FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 11, June, 2026, pp 134 – 141
DOI: https://doi.org/10.33003/fjs-2026-1011-5517

Spatio-temporal Assessment of Desert Encroachment in Maigatari Local Government Area, Jigawa State, Nigeria, Using Ndvi-Base Change Detection (2005-2025)

***[1]Sadiq Ahmed and [2]Abdulmajid Abubakar**

[1]Department of Environmental Science, Federal University Dutse, Jigawa State, Nigeria.
[2]Department of Geography, Faculty of Earth and Environmental Science, Bayero University, Kano, Nigeria.

*Corresponding authors' email: sadiq.a@fud.edu.ng

ABSTRACT

Desert encroachment poses a critical threat to dryland ecosystems and rural livelihoods in the Sudano-Sahelian region of northern Nigeria. This study assesses the spatiotemporal dynamics of vegetation change and desertification intensity in Maigatari Local Government Area (LGA), Jigawa State, between 2005 and 2025. Using multi-temporal Landsat satellite imagery (Landsat 5 TM, Landsat 8 OLI, and Landsat 9 OLI), the Normalized Difference Vegetation Index (NDVI) was computed and classified into three land cover categories: bare land, sparse vegetation, and moderate vegetation. Change detection analysis was performed to quantify transitions across two decadal intervals (2005–2015 and 2015–2025). Results reveal a substantial expansion of bare land from 0.0032 km² (0.0013%) in 2005 to 67.06 km² (26.21%) in 2015, representing an 80% increase, indicating accelerated degradation during the first decade. Sparse vegetation declined sharply from 97.66% to 45.06% over the same period. Between 2015 and 2025, bare land continued to expand to 74.70 km² (29.21%), while moderate vegetation increased locally from 28.72% to 38.59%, suggesting partial recovery in isolated areas. The overall trajectory, however, confirms progressive desert encroachment with net vegetation loss. The findings underscore the urgent need for integrated land management strategies, including sustainable grazing, agroforestry, and farmer-managed natural regeneration. This study demonstrates the efficacy of NDVI-based change detection within a GIS framework as a tool for evidence-based environmental planning and desertification monitoring in semi-arid regions.

Received: 12 June 2026

Accepted: 25 June 2026

Published: 12 June 2026

Keywords: Desertification, Land degradation, NDVI, Remote sensing, GIS, Change detection, Maigatari, Sudano-Sahelian, Nigeria

INTRODUCTION

Desertification and land degradation are widely recognized as major environmental challenges affecting dryland ecosystems globally. Drylands constitute approximately 41% of the Earth's terrestrial surface and sustain over two billion people who depend directly on land-based ecosystem services for food, water, and livelihoods (IPCC, 2022). However, these regions are increasingly threatened by climatic variability and anthropogenic pressures, resulting in declining soil fertility, vegetation loss, and reduced agricultural productivity (UNCCD, 2022; Giannini *et al.,* 2025). Land degradation in drylands is particularly alarming because of its direct linkage to food insecurity, poverty intensification, forced migration, and ecological instability (Reynolds *et al.,* 2007; UNCCD, 2022).

Desertification, as defined by the United Nations Convention to Combat Desertification (2022), refers to land degradation in arid, semi-arid, and dry sub-humid areas resulting from climatic variations and human activities. In the African Sahel, desertification is driven by the interaction between rainfall variability, increasing temperature trends, overgrazing, deforestation, and unsustainable agricultural expansion (Herrmann *et al.,* 2005; Brandt *et al.,* 2018; Dardel *et al.,* 2014). Studies across the Sahel have demonstrated that vegetation dynamics in this region are highly sensitive to interannual rainfall fluctuations, yet human population growth increasingly offsets climate-driven vegetation recovery (Brandt *et al.,* 2018; Hickler *et al.,* 2005). This complex interaction between climate variability and land-use pressure underscores the need for localized assessments of vegetation change (Seaquist *et al.,* 2009).

Jigawa State, located in northwestern Nigeria, exemplifies the environmental fragility of the Sudano-Sahelian region. Maigatari Local Government Area (LGA), situated along the Nigeria-Niger border, represents one of the frontline areas experiencing gradual desert encroachment. The economy of the area is predominantly dependent on rain-fed agriculture and livestock grazing, both of which are highly sensitive to vegetation stability and rainfall reliability (Adefolalu, 2007). Declining pasture availability, increased sand dune mobility, and reduced crop productivity have been reported across parts of northern Nigeria, indicating progressive land degradation (Salami *et al.,* 2021; Yahaya *et al.,* 2024). Despite these observations, there remains limited empirical, spatially explicit evidence quantifying the magnitude and rate of vegetation change in Maigatari LGA over time. Most desertification studies in Nigeria have focused on broader regional assessments, thereby limiting community-level insights necessary for targeted environmental intervention.

Advancements in satellite remote sensing and Geographic Information Systems (GIS) have revolutionized environmental monitoring by enabling large-scale, long-term observation of vegetation dynamics (Jensen, 2016; Zhu & Woodcock, 2014). Among vegetation indices, the Normalized Difference Vegetation Index (NDVI) is one of the most widely applied indicators for assessing vegetation health, biomass, and productivity (Xue & Su, 2017). NDVI is derived from the differential reflectance of near-infrared (NIR) and red wavelengths, making it highly sensitive to chlorophyll content and vegetation vigor (Jensen, 2016). Numerous studies have validated the reliability of NDVI in detecting desertification patterns and vegetation trends in arid and semi-arid environments (Herrmann *et al.,* 2005; Brandt *et al.,* 2018; Xue & Su, 2017; Fensholt *et al.,* 2012). Its ability to provide consistent multi-temporal analysis makes it particularly suitable for assessing long-term land degradation in data-scarce regions such as northern Nigeria.

Furthermore, change detection analysis using multi-temporal satellite imagery provides quantitative evidence of land cover transitions and degradation intensity (Singh, 1989; Jensen, 2016; Kennedy *et al.,* 2010; Wang & Sui, 2025). By comparing NDVI-derived classifications across different epochs, researchers can identify vegetation loss, recovery patterns, and the spatial distribution of degradation hotspots. Such analyses are critical for evaluating the effectiveness of restoration initiatives, including continental programs such as the Great Green Wall Initiative, which aims to restore degraded landscapes across the Sahel (UNCCD, 2022; TNC & World Economic Forum, 2024).

Given the ecological vulnerability of Maigatari LGA and the socio-economic dependence of its population on land resources, there is a compelling need for a robust, spatially explicit assessment of vegetation dynamics over time. Therefore, this study evaluates desert encroachment trends in Maigatari LGA between 2005 and 2025 using NDVI derived from Landsat satellite imagery within a GIS framework. Specifically, the study aims to quantify land cover distribution across three temporal epochs, and assess the intensity of desertification processes over time. By providing empirical geospatial evidence, this research contributes to sustainable land management planning and climate adaptation strategies in northern Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in Maigatari Local Government Area (LGA) of Jigawa State, Nigeria. The area is located between latitudes 12°23′00″ and 12°48′26″ N and longitudes 9°27′05″ and 9°30′05″ E. It shares boundaries with the Republic of Niger to the north, Kaugama LGA to the east, Gumel LGA to the south, and Sule Tankarkar LGA to the west (Figure 1).

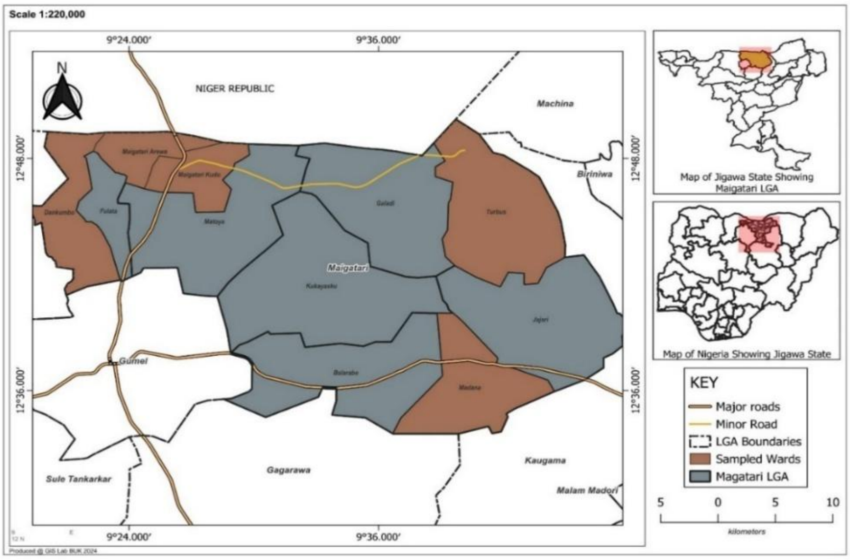

Figure 1: Map of Maigatari Local Government Area
Source: Arc Map 10.3, 2024

According to the National Population Commission (2022 Projection), Maigatari has an estimated population of about 300,000 people, most of whom depend on farming and livestock rearing for their livelihood (Mortimore & Harris, 1999).

The climate of Maigatari is semi-arid, characterized by two distinct seasons the rainy season (June to September) and the dry season (October to May). The average annual rainfall ranges between 500 and 800 mm, and average daily temperatures vary from 30°C to 40°C. During the dry season, the area experiences the harmattan, a cold, dry, and dusty northeasterly wind that lowers humidity and reduces soil moisture (Ibrahim *et al.,* 2020).

Vegetation in the area belongs to the Sudano-Sahelian ecological zone, consisting mainly of scattered drought-resistant trees, shrubs, and grasses (Olsson *et al.,* 2005). Common tree species include *Faidherbia albida*, *Acacia nilotica*, *Azadirachta indica*, *Piliostigma reticulatum*, and *Balanites aegyptiaca*. The dominant soils are sandy loam, with low organic matter and poor nutrient content, making them susceptible to erosion and degradation when the protective vegetation cover is removed (Saleh *et al.,* 2020). Agriculture is the mainstay of the local economy, with millet (*Pennisetum glaucum*) being the principal staple crop.

Study Design and Sampling

This study adopted a spatio-temporal analytical research design, integrating remote sensing-based change detection with a purposive spatial sampling approach to assess vegetation dynamics and desert encroachment in Maigatari Local Government Area (LGA), Jigawa State, Nigeria, over a 20 years period (2005-2025). The design is appropriate for capturing both the spatial distribution and temporal evolution of vegetation cover using NDVI-derived indicators.

Maigatari LGA was purposively selected due to its ecological and agricultural significance within the semi-arid zone of northern Nigeria. The area is recognized as a major millet-producing region and typifies smallholder rain-fed farming systems that are highly vulnerable to environmental stressors. Over the years, the region has experienced increasing pressure from continuous cultivation, fuelwood extraction, and deforestation, resulting in a decline in tree cover, species diversity, and overall vegetation density. These characteristics make Maigatari an appropriate case study for investigating patterns and processes of desert encroachment.

The sampling framework was based on spatial coverage of the entire study area using satellite imagery, rather than conventional point-based field sampling. Multi-temporal Landsat images were used to achieve wall-to-wall coverage, ensuring that all land cover types and vegetation conditions within the LGA were represented. This approach minimizes sampling bias and enhances the generalizability of findings across the study area.

To ensure analytical consistency, the study employed temporal sampling at decadal intervals (2005, 2015, and 2025), allowing for the detection of long-term vegetation trends and the identification of periods of accelerated degradation or relative stability. The choice of these epochs was informed by data availability and the need to capture meaningful environmental change over time.

Furthermore, a stratified interpretation approach was applied during analysis, whereby NDVI outputs were categorized into vegetation density classes (bare land, sparse vegetation, and moderate vegetation). This classification served as an indirect sampling of vegetation conditions across space, enabling quantitative comparison of vegetation states and transitions over time.

Data Sources and Image Acquisition

This study employed multi-temporal satellite imagery to assess vegetation dynamics in Maigatari Local Government Area (LGA). Landsat images for the years 2005, 2015, and 2025 were acquired from the United States Geological Survey (USGS) Earth Explorer platform, which provides freely accessible, radiometrically calibrated datasets suitable for environmental monitoring.

Landsat data were selected due to their extensive historical archive, moderate spatial resolution (30 m), and proven reliability in vegetation change detection studies (Jensen, 2016; Xue & Su, 2017; Zhu & Woodcock, 2014). Specifically, Landsat 5 Thematic Mapper (TM) imagery was used for 2005, Landsat 8 Operational Land Imager (OLI) for 2015, and Landsat 9 OLI for 2025. The 30 m spatial resolution offers an optimal balance between regional coverage and sufficient detail for land cover classification in semi-arid environments (Jensen, 2016). To ensure seasonal consistency and minimize phenological variability, all images were acquired during the dry season.

Image Preprocessing

Standard preprocessing procedures were applied to ensure data quality and comparability across time periods. The acquired images were geometrically corrected and projected to a common coordinate reference system to ensure spatial alignment.

Subsequently, image sub-setting was performed to extract the boundary of Maigatari LGA, restricting analysis strictly to the study area. Layer stacking was conducted to combine the relevant spectral bands required for vegetation index computation. These procedures are consistent with established remote sensing protocols for land cover and vegetation monitoring (Singh, 1989; Jensen, 2016).

Vegetation Index Computation (NDVI)

Vegetation condition was assessed using the Normalized Difference Vegetation Index (NDVI), a widely used indicator of vegetation vigor and biomass productivity. The NDVI is expressed as:

$$NDVI = \frac{NIR - Red}{NIR + Red} ---------- Equation\,1$$

where *NIR* represents near-infrared reflectance and *Red* represents red band reflectance.

NDVI values range from -1 to +1, with higher positive values indicating denser and healthier vegetation. The index has been extensively validated as a reliable proxy for vegetation greenness, chlorophyll activity, and biomass (Xue & Su, 2017). In semi-arid environments, NDVI is particularly effective for distinguishing between bare surfaces and sparse vegetation due to its sensitivity to vegetation reflectance characteristics (Herrmann *et al.,* 2005; Fensholt *et al.,* 2012).

NDVI Classification

The computed NDVI values were classified into three vegetation density categories to facilitate interpretation and comparison: Bare land: NDVI < 0.1, Sparse vegetation: NDVI = 0.1-0.5 and Moderate vegetation: NDVI > 0.5

These thresholds were adopted from established classification schemes commonly used in semi-arid vegetation studies (Xue & Su, 2017; Salami et al., 2021). The classification enabled quantification of vegetation cover distribution and assessment of temporal changes.

Change Detection Analysis

Change detection analysis was conducted to evaluate vegetation dynamics between 2005-2015 and 2015-2025. Multi-temporal comparison of classified NDVI maps provided quantitative evidence of land cover transitions and vegetation degradation intensity (Kennedy *et al.,* 2010; Wang & Sui, 2025).

The magnitude of change was quantified using percentage change analysis, expressed as:

$$Rate\ of\ Change(\%) = \left[\left(\frac{a^2}{a^1}\right)^{\frac{1}{n}} - 1\right] \times 100 \qquad \text{Equation- 2}$$

Where a^1=base year data (2000)

a^2 = end time data (2016)

` n = number of years between observations (UNDP, 2011)

This approach enabled the identification of both the direction and rate of vegetation change over time.

Analytical Framework

The integration of NDVI classification and percentage change analysis provided a robust framework for assessing vegetation trends and detecting patterns of degradation. By comparing decadal intervals, the study identified periods of accelerated vegetation loss and relative stabilization. Such quantitative assessments are essential for understanding the temporal progression of desert encroachment and for informing sustainable land management strategies (Brandt *et al.,* 2018).

RESULTS AND DISCUSSION

Land Cover Distribution in 2005

The NDVI-derived land cover classification for the year 2005 indicates that sparse vegetation dominated the landscape of Maigatari LGA, covering the overwhelming majority of the study area. Bare land constituted a relatively small proportion, while moderate vegetation was limited and spatially fragmented. This distribution suggests that, at baseline, the area maintained a relatively stable vegetation structure typical of Sudan savannah ecosystems, characterized by discontinuous plant cover adapted to semi-arid climatic conditions (Herrmann *et al.,* 2005).

The predominance of sparse vegetation reflects the ecological nature of Sahelian landscapes, where vegetation density is naturally constrained by rainfall variability and high evapotranspiration (IPCC, 2022). However, the limited extent of moderate vegetation even at baseline indicates inherent ecological fragility, as vegetation systems in semi-arid regions often operate near threshold levels of resilience (Reynolds *et al.,* 2007).

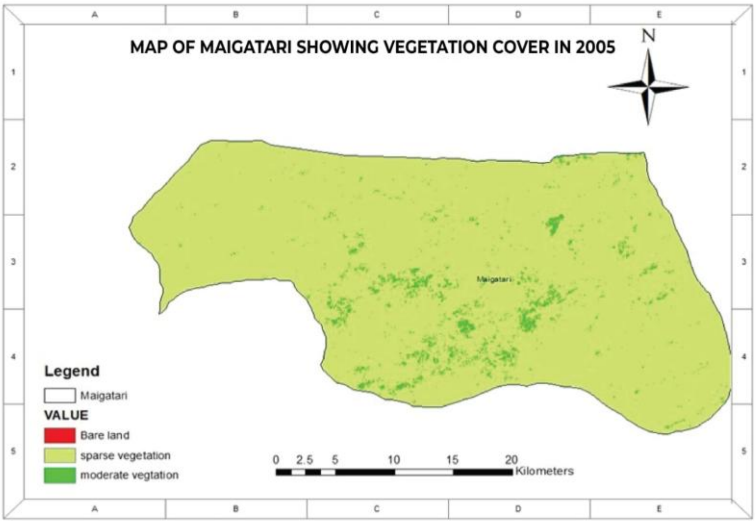

Figure 2: Map of Maigatari LGA Showing Various Land Cover Types in 2005

Table 1: Areas Covered by Various Land Covers in 2005

Land cover	Area covered (Sqkm)	Percentage (%)
Bare land	0.0032	0.0013
Sparse vegetation	249.75	97.66
Moderate vegetation	5.97	2.33
Total	255.72	100

Land Cover Distribution in 2015

The 2015 classification reveals a significant expansion of bare land relative to the year 2005. Concurrently, sparse vegetation declined markedly across large portions of the study area. Moderate vegetation exhibited slight increases in localized zones but remained limited in spatial coverage.

The pronounced increase in bare land between 2005 and 2015 suggests accelerated degradation during this decade. This pattern is consistent with regional observations across northern Nigeria and the broader Sahel, where prolonged dry spells and anthropogenic land pressure intensified vegetation loss during the early 2000s (Brandt *et al.,* 2018; Salami *et al.,* 2021). The reduction in sparse vegetation indicates a transition from low-density vegetative cover to exposed soil surfaces, which increases susceptibility to wind erosion and sand dune mobility (Geist & Lambin, 2004).

The decade 2005-2015 coincided with increased climatic variability in West Africa, including episodes of rainfall fluctuation and rising temperature trends (IPCC, 2022). Such climatic stressors, combined with overgrazing and fuelwood harvesting, may have reduced vegetation regeneration capacity, leading to expansion of barren surfaces.

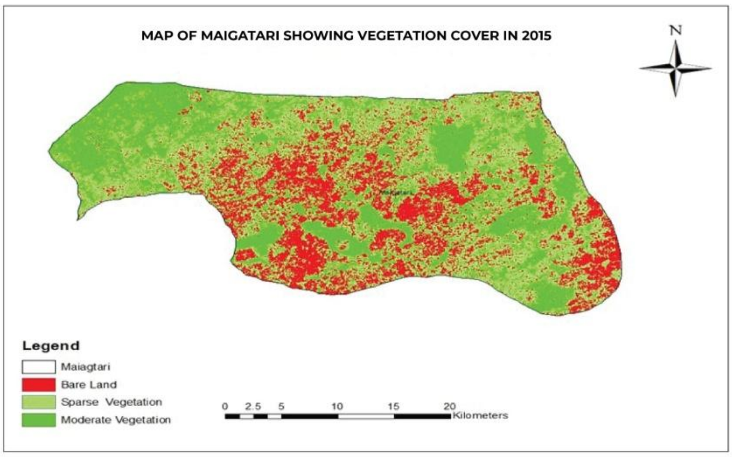

Figure 3: Map of Maigatari Showing Various Land Cover Types in 2015

Table 2: Areas Covered by Various Land Cover Types in 2015

Land cover	Area covered (Sqkm)	Percentage (%)
Bare land	67.06	26.21
Sparse vegetation	115.27	45.06
Moderate vegetation	73.48	28.72
Total	255.81	100

Land Cover Distribution in 2025

By 2025, bare land continued to expand, although the rate of increase appeared slower compared to the 2005-2015 period. Sparse vegetation further declined, while moderate vegetation showed localized recovery in certain areas.

The continued expansion of bare land confirms that desert encroachment remained active within the study area. However, the observed localized increase in moderate vegetation suggests possible intervention effects or natural vegetation regeneration in specific zones. Across parts of the Sahel, satellite-based studies have documented partial "greening" trends linked to rainfall recovery and land management interventions (Brandt *et al.,* 2018). Nonetheless, such recovery patterns are often spatially uneven and may not offset broader degradation trends.

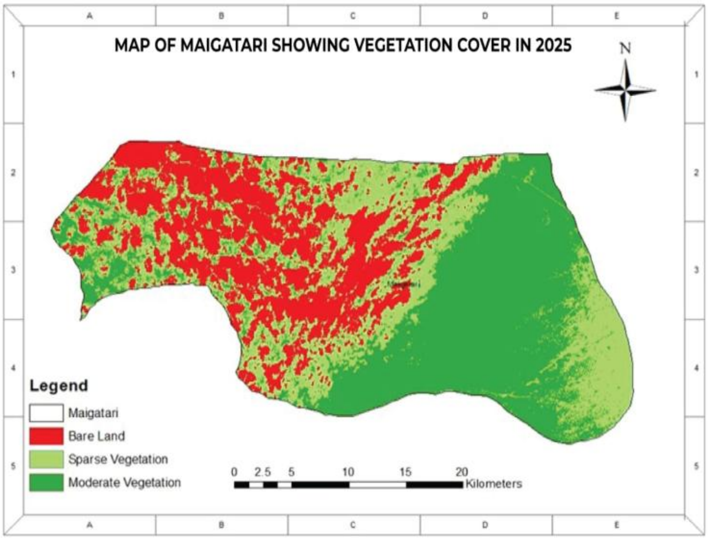

Figure 4: Map of Maigatri Showing Various Land Cover Types in 2025

Table 3: Areas Covered by Various Land Cover Types in 2025

Land cover	Area covered (Sqm)	Percentage (%)
Bare land	74.70	29.21
Sparse vegetation	82.34	32.20
Moderate vegetation	98.70	38.59
Total	255.74	100

Decadal Vegetation Cover Dynamics (2005–2015)

The rate of vegetation cover change between 2005 and 2015 reveals a dramatic restructuring of the landscape in Maigatari LGA. As shown in Table 4, bare land expanded from 0.0032 km² (0.0013%) in 2000 to 67.06 km² (26.21%) in 2015, representing an approximate 170 km² increase and an estimated 80% rise over the ten-year period. This substantial growth of barren surfaces indicates a phase of accelerated land degradation and signals a shift toward desert-like conditions across large portions of the study area.

Such rapid expansion of bare land is ecologically significant in semi-arid environments. Vegetation in the Sudan savannah serves as a protective layer that stabilizes soil, reduces evapotranspiration stress, and mitigates wind erosion. When vegetation density declines below resilience thresholds, exposed soil surfaces become highly susceptible to erosion and further degradation (Reynolds *et al.,* 2007). The observed increase in bare land during this decade is consistent with degradation patterns documented across the Sahel during periods of rainfall irregularity and rising temperature trends (Brandt *et al.,* 2018). According to the Intergovernmental Panel on Climate Change (2022), West Africa experienced significant climatic variability during the early 2000s, which likely intensified vegetation stress in semi-arid northern Nigeria.

Sparse vegetation, which dominated the landscape in 2005 at 249.75 km² (97.66%), declined sharply to 115.27 km² (45.06%) by 2015. Although the computed percentage change indicates a 3.61% decrease, the absolute spatial reduction reflects a substantial contraction of low-density vegetative cover. Sparse vegetation in dryland systems is critical for maintaining ecological balance, as it contributes to soil moisture retention and prevents dune mobilization (Herrmann *et al.,* 2005). Its decline suggests progressive weakening of ecological resilience and increasing vulnerability to desert encroachment.

Moderate vegetation, however, increased from 5.97 km² (2.33%) in 2005 to 73.48 km² (28.72%) in 2015, corresponding to a 13.88% increase. This apparent increase may reflect localized vegetation concentration rather than uniform ecological recovery. In some Sahelian regions, improved rainfall conditions or localized land management practices have resulted in pockets of vegetation improvement despite broader degradation (Brandt *et al.,* 2018). Nevertheless, the simultaneous expansion of bare land suggests that any gains in moderate vegetation were insufficient to counterbalance overall degradation.

Overall, the 2005-2015 decade represents the most critical phase of vegetation decline in the study period, characterized by rapid expansion of exposed surfaces and contraction of sparse vegetation.

Table 4: Rate of Change in Vegetation Cover from 2005-2015 in Maigatari LGA

Land use	Vegetation cover 2005		Vegetation cover 2015		Vegetation cover change 2005-2015	
	Sq km	%	Sq km	%	Sq km	%
Bare land	0.0032	0.0013	67.06	26.21	170	80
Sparse vegetation	249.75	97.66	115.27	45.06	-7.44	-3.61
Moderate vegetation	5.97	2.33	73.48	28.72	28.5	13.88
	255.72	100	255.81	100		

Decadal Vegetation Cover Dynamics (2015-2025)

The second decade (2015-2025) exhibits a more complex vegetation dynamic. Bare land increased from 67.06 km² (26.21%) in 2015 to 74.70 km² (29.21%) in 2025, representing a 13.67% increase over nine years. Although this expansion is smaller relative to the previous decade, it confirms that desert encroachment remained active within the landscape. The slower rate of increase may indicate partial stabilization or reduced degradation intensity compared to the earlier period.

Sparse vegetation continued to decline substantially, decreasing from 115.27 km² (45.06%) in 2015 to 82.34 km² (32.20%) in 2025, corresponding to a 45.35% reduction. This continued contraction is particularly concerning because sparse vegetation functions as a transitional ecological buffer between healthy vegetation and bare soil. Its loss suggests that areas previously categorized as low-density vegetation may be transitioning either into barren surfaces or more spatially concentrated vegetation patches.

Conversely, moderate vegetation increased from 73.48 km² (28.72%) in 2015 to 98.70 km² (38.59%) in 2025, representing a 40.97% increase. This growth may reflect localized ecological recovery processes, potentially influenced by improved rainfall patterns or restoration initiatives aligned with frameworks supported by the United Nations Convention to Combat Desertification (2022). Continental restoration efforts such as the Great Green Wall Initiative aim to enhance vegetation cover across the Sahel, and localized increases observed in this study may be partially associated with such interventions.

However, semi-arid ecosystems often exhibit heterogeneous vegetation responses, where localized greening can coexist with degradation elsewhere (Geist & Lambin, 2004). The simultaneous decline in sparse vegetation and continued expansion of bare land suggests that vegetation recovery is uneven and may represent redistribution rather than overall ecological improvement.

Table 5: Rate of Change in Vegetation Cover from 2010 – 2019 in Maigatari LGA

Land use	Vegetation cover 2015		Vegetation cover 2025		Vegetation cover change 2015-2025	
	Sq km	%	Sq km	%	Sq km	%
Bare land	67.06	26.21	74.70	29.21	0.998	13.67
Sparse vegetation	115.27	45.06	82.34	32.20	-3.31	-45.35
Moderate vegetation	73.48	28.72	98.70	38.59	2.99	40.97
	255.81	100	255.74	100		

Discussion

The findings of this study reveal clear evidence of progressive desert encroachment in Maigatari LGA between 2005 and 2015. The substantial increase in bare land and corresponding decline in sparse vegetation indicate intensified land degradation, particularly during the first decade of analysis. These results align with broader Sahelian vegetation dynamics documented in previous studies (Herrmann et al., 2005; Brandt *et al.,* 2018; Dardel *et al.,* 2014; Olsson *et al.,* 2005).

The pronounced degradation observed between 2005 and 2015 may be attributed to the interaction of climatic variability and anthropogenic pressure. The Intergovernmental Panel on Climate Change (2022) reports that West Africa experienced increasing temperature anomalies and rainfall irregularities during this period. In semi-arid systems, even slight reductions in rainfall can significantly affect vegetation productivity due to limited soil moisture retention capacity (Reynolds *et al.,* 2007). Reduced vegetation cover subsequently exposes soil surfaces to wind erosion, accelerating desertification processes (Giannini *et al.,* 2025).

Anthropogenic factors likely compounded climatic stress. Population growth in northern Nigeria has intensified land-use pressure through agricultural expansion and livestock grazing (Geist & Lambin, 2004; Mortimore & Harris, 1999). Continuous cultivation without adequate fallow periods depletes soil nutrients and reduces vegetation recovery capacity. Overgrazing further suppresses plant regeneration, particularly in fragile grassland ecosystems (Salami *et al.,* 2021; Yahaya *et al.,* 2024). The observed decline in sparse vegetation in this study is consistent with these degradation mechanisms.

Also, the 2010-2019 period shows a slower increase in bare land and localized improvement in moderate vegetation. This pattern may reflect partial ecosystem recovery driven by improved rainfall conditions or land restoration initiatives. Across the Sahel, studies have reported localized vegetation "greening" trends associated with rainfall recovery and farmer-managed natural regeneration practices (Brandt *et al.*, 2018; Hickler *et al.*, 2005; Seaquist *et al.*, 2009)). Furthermore, continental-scale initiatives such as the Great Green Wall Initiative have aimed to restore degraded lands across northern Nigeria (UNCCD, 2022; TNC & World Economic Forum, 2024; UNCCD, 2024). While this study does not directly evaluate program effectiveness, the localized increase in moderate vegetation may suggest emerging restoration impacts.

However, the overall trend remains one of net degradation. The persistent decline in sparse vegetation indicates that ecosystem resilience remains weak. In semi-arid systems, vegetation loss can push landscapes beyond ecological thresholds, making natural recovery increasingly difficult (Reynolds *et al.*, 2007; Reynolds & Stafford Smith, 2011; Ogle & Reynolds, 2004). Continued expansion of bare land may therefore increase vulnerability to dust storms, soil erosion, reduced agricultural productivity, and socio-economic instability.

The results underscore the importance of sustained geospatial monitoring in semi-arid regions. NDVI-based assessments provide cost-effective and reliable tools for detecting vegetation transitions and informing environmental policy. In regions like Maigatari, where livelihoods are tightly linked to land productivity, early detection of degradation trends is critical for adaptive land management planning.

When the two decades are analyzed collectively, a clear pattern emerges: the most intense degradation occurred between 2005 and 2015, while the subsequent decade exhibited moderated but ongoing desertification alongside partial vegetation recovery. The net effect across the 20 years period is a substantial increase in bare land and structural transformation of vegetation classes.

This pattern aligns with the conceptual understanding of desertification as a coupled human-environment process driven by the interaction of climatic variability and land-use pressure (Geist & Lambin, 2004). The early decade likely reflects climatic stress interacting with anthropogenic activities such as overgrazing, continuous cultivation, and fuelwood extraction. The later decade indicates partial ecological adaptation or intervention effects but does not reverse the overall degradation trajectory.

The findings are consistent with Sahel-wide vegetation studies that document both degradation hotspots and localized greening phenomena (Brandt *et al.*, 2018; Herrmann *et al.*, 2005; Fensholt *et al.*, 2012). Such dual dynamics highlight the importance of spatially explicit monitoring tools such as NDVI-based change detection for identifying both vulnerability zones and recovery areas.

In ecological terms, the continued expansion of bare land suggests that portions of Maigatari LGA may be approaching degradation thresholds beyond which natural regeneration becomes increasingly difficult (Reynolds *et al.*, 2007). This reinforces the need for proactive land management strategies and continuous satellite-based monitoring to prevent irreversible desertification processes.

CONCLUSION

This study presents a comprehensive spatio-temporal assessment of vegetation dynamics and desert encroachment in Maigatari Local Government Area, Jigawa State, Nigeria, over a 20-year period (2005–2025), using NDVI derived from multi-temporal Landsat satellite imagery. The findings reveal a consistent pattern of land degradation, evidenced by a significant expansion of bare land and a corresponding decline in vegetated surfaces, particularly sparse vegetation cover.

The analysis indicates that the most pronounced degradation occurred during the 2005–2015 period, suggesting intensified anthropogenic and climatic pressures within this decade. Although the 2015–2025 period shows a relatively slower rate of degradation, the continued expansion of barren surfaces, alongside pockets of localized vegetation recovery, reflects a complex and non-linear ecological response typical of semi-arid environments. These patterns underscore the sensitivity of vegetation systems in the study area to both human activities and environmental variability.

Overall, the study demonstrates the effectiveness of NDVI-based change detection in capturing long-term vegetation trends and provides empirical evidence of ongoing desert encroachment in Maigatari LGA. The integration of remote sensing with spatio-temporal analysis offers a robust framework for environmental monitoring and supports data-driven decision-making in fragile dryland ecosystems. Addressing this trend will require context-specific land and soil conservation practices (such as controlled grazing, agroforestry, and farmer-managed natural regeneration) backed by community engagement, enforceable land-use policies, and institutionalized satellite-based monitoring, with future research incorporating higher-resolution imagery and climate and socio-economic data to better understand the underlying drivers of change.

RFERENCES

Adefolalu, D. O. (2007). *Climate change and sustainable development in Nigeria*. Ibadan: Stirling-Horden Publishers.

Brandt, M., Rasmussen, K., Peñuelas, J., Tian, F., Schurgers, G., Verger, A., & Fensholt, R. (2018). Human population growth offsets climate-driven increase in woody vegetation in sub-Saharan Africa. *Nature Ecology & Evolution*, 2(4), 650-655.

Dardel, C., Kergoat, L., Hiernaux, P., Mougin, E., Grippa, M., & Tucker, C. J. (2014). Re-greening Sahel: 30 years of remote sensing data and field observations (Mali, Niger). *Remote Sensing of Environment*, 140, 350-364.

Fensholt, R., Langanke, T., Rasmussen, K., Reenberg, A., Prince, S. D., Tucker, C., & Wessels, K. (2012). Greenness in semi-arid areas across the Sahel 1982–2007: an analysis based on the GIMMS NDVI3g dataset. *Remote Sensing of Environment*, 121, 144-158.

Giannini, A., Ali, A., & Kelley, C. P. (2025). An imminent return to drought in the western Sahel? *Science Advances*, 11(34), eadu5415.

Geist, H. J., & Lambin, E. F. (2004). Dynamic causal patterns of desertification. *BioScience*, 54(9), 817-829.

Herrmann, S. M., Anyamba, A., & Tucker, C. J. (2005). Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environmental Change*, 15(4), 394-404.

Hickler, T., Eklundh, L., Seaquist, J. W., Smith, B., Ardö, J., Olsson, L., & Sjöström, M. (2005). Precipitation controls Sahel greening trend. *Geophysical Research Letters*, 32(21).

Ibrahim, A., Sani, A. A., & Mohammed, A. (2020). Assessment of drought vulnerability in Jigawa State, Nigeria. *Journal of Arid Environments*, 175, 104-112.

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Jensen, J. R. (2016). *Introductory Digital Image Processing: A Remote Sensing Perspective* (4th ed.). Pearson Education, Inc.

Kennedy, R. E., Yang, Z., & Cohen, W. B. (2010). Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr-Temporal segmentation algorithms. *Remote Sensing of Environment*, 114(12), 2897-2910.

Mortimore, M., & Harris, F. (1999). Livelihood diversification and land degradation in northern Nigeria. *Drylands Research Working Paper*, 17.

National Population Commission. (2022). *Population Projections for Nigeria*. Abuja, Nigeria.

Ogle, K., & Reynolds, J. F. (2004). Plant responses to precipitation in desert ecosystems: integrating functional types, pulses, thresholds, and delays. *Oecologia*, 141, 282-294.

Olsson, L., Eklundh, L., & Ardö, J. (2005). A recent greening of the Sahel-trends, patterns and potential causes. *Journal of Arid Environments*, 63(3), 556-566.

Reynolds, J. F., Smith, D. M. S., Lambin, E. F., Turner, B. L., Mortimore, M., Batterbury, S. P., & Huber-Sannwald, E. (2007). Global desertification: building a science for dryland development. *Science*, 316(5826), 847-851.

Reynolds, J. F., & Stafford Smith, D. M. (2011). From Theory to Rural Farms: Testing the Efficacy of the Dryland Development Paradigm of Desertification. *AGU Fall Meeting Abstracts*, GC51C-0999.

Salami, A. T., Balogun, E. E., & Ogunleye, O. O. (2021). Land degradation assessment in northern Nigeria using geospatial techniques. *Nigerian Journal of Environmental Science*, 15(2), 45-58.

Saleh, M. M., Bello, A. G., & Yusuf, M. B. (2020). Soil properties and land use impacts in Sudano-Sahelian zone of Nigeria. *Journal of Soil Science and Environmental Management*, 11(3), 89-97.

Seaquist, J. W., Hickler, T., Eklundh, L., Ardö, J., & Heumann, B. W. (2009). Disentangling the effects of climate and people on Sahel vegetation dynamics. *Biogeosciences*, 6(3), 469-477.

Singh, A. (1989). Review article: digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing*, 10(6), 989-1003.

TNC, & World Economic Forum. (2024). *The Great Green Wall: Unlocking the Potential of Carbon Markets*. White Paper.

UNCCD. (2022). *The Global Land Outlook* (2nd ed.). United Nations Convention to Combat Desertification.

UNCCD. (2024). Great Green Wall Observatory. Accessed via African Development Bank Report.

UNDP. (2011). *Calculating and Reporting Indicators: A Practical Guide*. United Nations Development Programme.

Wang, J., & Sui, Y. (2025). Comparative Global Assessment and Optimization of LandTrendr, CCDC, and BFAST Algorithms for Enhanced Urban Land Cover Change Detection Using Landsat Time Series. *Remote Sensing*, 17(14), 2402.

Xue, J., & Su, B. (2017). Significant remote sensing vegetation indices: A review of developments and applications. *Journal of Sensors*, 2017, 1-17.

Yahaya, I. I., Wang, Y., Zhang, Z., Inuwa, A. Y., Zhao, Y., You, Y., & Shoukat, W. (2024). Assessing desertification vulnerability and mitigation strategies in northern Nigeria: A comprehensive approach. *Heliyon*, 10(11), e31167.

Zhu, Z., & Woodcock, C. E. (2014). Continuous change detection and classification of land cover using all available Landsat data. *Remote Sensing of Environment*, 144, 152-171.