E-ISSN: 1115 – 831X P-ISSN: 3027-2963
MPRI-JAVS | INTERNATIONAL JOURNAL OF AGRICULTURAL AND VETERINARY SCIENCE
VOL. 05 NO. 1 - JULY, 2024

INFLUENCE OF CLIMATE ON VEGETATION DYNAMICS IN SAVANNAH REGION: A CASE OF KATSINA STATE, NIGERIA

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Abstract

Vegetation in Nigeria are under great threat due to anthropogenic activities such as unsustainable agricultural practices, illegal logging, grazing, medicinal use, wood energy etc. This paper aims at investigating the influence of climate on vegetation dynamics in savannah region: A case of Katsina state, Nigeria. The study utilized the MODIS13Q1 product from the Terra satellite to analyze the Normalized Difference Vegetation Index (NDVI) data for Katsina State over the years 2002, 2007, 2012, 2017, and 2022. The data was processed and reprojected to the WGS 84 coordinate system and clipped to the boundaries of Katsina State. The NDVI values were classified into five categories: Bare soil/No vegetation, Low vegetation, Moderate vegetation, Dense vegetation, and Very dense vegetation. The analysis revealed significant shifts in vegetation cover over the 20-year period. Moderate vegetation consistently dominated the land cover, reaching its highest level in 2017 at 83.07% before slightly decreasing in 2022 to 80.43%. Low vegetation showed fluctuations, with notable increases in 2007 and decreases in subsequent years. Dense vegetation saw fluctuations as well but showed a notable increase in 2022. Bare soil/No vegetation remained relatively low throughout the period, while very dense vegetation was absent until 2022 when a small amount was reported for the first time. Overall, the study underscores the dynamic nature of vegetation cover in Katsina State and the importance of continuous monitoring to inform sustainable land

Key word:
Vegetation Dynamics, Climate, NDVI, and Savannah

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management practices. As such, it is recommended that Implementation of continuous monitoring of vegetation cover using satellite imagery and NDVI data to track changes and identify areas requiring intervention also encourage practices that reduce bare soil and low vegetation areas, such as reforestation, afforestation, and sustainable agricultural practices.

Introduction

There have been increased concerns over the environmental effect of petroleum industry over the years and these impacts are mainly negative due to the toxicity of the petroleum which contributes to air pollution, acid rain and causes some illnesses to man. Petroleum fuels climate change due to the increased emissions of greenhouse gas during its extraction, refinement, transportation and consumption phases. One of the most important indicators for evaluating interactions between climate and terrestrial ecosystems is vegetation activity. Vegetation dynamics are highly sensitive to climate change, especially in arid and semiarid regions (Acreman *et al.*, 2009; Wang *et al.,* 2011). The monitoring of terrestrial vegetation dynamics thus underpins efforts to better understand the relational feedback between vegetation and the atmosphere (Bounoua *et al.,* 2010; Angelini *et al.,* 2011). The subsequent reduction in species diversity and vegetation cover is rendering the water-starved ecosystem increasingly fragile.

Vegetation in Nigeria are under pressure due to land use as a result of human population growth. Nigeria loses more than 350,000-400,000 hectares per year due to human activities (Food and Agriculture Organization, 2005). Furthermore, logging is one of the most common forest disturbances in Nigeria (Philip *et al.,* 2014). For instance, wood is a major source of energy in Nigeria (Forestry Outlook Studies in Africa, 2001). Moreover, grazing is a principal cause of tropical forest degradation (Food and Agriculture Organization of the United Nations, 2010). In general, with increasing population, expansion agriculture, unsustainable forest use and urbanization which are the major leading causes to deforestation in the tropical regions (Duveiller, Defourny, Desclée, and Mayaux, 2008).

Climate change is also impacting world's forests. For instance, the increase of global average temperature more than 1.5 to 2.5 °C, will affect about 20 to 30 percent of plant and animal species and the species increased the risk of extinction (Intergovernmental Panel on Climate Change, 2007). Warmer temperatures will increase the loss of water from evapo-transpiration and will reduce the plant water use efficiency (Mortsch, 2006). Such conditions can affect the phenology and health of trees (Mortsch, 2006). The vegetation is under a variety of disturbances that are themselves strongly influenced by

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climate (FAO, 2008). Deforestation is one of the greatest environmental problems in Guinea Savannah of Nigeria. According to FOSA (2001), management of Nigeria forest reserves has been inadequate and forest management seems to have been replaced by the project syndrome. Furthermore, According to FOSA, (2001), a lot of forest reserves particularly in the Guinea Savannah are destroyed due to anthropogenic activities and many of trees are cut for fuel wood by residents in Guinea Savannah areas or cleared to make room for agriculture (Geomatics, 1998). For example, Nasarawa State of Nigeria located in Guinea Savannah, its forestry development faces a very bleak future (Alao, 2009).

Vegetation in Nigeria are under great threat due to anthropogenic activities such as unsustainable agricultural practices, illegal logging, grazing, medicinal use, wood energy etc, because near the Sahel savanna, desertification and agricultural intensification is the major cause of land degradation. In the sudan savanna, intense cultivation, overgrazing and bush burning have depleted the grassland that covers large areas leading to the increase in temperature and then extreme event like drought which are common in this zone. Intense deforestation in guinea savanna increases the rate of flooding in the zone for example the Kogi flood, Benue flood etc. Many people are at risk from rising sea levels and extreme weather attributed to climate change which leads to extreme events like coastal erosion and flooding and damage to coastal habitats which leads to loss of unprotected dry land and wetlands and also destruction of existing economic infrastructures and commercial activities.

Only the fact that a few studies have been carried out on extreme events in Nigeria, but a good understanding of the inter-annual trends and variability of extreme temperature and rainfall for vegetation change as well as their vulnerability is imperative for facilitating appropriate measures to minimize the scourge of these extreme weather events. This forms the basis of this research with particular reference to Katsina state, Nigeria.

LITERATURE REVIEW

IPCC (2007) defines climate change as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and /or the variability of its properties, and that persists for an extended period typically decades or longer. Although the length of time it takes the changes to manifest matters, the level of deviation from the normal and its impacts on the ecology are most paramount. According to United Nation Framework Convention on Climate Change (UNFCCC) means a change of climate which is attributed directly to human activity that alters the composition of the

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global atmosphere and which in addition to natural climate variability observed over comparable time period (UNCCS, 2005), Another definition by the Intergovernmental Panel on Climate Change (IPCC) defines climate change as any change in climate over time whether due natural variability or as a result of human activity (IPCC, 2007).

Climate projections for the 21st century show a significant increase of temperature over all the ecological zones of Nigeria (Abiodun *et al.,* 2013) which may have negative impacts on agriculture and food security. According to Abdussalam (2015) who conducted a research in northwest Nigeria, the frequency of warm days has significantly increased while the frequency of cold days has significantly decreased. There is a significant decrease in daily temperature range and trends in rainfall indices showed an increase.

Vegetations in Nigeria are under great threat due to anthropogenic activities such as unsustainable agricultural practices, illegal logging, grazing, medicinal use, wood energy etc, because near the Sahel savanna, desertification and agricultural intensification is the major cause of land degradation. In the sudan savanna, intense cultivation, overgrazing and bush burning have depleted the grassland that covers large areas leading to the increase in temperature and then extreme event like drought which are common in this zone. Intense deforestation in guinea savanna increases the rate of flooding in the zone for example the Kogi flood, Benue flood etc. Many people are at risk from rising sea levels and extreme weather attributed to climate change which leads to extreme events like coastal erosion and flooding and damage to coastal habitats which leads to loss of unprotected dry land and wetlands and also destruction of existing economic infrastructures and commercial activities.

Only the fact that a few studies have been carried out on extreme events in Nigeria, but a good understanding of the interannual trends and variability of extreme temperature, rainfall and vegetation as well as their vulnerability is imperative for facilitating appropriate measures to minimize the scourge of these extreme weather events. This forms the basis of this research with particular reference to some selected stations in Nigeria.

STUDY AREA

Katsina is one of the sub-Saharan cities and one of the ancient Hausa settlements renowned for its culture, learning, trade, manufacture development was influenced by trans-Sahara trade. It lies between 12° 40¹N and 12° 59¹ N and longitude 7° 35¹ and 7° 40¹E. It is situated on the central plains of Hausa land (Fig.1.1 and 1.2). Katsina city is the capital

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city of Katsina state. It has a total land area of about 2,448km² (Katsina State Ministry of Environment, 2010).

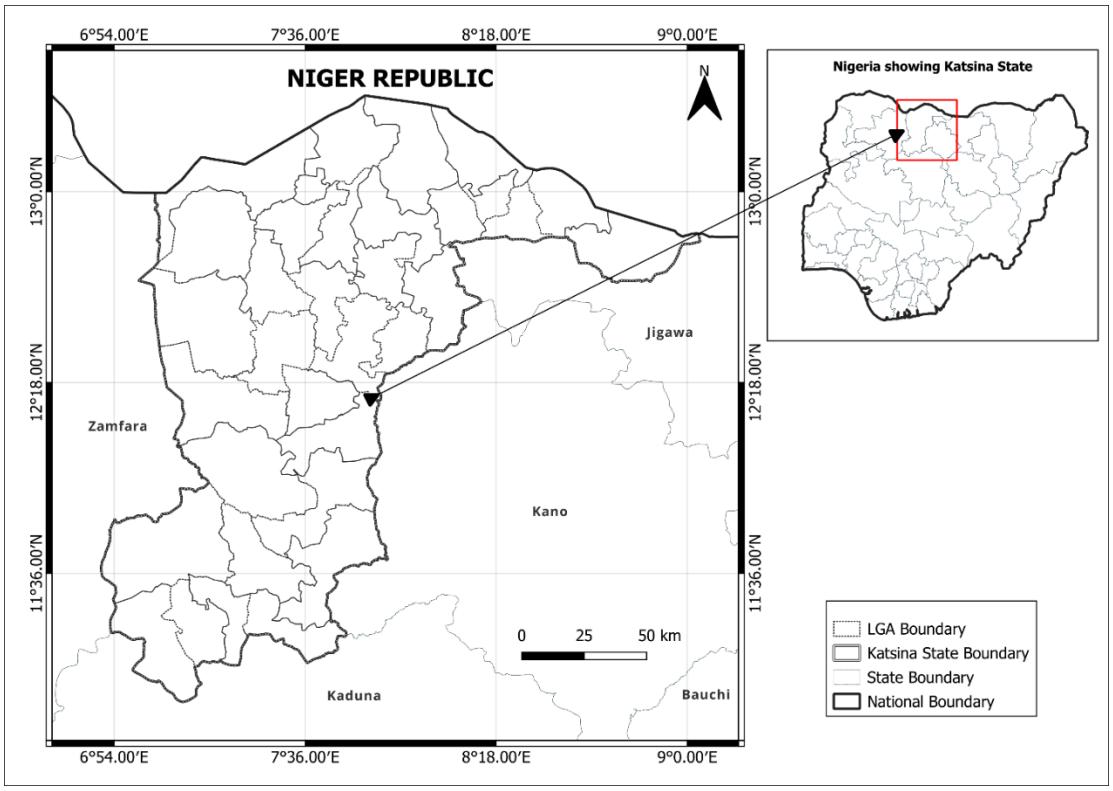

Figure 1: Map of Katsina state
Source: Adopted and Modified Administrative Map of Katsina, 2023

The climate of Katsina State is the tropical wet and hot semi-arid type (tropical continental climate) classified by Koppen as Aw and BSh climate. Rainfall is between May and September with a peak in August. The average annual rainfall is about 700 mm. The pattern of rainfall in the area is highly variable. This can result in severe and widespread droughts that can impose serious socio-economic constraints (Abaje, Ati and Iguisi 2012). The mean annual temperature ranges from 29°C 31°C. The highest air temperature normally occurs in April/May and the lowest in December through February.

The landscape of the study area is relatively flat; almost featureless, and about 510m high Survey Department, Ministry of Land and Survey Katsina State (2008). The plain region of the city is underlain by clayey sandstone and grits with small basal pebble. Rocky outcrops of basement complex and laterite capping occupied the southern part of the city (Zayyana 2010).

The main Rivers draining the study area are Ginzo and Tille Rivers. Ginzo River drains the northern part of the city, while Tille River with its dendritic drainage pattern passes

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through the town in south direction. The stream flow pattern according is seasonal, like other semi-arid rivers which experiences almost zero dry season (Zayyana, 2010).

The vegetation of the area is typically a grass land type and grossly affected by annual rainfall and its distribution. It is a Savannah area where scattered trees grow on virtual grass landscape.The trees species found in the study area include Parkiabilbosa, Adansoniadigitata, Khayaseneegelesis, Tamarindusindica, Borassusaethopium, Butyrospermomparki, exotic Azadichrataindiea and few fruits trees on farm such as Mangiferaindica. The vegetation of the area is he Sudan Savanna type which combines the characteristics and species of bothe the Guinea and Sahel Savanna (Abaje, 2007). Areas around the metropolis are worst affected, naturally vegetation is dominated with grasses and shrubs but many trees have been planted for their shed, fruits and to mitigate desertification problems. In the northern part of Katsina, trees like Moringaoleitera, Parkiabiblobosa, Acacianilotica, Tamarinadusindica and Vitexdomina were planted through the efforts of the European Economic Community (EEC) and the Katsina state Government (KTSG project, 2014).

Arable and subsistence farming are the chief occupations of the people in the area, Peanuts and cash crops are grown at a commercial level, millet and guinea corn are grown as staple food. Most of the people own cattle, sheep and goats which are domesticated mostly by women. Hides and skin are exported to neighboring local government area such as Jibia, Kaita, Rimi, Batagarawa and Batsari. Irrigation farming is practiced within the metropolis of Katsina as urban agriculture where vegetables are cultivated at commercial level.

METHODOLOGY

Data Source and Types

The primary dataset used in this study is the MODIS13Q1 product from the Terra satellite. MODIS (Moderate Resolution Imaging Spectroradiometer) on the Terra satellite provides 16-day composite data of the normalized difference vegetation index (NDVI) at a spatial resolution of 250 meters. The temporal coverage includes the years 2002, 2007, 2012, 2017, and 2022, for the months of January and August.

NDVI is a measure derived from the red and near-infrared bands of the MODIS sensor, indicative of vegetation health and coverage. The MODIS13Q1 data was downloaded from NASA's Earthdata portal for the specified years and months. The data was obtained in HDF format, containing NDVI values.

Data Processing

The data processing involved several crucial steps to prepare the MODIS13Q1 NDVI data for analysis:

First, the data was reprojected from its native sinusoidal projection to the WGS 84 coordinate system. This reprojection was necessary to ensure that the spatial data aligned

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with other geographical datasets and to facilitate accurate spatial analysis. The sinusoidal projection is often used for global datasets, but the WGS 84 coordinate system is more suitable for regional studies like this one because it is a standard geographic coordinate system widely used in mapping and spatial data applications.

Next, the NDVI (Normalized Difference Vegetation Index) layer was extracted from the HDF (Hierarchical Data Format) files. This extraction process involved isolating the specific NDVI data from the multi-layered HDF files, which contain various types of information. By focusing on the NDVI layer, the analysis could specifically assess vegetation health and cover, which is critical for the study's objectives.

Finally, the extracted NDVI data was clipped to the boundaries of Katsina State. Clipping the data to the specific study area ensured that the analysis was restricted to the geographic region of interest, thereby enhancing the relevance and accuracy of the results. This step involved delineating the exact borders of Katsina State and removing any extraneous data outside these boundaries, ensuring that all subsequent analyses were focused on the target area.

Data Analysis

The analysis concentrated on two main objectives: classifying the NDVI data into distinct vegetation categories and detecting changes in vegetation cover over the specified years and months.

First, the NDVI (Normalized Difference Vegetation Index) data was classified into various vegetation categories. This classification involved categorizing the NDVI values into different ranges that correspond to specific types of vegetation or land cover, such as dense forest, shrubland, grassland, and barren land. By assigning NDVI values to these categories, the analysis could provide a detailed map of vegetation distribution within Katsina State. This step is crucial for understanding the spatial distribution of different vegetation types and their relative health and density.

Second, the analysis aimed to detect changes in vegetation cover over the specified years and months. This temporal analysis involved comparing NDVI values across different time periods to identify trends and shifts in vegetation health and extent. By examining changes over both annual and monthly scales, the study could capture long-term trends as well as seasonal variations in vegetation cover. This aspect of the analysis is vital for monitoring environmental changes, assessing the impacts of climatic and human activities on vegetation, and informing land management and conservation strategies.

NDVI Classification

The NDVI (Normalized Difference Vegetation Index) values were classified into five distinct categories to represent varying levels of vegetation density. These categories are designed to provide a clear understanding of the vegetation cover and its health within the study area.

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i. **Bare soil/No vegetation:** This category includes areas with an NDVI value of less than 0.2. These regions are characterized by the absence of vegetation, indicating bare soil, built-up areas, or other non-vegetated surfaces. An NDVI value below 0.2 typically signifies minimal to no photosynthetic activity.

ii. **Low vegetation:** This category encompasses NDVI values ranging from 0.2 to less than 0.4. Areas falling within this range have sparse vegetation cover, such as grasslands or regions with scattered shrubs. The low NDVI values suggest limited vegetation density and health.

iii. **Moderate vegetation:** NDVI values between 0.4 and less than 0.6 are classified under this category. These areas have a moderate level of vegetation cover, indicating healthier and denser vegetation compared to the previous category. This range might include mixed forests, croplands, or regions with significant shrub coverage.

iv. **Dense vegetation:** This category includes NDVI values from 0.6 to less than 0.8. Areas within this range exhibit dense vegetation cover, such as healthy forests or regions with substantial plant growth. The high NDVI values indicate robust photosynthetic activity and healthy vegetation.

v. **Very dense vegetation:** NDVI values of 0.8 and above fall into this category. These regions have extremely dense and healthy vegetation cover, often representing tropical rainforests or areas with lush, vigorous plant growth. The very high NDVI values indicate maximum photosynthetic activity and optimal vegetation health.

Classification Thresholds:

- **Bare soil/No vegetation:** NDVI < 0.2
- **Low vegetation:** 0.2 ≤ NDVI < 0.4
- **Moderate vegetation:** 0.4 ≤ NDVI < 0.6
- **Dense vegetation:** 0.6 ≤ NDVI < 0.8
- **Very dense vegetation:** NDVI ≥ 0.8

By categorizing the NDVI values into these specific thresholds, the analysis can effectively differentiate between various levels of vegetation density, providing a detailed and comprehensive map of vegetation cover within the study area. This classification system is essential for understanding the spatial distribution of vegetation and monitoring changes in land cover over time.

Change Detection

The NDVI values for each year will be obtained from the satellite imagery analysis. To determine the magnitude of change (C) between two specific years, the formula below was used:

$$C = B - A$$

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Where:

C represents the change magnitude.

B is the NDVI value for the later year.

A is the NDVI value for the earlier year (reference value).

RESULT AND DISCUSSION

January Distribution

Table 4.1 showing area and percentage NDVI of 2002

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	60.16	0.25%
2	Low vegetation	3304.40	13.60%
3	Moderate vegetation	20064.36	82.57%
4	Dense vegetation	872.32	3.59%
5	Very dense vegetation	0.00	0.00%
	TOTAL	24301.24	100.00%

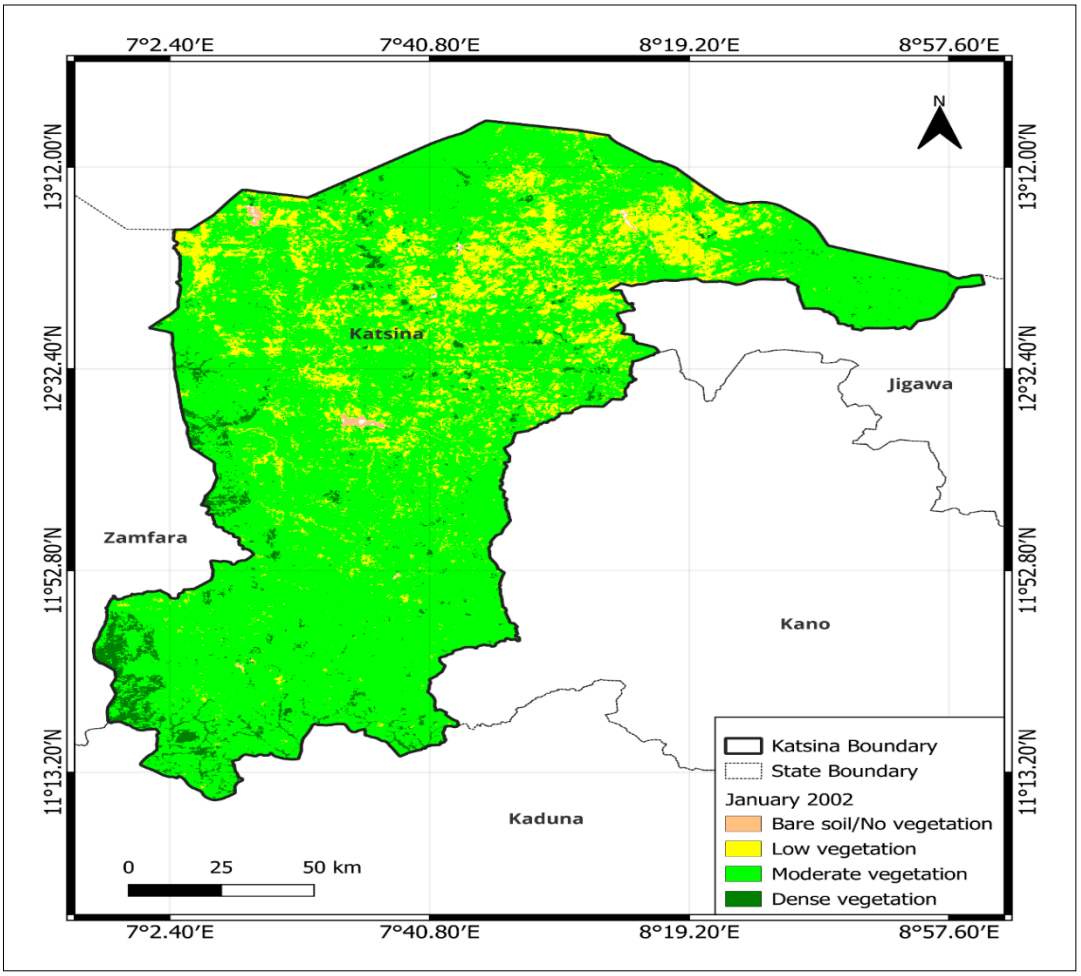

Figure 2: NDVI of January 2002

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In 2002, the land cover was predominantly moderate vegetation, which accounted for 20064.36 square kilometers (82.57%) of the area. Low vegetation covered 3304.40 square kilometers (13.60%), while dense vegetation made up 872.32 square kilometers (3.59%). Bare soil or areas with no vegetation were minimal, constituting only 60.16 square kilometers (0.25%). There was no very dense vegetation during this year.

Table 4.2 showing area and percentage NDVI of 2007

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	30.96	0.13%
2	Low vegetation	9556.07	39.36%
3	Moderate vegetation	14305.77	58.93%
4	Dense vegetation	383.06	1.58%
5	Very dense vegetation	0.00	0.00%
	TOTAL	24275.86	100.00%

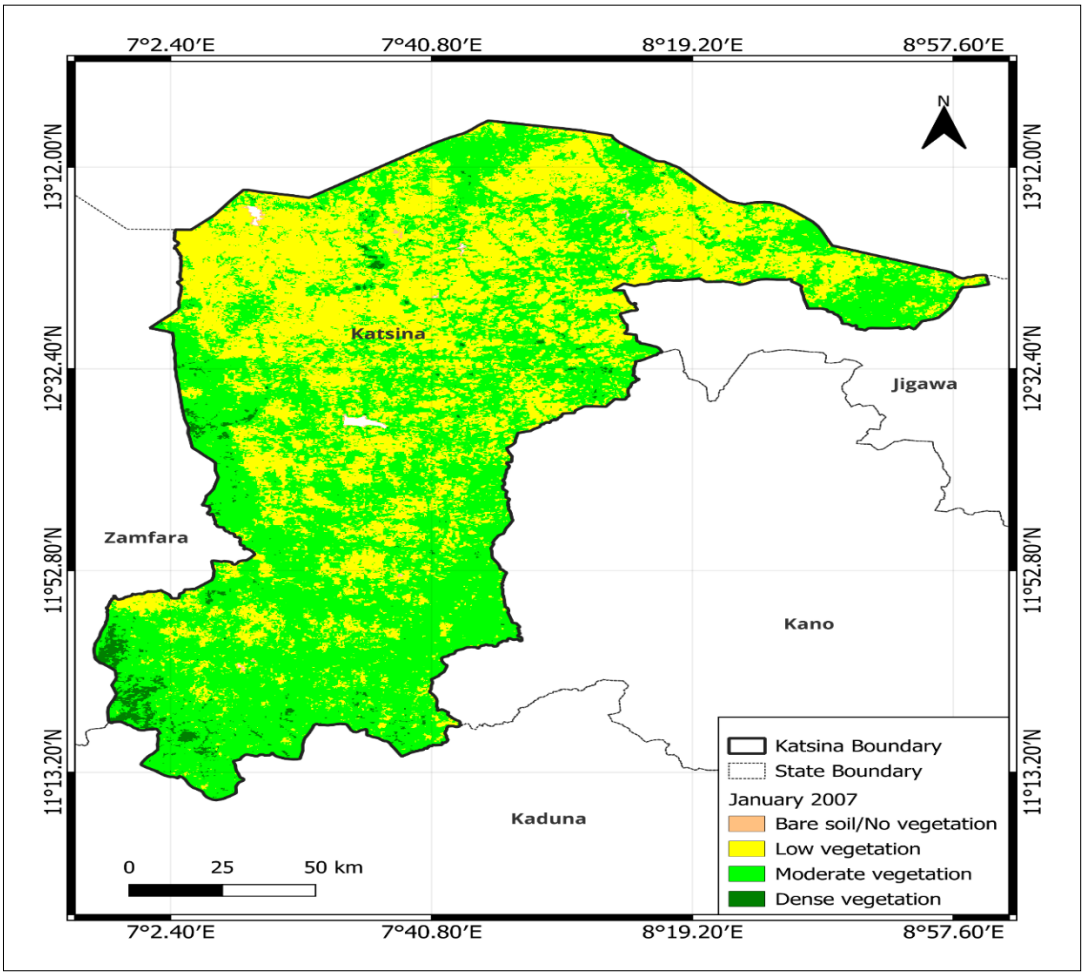

Figure 3: NDVI of January 2007

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By 2007, there was a significant change in the distribution of vegetation types. Moderate vegetation decreased to 14305.77 square kilometers (58.93%), while low vegetation increased substantially to 9556.07 square kilometers (39.36%). Dense vegetation dropped to 383.06 square kilometers (1.58%), and bare soil/no vegetation decreased to 30.96 square kilometers (0.13%). Similar to 2002, there was no very dense vegetation.

Table 4.3 showing area and percentage NDVI of 2012

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	33.06	0.14%
2	Low vegetation	6654.96	27.41%
3	Moderate vegetation	16742.30	68.97%
4	Dense vegetation	846.02	3.48%
5	Very dense vegetation	0.00	0.00%
	TOTAL	24276.34	100.00%

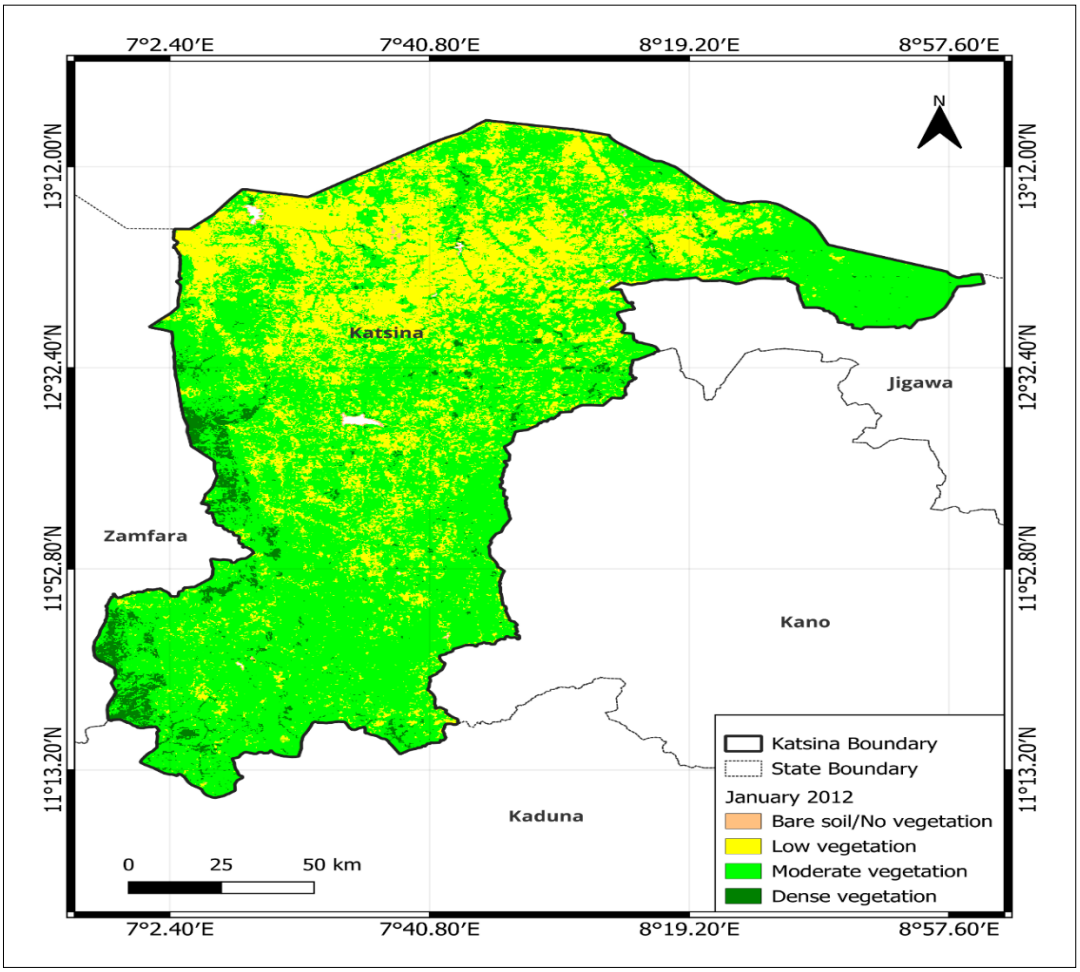

Figure 4: NDVI of January 2012

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In 2012, moderate vegetation saw a recovery, increasing to 16742.30 square kilometers (68.97%). Low vegetation decreased to 6654.96 square kilometers (27.41%). Dense vegetation slightly increased to 846.02 square kilometers (3.48%), and bare soil/no vegetation remained relatively low at 33.06 square kilometers (0.14%). Very dense vegetation continued to be absent.

Table 4.4 showing area and percentage NDVI of 2017

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	44.60	0.18%
2	Low vegetation	3465.61	14.26%
3	Moderate vegetation	20184.52	83.07%
4	Dense vegetation	603.14	2.48%
5	Very dense vegetation	0.00	0.00%
	TOTAL	24297.86	100.00%

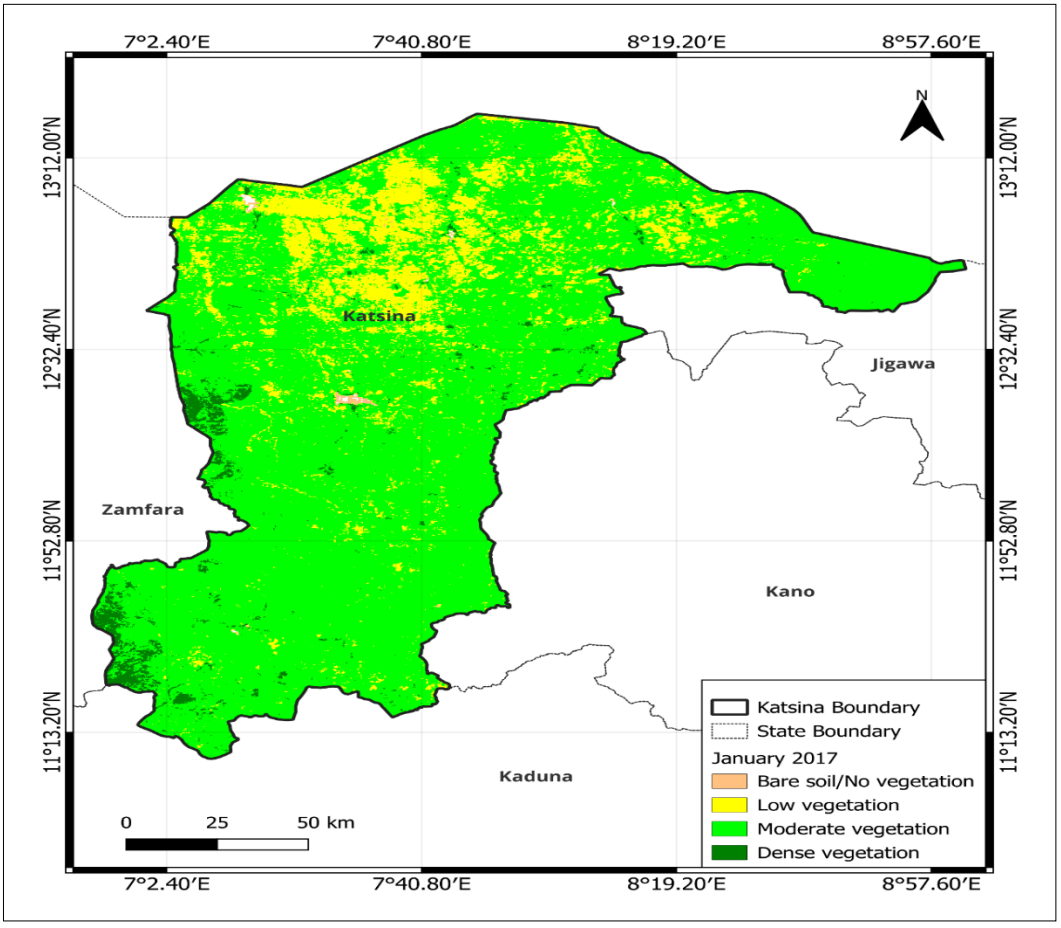

Figure 5: NDVI of January 2017

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The year 2017 marked another shift, with moderate vegetation reaching its highest level in the period at 20184.52 square kilometers (83.07%). Low vegetation dropped significantly to 3465.61 square kilometers (14.26%), and dense vegetation slightly decreased to 603.14 square kilometers (2.48%). Bare soil/no vegetation increased to 44.60 square kilometers (0.18%). Very dense vegetation remained unavailable.

Table 4.5 showing area and percentage NDVI of 2022

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	33.92	0.14%
2	Low vegetation	2545.32	10.48%
3	Moderate vegetation	19530.18	80.43%
4	Dense vegetation	2172.45	8.95%
5	Very dense vegetation	1.13	0.005%
	TOTAL	24282.99	100.00%

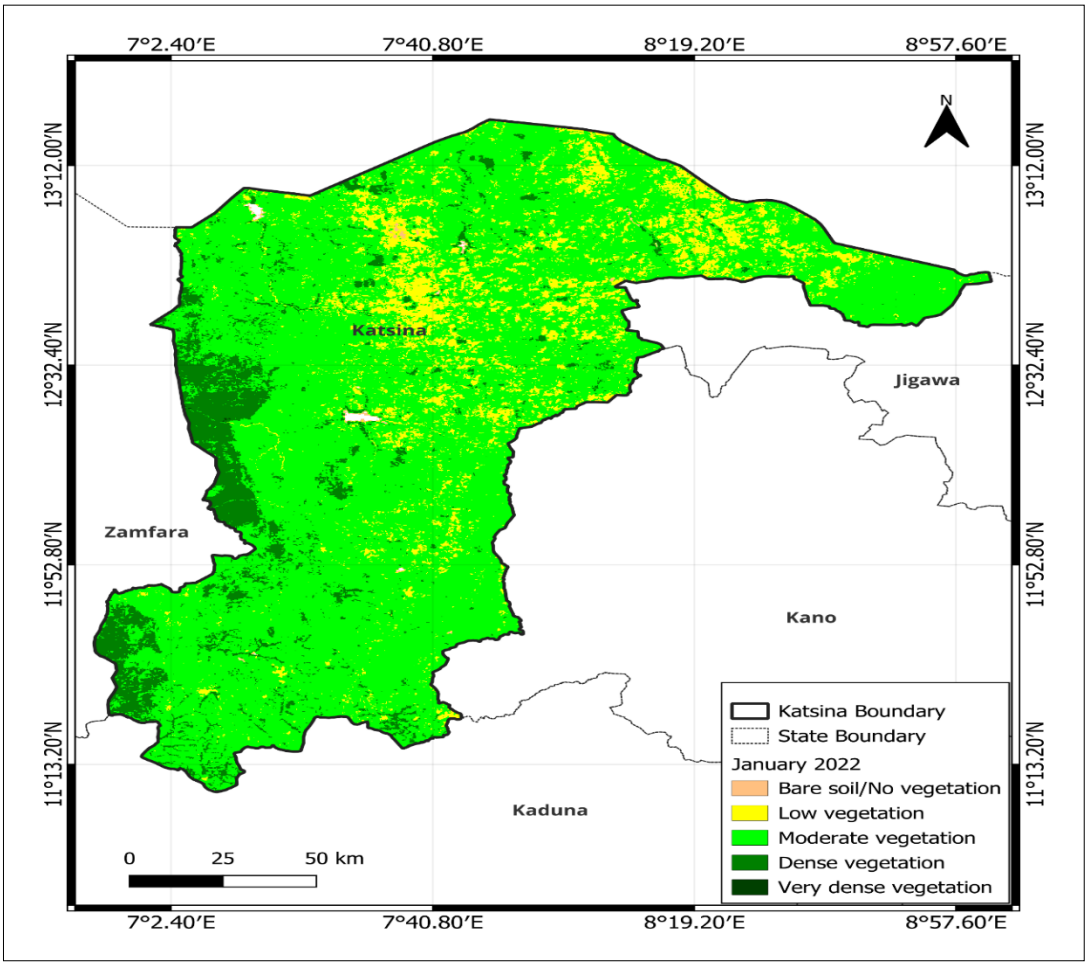

Figure 6: NDVI of January 2022

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In 2022, moderate vegetation slightly decreased to 19530.18 square kilometers (80.43%), still dominating the land cover. Low vegetation further decreased to 2545.32 square kilometers (10.48%), while dense vegetation saw a notable increase to 2172.45 square kilometers (8.95%). Bare soil/no vegetation was at 33.92 square kilometers (0.14%), showing a slight reduction. A small amount of very dense vegetation, 1.13 square kilometers (0.005%), was reported for the first time.

Over the period from 2002 to 2022, there were significant shifts in the distribution of vegetation types within the studied area. Moderate vegetation consistently dominated the land cover throughout the years, reaching its highest level in 2017 at 83.07% before slightly decreasing in 2022 to 80.43%. Low vegetation showed fluctuations, with notable increases in 2007 and decreases in subsequent years. Dense vegetation saw fluctuations as well but showed a notable increase in 2022. Bare soil/no vegetation remained relatively low throughout the period, while very dense vegetation was absent until 2022 when a small amount was reported for the first time.

January Changes

Table 4.6 showing the changes between 2002 and 2007

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	-29.19	-48.53%
2	Low vegetation	6251.67	189.19%
3	Moderate vegetation	-5758.59	-28.70%
4	Dense vegetation	-489.26	-56.09%
5	Very dense vegetation	0.00	

Between 2002 and 2007, land cover changes show significant shifts in vegetation types. Bare soil or areas with no vegetation decreased by 29.19 sq km (48.53%), while low vegetation areas increased dramatically by 6251.67 sq km (189.19%). In contrast, moderate vegetation saw a decline of 5758.59 sq km (28.70%), and dense vegetation areas reduced by 489.26 sq km (56.09%). Very dense vegetation remained unchanged.

Table 4.7 showing the changes between 2007 and 2012

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	2.09	6.76%
2	Low vegetation	-2901.11	-30.36%
3	Moderate vegetation	2436.54	17.03%
4	Dense vegetation	462.97	120.86%
5	Very dense vegetation	0.00	

Between 2007 and 2012, land cover changes reveal varying trends across different vegetation categories. Bare soil or areas with no vegetation increased slightly by 2.09 sq km (6.76%), suggesting minor expansion or re-exposure of bare ground. Low vegetation

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areas saw a substantial decrease of 2901.11 sq km (-30.36%), indicating significant conversion to other vegetation types or land uses. Moderate vegetation increased by 2436.54 sq km (17.03%), reflecting an expansion or recovery in these areas. Dense vegetation showed a remarkable increase of 462.97 sq km (120.86%), pointing to substantial growth or densification of vegetation.

Table 4.8 showing the changes between 2012 and 2017

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	11.54	34.90%
2	Low vegetation	-3189.34	-47.92%
3	Moderate vegetation	3442.21	20.56%
4	Dense vegetation	-242.89	-28.71%
5	Very dense vegetation	0.00	

Between 2012 and 2017, the changes in land cover continue to reflect dynamic shifts. Bare soil or areas with no vegetation increased by 11.54 sq km (34.90%), indicating a notable expansion of bare ground. Low vegetation areas experienced a significant decrease of 3189.34 sq km (-47.92%), suggesting further reduction or transformation into other land covers. Moderate vegetation increased substantially by 3442.21 sq km (20.56%), indicating continued growth or recovery in these areas. Dense vegetation, however, decreased by 242.89 sq km (-28.71%), showing a decline in highly vegetated areas.

Table 4.9 showing the changes between 2017 and 2022

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	-10.68	-23.95%
2	Low vegetation	-920.30	-26.56%
3	Moderate vegetation	-654.33	-3.24%
4	Dense vegetation	1569.32	260.19%
5	Very dense vegetation	1.13	

Between 2017 and 2022, the land cover changes reveal significant trends in vegetation dynamics. Bare soil or areas with no vegetation decreased by 10.68 sq km (-23.95%), indicating a reduction in bare ground. Low vegetation areas also saw a substantial decrease of 920.30 sq km (-26.56%), suggesting continued transformation or loss of sparsely vegetated regions. Moderate vegetation experienced a minor decline of 654.33 sq km (-3.24%), showing slight reduction in these areas. In contrast, dense vegetation increased remarkably by 1569.32 sq km (260.19%), indicating significant growth or densification of vegetation.

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Table 4.10 showing the changes between 2002 and 2022

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	-26.24	-43.62%
2	Low vegetation	-759.09	-22.97%
3	Moderate vegetation	-534.18	-2.66%
4	Dense vegetation	1300.13	149.04%
5	Very dense vegetation	1.13	

Between 2002 and 2022, the overall changes in land cover exhibit significant long-term trends. Bare soil or areas with no vegetation decreased by 26.24 sq km (-43.62%), indicating a substantial reduction in bare ground over the 20-year period. Low vegetation areas also experienced a decrease of 759.09 sq km (-22.97%), suggesting a notable loss or transformation of sparsely vegetated regions. Moderate vegetation showed a minor decline of 534.18 sq km (-2.66%), reflecting slight overall reduction. Dense vegetation, however, increased significantly by 1300.13 sq km (149.04%), indicating considerable growth or densification of vegetation. Very dense vegetation showed a minimal increase of 1.13 sq km, suggesting stability with a slight expansion.

Over the period from 2002 to 2022, significant shifts in land cover were observed. These changes included reductions in bare soil and low vegetation, alongside increases in moderate and dense vegetation. Notably, the landscape saw substantial expansion of dense vegetation, indicating significant growth or densification. While there were fluctuations in vegetation types over shorter time intervals, the overall trend over two decades showed a decrease in bare soil and low vegetation alongside an increase in dense vegetation, highlighting long-term environmental changes likely influenced by factors such as land management practices, climate variability, and natural processes.

August Distribution

Table 4.11 showing area and percentage NDVI of 2002

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	63.43	0.26%
2	Low vegetation	82.21	0.34%
3	Moderate vegetation	652.13	2.68%
4	Dense vegetation	18672.73	76.80%
5	Very dense vegetation	4842.97	19.92%
	TOTAL	24313.48	100.00%

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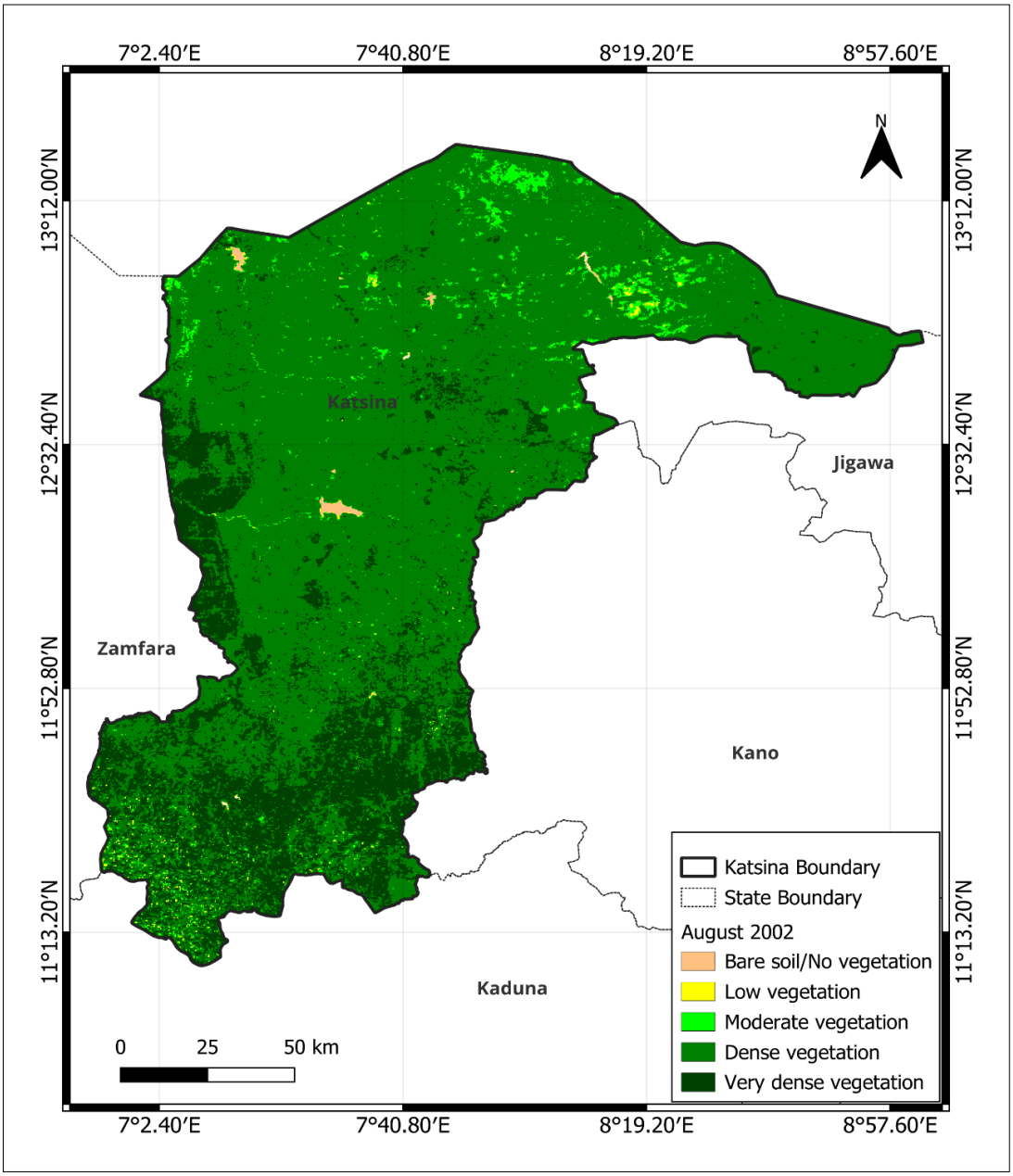

Figure 7: NDVI of August 2002

In 2002, Table 4.11 illustrates the distribution of vegetation density within the studied area, as measured by the Normalized Difference Vegetation Index (NDVI). Dense vegetation, comprising areas with high vegetation density, covered the largest portion of the landscape with an area of 18,672.73 sq km (76.80% of the total area), followed by very dense vegetation at 4,842.97 sq km (19.92%). Moderate vegetation, representing areas with moderate vegetation cover, covered 652.13 sq km (2.68%); low vegetation covered 82.21 sq km (0.34%), and bare soil/no vegetation accounted for 63.43 sq km (0.26%).

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Table 4.11 showing area and percentage NDVI of 2007

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	61.98	0.25%
2	Low vegetation	124.50	0.51%
3	Moderate vegetation	1240.94	5.10%
4	Dense vegetation	18133.77	74.58%
5	Very dense vegetation	4753.24	19.55%
	TOTAL	24314.44	100.00%

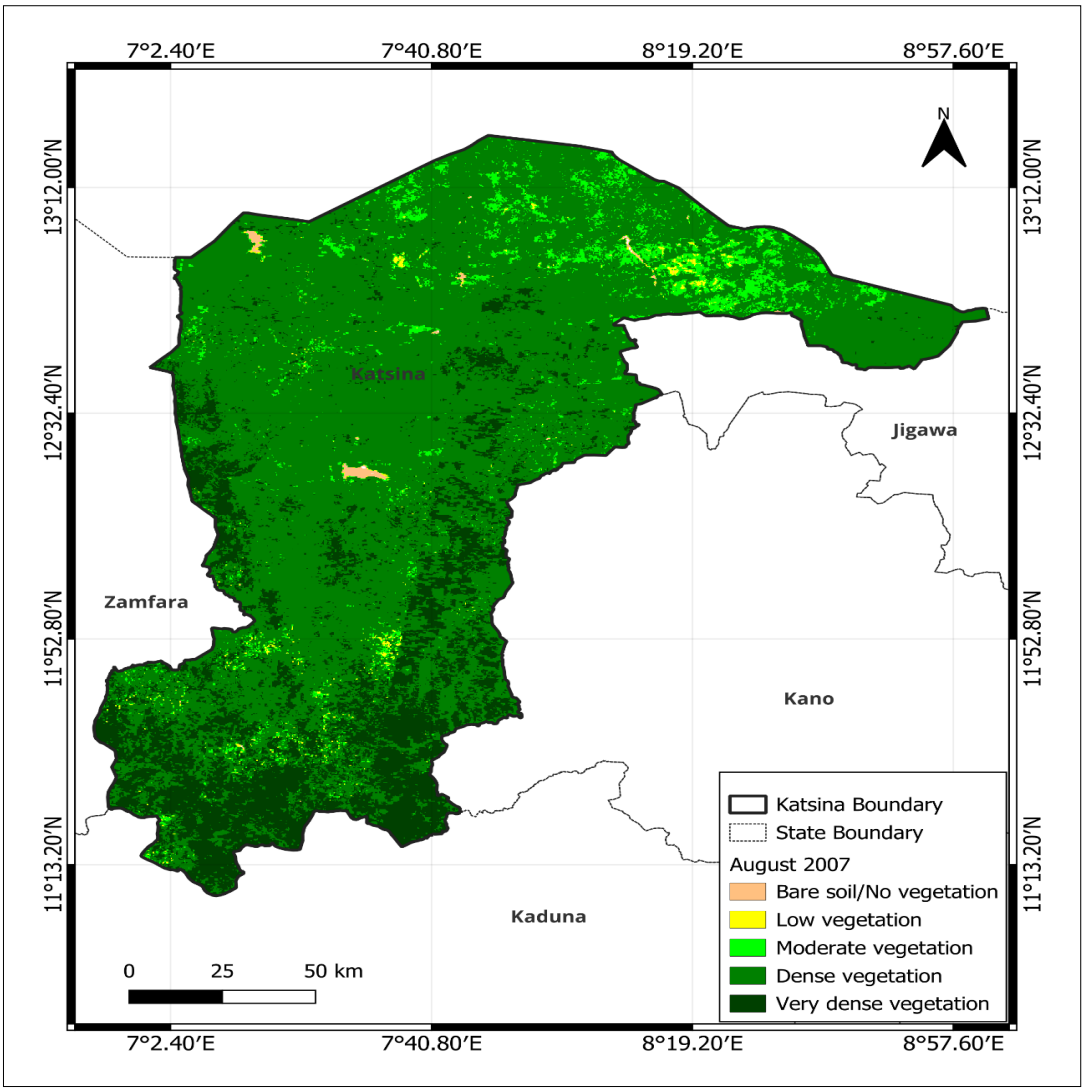

Figure 8: NDVI of August 2007

In 2007, according to Table 4.12, the Normalized Difference Vegetation Index (NDVI) revealed a landscape dominated by vegetation, with dense and very dense vegetation covering the majority of the studied area. Dense vegetation occupied the largest portion,

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accounting for 18,133.77 sq km (74.58% of the total area), followed by very dense vegetation at 4,753.24 sq km (19.55%). Moderate vegetation covered 1,240.94 sq km (5.10%), while low vegetation and bare soil/no vegetation comprised smaller percentages at 124.50 sq km (0.51%) and 61.98 sq km (0.25%) respectively

Table 4.13 showing area and percentage NDVI of 2012

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	86.78	0.36%
2	Low vegetation	450.30	1.85%
3	Moderate vegetation	1288.49	5.30%
4	Dense vegetation	16188.38	66.57%
5	Very dense vegetation	6302.75	25.92%
	TOTAL	24316.70	100.00%

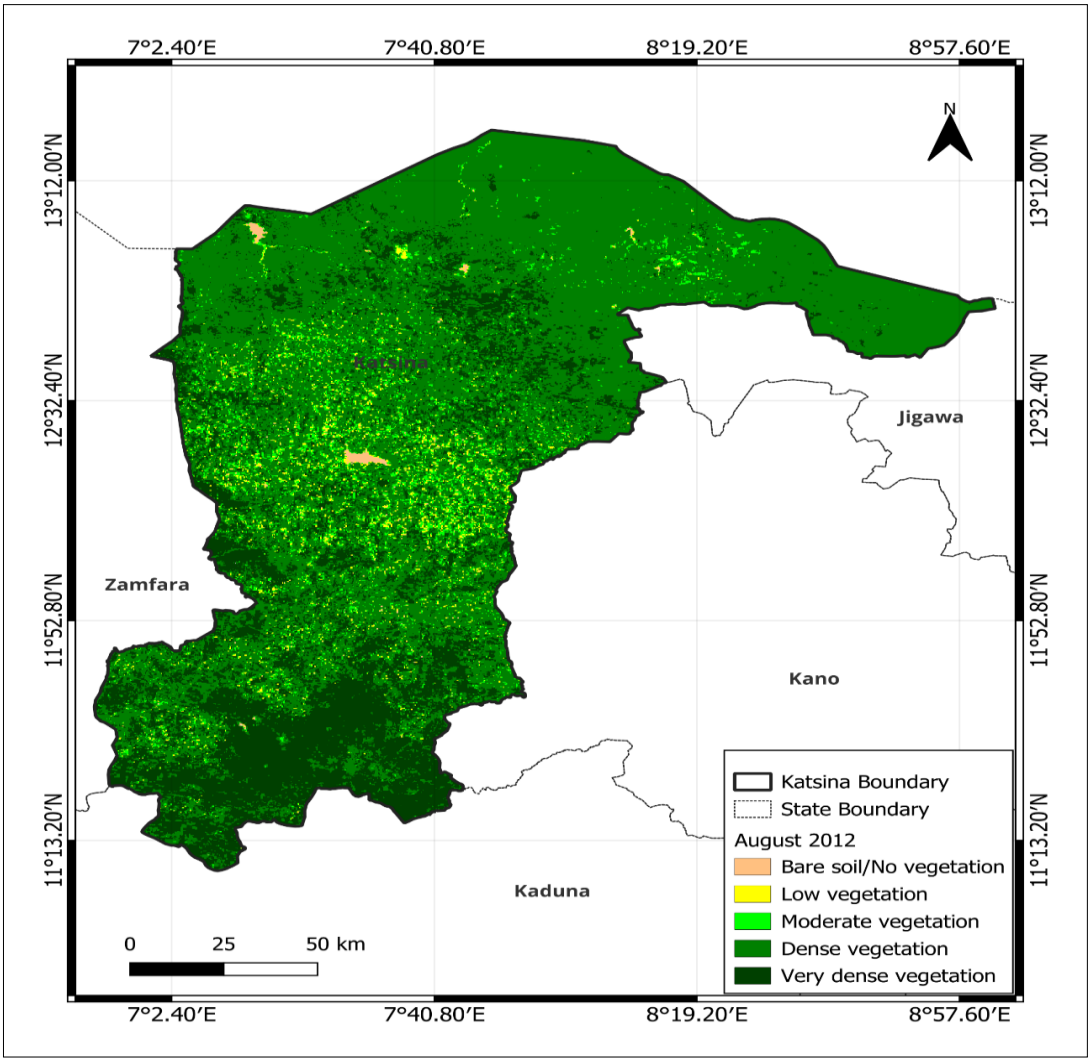

Figure 9: NDVI of August 2012

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Table 4.13 provides an overview of the area and percentage distribution of the Normalized Difference Vegetation Index (NDVI) for the year 2012, categorized by different vegetation types. In 2012, the landscape exhibited a substantial presence of vegetation, with dense and very dense vegetation covering the majority of the studied area. Dense vegetation accounted for the largest portion, with an area of 16,188.38 sq km (66.57% of the total area), followed closely by very dense vegetation at 6,302.75 sq km (25.92%). Moderate vegetation covered 1,288.49 sq km (5.30%), while low vegetation and bare soil/no vegetation constituted smaller percentages at 450.30 sq km (1.85%) and 86.78 sq km (0.36%) respectively.

Table 4.14 showing area and percentage NDVI of 2017

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	36.22	0.15%
2	Low vegetation	32.36	0.13%
3	Moderate vegetation	216.32	0.89%
4	Dense vegetation	17788.33	73.15%
5	Very dense vegetation	6243.72	25.68%
	TOTAL	24316.96	100.00%

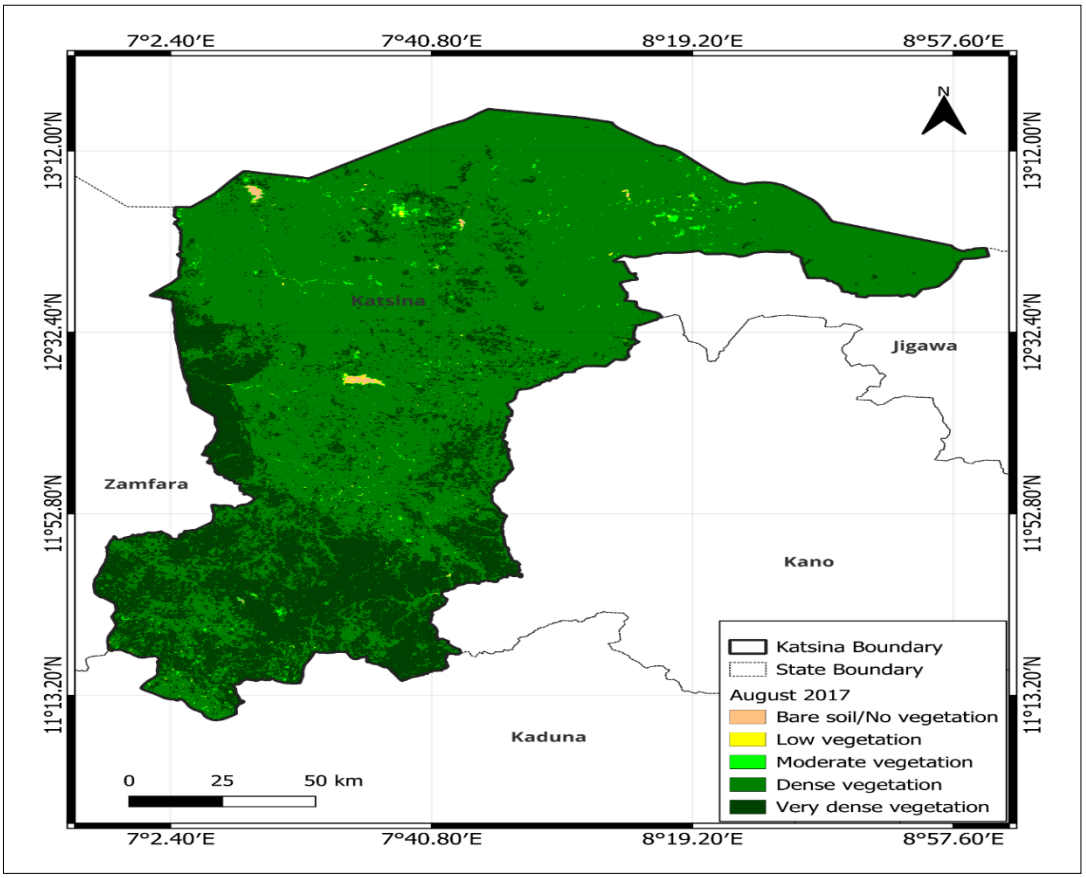

Figure 10: NDVI of August 2017

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Table 4.14 presents the area and percentage distribution of the Normalized Difference Vegetation Index (NDVI) for the year 2017, categorized by different vegetation types. In 2017, the landscape continued to exhibit a substantial presence of vegetation, with dense and very dense vegetation covering the majority of the studied area. Dense vegetation accounted for the largest portion, with an area of 17,788.33 sq km (73.15% of the total area), followed closely by very dense vegetation at 6,243.72 sq km (25.68%). Moderate vegetation covered 216.32 sq km (0.89%), while low vegetation and bare soil/no vegetation constituted smaller percentages at 32.36 sq km (0.13%) and 36.22 sq km (0.15%) respectively.

Table 4.15 showing area and percentage NDVI of 2022

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	51.36	0.21%
2	Low vegetation	501.01	2.06%
3	Moderate vegetation	1792.83	7.37%
4	Dense vegetation	16467.59	67.72%
5	Very dense vegetation	5503.74	22.63%
	TOTAL	24316.53	100.00%

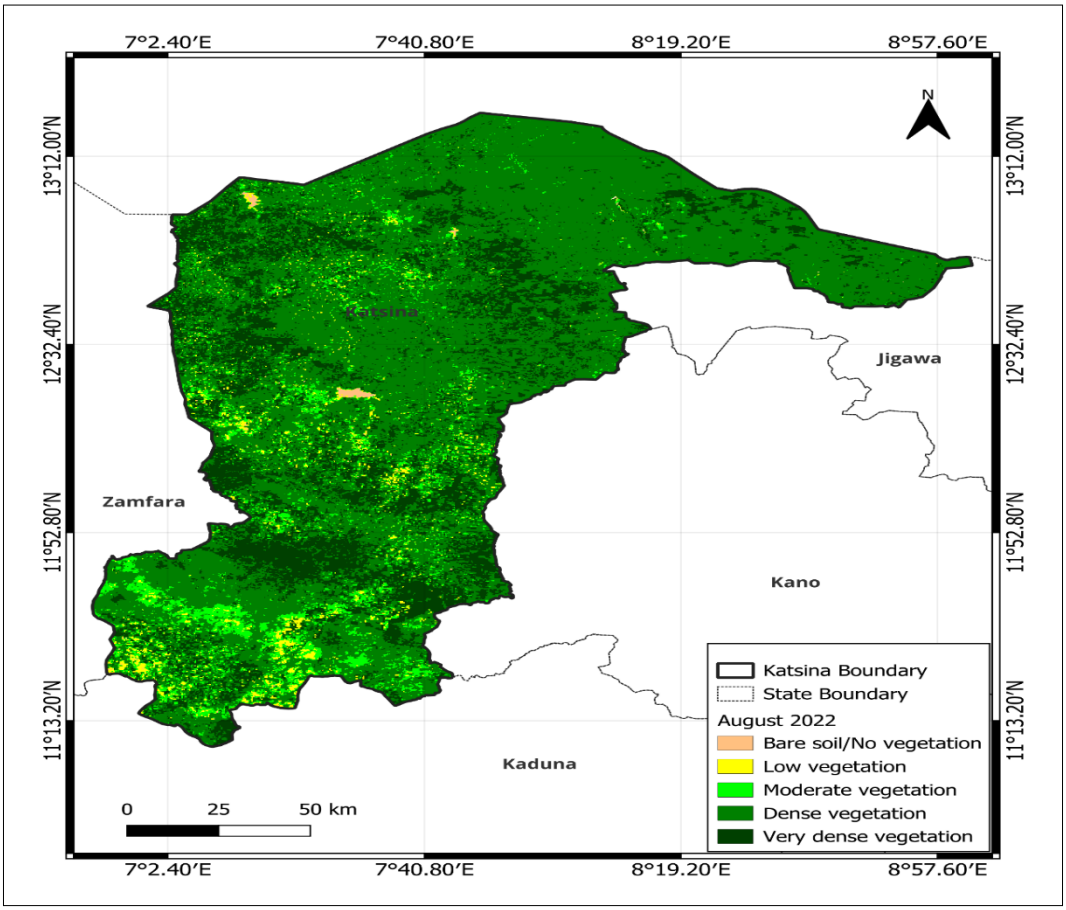

Figure 11: NDVI of August 2022

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Table 4.15 displays the area and percentage distribution of the Normalized Difference Vegetation Index (NDVI) for the year 2022, categorized by different vegetation types. In 2022, the landscape continued to exhibit a substantial presence of vegetation, with dense and very dense vegetation covering the majority of the studied area. Dense vegetation accounted for the largest portion, with an area of 16,467.59 sq km (67.72% of the total area), followed closely by very dense vegetation at 5,503.74 sq km (22.63%). Moderate vegetation covered 1,792.83 sq km (7.37%), while low vegetation and bare soil/no vegetation constituted smaller percentages at 501.01 sq km (2.06%) and 51.36 sq km (0.21%) respectively.

Over the period from 2002 to 2022, there has been a notable consistency in the dominance of vegetation cover in the studied area. Dense and very dense vegetation consistently covered the majority of the landscape, accounting for the highest percentages in each year. While there were fluctuations in the distribution of vegetation types over time, with minor increases or decreases observed in categories such as moderate vegetation and bare soil/no vegetation, the overall trend indicates a landscape characterized by dense vegetation cover.

August changes

Table 4.16 showing the changes between 2002 and 2007

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	-1.45	-2.28%
2	Low vegetation	42.29	51.44%
3	Moderate vegetation	588.81	90.29%
4	Dense vegetation	-538.95	-2.89%
5	Very dense vegetation	-89.73	-1.85%

Between 2002 and 2007, the land cover changes reveal varied trends across different categories. Bare soil or areas with no vegetation slightly decreased by 1.45 sq km (-2.28%), indicating a minor reduction. Low vegetation areas increased by 42.29 sq km (51.44%), showing significant growth in sparsely vegetated regions. Moderate vegetation saw a substantial increase of 588.81 sq km (90.29%), reflecting considerable expansion in these areas. Dense vegetation decreased by 538.95 sq km (-2.89%), indicating a slight reduction in highly vegetated areas. Very dense vegetation also decreased by 89.73 sq km (-1.85%), showing a minor reduction.

Table 4.17 showing the changes between 2007 and 2012

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	24.79	40.00%
2	Low vegetation	325.80	261.68%
3	Moderate vegetation	47.55	3.83%

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4	Dense vegetation	-1945.40	-10.73%
5	Very dense vegetation	1549.51	32.60%

Between 2007 and 2012, the land cover changes indicate significant shifts across various categories. Bare soil or areas with no vegetation increased by 24.79 sq km (40.00%), suggesting a notable expansion of bare ground. Low vegetation areas saw a dramatic increase of 325.80 sq km (261.68%), indicating significant growth in sparsely vegetated regions. Moderate vegetation experienced a moderate increase of 47.55 sq km (3.83%), showing slight expansion. Dense vegetation decreased substantially by 1945.40 sq km (-10.73%), indicating a notable reduction in these areas. Very dense vegetation increased significantly by 1549.51 sq km (32.60%), reflecting substantial growth or densification of highly vegetated regions.

Table 4.18 showing the changes between 2012 and 2017

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	-50.55	-58.26%
2	Low vegetation	-417.94	-92.81%
3	Moderate vegetation	-1072.17	-83.21%
4	Dense vegetation	1599.96	9.88%
5	Very dense vegetation	-59.03	-0.94%

Between 2012 and 2017, the land cover changes indicate substantial shifts in various categories. Bare soil or areas with no vegetation decreased by 50.55 sq km (-58.26%), reflecting a significant reduction in bare ground. Low vegetation areas saw a dramatic decrease of 417.94 sq km (-92.81%), indicating a major loss or transformation of these regions. Moderate vegetation also experienced a substantial decline of 1072.17 sq km (-83.21%), showing a significant reduction. Dense vegetation, however, increased notably by 1599.96 sq km (9.88%), indicating considerable growth or densification. Very dense vegetation decreased slightly by 59.03 sq km (-0.94%), showing a minor reduction.

Table 4.19 showing the changes between 2017 and 2022

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	15.13	41.78%
2	Low vegetation	468.65	1448.26%
3	Moderate vegetation	1576.51	728.78%
4	Dense vegetation	-1320.74	-7.42%
5	Very dense vegetation	-739.98	-11.85%

Between 2017 and 2022, the land cover changes exhibit substantial shifts across different vegetation categories. Bare soil or areas with no vegetation increased by 15.13 sq km

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(41.78%), indicating a notable expansion. Low vegetation areas saw a dramatic increase of 468.65 sq km (1448.26%), reflecting significant growth in sparsely vegetated regions. Moderate vegetation experienced an even more substantial increase of 1576.51 sq km (728.78%), showing considerable expansion. In contrast, dense vegetation decreased by 1320.74 sq km (-7.42%), indicating a notable reduction in these areas. Very dense vegetation also decreased by 739.98 sq km (-11.85%), showing a significant decline.

Table 4.20 showing the changes between 2002 and 2022

S/N	Category	Area (sqkm)	Percentage
1	Bare soil/No vegetation	-12.07	-19.04%
2	Low vegetation	418.80	509.40%
3	Moderate vegetation	1140.70	174.92%
4	Dense vegetation	-2205.13	-11.81%
5	Very dense vegetation	660.77	13.64%

Between 2002 and 2022, the land cover changes indicate significant shifts across different vegetation categories. Bare soil or areas with no vegetation decreased by 12.07 sq km (-19.04%), suggesting a notable reduction in bare ground over the two-decade period. Low vegetation areas saw a substantial increase of 418.80 sq km (509.40%), indicating significant growth in sparsely vegetated regions. Moderate vegetation experienced a remarkable increase of 1140.70 sq km (174.92%), showing considerable expansion. In contrast, dense vegetation decreased notably by 2205.13 sq km (-11.81%), indicating a significant reduction in these areas. Very dense vegetation, however, increased by 660.77 sq km (13.64%), reflecting growth in highly vegetated regions.

Between 2002 and 2022, significant changes in land cover were observed across various vegetation categories. The data illustrates dynamic shifts, with fluctuations in bare soil or non-vegetated areas alongside notable increases in low vegetation and moderate vegetation over the two-decade period. While there were fluctuations in dense vegetation cover, overall, there was a notable decrease, suggesting changes in land management or environmental conditions.

MAJOR FINDINGS

The findings highlight significant shifts in vegetation cover from 2002 to 2022, with moderate vegetation consistently dominating, indicating its resilience to environmental changes. Fluctuations occurred in low and dense vegetation, emphasizing their importance for ecosystem health. Dense and very dense vegetation remained consistent, underscoring their vital role. Overall, decreases in bare soil or non-vegetated areas suggest potential improvements in land management or environmental conditions. Seasonal analysis reveals that during the wet season (August), low vegetation and bare

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soil tend to decrease, while moderate and dense vegetation increase, indicating a conducive environment for growth. Conversely, during the dry season (January), decreases in moderate and dense vegetation may lead to expansions in bare soil, highlighting the need to understand these seasonal dynamics for effective land management and conservation.

SUMMARY

This study utilized the MODIS13Q1 product from the Terra satellite to analyze the Normalized Difference Vegetation Index (NDVI) data for Katsina State over the years 2002, 2007, 2012, 2017, and 2022. The data was processed and reprojected to the WGS 84 coordinate system and clipped to the boundaries of Katsina State. The NDVI values were classified into five categories: Bare soil/No vegetation, Low vegetation, Moderate vegetation, Dense vegetation, and Very dense vegetation.

The analysis revealed significant shifts in vegetation cover over the 20-year period. Moderate vegetation consistently dominated the land cover, reaching its highest level in 2017 at 83.07% before slightly decreasing in 2022 to 80.43%. Low vegetation showed fluctuations, with notable increases in 2007 and decreases in subsequent years. Dense vegetation saw fluctuations as well but showed a notable increase in 2022. Bare soil/No vegetation remained relatively low throughout the period, while very dense vegetation was absent until 2022 when a small amount was reported for the first time.

The study highlights the importance of understanding seasonal dynamics for effective land management and conservation. During the wet season (August), low vegetation and bare soil tend to decrease, while moderate and dense vegetation increase, indicating a conducive environment for growth. Conversely, during the dry season (January), decreases in moderate and dense vegetation may lead to expansions in bare soil, highlighting the need to understand these seasonal dynamics for effective land management and conservation.

CONCLUSION

The findings revealed significant shifts in vegetation cover from 2002 to 2022. Moderate vegetation consistently dominated the land cover, indicating its resilience to environmental changesLow vegetation and dense vegetation exhibited fluctuations, emphasizing their importance for ecosystem health. Notably, dense vegetation showed a substantial increase in 2022, highlighting significant growth or densification.

The study also observed a reduction in bare soil or non-vegetated areas, suggesting potential improvements in land management or environmental conditions. Seasonal analysis indicated that during the wet season (August), low vegetation and bare soil tend to decrease, while moderate and dense vegetation increase, indicating a conducive environment for growth. Conversely, during the dry season (January), decreases in

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moderate and dense vegetation may lead to expansions in bare soil, highlighting the need to understand these seasonal dynamics for effective land management and conservation. Overall, the study underscores the dynamic nature of vegetation cover in Katsina State and the importance of continuous monitoring to inform sustainable land management practices.

RECOMMENDATIONS

Based on the analysis of the NDVI data from 2002 to 2022, the following recommendations are proposed to enhance vegetation management and environmental sustainability in Katsina State:

i. Enhance Vegetation Monitoring: Implement continuous monitoring of vegetation cover using satellite imagery and NDVI data to track changes and identify areas requiring intervention.
ii. Promote Sustainable Land Management: Encourage practices that reduce bare soil and low vegetation areas, such as reforestation, afforestation, and sustainable agricultural practices.
iii. Support Dense Vegetation Growth: Focus on maintaining and expanding dense vegetation areas through conservation efforts, protection of natural habitats, and restoration projects.
iv. Address Seasonal Variations: Develop strategies to mitigate the impact of seasonal changes on vegetation cover, particularly during the dry season, to prevent land degradation and promote year-round vegetation health.

These recommendations aim to improve the overall vegetation health and contribute to the environmental sustainability of Katsina State.

REFERENCES

Acreman, M. C., J. R. Blake, D. J. Booker, R. J. Harding, N. Reynard, J. O. Mountford, and C. J. Stratford (2009), A simple framework for evaluating regional wetland ecohydrological response to climate change with case studies from Great Britain, Ecohydrology, 2, 1–17, doi:10.1002/eco.37.

Angelini, I. M., M. Garstang, R. E. Davis, B. Hayden, D. R. Fitzjarrald, D. R. Legates, S. Greco, S. Macko, and V. Connors (2011), On the coupling between vegetation and the atmosphere, Theor. Appl. Climatol., 105, 243–261, doi:10.1007/s00704-010-0377-5.

Bounoua, L., F. G. Hall, P. J. Sellers, A. Kumar, G. J. Collatz, C. J. Tucker, and M. L. Imhoff (2010), Quantifying the negative feedback of vegetation to greenhouse warming: A modeling approach, Geophys. Res. Lett., 37, L23701, doi:10.1029/2010GL045338.

Duveiller, G., Defourny, P., Desclée, B. and Mayaux, P., 2008. Deforestation in Central Africa: Estimates at regional, national and landscape levels by advanced processing of systematically distributed Landsat extracts. *Remote sensing of Environment*, 112, 1969-1981.

Katsina State Ministry of Environement, (2010). The Geography of the Southern Katsina State, Third Annual Report 2010.

Mortsch, L.D. (2006). Impact of climate change onagriculture, forestry and wetlands. *Applied Geography*, 22,139-159.

Philip, M. O. A. A. Glory, M. Tokunbo, O.Sammy, U. U. & Taiwo, A. (2014). Challenges of Deforestation in Nigeria and the Millennium Development Goals. *International Journal of Environment and Bioenergy,* 9(2): 76-94.

Zayyana Y. I. (2010). Some Aspects of Urban Farming in Urban Katsina, Katsina State. Unpublished M.Sc Thesis Submitted to the Department of Geography, Bayero University Kano.

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