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ANALYSIS OF VEGETATION COVER CHANGES USING NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) IN BIRNIN KEBBI, NIGERIA

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Abstract: *Vegetation absorbs carbon dioxide from the atmosphere, thereby mitigating the impact of global warming and climate change and also preventing desertification. In Nigeria, desertification poses a threat to the livelihoods of numerous communities, particularly in the northern region. Consequently, this study focused on the analysis of the changes in the vegetation cover in Birnin Kebbi, Kebbi State, Nigeria, from 1994 to 2021, using the Normalized Difference Vegetation Index (NDVI). This was with a view to projecting further changes the next decade through simple linear regression. The results indicate an irregular pattern of vegetation change. The NDVI maximum values decreased from 0.442 in 1994 to 0.411 2002. However, between 2002 and 2021, the values increased from 0.411 to 0.496, revealing a general vegetation increase of 4.01% over 27 years. Although, a gradual decline in vegetation cover occurred between 1994 and 2002, the vegetation cover in 2021 showed an improvement. Overall, the study revealed an irregular pattern of vegetation change. The projected vegetation changes showed that Very-Low-Dense Vegetation will increase by 4.72%, Low-Dense Vegetation will increase by 1.45%, and High-Dense Vegetation will increase by 0.76%, while Moderate-Dense Vegetation will decline by -0.53%. This trend indicated that natural vegetation growth is limited and therefore recommended continued afforestation efforts which play a pivotal role in fostering vegetal growth in the study area.*

Keywords: Impact, Afforestation, Desertification, Vegetation Cover Change, Climate Change

INTRODUCTION

The vegetation provides a variety of products and performs many essential environmental/ecological functions. Nigeria's vegetation reflects a close link between vegetation and climate, with a south-to-north progressive decline in vegetation, total rainfall, and length of the wet season (Adigun, 2019). Northwestern Nigeria falls within the

Sudano-Sahelian Savanna vegetation zone, characterized by grasslands with little or no thick forest. The vegetation characteristics of the area make the region prone to desertification. A series of afforestation programs have been implemented in the region to mitigate desertification, climate change, and pastoral clashes. Since 1977, the Nigerian Government established a National



Committee on Arid zone afforestation to tackle desertification (Gbadebo, 2022). Various other schemes, such as the African Great Green Wall in 2007, have been embarked upon since then to improve the vegetation cover of the semi-arid zone. Despite these efforts, desertification is still very active (Ibrahim and Muhammad, 2015). Annually, Nigeria loses about 350,000 hectares to desertification (Olagunju, 2015). The problem threatens the livelihoods of over 40 million people (Akah *et al.*, 2023; Sileshi *et al.*, 2023).

Likewise, the study area (Birnin Kebbi) is among the frontline regions where the problem is more intense. Although, Birnin Kebbi is among the frontline regions, there is limited research that quantifies and projects vegetation cover in the area. In light of emerging issues such as the prevalence of desertification, global warming and climate change there is a dire need for a quantitative and reproducible assessment of the vegetation cover to support policy development for sustainable development (Akinola and Akindele, 2020). Therefore, this study aimed at the analysis of the changes in the vegetation cover within the study area. The Normalized Different Vegetation Index (NDVI) was to be used to examine the spatio-temporal variation of the health of vegetation cover over the study area for twenty-seven years.

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator for assessing vegetation health,

based on the reflection of electromagnetic spectrum by plants. This index is directly related to the photosynthetic capacity and, consequently, the energy absorption of plant canopies (Patón, 2020). The Red (R) and the Near-Infrared (NIR) channels of satellite sensors are used for conducting studies of this nature (Asokan and Anitha, 2019). Theoretically, NDVI values range from -1 to +1. A positive result indicates the presence of vegetation cover in the cell, with higher positive values indicating greater greenery and density of the plant. Conversely, a negative value signifies non-green (vegetation) surfaces (Allawai and Ahmed, 2020).

This study acknowledges a correlation between precipitation and vegetation greenness, particularly in arid regions. The study research conducted by Dewald *et al.* (2022) asserts that rainfall events can influence NDVI (Normalized Difference Vegetation Index) by creating standing water, which obscures vegetation and subsequently reduces NDVI values. Additionally, rainfall has an impact on vegetation cover, as plants tend to exhibit increased greenness with the availability of additional water.

THE STUDY AREA

The study area, Birnin Kebbi, depicted in Figure 1, is situated in Kebbi State, in the north-western region of Nigeria. It lies approximately between latitudes 12°10'0"N and 12°50'0"N and longitudes 4°0'0"E and 4°40'0"E. It has a land area of approximately 1,387.162 square kilometers (Ismail and Oke, 2012).

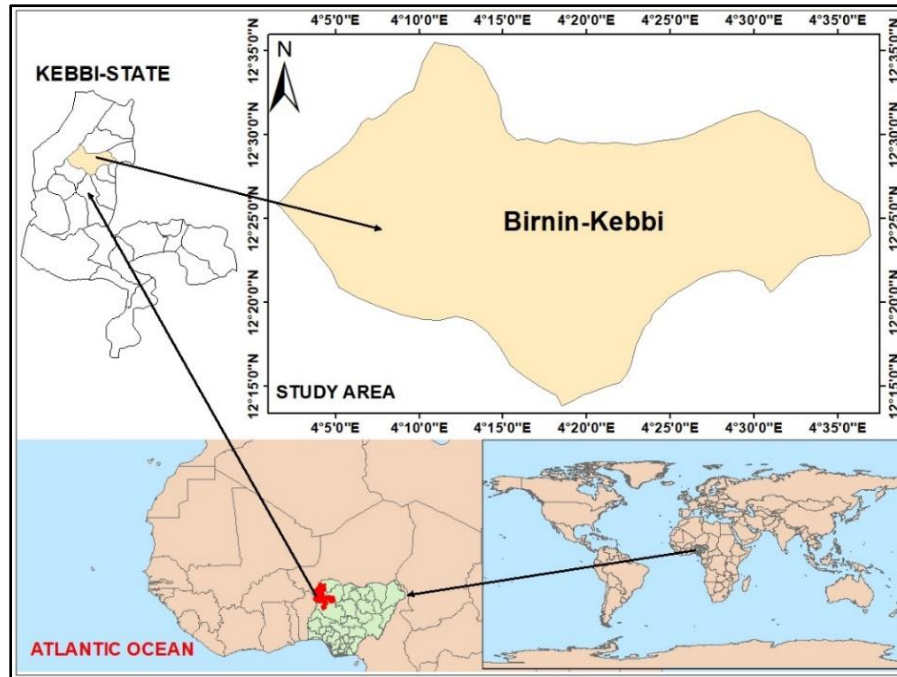


Figure 1: Location of the Study Area

Source: Author's 2024.

The climate of Birnin Kebbi is characterized by two distinct seasons of wet and dry, which is influenced by Tropical Maritime (mT) and Tropical Continental (cT) air masses respectively. The dry season features extremely hot weather, with an average temperature of about 34°C. The area receives a yearly precipitation average of 787.53mm

(Ismail and Oke, 2012). As shown in Table 1, rainfall in the study area occurs between the months of May and October while the dry season is usually experienced between November and April. During the wet season (May-October), while minimal rainfall takes place during the dry season, exerting little to no effect on vegetation.

Table 1: Mean monthly rainfall in Birnin Kebbi

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Average Rainfall	0.00	0.07	1.86	9.06	49.97	138.18	194.33	242.24	135.01	16.68	0.11	0.00

Source: NiMET, (2022)



The natural vegetation of Birnin Kebbi is characterized as Sudano-Sahelian Savanna. The vegetation type consists of shrubs, grasses of varying heights (less than 3m), and woody perennial plants with persistent woody stems without any defined main stem, less than 5m high (Usman *et al.*, 2016). The region faces a threat of desertification, a process through which dryland ecosystems (vegetation) are

continually degraded by anthropogenic factors. Intensive cultivation, grazing, fuel wood harvesting, and bush burning have altered the natural vegetation in many areas. However, various afforestation programs have been implemented by relevant stakeholders in the region as a means of mitigating desertification (Gbadebo, 2022).

METHODOLOGY

The Schematic diagram detailing the procedures undertaken in this study is succinctly outlined in Figure 2.

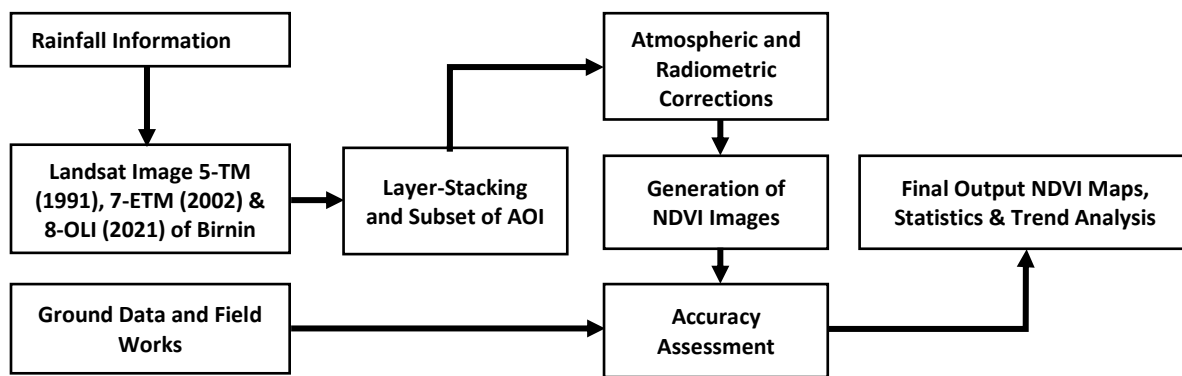


Figure 2: Overall flowchart of the study

Ground information was gathered through informal conversations and observations. Photographs, along with GPS coordinates of locations exhibiting distinct characteristics and featuring dominant vegetation, were captured. This process serves as ground truthing, aiding in comprehending the condition of the vegetation, particularly in areas where various characteristics coexist. During this phase, specific attention was given to locations with the following categorization of vegetation cover: class 1 (non-vegetation), class 2 (very low dense vegetation), class 3 (low dense vegetation), class 4 (moderate dense vegetation), and

class 5 (high dense vegetation). Identifiable places with the aforementioned vegetation cover were pinpointed, and their geographical coordinates were taken using GPS handheld receivers.

Landsat satellite imageries for dry seasons (Table 2) obtained from United States Geological Survey (USGS) archives at <http://glovis.usgs.gov> were used for this study. All the satellite imageries are cloud free and have UTM WGS84 projection system. Average rainfall data for 2022 obtained from NIMET was used to determine whether the capturing of any of the imageries



coincided with the rainfall period, which may thus potentially influence the overall NDVI

value. Accordingly, Imageries from dry seasons (April for 1994, March for 2002, and April 2021) were selected for this study.

Table 2: Landsat satellite datasets used for this study

Satellite	Band		Path	Row	Image Resolution	Wavelength (micrometers)		Image Acquisition Date
	Red	NIR				Red	NIR	
LANDSAT_8 OLI	B4	B5	191	51	30m	0.64-0.67	0.85-0.88	2021-04-28
LANDSAT_7 ETM	B3	B4	191	51	30m	0.63-0.69	0.77-0.90	2002-03-31
LANDSAT_5 TM	B3	B4	191	51	30m	0.63-0.69	0.76-0.90	1994-04-20

Source: USGS archives <http://glovis.usgs.gov>

Pre-processing of satellite imageries was undertaken using ERDAS IMAGINE 2014. Because satellite imagery is often extensive, with datasets comprising large files of imagery across different bands, a multi-band image was created by combining individual bands of the data. The process of Layer-Stacking was employed to produce a consolidated multispectral image for each year (Figure 2). Layer stacking involves amalgamating distinct bands to generate a new multi-band image. For the year 2021, Image bands 1, 2, 3, 4, 5, 6, and 7 from Landsat_8 OLI were selected, while bands 1, 2, 3, 4, 5, and 7 were chosen for 2002 and 1994 (Landsat_7 ETM and Landsat_5 TM, respectively). Nonetheless, for NDVI

analysis, only two bands (Red band and NIR band) were used and additional bands were included to enhance the operation of the multispectral image.

The subsequent step involves extracting an Area of Interest (AoI) from the images for analysis. A subset was done, it refers to extracting a section of a larger image, and since satellite data typically cover more area than needed, a specific region of interest can be subset from the larger image. The Area of Interest represents the study area was identified and extracted from the fully stacked images by overlaying a Shape-file vector data of the study area, as illustrated in Figure 3.

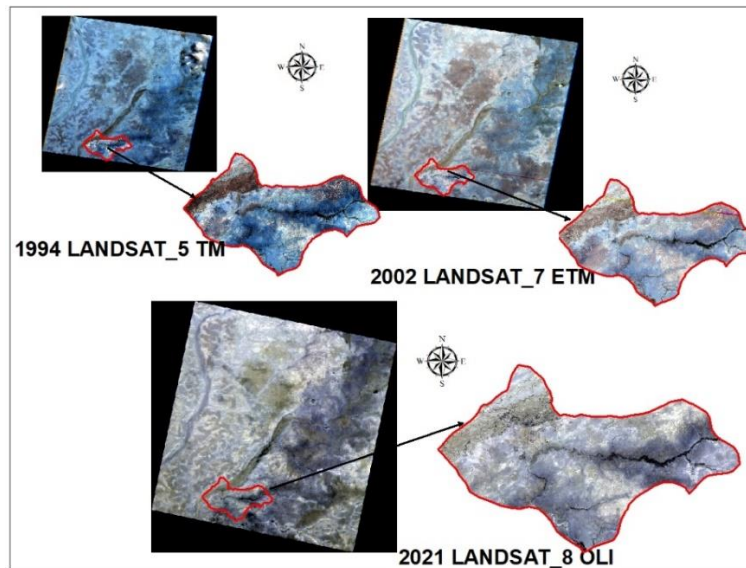


Figure 3. Image subsets of the study area [Landsat 5 TM (1994), Landsat 7 ETM+ (2002), Landsat 8 OLI/TIRS (2013)].

Source: Authors Analysis (2024)

The NDVI was used for the vegetation cover analysis in this study. The NDVI results range from -1 to +1. A negative value means no vegetated area (such as water body, build up, bare surface etc). Low NDVI value means low vegetation cover. A high NDVI value shows high vegetation cover. The NDVI was calculated using the formula;

$$\text{For Landsat}_8 \text{ OLI/TIRS; NDVI} = \frac{(\text{NIR (band 5)} - \text{RED (band 4)})}{(\text{NIR (band 5)} + \text{RED (band 4)})} \quad \text{Equation 1}$$

$$\text{For Landsat}_5 \text{ TM/7ETM; NDVI} = \frac{(\text{NIR (band 4)} - \text{RED (band 3)})}{(\text{NIR (band 4)} + \text{RED (band 3)})} \quad \text{Equation 2}$$

Where: NIR is near-infrared band and Red is the red reflectance band. The NDVI calculate the differences between NIR (near-infrared) and RED (red) reflectance, then divided by their accumulative. The NDVI generated is classified to reflect the pattern of vegetation of the study area. The classes are shown in Table 3. ArcGIS 10.5 was used for the reclassification of the NDVI values and for further analysis.

Table 3: NDVI Classification

Class	class 1	class 2	class 3	class 4	class 5
Description	non-vegetation Area	Very dense low dense vegetation	Low dense vegetation	Moderate dense vegetation	High dense vegetation
NDVI Value	-1 to 0.05	0.06 to 0.15	0.16 to 0.25	0.26 to 0.35	0.36 to 1

Source: Modified from Aburasa et al., (2015)



Maps, tables and graphs were subsequently to describe results generated from the NDVI analysis. Descriptive statistics (such as percentage and frequency) were used to present vegetation cover changes, trends and patterns of the study area. In the present study, simple linear regression analysis was computed in Microsoft Excel to further describe the trend of vegetation change. The future trends of each class of vegetation cover were predicted using the regression analysis. The formula for the simple linear regression is of the form:

$$y = bx + a \quad \text{Equation 3}$$

Where: 'y' is the dependent variable, 'b' is the slope (beta coefficient), 'a' is the intercept and 'x' is constant. Through the generated linear regression equation, the prediction of vegetation cover for 2031 was carried out.

To assess the accuracy of generated vegetation cover classes, an error matrix (confusion matrix) was prepared using ground information collected during the field survey with the post-classification NDVI images of 1994, 2002 and 2021. The data for the accuracy assessment were selected from the field knowledge and aerial photos from Google Earth. The accuracy assessment shows whether the model vegetation cover classes generated from NDVI values correlate well with the observed information generated from field survey or past information generated from aerial photos. The Error Matrix shows how the generated vegetation cover classes are correctly modelled. From the confusion matrix analysis, overall accuracy and Kappa coefficient were derived using the following formulas.

$$\text{Overall Accuracy} = \frac{TP}{TP+FP}$$

Equation 4

Where TP: The number of samples that were correctly predicted, FP: The number of samples that were incorrectly predicted. The kappa coefficient is calculated using both the observed (total) accuracy and the random accuracy: Where; $p_{(a)}$ is total accuracy, and $p_{(r)}$ is random accuracy.

$$Kappa = (p_{(a)} - p_{(r)}) / (1 - p_{(r)})$$

Equation 5

A value of 0 to 1 indicates that the classification is significantly better than random with each value between 0 to 1 representing a certain degree of acceptance (McHugh, 2012). Interpreted as follows; <0.20=Poor, 0.21–0.40=Fair, 0.41–0.60=Moderate, 0.61–0.80=Substantial, 0.81–1.00=Perfect.

RESULTS AND DISCUSSION

VEGETATION COVER CHANGES ANALYSIS

The results obtained from the Normalized Difference Vegetation Index (NDVI) analysis of three Landsat images captured in different years (1994, 2002, and 2021) indicated vegetation health indices on a linear measurement scale spanning from -1.0 to +1.0. The NDVI images, derived from the analysis, are depicted in Figure 4. The pixel values in the images have been reclassified according to the specifications outlined in Table 3.

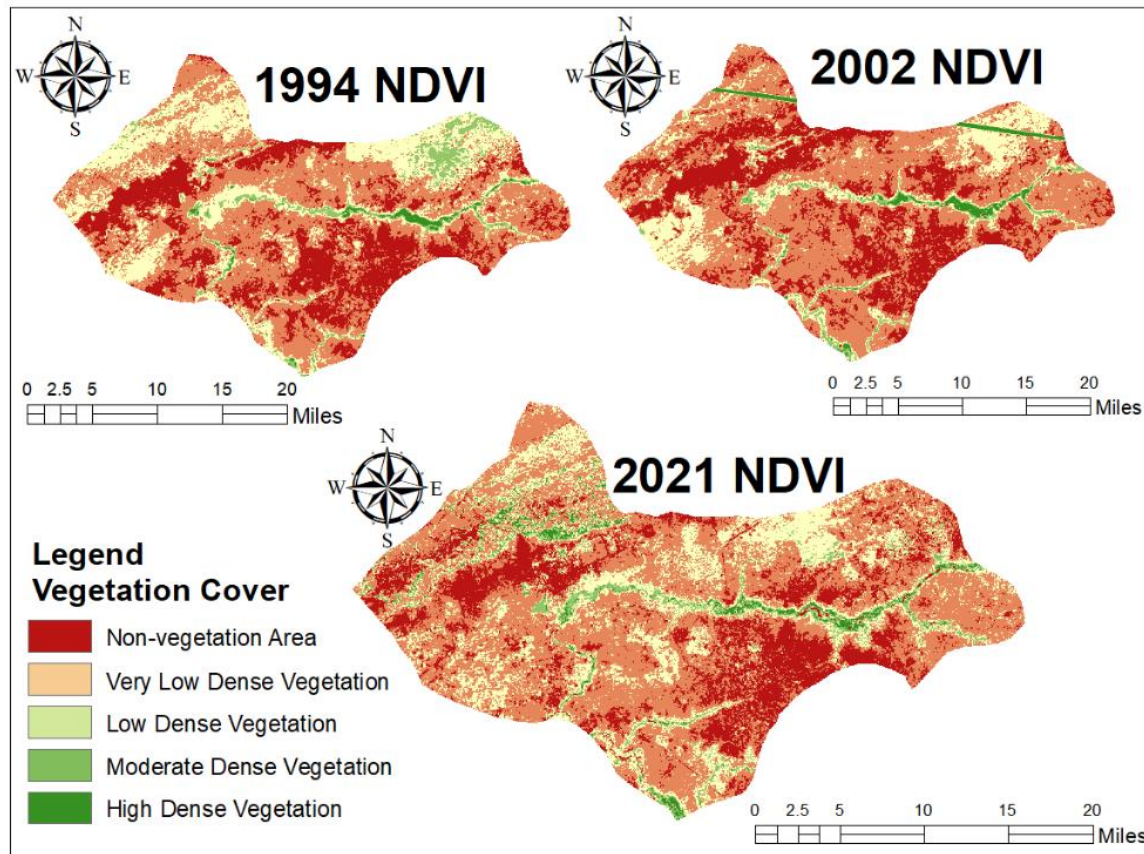


Figure 4: Classify NDVI images of 1994, 2002 and 2021
Source: Authors Analysis (2024).

The NDVI images provide insight into the spatial distribution of vegetation cover in the study area. The result revealed that non-vegetated areas exhibit NDVI values ranging from -1 to 0.05, this encompasses land areas covered with bare soil, built-up structures, water bodies, rocks, and other non-vegetated features. All pixels with values above 0.05 are considered vegetated areas.

These vegetated areas were further classified into different categories based on NDVI values. Very Low Dense Vegetation (degraded vegetation) falls within the range of 0.06 to 0.15, Low Dense Vegetation (sparse vegetation) ranges from 0.16 to 0.25, Moderate Dense Vegetation (scattered trees) spans from 0.26 to 0.35, and High Dense

Vegetation (healthy trees/dense forest) was identified with NDVI values ranging from 0.36 to 1.

The interpretation of vegetation cover change from the NDVI analysis was presented in Table 4. The analysis revealed a decrease in the Non-Vegetation Area from 469.7 km² (33.9%) in 1994 to 436.9 km² (31.5%) in 2002 and further to 242.2 km² (17.5%) in 2021. This result shows that, despite the constant increase in the built-up area due to urban development and urbanization, the overall vegetation covered area in this study area is on the increase. This observation is in agreement with Gbadebo (2022) who observed that in 1987.



Table 4: Changes in Vegetation Covered Area (1994, 2002 and 2021)

Class	NDVI Value	Description	1994		2002		2021	
			Km ²	%	Km ²	%	Km ²	%
1	-1 to 0.05	Non-vegetation Area	469.737	33.9	436.923	31.5	242.114	17.5
2	0.06 to 0.15	Very Low Dense Vegetation	565.352	40.8	633.223	45.6	691.031	49.8
3	0.16 to 0.25	Low Dense Vegetation	260.787	18.8	237.869	17.1	343.926	24.8
4	0.26 to 0.35	Moderate Dense Vegetation	76.054	5.5	47.334	3.4	79.606	5.7
5	0.36 to 1	High Dense Vegetation	15.232	1.1	31.813	2.3	30.485	2.2
TOTAL Area			1387.16	100	1387.16	100	1387.16	100

Source: Authors Analysis (2024).

An afforestation project funded by the World Bank was launched in eleven frontline states, including the study area (Gbadebo, 2022). The project spanned nine years and proved to be the most successful afforestation initiative in Northern Nigeria. Subsequently, tree planting campaigns were intensified by state governments, yielding positive impacts on the socio-economic development of the region.

Similarly, the land cover of Very Low Dense Vegetation followed a consistent increasing trend, from 565.4 km² (40.8%) in 1994 to 633.2 km² (45.6%) in 2002, and subsequently to 691.1 km² (49.8%) in 2021. The Low Dense Vegetation cover exhibited a

fluctuating trend pattern, with a coverage of 260.8 km² (18.8%) in 1994, slightly decreasing to 237.9 km² (17.1%) in 2002, and subsequently increasing to 343.9 km² (24.8%) in 2021. The areas occupied by Moderate Dense Vegetation cover (Figure 5) displayed a similar fluctuating trend. In 1994, it covered a total area of 76.1 km² (5.5%) in 2021, which decreased to 47.4 km² (3.4%) in 2002 and later increased to 79.6 km² (5.7%). As for the High Dense Vegetation cover, its coverage increased from 15.3 km² (1.1%) in 1994 to 31.8 km² (2.3%) in 2002, and slightly decreased to 30.5 km² (2.2%) in 2021 (Figure 5).

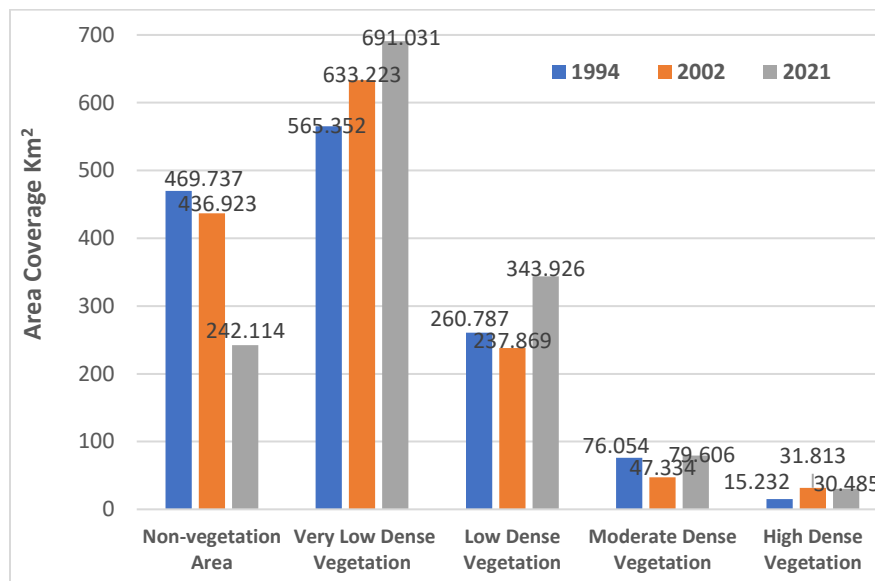


Figure 5: Vegetation change distribution in Birnin Kebbi (1994–2022)
Source: Authors Analysis (2024).

NDVI PATTERN AND TREND ANALYSIS

For a more comprehensive understanding of the health of vegetation cover, a trend pattern analysis of NDVI (Normalized Difference Vegetation Index) maximum values was conducted. The overall pattern of vegetation change over the study period and the relationship between the observed years of 1994, 2002, and 2021 are shown in Table 5.

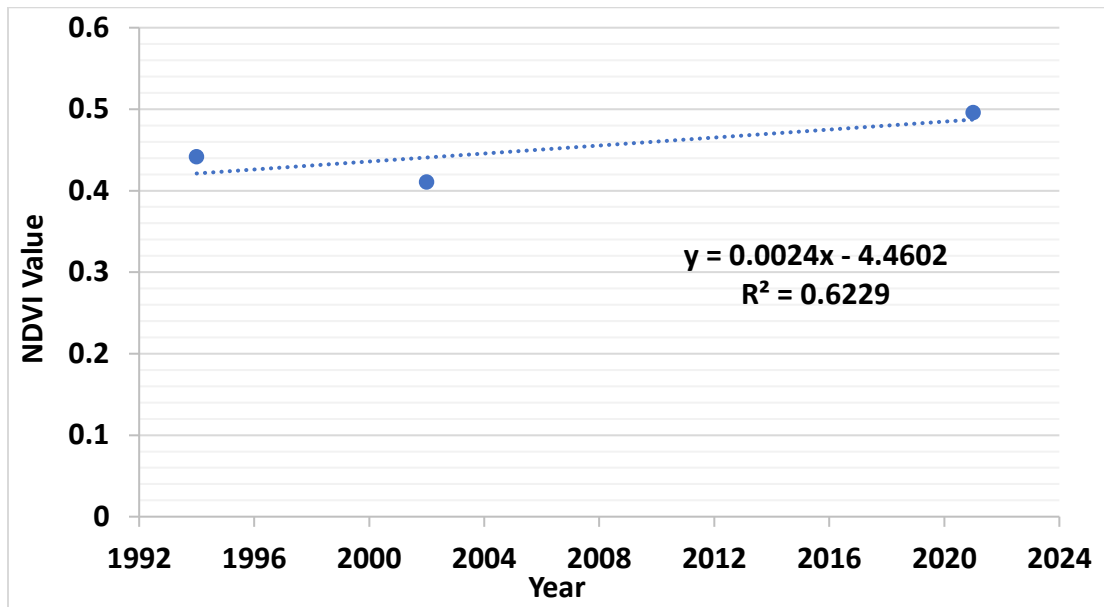
Table 5: Vegetation change pattern in the study area

Year	NDVI Max Values	NDVI %
1994	0.442	32.77031
2002	0.411	30.44643
2021	0.496	36.78326

Authors Analysis (2024).

An irregular pattern was observed, with the NDVI maximum values decreasing from 0.442 and 0.411 in 1994 and 2002, respectively. However, between 2002 and 2021, there was an increase from 0.411 to 0.496. Similarly, the value in 2021 exceeded the initial value of 0.442 in 1994. This pattern indicates a vegetation increase of 4.01% over 27 years. Although, there appeared to be a gradual decline in vegetation cover between 1994 and 2002, the vegetation cover in 2021 showed an improvement.

This trend was further confirmed by regression analysis conducted on the NDVI maximum values, revealing a strong relationship with a regression squared (R^2) of 0.62, as depicted on the line of least squared fit in Figure 6. Although, a slight decrease was observed from 1994 to 2022, increasing rates were recorded from 1994 to 2002 and from 2002 to 2021. These findings indicate a positive impact on the ecological resilience of the study area.



**Figure 6: Trend of vegetation change
Authors Analysis (2024).**

The positive trends in vegetation cover observed from the analysis can be attributed to the successful implementation of various tree planting programs within the study area (Birnin Kebbi). Over the past several years, the state government has been dedicated to combating the menace of desertification, it has introduced the Kebbi State Afforestation Programme (KSAP) and the Kebbi State Environmental Protection Agency (KSEPA). These agencies have enacted various regulations to curb the indiscriminate destruction of forest resources. Furthermore, they have undertaken campaigns to enhance the quality and quantity of forest reserves in the state (Aliero *et al.*, 2017). The results obtained in this study thus shows that the series of afforestation and tree planting programs previously implemented by the government have been successful.

One of the key factors which has contributed to the success of afforestation programs in the study area has been community involvement (Galadima *et al.*, 2020). Through our interactions with the locals, it was observed

that local communities have actively participated in tree planting campaigns, taking ownership of the initiatives and ensuring the survival and growth of newly planted trees. These collaborative efforts have not only increased greenery but also fostered a sense of environmental stewardship among the people of Birnin Kebbi. Similarly, there is strong legislation against the cutting down of trees, which also aids in preserving vegetation cover (Abuza, 2017). It has also been observed that the development of new communities in semi-arid regions improves vegetation. This is because people plant trees around their new houses for protection against the wind or to provide shelter. Increased vegetation cover contributes to the overall well-being of the community.

ACCURACY ASSESSMENT ANALYSIS

In this study, confusion matrices were employed to evaluate the accuracy of the vegetation classes generated from NDVI analysis results. The classified vegetation covers for 1994, 2002, and 2021 were compared with ground truth information



collected during field surveys. As depicted in Table 6, the vegetation classifications for all three years achieved overall accuracies exceeding 54%. The overall accuracy for the 1994 vegetation classification is 60.87%, with a Kappa Coefficient of 0.51 indicating substantial accuracy. For the 2002 vegetation classification, the overall class accuracy is

54.34%, with a Kappa Coefficient of 0.43 indicating moderate accuracy. Meanwhile, the overall accuracy of the 2021 vegetation classification is 70%, with a Kappa Coefficient of 0.63 indicating substantial accuracy. The Producer's Accuracy (%) and User's Accuracy (%) for each class of vegetation for the years under observation are as presented in Table 6.

Table 6: Error matrices of NDVI classification of 2021, 2002 and 2021

Class Name	Ground Truth (Observation) Totals	Classify NDVI Totals	Number Correct	Producer's Accuracy %	User's Accuracy %
2021					
Non-vegetation Area	25	16	15	60.00	93.75
Very Low Dense Vegetation	17	23	14	82.35	60.87
Low Dense Vegetation	19	17	13	68.42	76.47
Moderate Dense Vegetation	16	24	14	87.50	58.33
High Dense Vegetation	15	12	9	60.00	75.00
Total:	92	92	65		
2021 Overall Class Accuracy: 70%			Kappa Coefficient: 0.63		
2002					
Non-vegetation Area	25	22	15	60.00	68.18
Very Low Dense Vegetation	17	24	10	58.82	41.67
Low Dense Vegetation	19	15	7	36.84	46.67
Moderate Dense Vegetation	16	19	9	56.25	47.37
High Dense Vegetation	15	12	9	60.00	75.00
Total:	92	92	50		
2002 Overall Class Accuracy: 54.34%			Kappa Coefficient: 0.43		
1994					
Non-vegetation Area	25	16	14	56.00	87.50
Very Low Dense Vegetation	17	28	12	70.59	42.86
Low Dense Vegetation	19	17	10	52.63	58.82
Moderate Dense Vegetation	16	19	11	68.75	57.89
High Dense Vegetation	15	12	9	60.00	75.00
Total:	92	92	56		
1994 Overall Class Accuracy: 60.87%			Kappa Coefficient: 0.51		

Authors Analysis (2024).

PROJECTED VEGETATION COVER

To provide a deeper understanding of the prospective status of vegetation cover in the study area, a trend pattern analysis was conducted for each category of vegetation cover to forecast future trends. Table 7

displays the anticipated pattern of vegetation cover changes. The projection revealed an increase in very low and low-density vegetation cover (4.72% and 1.45%, respectively). However, the augmentation in very low and low-density vegetation cover was deemed inconsequential, as these



vegetation types mainly consist of degraded and scattered plants. They are also regarded as unhealthy vegetation cover, susceptible to rapid depletion and highly sensitive to short-

term climatic variations (Jiang *et al.*, 2017). Such vegetation cover typically undergoes fluctuations over time, diminishing, for instance, due to grazing or disappearing entirely as a result of burning, agricultural activities, and urban expansion.

Table 7: Projected change of vegetation cover

Class	2021	%	2031	%	Projected Change %
Very Low Dense Vegetation	691.031	49.81617	756.55	54.53949	4.72
Low Dense Vegetation	343.926	24.7935	364	26.24066	1.45
Moderate Dense Vegetation	79.606	5.738767	72.217	5.206105	-0.53
High Dense Vegetation	30.485	2.197652	41.093	2.962384	0.76

Authors Analysis (2024).

The anticipated trends for moderately dense vegetation and highly dense vegetation are - 0.53% and 0.76%, respectively. These represent significant vegetation covers, encompassing scattered trees and robust tree/dense forest formations. They play a crucial role in facilitating climate change adaptation and mitigating desertification (Prevedello *et al.*, 2017). There appears to be an imbalanced pattern in the projected vegetation changes in the area. Despite an increase in highly dense vegetation cover, there is also a reduction in scattered trees and moderately dense vegetation cover. This trend suggests that the vegetation cover is not growing naturally but rather through afforestation. The study observes that areas

with healthy and dense vegetation are typically forest reserved areas (e.g., Bulasa Area) or shelter-belt areas (e.g., Hokon Idi), which are highly protected by authorities, or along waterways (rivers and streams). Another contributing factor to the depletion of moderately dense vegetation is population growth and urbanization process.

To enhance vegetated areas and maintain environmental quality, it is recommended, land optimization through replanting in areas with little or no vegetation should be encouraged. This strategic endeavor will not only serve as booster to the aesthetic appeal of landscapes but also contributes significantly to ecological balance and sustainability (Chen



et al., 2023). Encouraging the deliberate restoration of greenery in underutilized or barren spaces, will foster biodiversity, mitigate the adverse effects of urbanization, and enhance the overall resilience of ecosystems (Shi *et al.*, 2022; Ruas *et al.*, 2022). Additionally, such replanting efforts play a crucial role in combating desertification, as the restored vegetation helps stabilize soil, prevent erosion, and protect against the encroachment of desert landscapes (Kulik *et al.*, 2023). Moreover, the act of replanting do not only help in combating deforestation but also aids in carbon sequestration, playing a pivotal role in climate change mitigation (Hof *et al.*, 2017; Kirschbaum *et al.*, 2024). The recommendation to prioritize such reforestation efforts underscores a commitment to preserving and fortifying the delicate equilibrium between human activities and the natural environment, thereby fostering a harmonious coexistence that benefits both present and future generations.

CONCLUSION

This study has documented a noteworthy augmentation in vegetation cover within the Birnin Kebbi study area from 1994 to 2022. The results indicate an irregular pattern of vegetation change. The observed positive trends in vegetation cover can be ascribed to the effective implementation of various tree planting programs spanning the last three decades. Should this ongoing afforestation programmes continue into the next decade, a projected increase of 0.76% in dense vegetation is anticipated.

While this study notes an increase in very low and low-density vegetation cover, it is regarded as inconsequential due to the predominantly degraded and sparse nature of these vegetation types. Such vegetation is

deemed unhealthy, prone to depletion, and highly susceptible to short-term climatic fluctuations. Additionally, there is a discernible decline in scattered trees and moderately dense vegetation cover.

This observation suggests that natural vegetation growth is limited, and that afforestation effort is playing a vital role in vegetation development in the study area. Areas exhibiting robust and dense vegetation are predominantly found in forest reserved zones, shelter-belt areas, or along waterways. These findings underscore the importance of afforestation initiatives in sustaining and enhancing the overall vegetation cover in the studied region.

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