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ORIGINAL RESEARCH ARTICLE

Evaluating the Dynamics of Vegetation Cover Along the Great Green Wall in Yobe State, Nigeria Using NDVI Analysis

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ABSTRACT

The Great Green Wall (GGW) is an important project in northern Nigeria that helps restore degraded lands and reduce desertification and the risks associated with shifting Sahara deserts and sand dunes while promoting land restoration and conservation using both commercial and forest tree species. However, there is a serious risk that these objectives won't be met due to insecurity, conflicts, and poor weather conditions. Even though Governmental and Non-Governmental Organizations (NGOs) have funded the project and included it in the state's development plans for GGW initiatives, the scientific method for analyzing vegetation cover dynamics since its inception has not received the necessary attention. In this regard, this study decided to monitor the changes in the vegetation cover of the Great Green Wall within Yobe State, Nigeria, from 2015 to 2023. The vegetation dynamics were monitored using Landsat 8 Operational Land Imager (OLI) for 8 years at 2-year intervals. The result shows that there was an increase in vegetation cover from 35,000 hectares in 2017 to 78000 hectares in 2021. However, there was a total decrease of 23,498 hectares in the spatial distribution of vegetation cover from 2021 to 2023. This decrease can be attributed to climate change and anthropogenic activities that will be included in the design and implementation of policies of the GGW to achieve its objectives.

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Monitoring, Vegetation Cover, Dynamics, Green Wall, Landsat 8.

INTRODUCTION

Launched in 2007 by the African Union, the game-changing African-led Great Green Wall initiative aims to restore the continent's degraded landscapes and transform millions of lives in the Sahel. The project, carried out in 22 African nations, is anticipated to bring thousands of communities back to life. With a wall of trees planted from Dakar to Djibouti, it is anticipated that the Wall would reverse land deterioration and desertification. By 2030, the goal of the GGW effort is to trap 250 million tons of carbon, restore 100 million hectares of degraded land, and generate 10 million green employments (Sacande et al., 2021). This will foster the growth of the communities residing along the Wall. The GGW idea of effective land management and climate change adaptation and mitigation, security and migration, poverty reduction and job creation, food security, and drought were far from reached (Goffner et al., 2019).

The predicted outcome of implementing GGW was not met, even with the funding of international agencies and government organizations (Orakwue, 2020). The various socioeconomic and ecological issues in the Sahel (Turner et al., 2021; Goffner et al., 2019) were one of the hurdles facing the GGW, even though the security situation was one of its bottlenecks (Gwaza & Akpan, 2022). The fact that a large number of trees had been planted in places with few or no people to take care of them posed a significant challenge to the initiative's growth. Due to a lack of water, protection, and proper maintenance in the early stages of reforestation, up to 80% of trees died within two months of being planted. The few that survive, especially in arid regions, do little to mitigate climate change. They struggle to grow, are eventually cut down for fuel, or may even be used by local pastoral communities. Since the GGW initiative was aimed to combat desertification and improve livelihoods in the Sahel, it can be seen that the effectiveness of this program remains under scrutiny due to inconsistent monitoring and environmental challenges. Many studies were conducted to evaluate the vegetation cover dynamics in some states in Nigeria (Nse et al., 2020), and Nigeria as a whole (Makinde, 2021). Changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria were also evaluated (Arowolo et al., 2018). However, few studies, if ever conducted, evaluated the vegetation cover dynamics in the Sahel region of Nigeria and Yobe state in particular. This study

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addresses this gap using satellite-based NDVI data to inform future policy and management strategies.

The vegetation cover changes were analysed at 2-year intervals. The result obtained from this study will contribute immensely to the policy formulation and implementation exercise of the GGW for it to achieve the desired objectives. It can also contribute to realizing the United Nations Sustainable Development Goal 13: Integrating climate change measures into National policies, strategies, and planning.

MATERIALS AND METHODS

2.1 Study Area.

The GGW Zone under study was located in the northern part of Yobe State-Nigeria. It stretches from Machina in the west to Geidam in the east, covering a distance of approximately 300km with an area of 7,789,134 hectares. The zone passes through the State's Yusufari, Nguru, Karasuwa, Yunusari, and Bursari Local Government Areas (LGAs). Figure 1 is the study area of the GGW within the northern part of Yobe state, ~~in~~ Nigeria.

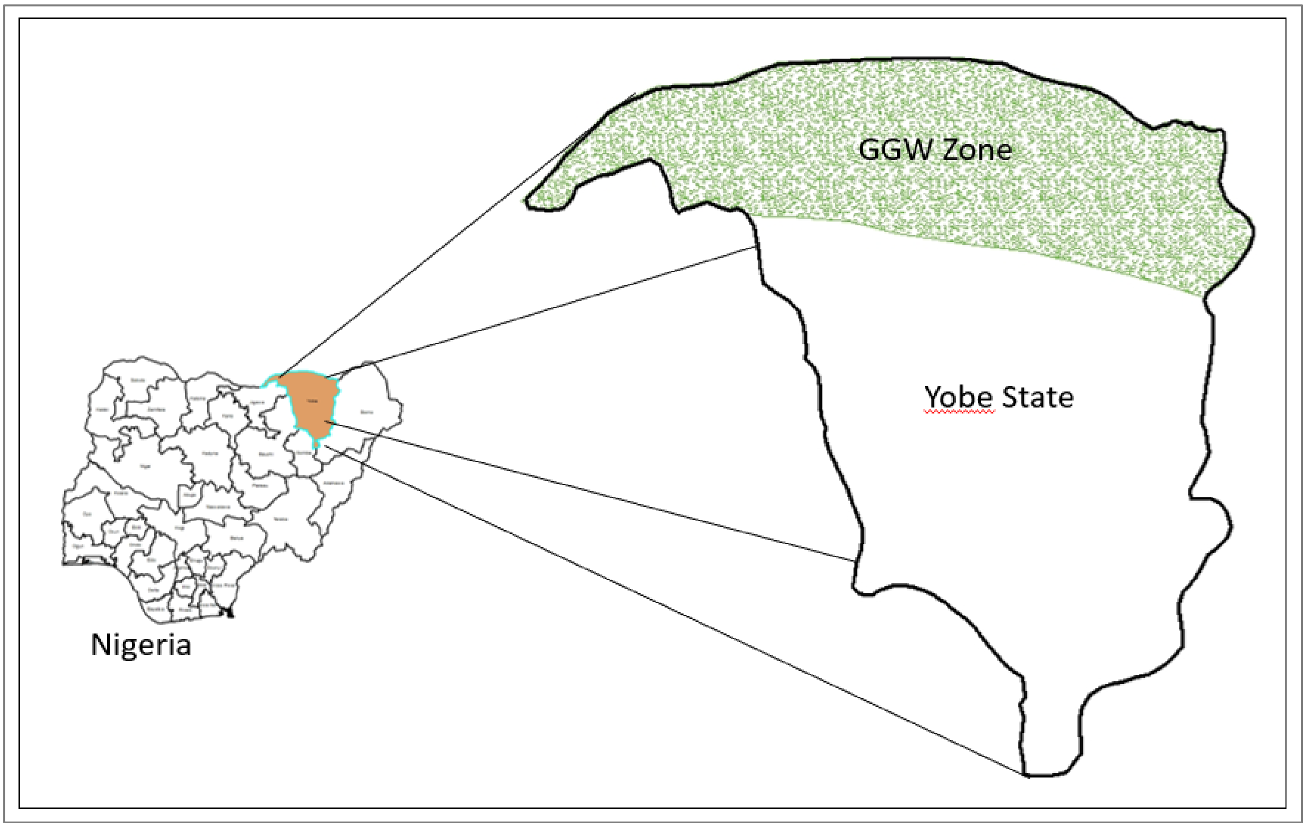

Figure 1. GGW zone in Yobe State-Nigeria
Source: Author.

2.2 Materials Used

The materials used were Landsat 8 (OLI) satellite images covering the northern part of Yobe State. The images were for the year 2015, 2017, 2019, 2021 and 2023. Landsat satellites have the optimal ground resolution and spectral bands to efficiently track land use and to document land cover changes due to climatic variations, and vegetation cover dynamics.

2.3 Methods

The Red and the Near Infra-Red (NIR) bands of Landsat 8 (OLI) satellite images were downloaded from the United States Geological Survey (USGS) Earth Explorer portal. These two spectral bands were particularly suitable for vegetation studies. The ratio between red and NIR bands was shown to be a good predictor of the quantity of photosynthetically active green biomass (Zumo & Hashim, 2020). The downloaded images were at a regular intervals of two years each. A total of thirty images comprising red and NIR bands were downloaded together. Table 1 presents some of these images that were downloaded from the Earth Explorer from 2015 to 2023.

Three sets of Red and the NIR spectral bands for the years 2015, 2017, 2019, 2021, and 2023 were mosaicked for each selected year. These images cover a large portion of Yobe State that was not within the area of interest. Therefore, the area of interest, the GGW zone, was extracted from the images. Using the extraction by mask from the spatial analyst, the GGW was extracted from the mosaicked red and NIR bands. The GGW zone was created from the ArcGIS catalogue from the Yobe State shapefile. It was then extracted using the extraction tool by attribute from the arc toolbox.

The data analysis in this study comprises Normalized Difference Vegetation Index (NDVI) calculation, extraction, and determining the area of vegetation spatial coverage for each year. The Calculation of the changes in vegetation cover dynamics was also included in this section. The NDVI performed well in assessing the spread and health of vegetation. Additionally, it was utilized to measure the greenness of the plants and evaluate changes in plant density. The ratio of the red (R) to near-infrared (NIR) bands was used to compute the index. The standard formula used to determine the NDVI was:

$$NDVI = (NIR - R) / (NIR + R) \quad -- \quad - \quad 1$$

The NDVI values range from +1 which indicates healthy green vegetation, and -1, which indicates non-vegetation features. Since the GGW is green in nature and linear in shape, areas within the GGW zone with values from +0.1 were expected to be the vegetation cover within the GGW. Since all vegetation values start from +0.1 to 1, vegetation with a wider and thicker canopy, such as trees, was expected to have values close to +1, while vegetation with thinner and smaller canopy, like grasses, was expected to have values close to +0.1. Using the raster calculator from the analyst tool, a query was created to extract NDVI values that were more than 0.4. Woody vegetation must have values from 0.4 to +1. The areas that were only covered with woody were generated as the possible GGW as it was linear in shape.

Table 1: Red and NIR bands downloaded from USGS Earth Explorer.

S/N	Image Data	Year of Acquisition
1	LC08_L2SP_186051_20150409_20200909_02_T1_SR_B4.TIF	2015
2	LC08_L2SP_188051_20150423_20200909_02_T1_SR_B5.TIF	
3	LC08_L2SP_186051_20170430_20200904_02_T1_SR_B4.TIF	2017
4	LC08_L2SP_186051_20170430_20200904_02_T1_SR_B5.TIF	
5	LC08_L2SP_186051_20190404_20200829_02_T1_SR_B4.TIF	2019
6	LC08_L2SP_186051_20190404_20200829_02_T1_SR_B5.TIF	
7	LC08_L2SP_186051_20210527_20210607_02_T1_SR_B4.TIF	2021
8	LC08_L2SP_186051_20210527_20210607_02_T1_SR_B5.TIF	
9	LC08_L2SP_188051_20230413_20230421_02_T1_SR_B4.TIF	2023
10	LC08_L2SP_188051_20230413_20230421_02_T1_SR_B5.TIF	

Landsat 8 has a spatial resolution of 30m. Therefore, the total pixels occupied in each of the analyzed images indicates the total area of coverage by vegetation for that year. The vegetation cover for 2015, 2017, 2019, 2021 and 2023 were calculated. The vegetation cover dynamics were determined by comparing the total area of the vegetation cover of the specific year with the preceding year. This reveals whether the vegetation cover has increased or decreased or is at the state of equilibrium.

RESULTS.

3.1 Normalized Difference Vegetation Index (NDVI) Calculation

The NDVI values for the entire zone were from -0.11 to 0.46. From 0.1 to 0.46 were vegetative areas, while the values with negative signs indicate non-vegetation areas. Figure 2 shows NDVI maps for 2015, 2017, 2019, 2022, and 2023.

These NDVI values were represented statistically in Figure 4 below. The green bars represent the vegetative values, and the brown bars represent the non-vegetation values.

3.2 Extraction of Woody Areas

Since vegetation values start from 0 to 0.46, the woody vegetation will have values close to 0.46, and smaller vegetation such as grasses will have values that tend to 0. In this study, we set values greater than 0.15 to be woody vegetation. Figure 3 was the NDVI map showing areas with woody vegetation only.

From 2015 to 2017, there is a slight decrease in vegetation cover of 197 hectares. But from 2017 to 2019 the vegetation cover has increased with an amount of 19,149 hectares. From 2019 to 2021, there was a drastic increase of 24,597 hectares of land covered by woody vegetation. However, a decrease in vegetation cover of 23,498 hectares was experienced from 2021 to 2023. This indicates that there are some fluctuations in the vegetation cover dynamics within the GGW zone of Yobe state. But generally, there was an increase of 20,054 hectares of woody vegetation cover from 2015 to 2023. This result was demonstrated statically in Figure 5.

3.3 Vegetation Cover Dynamics

The drivers of vegetation cover dynamics in the Sahel region of West Africa include climatic changes, overgrazing, insecurity, and population expulsion (Leroux et al., 2017). These drivers contribute to the fluctuation of the GGW in the northern part of Nigeria. This study's result indicates an increase in the spatial distribution of vegetation cover from 2017 to 2021. However, there was a drastic reduction in vegetation cover from 2021 to 2023. This result is similar to the study conducted by Nse et al., 2020, whereby the vegetation cover of Uyo, Nigeria, decreased from 278km^2 in 1986 to 219km^2 in 2018. Future studies should investigate these sudden changes within the years under review. This could be attributed to any of the aforementioned drivers of vegetation changes. Figure 6 shows a line graph showing the fluctuations of GGW vegetation cover in northern Yobe State, Nigeria.

Overgrazing, cropland expansion, and water scarcity are the major contributing factors to desertification, which is the environmental basis of some of the conflicts in Northern Nigeria (Naah & Braun, 2019). Farmers and cattle herders are the main parties involved in the ongoing disputes. Conflicts between communities have resulted from the struggle over the loss of farmlands, and cattle herders are invading people's fields as they migrate southward in search of grazing land for their animals, eventually leading to conflict. Due to desertification, there is not enough pasture for cattle grazing.

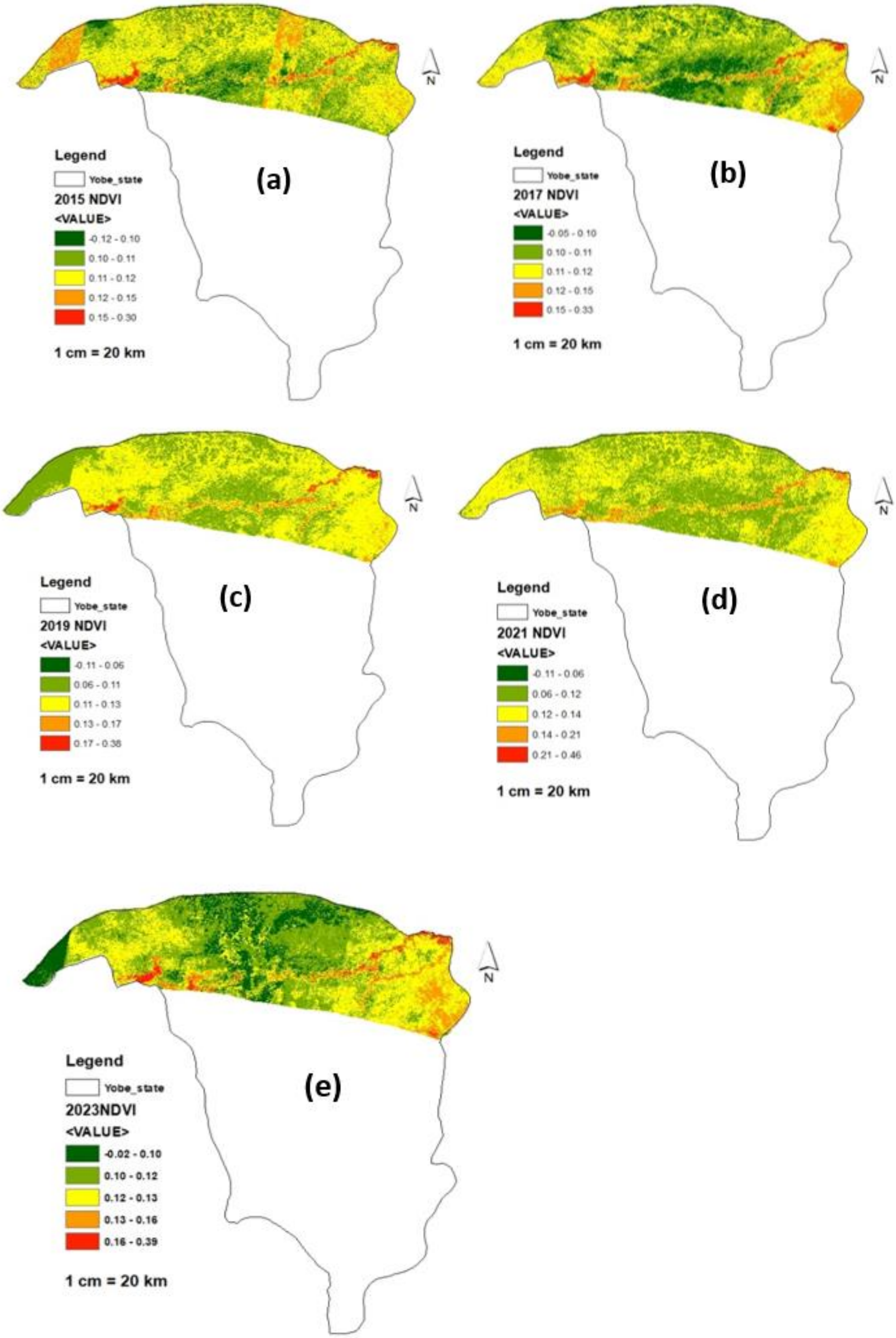

Figure 2. NDVI maps for (a) 2015, (b) 2017, (c) 2019, (d) 2022 and (e) 2023.

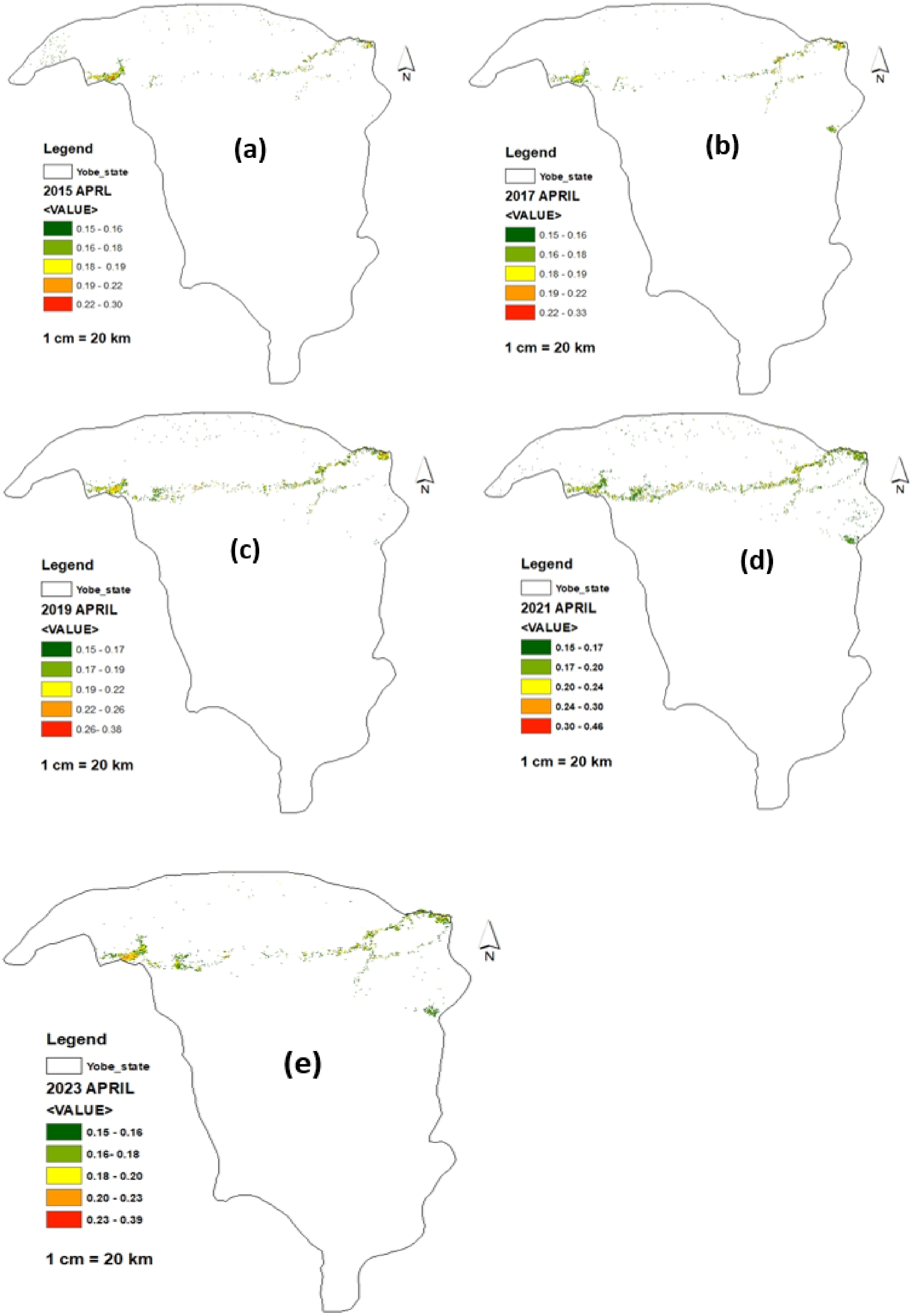

Figure 3. NDVI map showing areas with woody vegetation only.

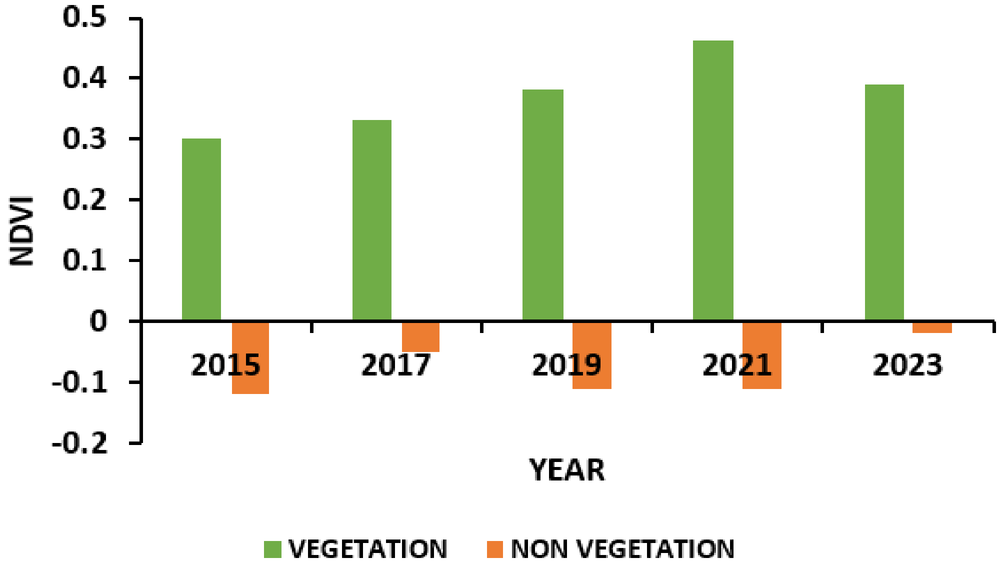

Figure 4. A statistical representation of NDVI values for vegetation and non-vegetation features.

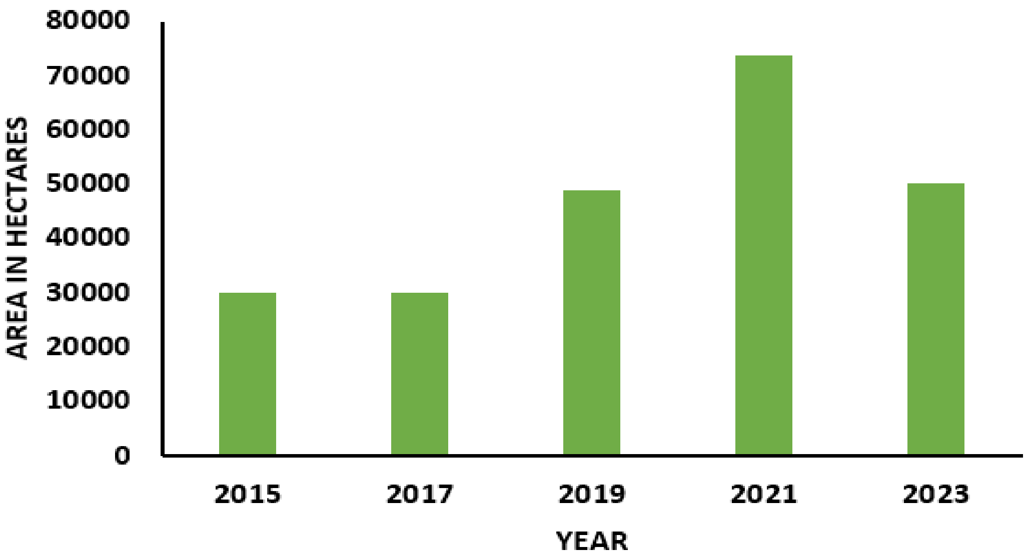

Figure 5. Vegetation cover dynamics within the GGW zone of Yobe State from 2015 to 2023

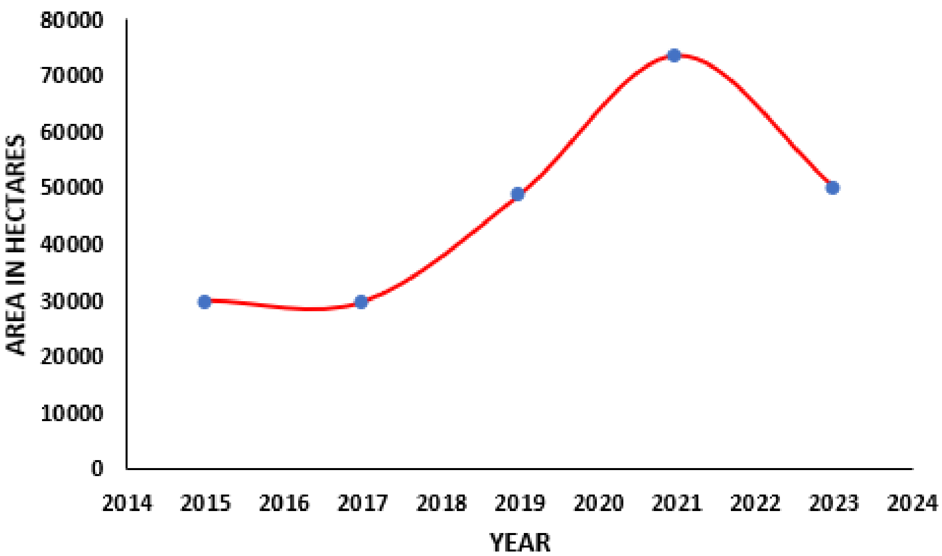

Figure 6. Vegetation covers fluctuations within the GGW in Yobe state.

CONCLUSION

The vegetation cover dynamics of the Great Green Wall in the northern part of Yobe State were monitored from 2015 to 2023. The vegetation cover of the GGW was found to have increased from 35,000 hectares in 2017 to 78000 hectares in 2021. However, there was a total decrease of 23,498 hectares in the spatial distribution of vegetation cover from 2021 to 2023. This decrease is signalling danger specifically on the security of the inhabitants living within the Yobe State GGW corridor and Nigeria at large. Reduction in the vegetation cover in the Sahel was one of the causes of farmers and herders' conflict for years, an increase in poverty due to low crop production, and an increase in insurgency and other forms of insecurity in the area. This study recommends integrating additional indices, such as the Enhanced Vegetation Index (EVI) or Soil-Adjusted Vegetation Index (SAVI), to complement NDVI results for future studies. It may useful also if future studies will collect environmental data (e.g., soil nutrients, temperature, human activity) to analyse their influence on plant diversity. This study's results may also be verified with ground truth data or ancillary datasets. It is hoped that the result of this study will be used by government and non-governmental organizations in the policy formulation and implementation towards sustaining the mitigation process of the desert in Nigeria. The result can also contribute to the realization of Sustainable Development Goals (SDG) Goal number 2. End hunger, achieve food security, and 13. Take urgent action to combat climate change and its impacts.

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