of degree with 58 columns and 49 rows both images were converted to the same reference system of Lat long and a total of 58 columns together with 49 rows using reformat and project tabs together with grid referencing transformation in Idris software.

The EVI is more responsive to canopy structural variations, including leaf area index (LAI), canopy type, plant physiognomy and canopy architecture whereas Normalized Difference Vegetation Index (NDVI) is chlorophyll sensitive but the two vegetation indices complement each other in global vegetation studies and improve upon the detection of vegetation changes and extraction of canopy biophysical parameters.

About 250m resolution EVI images derived from MODIS land product were downloaded via http://ipdaac.usgs.gov/ as monthly synthesis sets, dating from January, 1990 to December, 2009 i.e. about 240 images.

The two hundred and forty (240) monthly Enhanced Vegetation Index (EVI) images at 250m resolution from Aqua MODIS Satellite System covering the study area from 1990 to 2009 were extracted and windowed in Idrisi32, release2 Geographical Information System (GIS) and image processing software within a GIS environment. All data were converted into ASCII format and imported into EXCEL where they were re-composed into annual mean for each year and later to 5years interval thereby getting four Mean annual images.

These were further re-converted and exported back to the idrisi32, release2 software and the data was finally utilized in a GIS environment and analyzed.

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IV. RESULTS AND DISCUSSION

Results Shows the output of the study area EVI trend images of 1990-1994, 1995-1999, 2000-2004 and 2005-2009 quasi-five years' periods in Figures 2, 3, 4 and 5 respectively. The southern part of the state clearly shows a relatively high vegetation biomass with dark green colour that might result to more intensive agricultural activity compares to the northern part with moderate to low vegetation biomass. The trend EVI scale values of low and high indicates the level of vegetation biomass within the study area inform of light to dark green colours. It confirms that the northern part of the state is clearly with low vegetation coming down to a moderately sparse vegetation around the central region of the state to the areas of increasing vegetation biomass cover around the southern part of the state. The high vegetation density could also be as a result of low population density in the area which could also mean less anthropogenic activities on the environment.

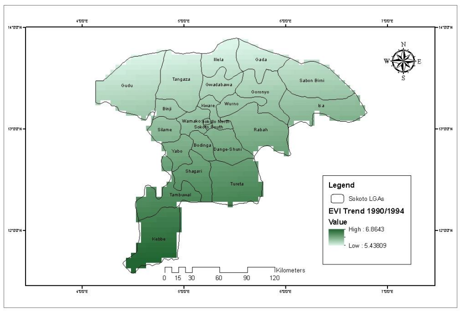

Figure 2. Trend EVI Image of 1990-1994

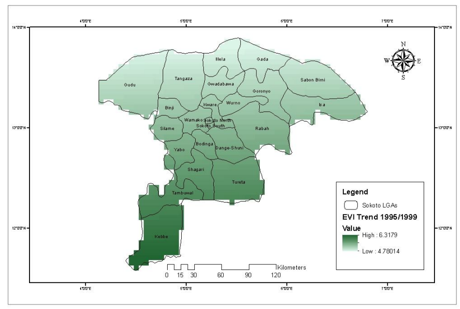

Figure 3. Trend EVI Image of 1995-1999

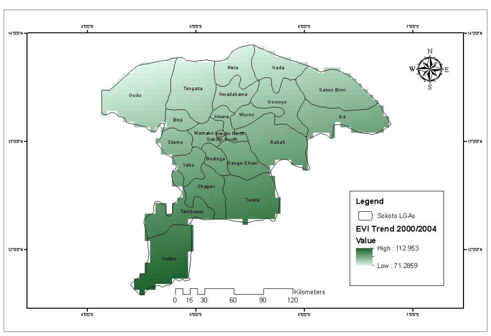

Figure 4. Trend EVI Image of 2000-2004

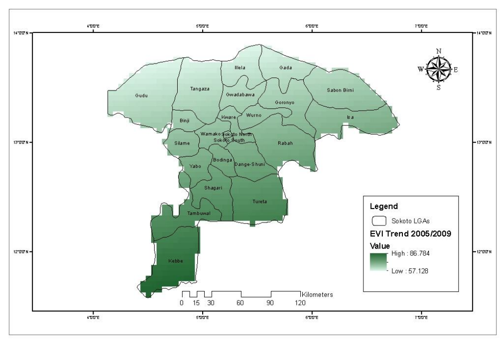

Figure 5. Trend EVI Image of 2005-2009

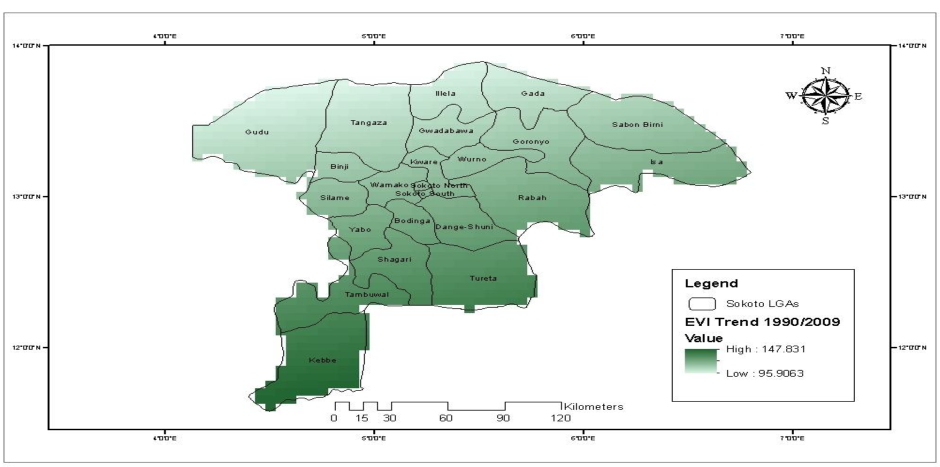

Figure 6. Overall Trend EVI Image of 1990-2009

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Figures 6 indicates the overall trend of vegetation within the study area dated 1990–2009 (20years). A downward trend of vegetation greenness within the study area was observed from the north western area of the map moving diagonally to the extreme southern part of the state. The implication of this trend is that with time the vegetation trend will continue to diminish and the direction of vegetation degradation maintains a northwest to southeast direction.

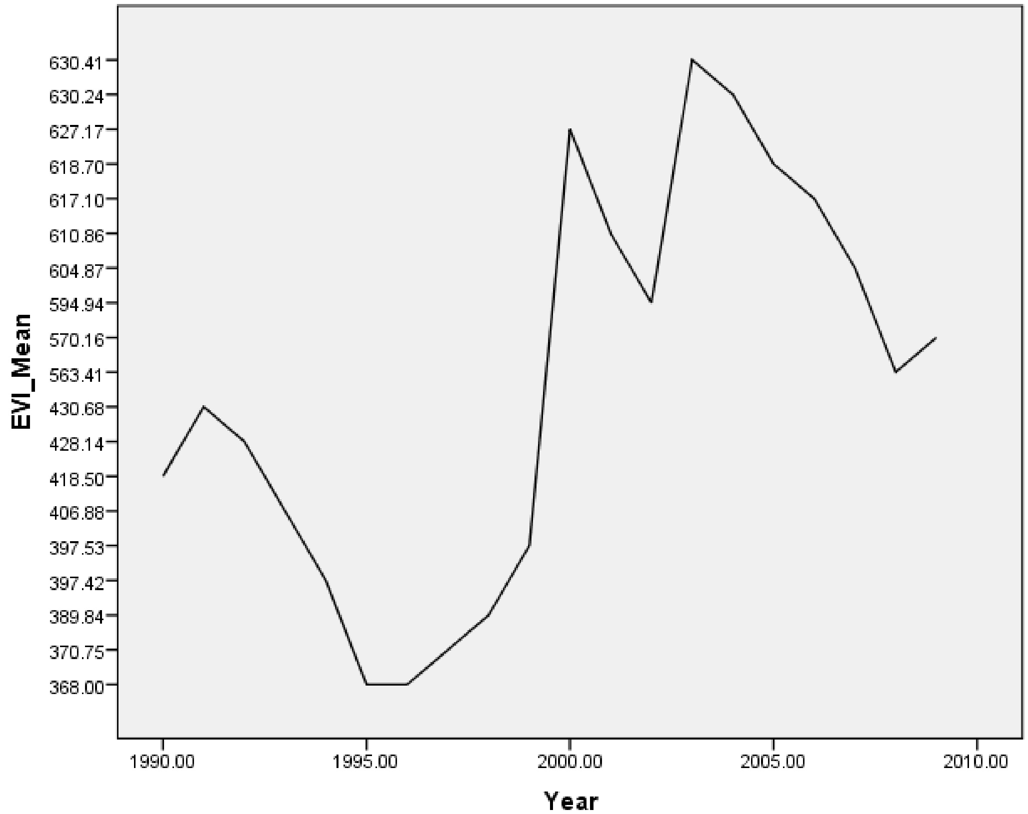

Figure 7. Overall Trend in Vegetation EVI (1990-2009)

Figure 7 is a line graph of vegetation EVI values from SPSS IBM statistical software the results indicate the trend with a general down shift trend in EVI Values in all years as presented in the above figure though the EVI indicate its peak in the year 2005.

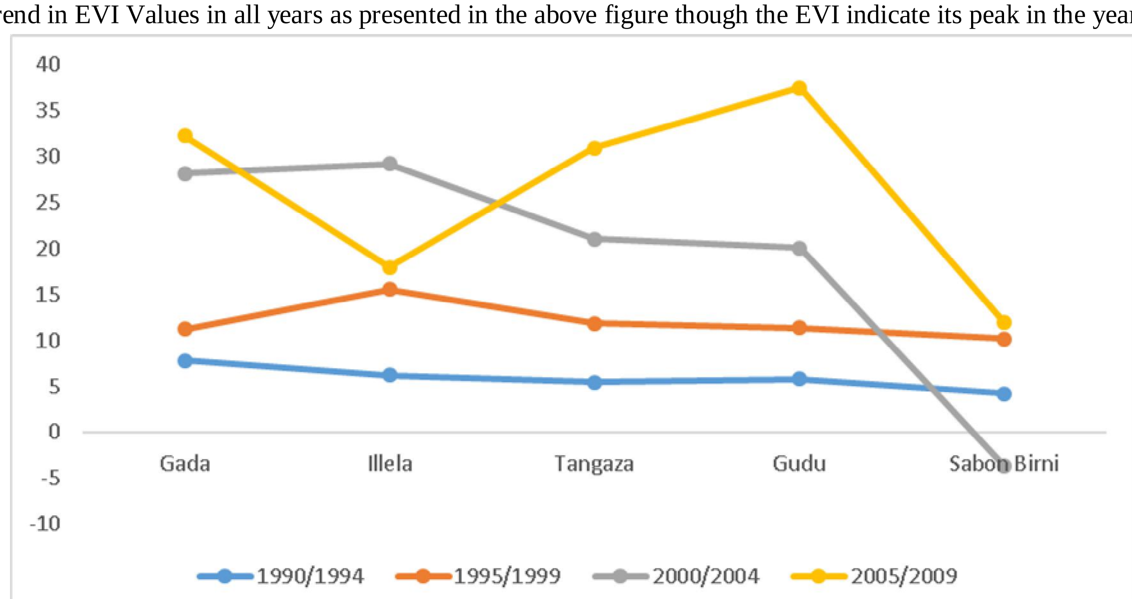

Figure 8. Quasi-five years' periods' coefficient of variation (1990-2009)

Figure 8. the quasi-five years' periods of the coefficient of variation of the selected sites within the study area. The results indicate an up and downward trend of unequal pattern coefficient of variation in 20 years within the selected sites. The highest was in Gada in the first five years, followed by Illela in the second and the third five years then Gudu in the last five years of the study time. However, the first and the second five years maintain a down ward trend of the same pattern while the third and the last five years maintained an upward and downward trend.

V. CONCLUSION

The results obtained from the study reveals that the EVI AQUA-MODIS data can successfully monitor and identify areas under the several process of desertification. The EVI time trend clearly recognizes the areas with long- and short-term vegetation degradation indicating the ongoing desertification process. The study reveals that about half of the Local Government found in the northern region of the state have undergone a declining trend of vegetation cover indicating the ongoing process of desertification. Also, this remote sensing-based technique has become helpful to identify areas under the process of greening as an impact of anthropogenic effect. The declining trend in vegetation explicitly supports the information on encroachment of the Sahara Desert. The study reveals that the global availability of coarse scale, multi- temporal data archives of MODIS EVI have great potential to answer the questions arrived from long -and short- term vegetation changes.

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