

Monitoring Vegetation Change using Normalized Different Vegetation Index in Semi-Arid Regions of North-western Nigeria: Arewa Local Government Area

Kaoje, I. U.¹, Shera I. M.¹, Tukura, B. A.¹, and Mansur, A. S.²

¹Department of Geography, Federal University Birnin Kebbi, Kebbi State, Nigeria.

²Department of Physical Planning and Development, Federal University Birnin Kebbi, Kebbi State, Nigeria.

Corresponding author's e-mail: ismail.kaoje@fubk.edu.ng

ABSTRACT

The declining trend of natural vegetation is of great concern to humans especially in the semi-arid region of northern Nigeria as global warming, desertification and increased deforestation impact negatively on the vegetation cover and threaten the livelihoods of over 40 million people. This paper, therefore, aims to identify the change pattern of vegetation/green coverage of the Arewa Local Government Area using Normalized Difference Vegetation Index (NDVI) techniques. Two Landsat images for January 1991 and January 2021 were acquired from USGS Glovis interface for the NDVI analysis. The NIR band and RED band imagery of 1990 Landsat 5 TM (Thematic Mapper) and 2021 Landsat 8 OLI (Operational Land Imager) both with a spatial resolution of 30 meters, were used in this study. The results visualisation was based on Remote Sensing (RS) and Geographical Information System (GIS) techniques. The result shows an increase in total vegetation cover with a gain of about 128.88 km² from 1991 to 2021, attributed to increased afforestation and irrigated farming. However, there is a significant decrease in dense and healthy vegetation cover with a loss of about 146.98km². The study concludes that a reduction of healthy and dense vegetation in a semi-arid area as observed in the study area strongly suggests desertification as the study has provided indicative data at the local spatial scale. However, areas for further study will include enhancing the ability of NDVI to forecast future changes in vegetation in the study area for effective future monitoring of vegetation trends.

Keywords: Desertification, Vegetation, NDVI, GIS, Remote Sensing

1. INTRODUCTION

The need to detect vegetation cover change to monitor processes such as desertification synoptically has led to the increasing use of multi-temporal imagery, a sequence of images of landscapes taken at regular intervals over time (Genesis *et al.*, 2014). The advancement of Geographical Information System (GIS) and widespread availability and affordability of satellite data have allowed earth scientists to examine vegetation degradation on a global, continental and regional basis (Thomas and Elias, 2014). However, field data currently available make prediction of

large-scale vegetation changes generally difficult because such data are traditionally collected at small spatial and temporal scales and vary in their type and reliability (Muoghalu, 2021). Therefore, satellite imagery has become a “goldmine” in the context of vegetation degradation analysis (Thomas and Elias, 2014).

Monitoring terrestrial ecosystems is routinely achieved with remote sensing measurements processed into spectral vegetation indices, one of which is the normalized difference vegetation index (NDVI), an index of plant greenness or

photosynthetic activity (Genesis *et al.*, 2014). It is a commonly used and easily calculated satellite image-based proxy for vegetation productivity (Kunkel, 2011). The NDVI is a simple numerical indicator (Demirel *et al.*, 2010; Ricotta *et al.*, 1999) that is related to Photosynthetically Active Radiation (PAR). It basically measures the capability of leaves (Malo *et al.*, 1990) and gives a measure of the vegetative cover on the land surface over wide areas. This index positively correlates with photosynthetic activity, vegetation cover, biomass, and Leaf Area Index (LAI) (Munyati and Sinthumule, 2014).

According to Audu and Adie (2018), states in Northern Nigeria are threatened with desertification, the process by which dryland ecosystems are continually degraded by the removal of tree and plant cover, mostly by human activity. Desertification threatens the livelihoods of some 40 million people in northern Nigeria (Unah, 2017). The regions affected are key areas of livestock rearing and agricultural production. Thus, the need to monitor vegetation cover degradation and desertification to develop preventive mechanisms (Usman *et al.*, 2013; Unah, 2017; Aleiro *et al.*, 2022). Aleiro *et al.*, (2022) observed that the major drivers of vegetation degradation leading to desertification are the pressing need for more farmlands, fuel wood and endemic poverty. The impacts include land and vegetation degradation and the loss of biodiversity.

In Kebbi State, various studies have been carried out to examine changes in vegetation conditions using different techniques. For example, Usman *et al.*, (2013) in their study of the spatiotemporal assessment of land cover change and vegetation degradation using remote sensing in Kebbi State, Nigeria, found that the Sahara Desert is encroaching and advancing southwards at the rate of 0.6 percent every year. The study recommended raster-based NDVI analyses

for monitoring vegetation cover changes in the Sahelian region of northern Nigeria.

Even though NDVI is a commonly used technique for vegetation cover assessment, there is a dearth of information on NDVI studies in relation to drought, desertification and vegetation degradation in the study area (Adegboyega *et al.*, 2016). Therefore, the paper aims to identify changes in vegetation pattern and decline in green coverage of the Arewa Local Government Area, Kebbi State, Nigeria. Specifically, the objectives include assessing the magnitude and rate of vegetation/green coverage through the NDVI technique based on Remote Sensing (RS) and Geographical Information System (GIS). This is with the view to establishing a vegetation/green coverage change pattern and desertification trend for the study area.

2. MATERIALS AND METHODS

2.1 Study Area

Arewa Local Government Area is located in Kebbi State, Nigeria. The region is located between latitude 12° 10'N - 13°10'N and longitude 3°20'E - 4°40'E (see Figure 1). With a population of 184,030 (Census, 2006), it has an area of 3,901 km² and shares a boundary with the Republic of Niger. The region has two distinct seasons of wet and dry. The dry seasons feature extremely hot weather, with the average temperature of the area estimated at 34°C. The average humidity of the area is put at 24%, while the landscape is characterized by dry, arid plains with a litter of hills and other elevations. The vegetation cover of the study area is mostly classified as semi-arid vegetation consisting of shrubs or grasses with varying sizes (less than and greater than 3m), woody perennial plants with persistent woody stems without any defined main stem, less than 5m high (Usman *et al.*, 2016). The region is threatened with desertification, the process by which dryland ecosystems are continually degraded through anthropogenic factors.

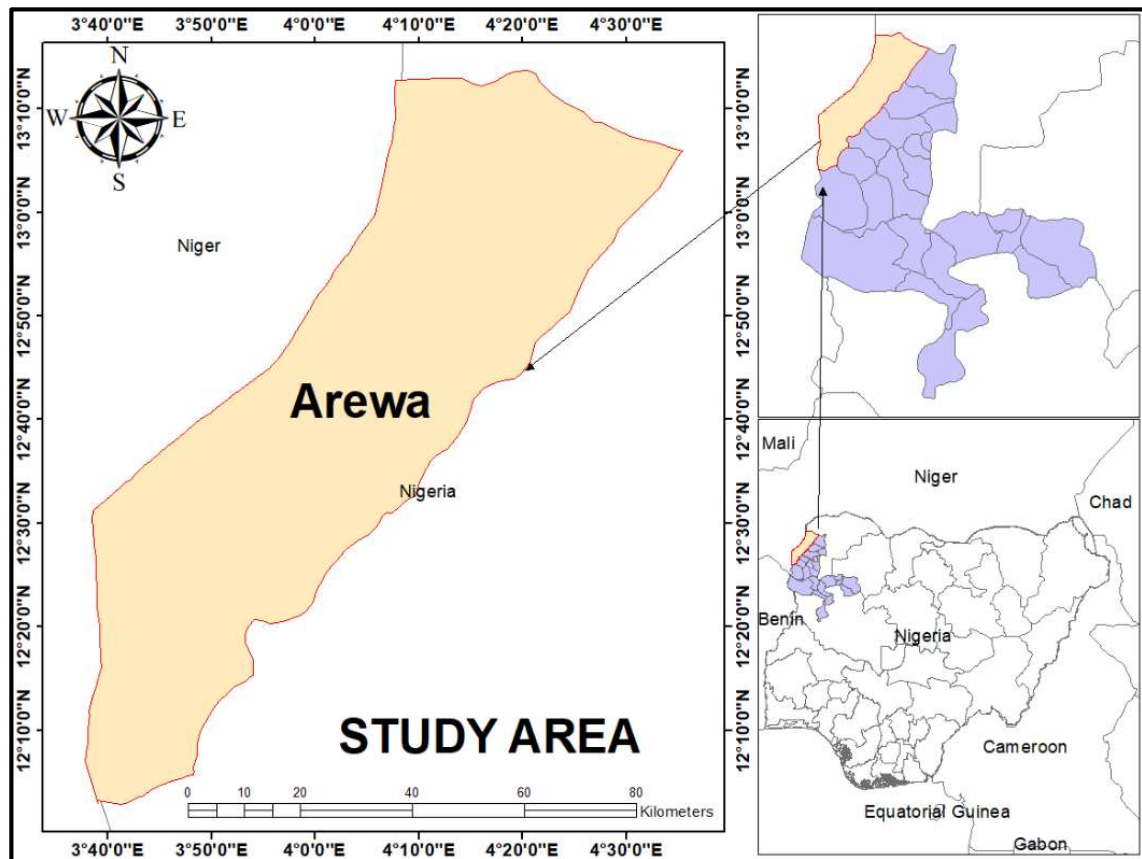


Figure 1: Geographical Location of Study area

1.2 Assessing Changes in Vegetation/Green Coverage in the Study Area

The change pattern in vegetation/green coverage for the study area was determined using Normalized Difference Vegetation Index (NDVI) techniques. The NDVI is a commonly used and easily calculated satellite image-based proxy for vegetation productivity (Scanlon, 2002; Kunkel, 2011). The index shows positive correlation with photosynthetic activity, vegetation cover, biomass, and Leaf Area Index (LAI) (Schmidt *et al.*, 2000).

Landsat data is one of the most important and accurate datasets for understanding the global land cover status, freely provided by the United States Geological Survey (USGS). Two Landsat images were downloaded from www.glovis.usgs.gov for January 1991 and January 2021 to detect changes in vegetation cover in the study area. The NIR band and RED band images of 1990 Landsat 5 TM (Thematic Mapper)

and 2021 Landsat 8 OLI (Operational Land Imager) both with spatial resolution of 30 meters, were used in this study.

The NDVI algorithm is computed by subtracting the red reflectance values from the near-infrared and dividing them by the sum of near-infrared and red bands (after Tucker, 1979).

$$NDVI = (NIR - RED) / (NIR + RED)$$

Where, NIR represents the spectral reflectance in the near-infrared band while RED represents the red band.

Surfaces and corresponding NDVI values are shown in Table 1. NDVI values range from -1 to 1. Very low values of NDVI correspond to barren areas of rock, sand, and water body. Moderate values represent

Table1: Surfaces and Corresponding NDVI Values

Range of NDVI Value	Name of the Objects
-1	Water Body
0	Bare Soil, Rock, Sand and
0.1-0.2	Shrub and Grassland
0.2-0.3	Sparse and Unhealthy Forest
>0.3	Dense and Healthy Vegetation

shrub and grassland, while high values indicate temperate and tropical rainforests. Bare soil is represented with NDVI values closest to 0, while water bodies are represented with negative NDVI values (Karaburun, 2010).

Data was processed using ArcGIS 10.5 software. Separation of each band is essential to creating NDVI from the multispectral remote sensing image. For the extraction of vegetation features, the NDVI method is used at four different threshold values such as 0.2, 0.3, 0.4 and 0.6 through the observation of maximum and minimum NDVI values. The final layout map of three

different categories of NDVI values is created manually using Arc GIS 10.5 software. Finally, to investigate NDVI values, it is categorized into four classes of 0.2-0.3 NDVI value represent shrub and grassland, 0.3-0.4 indicate sparse and unhealthy forest, whereas >0.4 NDVI value represents healthy and dense vegetation. Here, the study uses remote-sensing techniques to determine the extent of vegetation loss and desertification over a period of 30 years.

3. RESULTS AND DISCUSSION

The NDVI values as shown in Figure 2 indicate that the range of NDVI values in

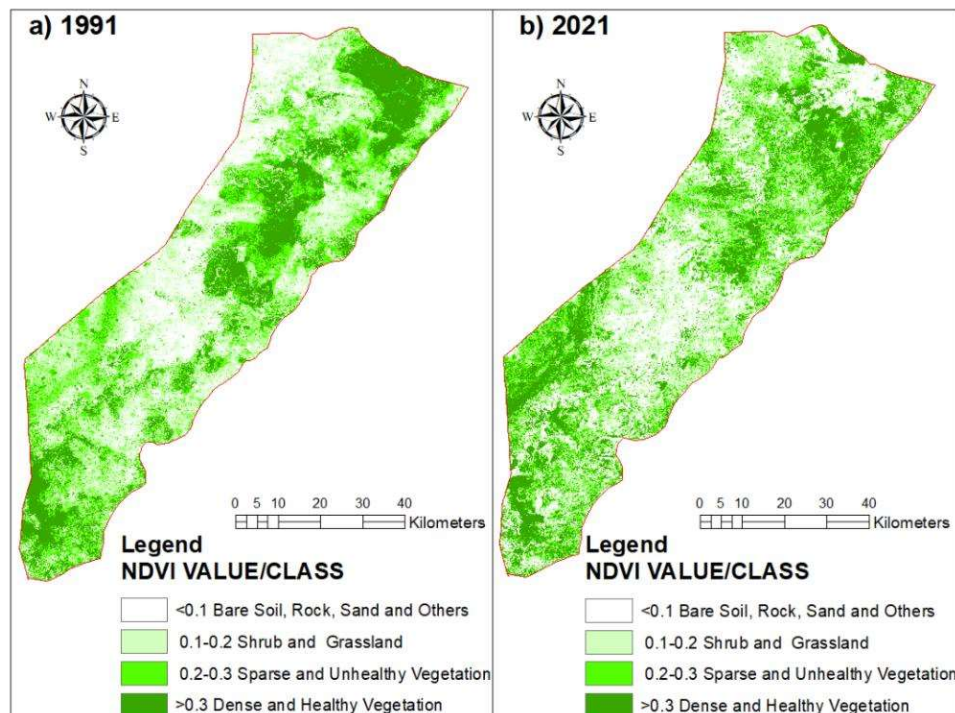


Figure 2: NDVI map of the study area in 1991 (a) and 2021 (b)

the 1991 image is from -1 to 0.39 and in the 2021 image, from -1 to 0.35. As shown in Figure 2, the NDVI value of >0.3 indicates dense and healthy vegetation. The value of 0.2-0.3 indicates sparse and unhealthy vegetation, and the value of 0.1-0.2 is for areas of shrub and grassland. Non-vegetation areas are represented with a value of <0.1 . These are areas with bare soil, rock, sand, built-up areas and water bodies.

The changes in vegetation pattern are shown in Table 2 and Figure 3. The area covered by vegetation was 3746.77km² in 1991 and 3875.65km² in 2021, indicating a gain of about 128.88km² in vegetation cover. This may be attributed to increased afforestation and cultivation through

irrigation. However, there is a significant decrease in dense and healthy vegetation cover with a loss of 146.98km². Field survey showed that the increase in vegetation cover is due to an increase in irrigation activities within the local communities.

In 1991, dense and healthy vegetation cover was 1258.42 km², a 25.45% share of the total land cover of the area. In 2021, the dense and healthy vegetation decreased to 1111.44 km², a 2.9% decrease from 1991. Although the decrease in healthy and dense vegetation is not rapid, the categories of other vegetation increase are either unhealthy vegetation or grass/shrub. The result also shows a gradual conversion of dense and healthy vegetation to unhealthy

Table 2: Changes in Vegetation Cover from 1991 to 2021

	1991			2021		
	COUNT	Area (KM ²)	%	COUNT	Area (KM ²)	%
Bare Soil, Rock, Sand	1301807	1177.93	23.79	1165960	1049.36	21.31
Shrub and Grassland	1478899	1334.01	27.03	1686882	1518.19	30.83
Sparse/Unhealthy Vegetation	1299025	1154.34	23.74	1384467	1246.02	25.30
Dense/Healthy Vegetation	1392511	1258.42	25.45	1234933	1111.44	22.57
Total	5472242	4924.7	100	5472242	4925.07	100

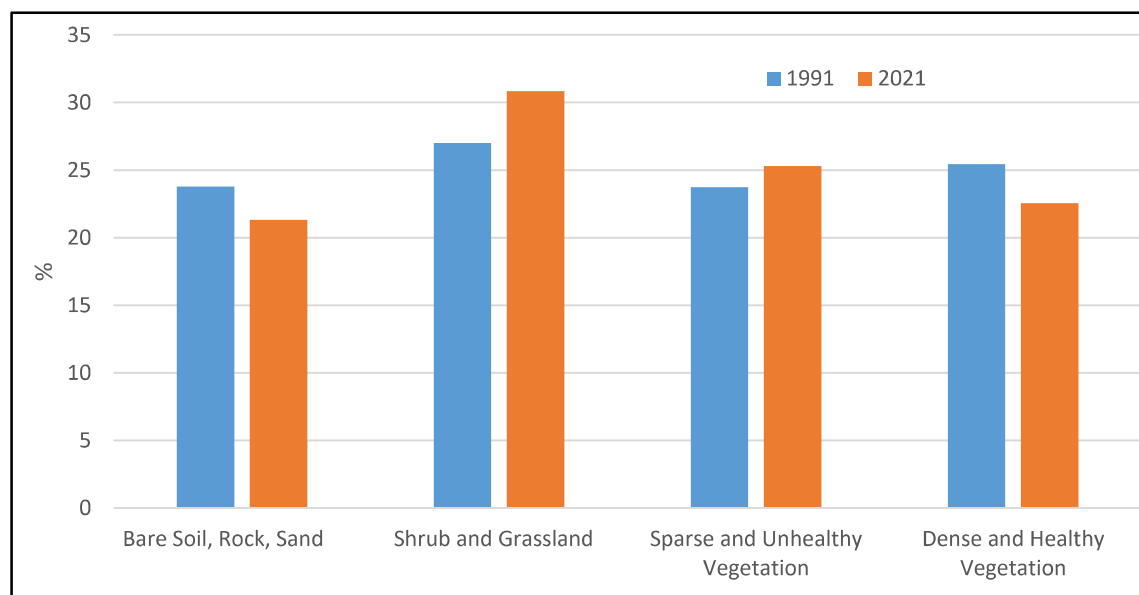


Figure 3: Percentage change of vegetation cover (1991 - 2021)

vegetation. This indicates a slow and insidious transition to desertification (Genesis *et al.*, 2014).

4. Conclusion

This paper assessed the change pattern of vegetation coverage of the Arewa Local Government Area of Kebbi State, using Normalized Difference Vegetation Index (NDVI) techniques. The findings show a 2.9% decrease in the dense and healthy vegetation between 1991 and 2021. This has implications for both local and global biodiversity due to increased warming. The reduction of healthy and dense vegetation in a semi-arid area as observed in the study area strongly suggests desertification as the study has provided indicative data at the local spatial scale. Such data could provide a basis for monitoring desertification through changes in vegetation cover in the long term. The study has successfully identified the change in vegetation pattern for monitoring desertification through the NDVI technique based on GIS and Remote Sensing. However, areas for further study will include enhancing the ability of NDVI to forecast future changes in vegetation in the study area for effective future monitoring of vegetation trends. Therefore, future research should aim at filling this gap.

References

- Adegboyega, S.A., Olayuyigbe, A.E., Balogun, I. and Olatoye, O. (2016). Monitoring Drought and Effects on Vegetation in Sokoto State, Nigeria using Statistical and Geospatial Techniques. *Ethiopian Journal of Environmental Studies & Management*. 9(1) pp 56 – 69. <http://dx.doi.org/10.4314/ejesm.v9i1.6>
- Aliero, M.M., Ismail, M. H., Alias, M., Ambursa, A. S., Muhammed, A., Umar, I., and Bunza, R. M. (2022). *Spatiotemporal Assessment of Land Cover Change and Vegetation Degradation Using Remote Sensing in Kebbi State, Nigeria*. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham. https://doi.org/10.1007/978-3-030-72896-0_79
- Audu., I. A. and Adie, L. A (2018). Desertification in Northern Nigeria: Causes and Consequences. *The Environmental Studies*. 1(2) pp 20-30.
- Demirel, H., Ozcinar, C., and Anbarjafari, G., (2010). Satellite image contrast enhancement using discrete wavelet transform and singular value decomposition, *IEEE Geosciences and remote sensing letters*, 7 (2), pp. 333-337.
- Genesis T. Yengoh, David Dent, Lennart Olsson, Anna E. Tengberg and Compton J. Tucker (2014). *The use of the Normalized Difference Vegetation Index (NDVI) to assess land degradation at multiple scales: a review of the current status, future trends, and practical considerations*. Lund University Center for Sustainability Studies (LUCSUS), and The Scientific and Technical Advisory Panel of the Global Environment Facility (STAP/GEF).
- Karaburun, A., (2010). Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed, *Ozean journal of applied sciences*, 3, pp.77-85.
- Kunkel, M.L., Flores, A.N., Smith. T.J., McNamara, J.P., Benner, S.G., (2011). A simplified approach for estimating soil carbon and nitrogen stocks in semi-arid complex terrain, *Geoderma*, 165, pp.1–11.
- Malo, A.R., and Nicholson, S.E., (1990). A study of Rainfall dynamics in African Sahel using Normalized Difference Vegetation Index, *Journal of Arid Environment*, 19, pp.1-24.

- Munyati, C and Sinthumule, N. I (2014). Cover Gradients and the Forest-Community Frontier: Indigenous Forests Under Communal Management at Vondo and Xanthia, *South Africa, Journal of Sustainable Forestry*, 33:8, pp 757-775, DOI:10.1080/10549811.2014.925809
- Muoghalu J. I. (2021). Desertification and Vegetation Monitoring. *Environmental Monitoring*. 2 (1), pp.1-7.
- Ricotta, C., Avena, G., and Palma, A.D (1999). Mapping and monitoring net primary productivity with AVHRRNDVI time-series: statistical equivalence of cumulative vegetation indices, *ISPRS journal of photogrammetry & remote sensing*, 54, pp. 325-331.
- Thomas P. Higginbottom and Elias Symeonakis (2014). Assessing Land Degradation and Desertification Using Vegetation Index Data: Current Frameworks and Future Directions. *Remote Sensing MDPI Journal*. 6(1), pp.9552-9575. doi:10.3390/rs6109552.
- Unah, L (2017) Briefing: Nigerian farmers can't fight desertification alone, *The New Humanitarian*, <https://www.thenewhumanitarian.org/analysis/2017/11/14/briefing-nigerian-farmers-can-t-fight-desertification-alone>
- Usman, A.S., Noma S. S and Kudiri A. M (2016). Dynamic surface soil components of land and vegetation types in Kebbi State Nigeria, *Eurasian Journal of Soil Science*, 5(2), pp:113-120. DOI: 10.18393/ejss.2016.2.113-120