Spatio-temporal Patterns of Normalised Difference Vegetation Index Trends in Parts of Northern Nigeria

Mustapha Zakariya Karkarna

Department of Environmental Management, Bayero University, Kano, Nigeria

Corresponding email: mzkrkarna@gmail.com

Abstract

Vegetation cover change has been, and still is a problem in Nigeria. The main objective of the study is to assess Spatio-temporal variability of vegetation cover in parts of Northern Nigeria using remotely sensed SPOT VEGT data sets. The data covers between 1999 and 2018 and consists of 10-day synthesis NDVI (S10) data. The maximum value composite technique was used to remove atmospheric moisture, cloud and simple haze in the imageries. The 10 days, monthly and later annual composites were generated in image calculator tool in IDRISI selva 17.0 software. Time series trend analysis was performed to determine the Spatio-temporal trends of the annual NDVI. The annual composites were imported into GIS environment to analyse spatial variations of NDVI in the study area. The composite of 2011 was noisy hence was not used in the analysis. The result indicated that NDVI is characterised by moderate Spatio-temporal heterogeneity. The relatively high value of NDVI (above 0.4) is mainly distributed in Jos East, Riyom, Bokkos which are located south of the area while the low value (slightly below 0.3) is obtained in Gamawa Gurri and Ringim. Furthermore, significant positive trends in overall greenness were observed in the southern region while negative trends are also present in the north. This study recommended studies on vegetation dynamics (with climate and anthropogenic influences) with high-resolution satellite data to remove the uncertainties associated with coarser resolution remote sensing-based vegetation data.

Keywords: *vegetation cover, Spatio-temporal, time-series imageries, NDVI*

Introduction

Everyone in the world depends on natural ecosystems to provide the resources for a healthy and secured life (Millennium Development Goal, 2010). In most countries of sub-Saharan Africa, people depend strongly on ecosystem services obtained from natural resources for sustenance. They provide food, animal feed, fuel, fibre and raw materials. However, unprecedented land-use changes resulting from the needs of a burgeoning population, economic development and global markets, and exacerbated by land governance issues locally, continue to cause depletion and degradation on an unprecedented scale (United Nations Environmental Programme, 2012).

Other drivers include a rapid increase in household numbers, often manifested as urban sprawl, and resultant higher per capita resource consumption pose serious challenges to biodiversity (Liu, et al., 2001) as well as wild biotic resources especially vegetation (Osemeobo, 1993; David, 2008).

Vegetation is the primary producer of any ecosystem and one of the most important components on earth ecosystems that governs all forms of life (Christie et al., 2012), thus changes in their growth and distribution in any region affect not only the environment but also the socio-economic activities. The unprecedented rate of plant species loss has significant impact the ecosystem wellbeing (Chuai et al., 2013).

In Nigeria, increase perturbation of natural vegetation cover as well as forest fragmentation by anthropogenic activities e.g government road projects, fuelwood and timber consumption, population increase, and livestock production and deforestation have been quite instructive in the new vegetation cover characterization observed throughout the country (David, 2008). Osunmadewa et al. (2016) pointed out that there is a significant shift in land use land cover across the Niger state. This trend most affects vegetation in countries such as Nigeria where uncertain economic situations often conflict with environmental preservation.

Several studies have used remote sensing to assess vegetation change in the Sahel and Northern Nigeria at various scales. Some of these works that continue till today were on vegetation status, health, distribution and/or dynamics. Recent works included Hountondji et al. (2006), (Garba, 2008), (Adeofun et al., 2011), (Badamasi, 2014), (Hula and Ukpong, 2013), (Dardel et al., 2013), (Osunmadewa et al., 2015) most at local spatial scale (Brandt et al., 2014; Brandt et al., 2016) or at the regional scale (Danjuma, 2017) which focused basically on the Sahelian vegetation. However, there are several neglected ecosystems with relative importance and suffer from species dynamics in sub-Saharan Africa.

One such is northern Nigeria which has suffered decades of marked changes in land use and land cover in all ecosystems (Zayyana, 2017). As indicated by, Spatio-temporal changes in NDVI has been used as a proxy for determining and analyzing the long-term trends in vegetation dynamics in an environment.

Northern Nigeria being threatened by numerous natural and anthropogenic causes requires attention by researchers, hence the main aim of the study is to apply remote sensing techniques (NDVI-algorithm based measure of the quantitative value of vegetation greenness) to assess Spatio-temporal dynamics of vegetation in the area. This work differs from others for its ability to use the versatility of remotely sensed data to map out trends of NDVI from 1998 and 2018 which is not covered by most studies mentioned above.

Study Area

The study area focused on northern Nigeria where significant environmental change has taken place. The region is located between Latitude 8°24'N and 12°33'N and Longitude 8°32'E and 10°34'E. The climate of the region is described as the tropical wet and dry type and coded Aw by Koppen. Climatic elements vary greatly from the southern tip through the central and extreme northern parts of the region.

Being a 'Sudanic' type (van Apeldoorn, 1981), the climate has one rainy season of 2½ - 5 months to the north around Jigawa and 7 months in the Plateau States respectively. Temperatures are high throughout the year in the region and range between 39°C and 40°C in the north around Jigawa while Plateau has a near temperate climate with an average temperature of between 13°c to 22°c.

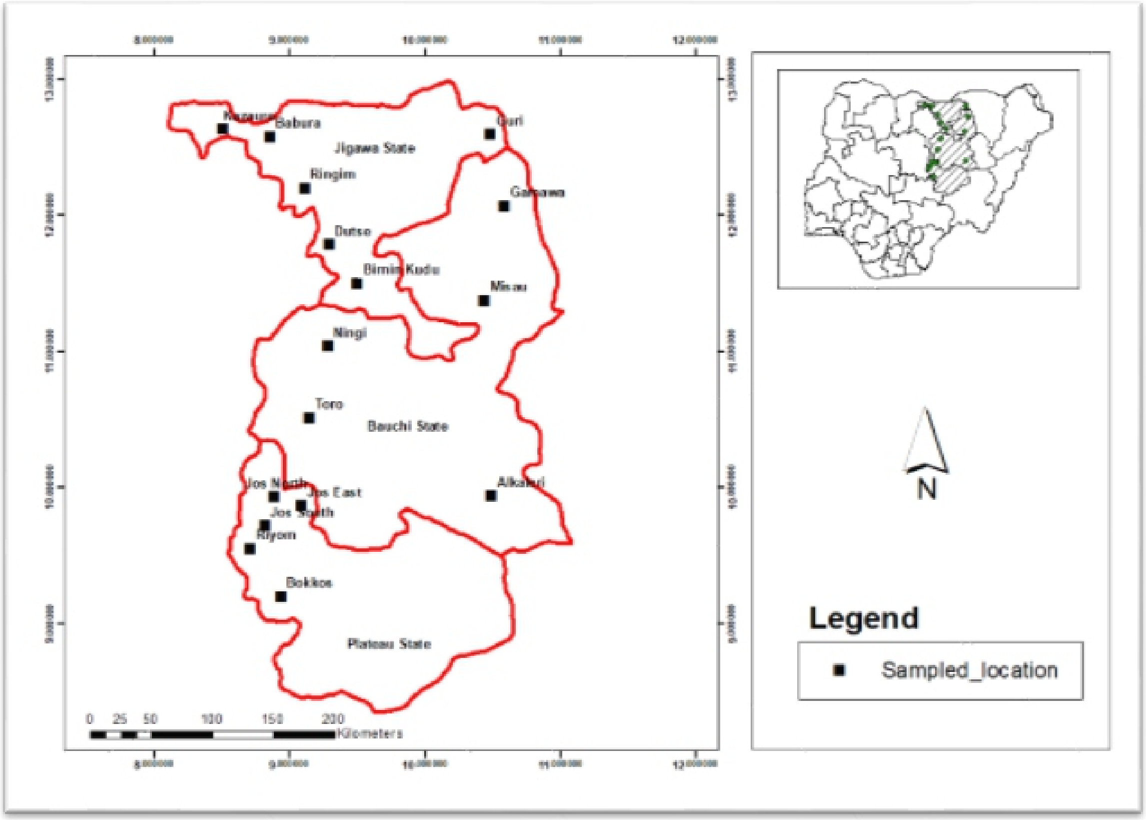


Figure 1: Study Area and Sampled Locations

Northern Nigeria falls within the Sudan Savanna zone of the country which is distinguished by the large expanse of grasslands with widely spaced trees of varying heights and diversity. Based on that, three vegetation belts covered the study area namely Sahel Savanna (Semi-arid Zone) in the north – east corner of the region stretching from approximately latitude 12°N, Sudan Savanna (Dry Sub – Humid Zone) at the middle and the Guinea Savanna (Humid zone) at the south. The Sudan Savanna is characterized by abundant short grasses of 1.5-2m and few stunted trees hardly above 15m while the Guinea Savanna. Some of the most frequent species in the north and middle of the region are *Hyphaene thebaica, Parkia biglobosa, Adansonia digitata, Faidherbia albida, Tamarindus indica, Borassus aethiopum, Prosopis africana, Balanite aegyptiaca* and *Acacia nilotica*. Many exotic species including *Acacia senegalensis, Azadirachta indica, Cassia siammea, Dolonix regia,* and

Eucalyptus camaldulensis dominate the southern part of the region.

Materials and Methods

Remotely sensed time-series SPOT VEGT dataset of 1998 to 2018 were downloaded from the Belgian Research Institute VITO web at http://free.vgt.vito.be. The data set is free at 1km^2 resolution. It consists of 10-day synthesis NDVI (S10) data.

Several methods e.g Maximum Value Composite (MVC) have been described that remove noise caused by cloud contamination, aerosol concentrations, atmospheric perturbations or variable solar zenith angles from time-series data (Swets et al., 1999). MVC technique is selected because it effectively eliminates: the undesirable in a sequence of solar zenith angle and viewing angle, the concentration of water vapour, aerosols and cloud-free conditions in time series imageries (Holben 1986; Atzberger and Eilers, 2011). One advantage of MVC which this study utilised is that only the highest NDVI value in a predefined compositing period (typically: 10 days) is retained (Danjuma 2017).

The maximum value composite technique was used to remove atmospheric moisture, cloud and simple haze in the SPOT VEGT NDVI imageries of 1998 and 2018. The original 10-day SPOT NDVI composite data covering the period from 1998 to 2018 were aggregated to monthly data in the image calculator tool in IDRISI selva 17.0. Observations with the highest NDVI values were selected and the new image created (monthly maximum value composites). The monthly maximum value NDVI composites were generated from 591 (10-day synthesis NDVI) imageries covering April 1998 to December 2018. The monthly images were used to generate annual composites using the same method. The formula for this analysis is:

$$NDVIi = \max(NDVIij) \quad \text{Eq. 1}$$

where NDVIi is the NDVI of the i-th month and NDVIij is the NDVI of the j-th 10-days in the i-th month.

Time series trend analysis was performed to determine the trends of NDVI from 1998 to 2018 in the study area because it facilitates the characterization of inter-annual and intra-annual variations of the vegetation canopy in remote sensing (Bradley et al., 2007). It also determined trends of NDVI and its derivatives by linear regression (Stow et al., 2003).

The processed annual composites were imported into GIS environment and using ArcGIS 10.1 version was used in analysing spatial variations of NDVI in the study. The

NDVI values were extracted directly from the images. The data of 2011 was noisy hence was not used in the analysis.

Result and Discussions

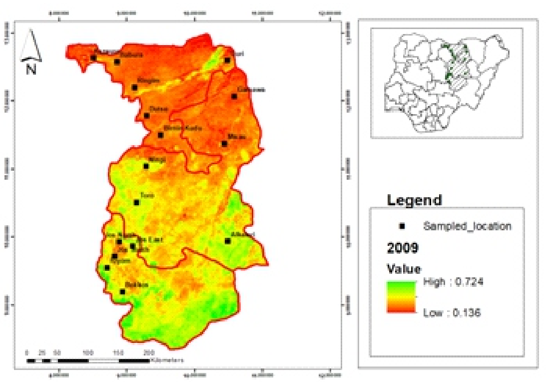
From the extracted NDVI, the study area is characterised by moderate spatial heterogeneity. Based on the understanding that NDVI range from -1 to +1, the findings of this study showed that it is generally low in the area. As indicated in Table 1, the relatively high value of NDVI (above 0.4) is mainly distributed in Jos East, Riyom, Bokkos which are located south of the study area while the low value (slightly below 0.3) is obtained in Gamawa Gurri and Ringim. It was surprisingly low in Jos north owing largely to the mining of tin in several parts of the area in line with Haruna and Jiya, (2011) who reported similar findings in the area. The high NDVI regions are covered by moderate vegetation cover and large shrubby grassland which contributed to the measure of green vegetation in the area.

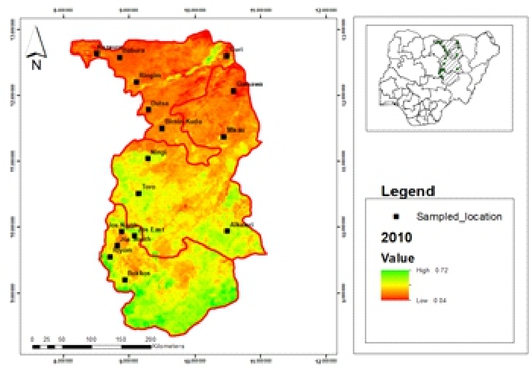
The areas with low NDVI value are virtually dry and located in the north of the study area. These areas consist of mainly dispersed and degraded vegetation which has suffered from seasonal drought and erratic pattern of rainfall. Most of these areas are corridors of fuelwood extraction and overgrazing in the country. Shedding of leaves by deciduous plants (mostly trees) and mortality of herbaceous species during drought periods may also influence low annual NDVI values in the study area as the area is prone to widespread climate-related local extinctions. This was already indicated in (Wiens, 2016) that local extinction of plant and animals is now a global phenomenon.

The finding of this study on the influence of climate on vegetation in the area corroborates UNEP (2012) that reported that climatic factors such as rainfall and relative humidity have a dominant influence on vegetation growth and composition in sub-Saharan Africa. The finding is also in line with several studies including FORMECU (1998), Vanacker et al. (2005) and Danjuma (2017) who reported that vegetation in sub-Saharan Africa and indeed Nigeria reflects steep south to north decline in rainfall. Danjuma (2017) however, maintained that low NDVI areas may be affected by limited moisture and anthropogenic activities (deforestation) which could lead to loss of plant biomass and mortality of herbaceous species and shrubs.

Time-series analyses based on moderate and coarse resolution satellite data are widely used for monitoring vegetation (Brandt et al., 2014). This study considers annual NDVI time-series an indicator of vegetation productivity based on the premise that with such data, trends and localized abrupt changes, or discontinuities, resulting from disturbance events can be observed. From 2009 to 2019, NDVI of the study area showed a nuanced trend (Figure 1 a-i). The result showed a remarkable increase in NDVI between 2013 and 2017 as well as a decrease in 2018. The highest value was obtained in 2015 while the lowest in 2012. This trend is strongly connected with fluctuations in precipitation. However, not all increases in vegetation index are related to climate. Similar inferences have emerged in the previous study (Li et al., 2016).

Furthermore, the NDVI values of the study villages were mapped to show good visual indicators of vegetation vigour of the area. The maps depicted a discerning pattern with varying colours as green and light green for high vegetation (0.3 above), yellow for moderate value (0.25) and red for low vegetation (below 0.2).





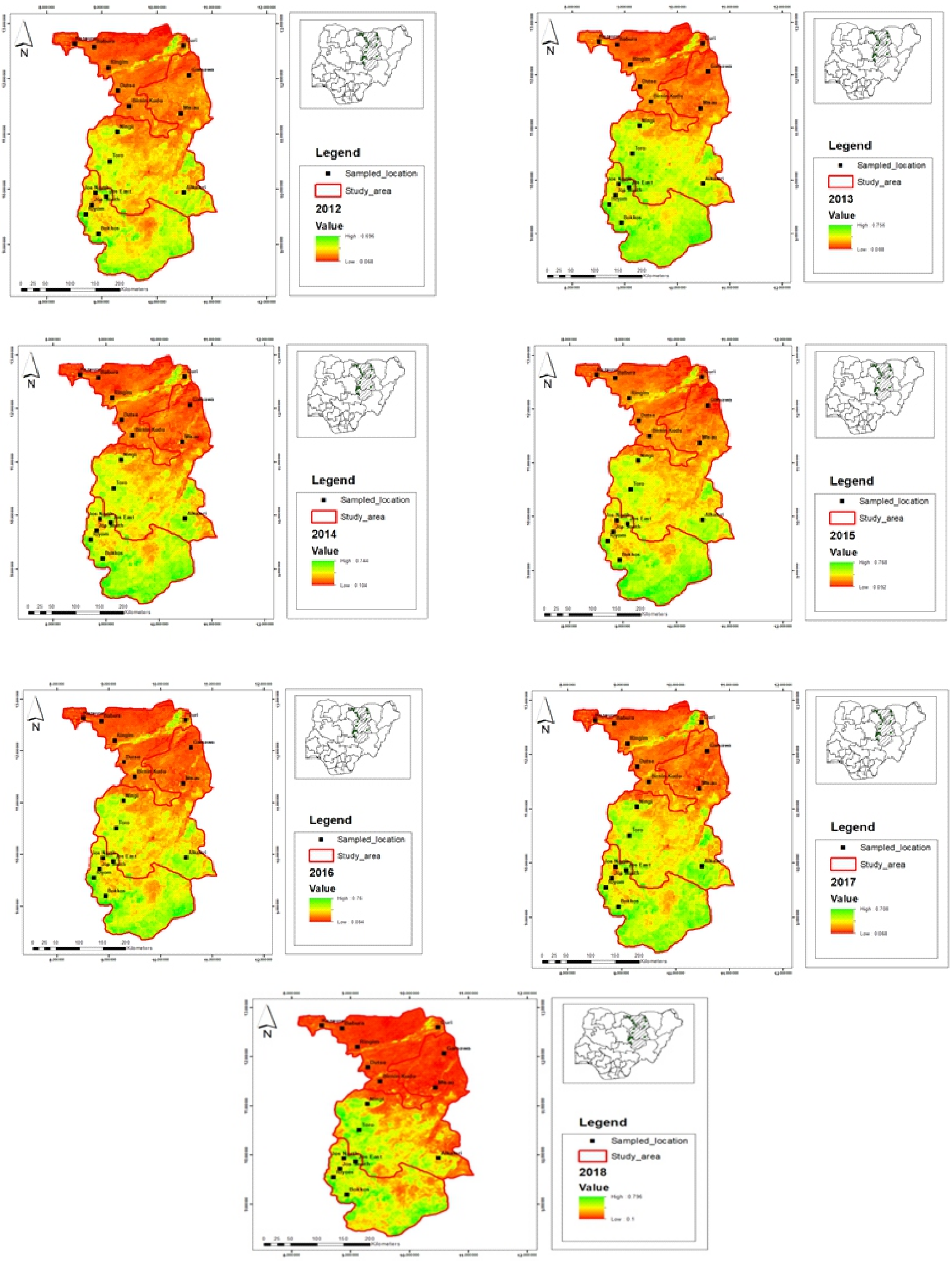


Figure 1 (2009 to 2018): Spatial Patterns of NDVI

Figure 1 (2009 to 2019) covers the period between 2009 and 2018 except 2011 as indicated in the methods section. In this study, vegetation greenness was observed in variations in minimum and maximum NVDI as observed in the selected locations. As indicated the Figure 1 (2009 to 2018), significant positive trends in overall greenness were observed in the southern region while negative trends are also present in the north (Fig. 1-2009 to 2018). Vegetation mapping from satellite images is possible because plants only use the light of certain wavelengths for photosynthesis (Meneses-Tovar, 2009).

Conclusion and Recommendations

From the foregone, the vegetation of the area has relatively low biomass which was reflected in the low NDVI (0.5) because of more herbaceous plants which are characterized by a short life-span (months or years) and large inter-annual variability driven by water availability and anthropogenic disturbances such as deforestation and overexploitation of forest resources. The following recommendations were drawn from the conclusion;

1. Further studies on vegetation dynamics to climate and anthropogenic influences are still needed with high-resolution satellite data to remove the uncertainties associated with low-resolution remote sensing-based vegetation data. This will provide detailed and accurate information for environmental policymaking and decision.

2. Large scale restoration of plants is recommended especially in the northern part of the study area. This can be achieved through a combination of investments in the tree and non-tree technologies and the use of information technology. The government can tap from the available easy-to-use IT applications to provide adequate information to field officers in charge of vegetation restoration.

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