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Monitoring Vegetation Dynamics Using NDVI And Post-Classification Change Detection In Yewa North Local Government Area, Ogun State, Nigeria

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Abstract

Vegetation dynamics are important indicators of ecosystem health and environmental sustainability, particularly in regions experiencing rapid land-use transformation. This study evaluated the effectiveness of the Normalized Difference Vegetation Index (NDVI) and GIS-based Post-Classification Change Detection (PCCD) for monitoring spatio-temporal vegetation changes in Yewa North Local Government Area, Ogun State, Nigeria, between 1999 and 2024. Multi-temporal Landsat imagery for 1999, 2008, 2014, and 2024 was acquired from the United States Geological Survey (USGS), while administrative boundary data were obtained from the Office of the Surveyor General of the Federation (OSGOF). Following image pre-processing, atmospheric correction, and radiometric normalization, NDVI was computed, classified into vegetation density categories, and analysed using post-classification change detection and spatial overlay techniques to quantify vegetation transitions. The results revealed a substantial decline in dense vegetation from 750.95 km² (36.34%) in 1999 to 230.25 km² (11.14%) in 2024, representing an overall reduction of 69.3%. Conversely, moderate vegetation increased from 745.87 km² (36.10%) to 1,229.31 km² (59.49%), indicating widespread transformation of dense vegetation into moderately vegetated landscapes. Bare surfaces showed moderate temporal fluctuations, reflecting the dynamic influence of agricultural expansion and land-use activities. The PCCD analysis identified vegetation transition hotspots, particularly within rapidly developing communities, highlighting progressive landscape modification over the study period. The integration of NDVI with GIS-based post-classification change detection proved effective for long-term vegetation monitoring and generated spatially explicit information to support biodiversity conservation, sustainable land-use planning, ecosystem restoration, and evidence-based environmental management in Yewa North and similar tropical landscapes.

Keywords: Change detection; Environmental monitoring; GIS; Post-Classification Change Detection (PCCD); Landsat; NDVI; Remote sensing; Vegetation dynamics.

Introduction

Vegetation is a fundamental component of terrestrial ecosystems because it regulates energy exchange, carbon sequestration, hydrological processes, biodiversity conservation, and numerous ecosystem services that sustain human well-being. Vegetation cover influences ecosystem productivity, climate regulation, soil conservation, water cycling, and landscape resilience, making its monitoring indispensable for sustainable environmental management and climate change adaptation (Pettorelli et al., 2021; Huang et al., 2021; Seddon et al., 2020). Consequently, accurate and continuous assessment of vegetation dynamics has become a global research priority for evaluating ecosystem health, detecting land degradation, supporting biodiversity conservation, and informing evidence-based land-use planning (Frantz, 2019; Wulder et al., 2022; Zhu et al., 2024).

In recent decades, rapid urbanization,

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agricultural intensification, infrastructure development, deforestation, and climate variability have accelerated vegetation degradation across many tropical and subtropical regions, particularly in sub-Saharan Africa. These anthropogenic and climatic pressures have resulted in habitat fragmentation, biodiversity loss, declining ecosystem resilience, altered carbon cycling, and reduced ecosystem service provision (Roy et al., 2022; Simmonds et al., 2023; Afuye et al., 2021). The increasing interaction between human activities and climate-related disturbances has intensified the demand for reliable geospatial techniques capable of monitoring vegetation changes over extensive spatial and temporal scales (Mashala et al., 2023; Zhao et al., 2024).

Recent advances in Earth Observation (EO) technologies have significantly enhanced the capability to monitor vegetation dynamics through consistent, long-term satellite observations. Freely available satellite archives, cloud-computing platforms, and improved image-processing algorithms now enable efficient monitoring of vegetation changes at regional and global scales with increasing temporal frequency and spatial consistency (Wulder et al., 2022; Hemati et al., 2021; Frantz, 2019). The Landsat programme provides one of the longest continuous Earth observation records, spanning more than five decades, thereby offering unparalleled opportunities for analysing long-term vegetation dynamics and landscape transformation (Wulder et al., 2022; Hemati et al., 2021).

Traditional field-based vegetation surveys provide detailed ecological information but are often constrained by high operational costs, limited spatial coverage, logistical challenges, and the considerable time required for data acquisition. These limitations become increasingly significant when monitoring extensive landscapes over prolonged periods. Consequently, remote sensing has emerged as one of the most effective approaches for large-area vegetation assessment because it enables repeated, objective, synoptic, and cost-effective observations of land surface conditions (Hemati et al., 2021; Mashala et al., 2023; Nizamani et al., 2024).

Among the numerous vegetation indices developed for remote sensing applications, the Normalized Difference Vegetation Index (NDVI) remains one of the most widely used indicators of vegetation greenness, biomass, canopy vigour, and photosynthetic activity. NDVI exploits the spectral contrast between high reflectance in the near-infrared (NIR) wavelength and strong absorption in the red wavelength by healthy vegetation. NDVI values theoretically range between –1 and +1, where higher positive values generally indicate dense and healthy vegetation, values close to zero represent sparse vegetation or bare surfaces, and negative values usually correspond to water bodies or other non-vegetated surfaces (Huang et al., 2021; Yengoh et al., 2015). Owing to its computational simplicity, robustness, and compatibility across multiple satellite sensors, NDVI has become a standard indicator for vegetation monitoring, drought assessment, ecosystem productivity analysis, land degradation studies, and climate change research (Frantz, 2019; Huang et al., 2021; Abbas et al., 2021).

Although NDVI effectively characterises vegetation conditions at individual time periods, understanding vegetation dynamics requires complementary change detection techniques capable of identifying the magnitude, direction, and spatial distribution of vegetation transitions. Post-Classification Change Detection (PCCD) is regarded as one of the most robust approaches for detecting temporal land-cover changes because it compares independently classified datasets acquired at different dates, thereby minimizing radiometric inconsistencies among images while explicitly identifying transition pathways between vegetation classes (Singh, 1989; Lunetta et al., 2022). Integrating NDVI with PCCD enables simultaneous assessment of vegetation condition and temporal transition patterns, thereby providing a more comprehensive understanding of ecosystem transformation than either technique alone. This integrated framework has been successfully applied in studies of deforestation, vegetation degradation, agricultural expansion, ecological restoration, and environmental change across diverse ecological environments (Hemati et al., 2021; Ezaidi et al., 2022; Zhao et al., 2024).

Nigeria has experienced substantial vegetation transformation during the past three decades because of rapid population growth, agricultural expansion, fuelwood exploitation, urbanization, infrastructure development, and changing climatic conditions. Southwestern Nigeria, including Ogun State, has witnessed progressive conversion of natural vegetation into cultivated land and built-up areas, resulting in habitat fragmentation, biodiversity decline, and increasing ecological vulnerability (Ojo et al., 2022; Roy et al., 2022). Despite increasing concern regarding these environmental changes, long-term quantitative assessments of vegetation dynamics at the local government level remain relatively limited, particularly those integrating NDVI with PCCD using consistent multi-temporal Landsat observations. Such information is essential for developing evidence-based conservation strategies, ecosystem restoration

programmes, and sustainable land management policies (Simmonds et al., 2023; Mashala et al., 2023).

Yewa North Local Government Area represents one of the largest administrative regions in Ogun State and encompasses diverse vegetation formations ranging from secondary forests to agricultural landscapes and rural settlements. The area has experienced increasing anthropogenic pressure arising from agricultural intensification, settlement expansion, timber exploitation, and infrastructure development. These land-use transformations have the potential to alter vegetation composition, ecosystem functioning, biodiversity, and landscape connectivity, yet comprehensive long-term spatial assessments of vegetation dynamics within the area remain scarce. Consequently, evaluating historical vegetation changes provides important baseline information for environmental monitoring, ecosystem restoration, and sustainable natural resource management (Koowe et al., 2021; Ojo et al., 2022).

Although numerous studies have employed NDVI to monitor vegetation conditions in different ecological environments, comparatively fewer investigations have integrated NDVI-based vegetation assessment with GIS-based Post-Classification Change Detection to quantify long-term vegetation transition pathways within Yewa North Local Government Area. Furthermore, previous studies have largely emphasized descriptive vegetation mapping without explicitly analysing the persistence, gains, losses, and conversion trajectories among vegetation classes. This study addresses this knowledge gap by integrating multi-temporal NDVI analysis with GIS-based PCCD to characterise vegetation dynamics over 25 years using harmonised Landsat observations.

The novelty of this study lies in integrating multi-temporal NDVI analysis with GIS-based Post-Classification Change Detection to quantify not only changes in vegetation condition but also the spatial trajectories of vegetation conversion across Yewa North between 1999 and 2024. Unlike previous local assessments, the study provides a comprehensive long-term geospatial evaluation of vegetation transformation that can support environmental monitoring, ecosystem conservation, biodiversity management, and sustainable land-use planning.

Therefore, this study aims to evaluate the effectiveness of the Normalized Difference Vegetation Index (NDVI) and GIS-based Post-Classification Change Detection (PCCD) techniques for monitoring spatio-temporal vegetation changes in Yewa North Local Government Area, Ogun State, Nigeria, between 1999 and 2024.

Study Area

The study was conducted in Yewa North Local Government Area (LGA), Ogun State, southwestern Nigeria (Figure 1). Yewa North is the largest LGA in Ogun State, covering approximately 2,087 km², with its administrative headquarters located at Ayetoro. The area lies between approximately latitudes 6°50′N and 7°30′N and longitudes 2°40′E and 3°20′E, sharing an international boundary with the Republic of Benin to the west. It is bordered by Imeko-Afon LGA to the north, Abeokuta North LGA to the east, and Yewa South LGA to the south. According to the 2006 National Population Census, the LGA had a population of 281,826, although the population has continued to increase due to natural growth and expanding economic activities. Figure 1 illustrates the location of the study area within Nigeria and Ogun State.

Yewa North experiences a tropical wet-and-dry climate, characterised by a rainy season extending from March to October and a dry season from November to February. The area receives an average annual rainfall of approximately 1,100–1,500 mm, with mean annual temperatures ranging between 25 and 32 °C. The terrain is predominantly gently undulating and is drained by several seasonal and perennial streams that support agricultural activities. The natural vegetation belongs to the Derived Savanna ecological zone, although much of the original vegetation has been modified through agricultural expansion, settlement development, timber extraction and other anthropogenic activities. Agriculture is the dominant land use, with cassava, maize, yam, cocoa and oil palms being the major crops cultivated. The combination of increasing land-use pressure and ecological importance makes Yewa North an appropriate case study for evaluating long-term vegetation dynamics using multi-temporal Landsat imagery, NDVI and PCCD techniques.

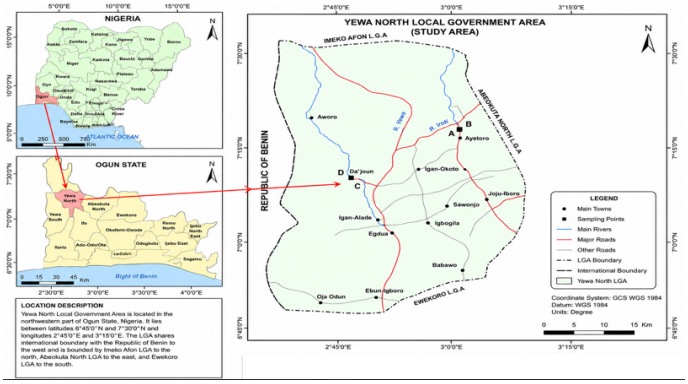


Figure 1: Location of Yewa North Local Government Area, Ogun State, Nigeria (NIPOST, 2009)

Materials and Methods

Data Sources

Multi-temporal Landsat satellite imagery acquired for 1999, 2008, 2014, and 2024 was used to evaluate vegetation changes in Yewa North Local Government Area. The images were downloaded from the United States Geological Survey (USGS) EarthExplorer platform, while the administrative boundary of the study area was obtained from the Office of the Surveyor General of the Federation (OSGOF), Nigeria. All Landsat images have a spatial resolution of 30 m, making them suitable for long-term vegetation monitoring.

To minimize seasonal variability and atmospheric effects, images with minimal cloud cover (<10%) and acquired during comparable phenological periods were selected. The datasets employed in this study are summarized in Table 1.

Table 1: Datasets used in the study.

Dataset	Source	Spatial Resolution	Acquisition Year	Purpose
Landsat imagery	USGS EarthExplorer	30 m	1999, 2008, 2014, 2024	NDVI computation and vegetation change detection
Administrative boundary	OSGOF	Vector	2024	Delineation of the study area

Image pre-processing

Before analysis, all satellite images were pre-processed to ensure consistency among acquisition dates. Image pre-processing included radiometric calibration, atmospheric correction, geometric verification, layer stacking, image subsetting, and clipping to the study area boundary. These procedures minimize sensor-related and atmospheric variations, thereby improving the reliability of multi-temporal comparisons.

For Landsat imagery, Top-of-Atmosphere (TOA) reflectance was computed using calibration coefficients provided in the image metadata. Atmospheric correction was subsequently performed to reduce the effects of atmospheric scattering and absorption on surface reflectance values. Finally, all images were projected to a common coordinate reference system (WGS 84 / UTM Zone 31N) to ensure spatial consistency throughout the analysis. Figure 2 presents the methodological workflow adopted for monitoring vegetation changes in Yewa North Local Government Area using multi-temporal Landsat imagery, NDVI, and Post-Classification Change Detection (PCCD).

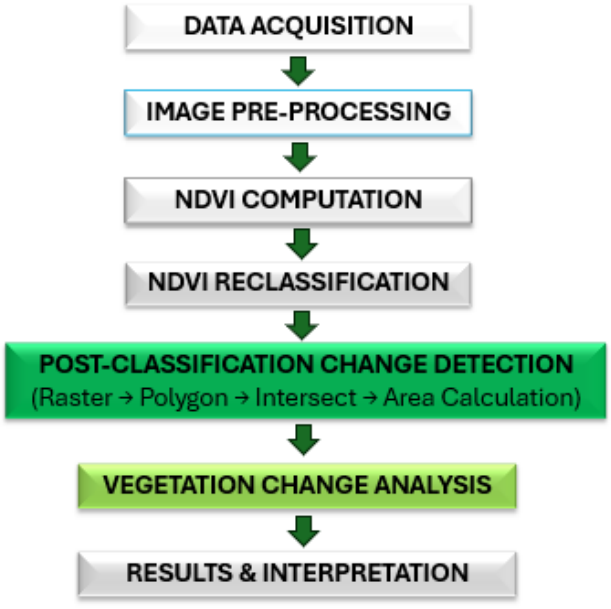


Figure 2: Methodological workflow adopted in this study.

Computation of NDVI

Vegetation condition was evaluated using the Normalized Difference Vegetation Index (NDVI), which exploits the spectral contrast between the near-infrared (NIR) and red spectral bands. NDVI was computed using Equation (1).

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad \text{Equation (1)}$$

where:

- NIR = Near-Infrared reflectance;
- Red = Red reflectance.

NDVI values theoretically range from −1 to +1, where higher positive values indicate dense and healthy vegetation, values near zero represent sparse vegetation or bare land, and negative values generally correspond to water bodies or other non-vegetated surfaces.

Following NDVI computation, the index was reclassified into vegetation density classes using threshold values adopted from previous studies. The classification scheme is presented in Table 2.

Table 2: NDVI classification scheme.

NDVI Range	Land Cover Class
< 0.00	Water bodies
0.00–0.25	Bare surface
0.26–0.35	Sparse vegetation
0.36–0.50	Moderate vegetation
> 0.50	Dense vegetation

Vegetation Change Detection

Post-classification change detection was employed to quantify vegetation transitions between successive observation years. The classified NDVI maps for 1999, 2008, 2014, and 2024 were converted from raster to polygon format and overlaid using the Intersect tool in ArcGIS. Area statistics were subsequently computed to determine transitions among vegetation classes, including vegetation persistence, gain, and loss. This approach enabled the identification and quantification of spatial changes in vegetation cover over the study period.

The Post-Classification Change Detection (PCCD) procedure involved several sequential steps. First, Normalized Difference Vegetation Index (NDVI) maps were generated for each study year. Next, the resulting NDVI maps were reclassified into distinct vegetation classes. These classified raster datasets were then converted into vector polygons. After conversion, a spatial overlay and intersection were performed on the successive datasets. Finally, the total vegetation gains, losses, and persistence were computed.

This approach enabled the identification of areas experiencing vegetation degradation, recovery, and stability over the 25-year study period. The workflow is summarized in Figure 2.

Results

Spatio-Temporal Distribution of Vegetation Cover

The classified NDVI maps generated for 1999, 2008, 2014, and 2024 reveal progressive changes in vegetation distribution across Yewa North Local Government Area over the 25-year study period (Figure 3). The spatial patterns demonstrate that vegetation dynamics were characterised by a gradual decline in dense vegetation and a corresponding expansion of moderately vegetated areas, indicating continuous modification of the landscape. Although vegetation remained widespread throughout the study area, the composition and spatial arrangement of vegetation classes changed considerably between successive observation years.

Visual comparison of the classified maps indicates that areas occupied by dense vegetation became increasingly fragmented over time, while moderate vegetation expanded into locations previously occupied by dense vegetation. In contrast, the spatial extent of bare surfaces and sparse vegetation exhibited relatively smaller fluctuations, suggesting that vegetation degradation occurred primarily through progressive reductions in vegetation density rather than widespread conversion to completely unvegetated surfaces.

The descriptive statistics of the NDVI images (Table 3) further support these observations. The minimum NDVI values remained relatively stable throughout the study period, indicating that areas with little or no vegetation changed only marginally. Conversely, reductions in the maximum and mean NDVI values reflect a gradual decline in vegetation vigour and canopy density. Collectively, these statistics indicate a long-term deterioration in vegetation conditions across the study area.

Table 3. Descriptive statistics of NDVI values from 1999 to 2024.

Statistic	1999	2008	2014	2024
Maximum	0.46	0.26	0.50	0.43
Minimum	0.01	0.03	−0.00	0.07
Mean	0.28	0.14	0.19	0.19
Standard Deviation	0.06	0.03	0.05	0.06

Source: Authors' analysis (2024).

Temporal Changes in Vegetation Classes

The classified NDVI maps reveal significant temporal changes in the areal extent of the vegetation classes during the study period (Table 4). Among these, dense vegetation experienced the greatest reduction, while moderate vegetation recorded the most substantial increase. These changes indicate a progressive shift in vegetation structure rather than complete vegetation removal.

Dense vegetation declined from approximately 750.95 km² in 1999 to 230.25 km² in 2024, representing a reduction of more than two-thirds of its original extent. Conversely, moderate vegetation increased steadily throughout the study period, reaching approximately 1,229.31 km² in 2024. The expansion of moderate vegetation largely compensated for the reduction in dense vegetation, suggesting that many formerly dense vegetation areas transitioned into moderately vegetated landscapes.

The relatively small variations observed in the extent of bare surfaces and sparse vegetation indicate that vegetation change was dominated by transformations between vegetated classes rather than extensive land degradation leading to bare land. This pattern suggests that vegetation modification within Yewa North was gradual and progressive, with vegetation density declining over time while maintaining overall vegetative cover across much of the landscape.

The observed changes demonstrate that vegetation dynamics in the study area were characterised by continuous transitions among vegetation classes, reflecting the evolving interaction between natural vegetation processes and anthropogenic land-use activities.

Table 4: Spatial distribution of vegetation classes derived from NDVI.

Vegetation Class	1999	2008	2014	2024
Bare Surface (km²)	648.49	764.37	764.37	606.84
Moderate Vegetation (km²)	745.87	745.87	863.15	1229.31
Dense Vegetation (km²)	671.99	671.99	438.83	230.25

Source: Authors' analysis (2024).

NDVI-Based Post-Classification Change Detection

Post-classification change detection provided a quantitative assessment of vegetation transitions between successive observation years. Following NDVI classification, the raster datasets were converted into vector polygons and analysed using GIS overlay operations to determine the spatial transitions among vegetation classes. This approach enabled the identification of vegetation persistence, gains, and losses, while simultaneously quantifying the magnitude of change between observation periods.

Vegetation Transitions (1999–2008)

The transition matrix (Table 5) indicates that a substantial proportion of dense vegetation remained unchanged during the first observation period, reflecting relative landscape stability. Nevertheless, measurable transitions from dense vegetation to moderate vegetation were observed, indicating the initial stages of vegetation modification. Limited conversions from vegetated classes to bare surfaces further suggest that vegetation degradation during this period occurred primarily through reductions in vegetation density rather than complete vegetation removal.

Table 5: Statistical analysis of vegetation cover change from 1999 to 2008

Change class	Change area km²
Bare surface - Bare surface	336.772
Bare surface - Moderate vegetation	98.274
Bare surface - Dense vegetation	21.123
Moderate vegetation - Bare surface	268.186
Moderate vegetation - Moderate vegetation	393.459
Moderate vegetation - Dense vegetation	197.294
Dense vegetation - Bare surface	43.413
Dense vegetation - Moderate vegetation	253.961
Dense vegetation - Dense vegetation	453.421

Source: Authors' analysis (2024).

Table 6: Statistical analysis of vegetation cover change from 2008 to 2014

Change class	Change area km²
Bare surface - Bare surface	453.904
Bare surface - Moderate vegetation	178.61
Bare surface - Dense vegetation	15.877
Moderate vegetation - Bare surface	196.562
Moderate vegetation - Moderate vegetation	416.398
Moderate vegetation - Dense vegetation	132.735
Dense vegetation - Bare surface	113.795
Dense vegetation - Moderate vegetation	267.97
Dense vegetation - Dense vegetation	290.093

Source: Authors' analysis (2024).

Vegetation Transitions (2008–2014)

During the second observation period, vegetation transitions became more pronounced (Table 6). Increased conversion of dense vegetation into moderate vegetation indicates an acceleration of vegetation modification compared with the previous period. Moderate vegetation also expanded through transitions from sparse vegetation, illustrating continuous restructuring of vegetation composition across the study area. Despite these changes, portions of the dense vegetation remained persistent, indicating that vegetation degradation was spatially variable rather than uniform.

Vegetation Transitions (2014–2024)

The largest vegetation transitions occurred during the final observation period (Table 7). Dense vegetation experienced its greatest reduction, while moderate vegetation recorded the highest gains, indicating that vegetation modification intensified during the last decade of the study. The transition matrix shows that most vegetation changes occurred between vegetated classes, particularly from dense to moderate vegetation, rather than through direct conversion to non-vegetated land.

Overall, the transition matrices demonstrate that vegetation dynamics in Yewa North were characterised by continuous redistribution among vegetation classes. The predominance of transitions from dense vegetation to moderate vegetation indicates progressive vegetation degradation rather than abrupt landscape transformation.

Table 7: Statistical analysis of vegetation cover change from 2014 to 2024

Change class	Change area km²
Bare surface - Bare surface	470.007
Bare surface - Moderate vegetation	277.917
Bare surface - Dense vegetation	16.334
Moderate vegetation - Bare surface	132.394
Moderate vegetation - Moderate vegetation	650.584
Moderate vegetation - Dense vegetation	80.008
Dense vegetation - Bare surface	4.378
Dense vegetation - Moderate vegetation	300.587
Dense vegetation - Dense vegetation	133.774

Source: Authors' analysis (2024).

Spatial Pattern of Vegetation Transitions

A comparison of the three transition periods demonstrates a gradual increase in vegetation transformation over time. While the 1999–2008 period was characterised by relatively stable vegetation conditions, the magnitude of vegetation transitions increased noticeably during 2008–2014 and became most pronounced between 2014 and 2024. The dominant pathway of change throughout the study period was the transition from dense vegetation to moderate vegetation, highlighting progressive reductions in vegetation density as the principal characteristic of landscape change in Yewa North.

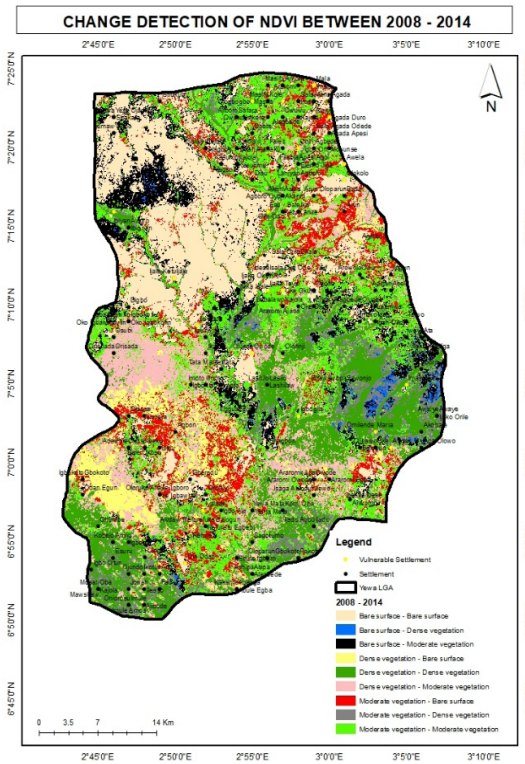
The vegetation transition maps (Figure 3) illustrate the spatial distribution of vegetation persistence, gains, and losses across the study area. Persistent dense vegetation was concentrated in relatively less disturbed areas, whereas vegetation losses were predominantly observed around agricultural lands and expanding settlements. Moderate vegetation exhibited widespread spatial expansion, particularly in areas previously occupied by dense vegetation, further supporting the transition matrix results.

The spatial distribution of vegetation transitions indicates that vegetation change was heterogeneous across the landscape. Rather than occurring uniformly, vegetation degradation was concentrated within localized areas experiencing greater land-use pressure. This spatial variability highlights the importance of integrating GIS-based post-classification change detection with remotely sensed vegetation indices to identify priority areas for conservation and sustainable land management.

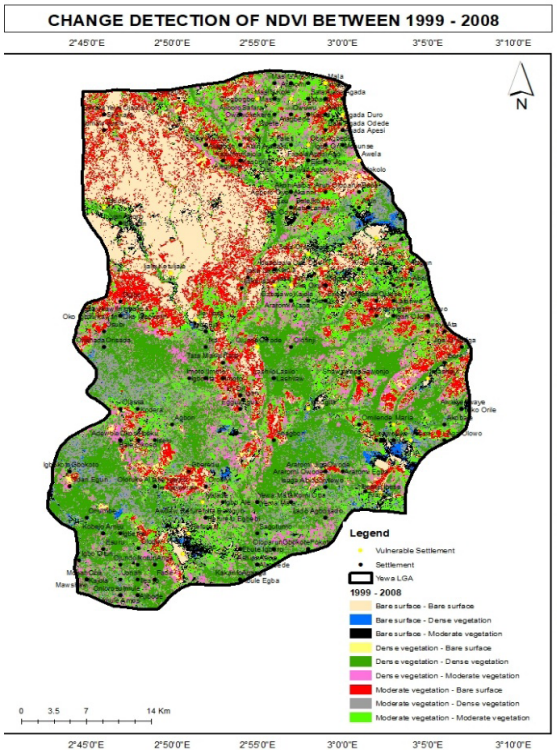
The post-classification change detection analysis confirms that vegetation dynamics were driven primarily by internal redistribution among vegetation classes rather than wholesale conversion to non-vegetated land. This pattern reflects a landscape undergoing continuous ecological modification, with vegetation persistence, degradation, and regeneration occurring simultaneously across different parts of the study area.

Figure 3 presents the Vegetation change detection maps derived from NDVI differencing for (a) 1999–2008, (b) 2008–2014, (c) 2014–2024, and (d) 1999–2024 in Yewa North Local Government Area.

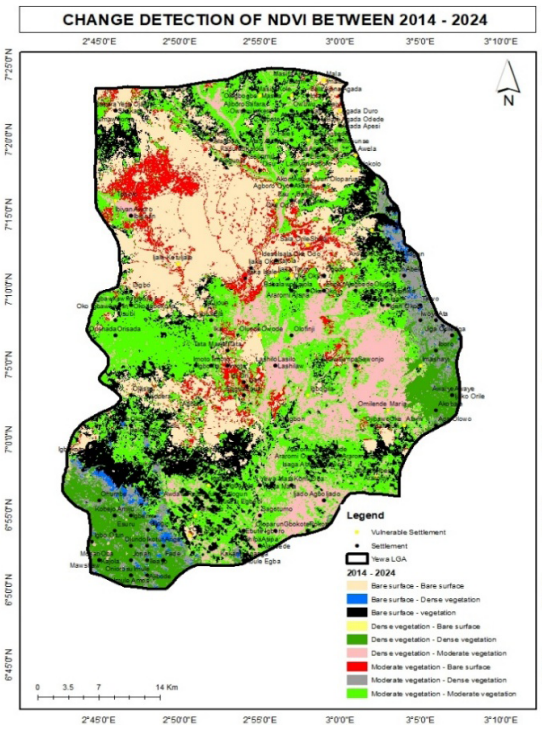
Figure 4 presents the NDVI maps for (a) 1999–2008, (b) 2008–2014, (c) 2014–2024, and (d) 1999–2024 in Yewa North Local Government Area.



(a)

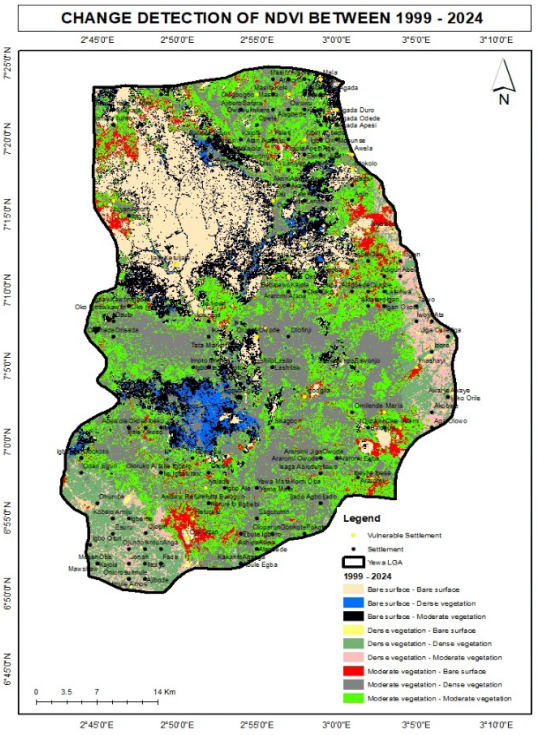


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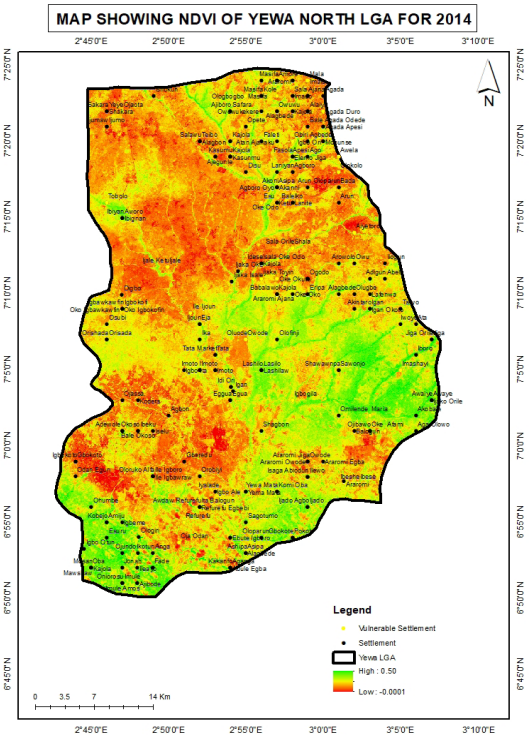


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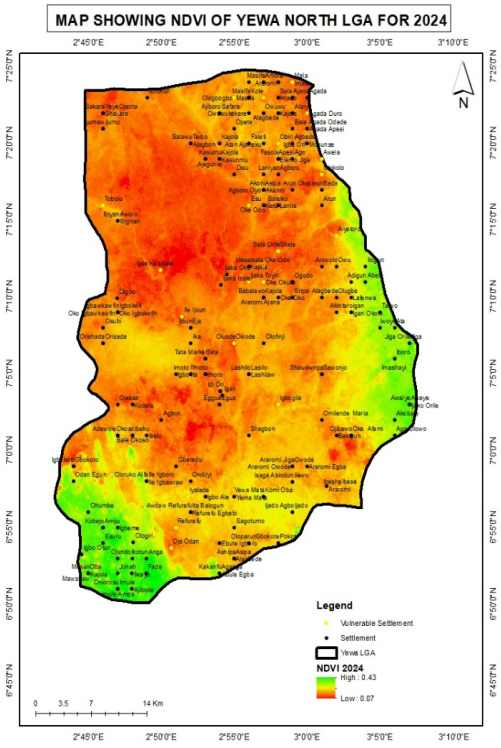
Figure 3: Change detection of NDVI (a) from 1999 to 2008, (b) from 2008 to 2014, (c) from 2014 to 2024, (d) from 1999 to 2024.



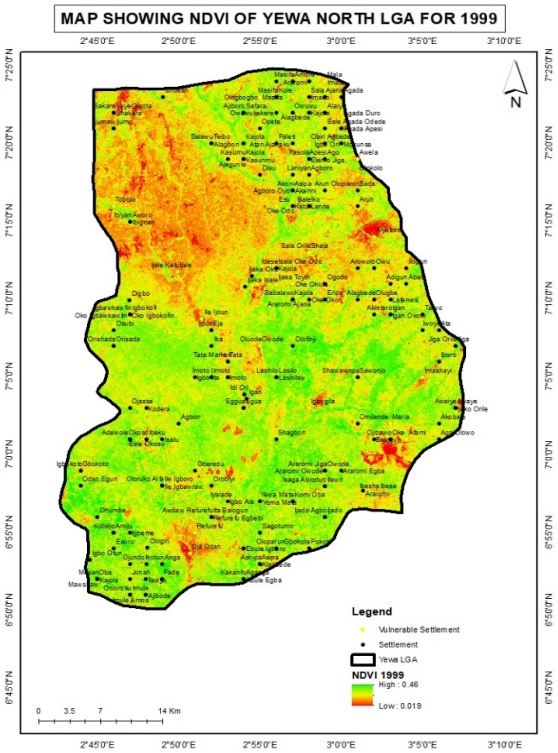
(c)



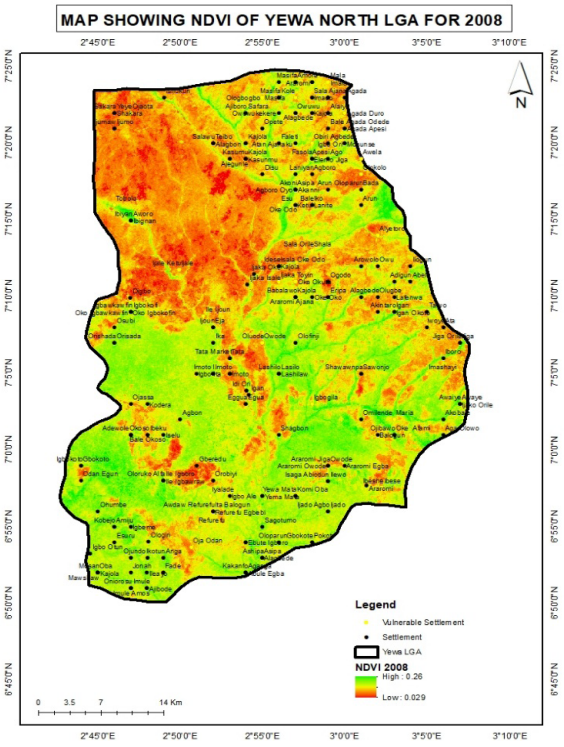
a)



(b)



(d)



(c)

Figure 4: NDVI maps (a) 1999 (b) 2008 (c) 2014 (d) 2024.

Discussion

The integration of multi-temporal Landsat imagery, NDVI classification, and GIS-based post-classification change detection provided a comprehensive assessment of vegetation dynamics in Yewa North Local Government Area over the 25-year study period. The findings consistently demonstrate a progressive transformation of vegetation structure, characterised by a substantial decline in dense vegetation and a corresponding increase in moderate vegetation. This pattern indicates that vegetation change within the study area occurred primarily through gradual reductions in vegetation density rather than widespread conversion to non-vegetated surfaces. Such transitions are typical of landscapes subjected to sustained anthropogenic disturbances, where natural vegetation is progressively modified by agricultural expansion, settlement development, and other land-use activities rather than being completely removed (Roy et al., 2022; Simmonds et al., 2023).

The reduction in dense vegetation observed in this study is consistent with the broader pattern of vegetation degradation reported across many tropical and subtropical regions. Using long-term Landsat-derived NDVI, Ezaidi et al. (2022) similarly reported progressive degradation of vegetation cover within the Arganeraie Biosphere Reserve in Morocco,

where dense vegetation gradually transitioned into less vigorous vegetation communities over time. Likewise, Abbas et al. (2021) demonstrated that long-term vegetation productivity is highly responsive to both climatic variability and anthropogenic influences, emphasising that changes in vegetation conditions often manifest as gradual declines in vegetation productivity rather than abrupt land-cover conversion. Although the present study did not explicitly evaluate climatic drivers, the observed decline in dense vegetation suggests that increasing human activities have altered vegetation structure within the study area.

The temporal pattern of vegetation transitions further indicates that landscape modification intensified during the latter years of the study, particularly between 2014 and 2024. The transition matrices revealed that the dominant pathway of change throughout the study period was the conversion of dense vegetation into moderate vegetation, while comparatively few areas were transformed directly into bare surfaces. This finding suggests that vegetation degradation occurred incrementally through reductions in canopy density and vegetation vigour. Similar observations have been reported by Wang et al. (2020), who found that vegetation dynamics are often characterised by progressive changes in vegetation condition driven by the combined effects of environmental variability and human activities. The predominance of intermediate vegetation classes in the present study further indicates that portions of the landscape continue to retain vegetative cover despite ongoing disturbance, highlighting the dynamic nature of vegetation recovery and degradation.

The spatial distribution of vegetation transitions provides additional insight into the processes shaping vegetation dynamics within Yewa North. Vegetation losses were concentrated around areas experiencing greater human activities, whereas relatively undisturbed locations retained a higher proportion of dense vegetation. This heterogeneous pattern demonstrates that vegetation degradation was spatially variable rather than uniform across the landscape. Similar relationships between human activities and vegetation fragmentation have been documented by Koowe et al. (2021), who observed that expanding settlements and increasing land-use intensity contribute significantly to changes in vegetation structure and landscape fragmentation. At the regional scale, Ojo et al. (2022) also reported substantial land-use and land-cover changes within the neighbouring Yewa South Local Government Area, suggesting that landscape transformation is a broader phenomenon affecting the Yewa region of Ogun State.

The increase in moderate vegetation observed during the study period should not necessarily be interpreted as an improvement in ecosystem conditions. Instead, the transition matrices indicate that much of this increase resulted from the conversion of previously dense vegetation into vegetation of lower density. Consequently, the expansion of moderate vegetation reflects structural modification of vegetation rather than ecological restoration. This observation supports the argument of Peñuelas and Sardans (2021) that changes in vegetation composition and structure may substantially alter ecosystem functioning even where total vegetation cover remains relatively high. Similarly, Simmonds et al. (2023) emphasised that maintaining natural vegetation in its intact state is essential for preserving biodiversity, ecosystem resilience, and the ecosystem services upon which human well-being depends.

From a methodological perspective, the combination of NDVI classification and post-classification change detection proved effective for quantifying long-term vegetation dynamics within the study area. Unlike simple temporal comparisons of NDVI values, post-classification change detection provides explicit information on both the magnitude and direction of transitions among vegetation classes. This enables detailed assessment of vegetation persistence, gains, and losses while reducing ambiguity associated with direct spectral comparisons. The robustness of Landsat imagery for long-term environmental monitoring has been extensively documented by Hemati et al. (2021), who identified Landsat as one of the most reliable satellite datasets for multi-decadal change detection because of its long historical archive and consistent spatial resolution. Furthermore, Huang et al. (2021) noted that NDVI remains one of the most widely applied vegetation indices owing to its simplicity, robustness, and effectiveness in monitoring vegetation conditions across diverse environments. Recent reviews by Mashala et al. (2023) further highlight the importance of integrating remote sensing and GIS techniques for assessing land-use and vegetation changes to support sustainable environmental management.

Although the adopted methodology effectively characterised vegetation dynamics over time, several limitations should be acknowledged. The 30 m spatial resolution of Landsat imagery may not adequately capture small or fragmented vegetation patches, potentially resulting in mixed-pixel effects within heterogeneous landscapes. Additionally, differences in acquisition dates and seasonal vegetation conditions may introduce variability in NDVI values despite

image pre-processing. The study also relied exclusively on remotely sensed observations, and the absence of independent field validation limits the direct assessment of classification accuracy. Future studies should therefore integrate higher-resolution satellite imagery, unmanned aerial vehicle (UAV) observations, or field-based vegetation surveys to improve spatial accuracy and strengthen validation of vegetation classifications. Advances in high-resolution remote sensing and integrated Earth observation platforms provide promising opportunities for enhancing vegetation monitoring at local scales (Ojeilua et al., 2025; Zhao et al., 2024).

Overall, the findings demonstrate that vegetation dynamics in Yewa North during the last two and a half decades have been dominated by progressive reductions in vegetation density rather than widespread vegetation removal. The generated NDVI maps, vegetation transition matrices, and change maps provide valuable baseline information for monitoring ecosystem conditions, identifying areas vulnerable to continued vegetation degradation, and supporting evidence-based land-use planning. The integration of multi-temporal Landsat imagery with GIS-based post-classification change detection therefore represents a practical and reproducible framework for long-term vegetation monitoring and can support informed decision-making aimed at promoting sustainable landscape management and vegetation conservation within the study area.

Conclusion and Recommendations

This study employed multi-temporal Landsat imagery, the Normalized Difference Vegetation Index (NDVI), and GIS-based post-classification change detection to evaluate vegetation dynamics in Yewa North Local Government Area, Ogun State, Nigeria, over 25 years (1999–2024). The integrated geospatial approach provided a robust framework for characterising changes in vegetation distribution, quantifying transitions among vegetation classes, and assessing long-term landscape dynamics.

The findings revealed substantial changes in vegetation composition and structure during the study period. Dense vegetation declined considerably, while moderate vegetation expanded, indicating that vegetation change was primarily characterised by progressive reductions in vegetation density rather than widespread conversion to bare land. The post-classification change detection analysis further demonstrated that the dominant pathway of landscape transformation was the transition from dense vegetation to moderate vegetation, reflecting gradual modification of the natural vegetation cover. Spatial analysis showed that vegetation degradation was unevenly distributed across the study area, with greater changes occurring around areas subjected to intensive human activities, while relatively undisturbed areas retained higher proportions of dense vegetation.

Methodologically, the study demonstrates the effectiveness of integrating NDVI with GIS-based post-classification change detection for long-term vegetation monitoring. The approach enabled both quantitative and spatial assessment of vegetation transitions, providing more detailed information on vegetation persistence, gains, and losses that could be obtained from NDVI analysis alone. The study therefore contributes to the growing application of geospatial technologies for environmental monitoring and provides a replicable framework for assessing vegetation dynamics in tropical landscapes.

The findings have important implications for environmental management and sustainable land-use planning in Yewa North and similar environments. The observed decline in dense vegetation highlights the need for proactive measures to conserve remaining natural vegetation and minimise further ecosystem degradation. The vegetation transition maps and spatial analyses generated in this study provide valuable baseline information for identifying priority areas for conservation, ecological restoration, and sustainable landscape management.

Based on the findings, the study recommends that environmental management agencies and relevant stakeholders strengthen vegetation conservation programmes through sustainable land-use planning, community-based afforestation and reforestation initiatives, and improved regulation of land conversion activities. Routine monitoring of vegetation dynamics using multi-temporal satellite imagery should be institutionalised to enable timely detection of vegetation changes and support evidence-based decision-making. In addition, future studies should integrate higher-resolution satellite imagery, unmanned aerial vehicle (UAV) observations, and field-based vegetation assessments to improve the spatial accuracy and validation of vegetation mapping. The incorporation of advanced machine learning algorithms and complementary vegetation indices, such as the Enhanced Vegetation Index (EVI) and Soil-Adjusted Vegetation Index (SAVI), could further improve the detection and characterisation of vegetation changes in heterogeneous tropical landscapes.

This study provides an important geospatial baseline for understanding vegetation dynamics in

Yewa North and demonstrates the value of integrating remote sensing and GIS techniques for long-term environmental monitoring. The generated information can support policy formulation, ecosystem conservation, and sustainable natural resource management while contributing to the broader application of geospatial technologies in vegetation monitoring and land-use planning.

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