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Monitoring Land Cover Changes in Shasha Forest Reserve, Osun State, Nigeria (1987–2023) Using Remote Sensing and GIS Techniques

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ABSTRACT: Forests in Nigeria continue to face substantial pressure from agriculture, population growth, logging, and other forms of land conversion. Reliable information on land use and land cover dynamics is therefore essential for sustainable forest management and biodiversity conservation. This study assessed land cover changes within Shasha Forest Reserve, Osun State, Nigeria, over 36 years using Landsat satellite imagery acquired in 1987, 2002, and 2023. Landsat TM, ETM+, and OLI imagery obtained from the United States Geological Survey was processed and classified using a supervised maximum-likelihood classification approach. Four land cover categories were identified as dense forest, built-up area, sparse vegetation, and water bodies. Post-classification change-detection techniques were applied to quantify the magnitude and rate of change between the study periods. The findings showed a decline in dense forest cover throughout the study period. Dense forest decreased from 185.13 km² in 1987 to 152.19 km² in 2023, representing a loss of 14.06%. Built-up area increased substantially from 18.61 km² in 1987 to 49.18 km² in 2023. Sparse vegetation fluctuated during the study period, while water bodies declined by 2023. The observed changes indicate anthropogenic pressure on the reserve, particularly from settlement increase and land conversion activities. The usefulness of remote sensing and GIS techniques for long-term forest monitoring displayed in the study highlights the need for improved conservation measures and sustainable land use management practices within Shasha Forest Reserve.

Keywords: Deforestation, GIS, Remote-sensing, Landsat, Forest.

Introduction

Forests remain one of the most important terrestrial ecosystems because they sustain biodiversity, regulate climate, maintain hydrological cycles, and provide economic resources for human populations (Anjaneyulu, 2005; Santilli *et al.*, 2005). In many tropical regions, forest ecosystems are increasingly threatened by land conversion driven by agricultural, urban, and logging activities, as well as population growth. These activities have added to widespread forest degradation and biodiversity loss across many developing countries.

Nigeria has diverse forest ecosystems that support many plant and animal species. In spite of their ecological and economic importance, many forest reserves in the country have experienced degradation over the past decades. Activities such as farming, logging, infrastructure development, and settlement expansion (Igboanugo, 2011) have increased forest loss and altered natural vegetation patterns.

Land-use and land-cover change studies provide valuable insights into environmental change over time (Alo *et al.*, 2020). Land cover refers to the physical characteristics of the Earth's surface, including vegetation, water bodies, and built-up structures, whereas land use refers to how humans use land resources. Remote sensing and

Geographic Information System (GIS) techniques have become widely used tools for monitoring environmental changes. Satellite imagery provides consistent spatial and temporal information, enabling researchers to analyse land cover changes over a long period of time. Combined with GIS analysis, remote sensing enables the detection, mapping, and quantification of environmental changes with improved accuracy. Recent studies have shown that tropical forest ecosystems in Africa continue to undergo rapid land-cover transformation caused by agriculture, infrastructure expansion, and population growth (FAO, 2022; Hansen *et al*., 2013; Adeyemi and Oyeleye, 2021). Advances in remote sensing technology and the availability of freely accessible satellite imagery have further improved the monitoring of forest disturbance and landscape dynamics at regional and local scales (Wulder *et al*., 2019). Several recent studies in West Africa have also shown the effectiveness of integrating Landsat imagery with GIS-based spatial analysis for long-term forest monitoring and deforestation assessment (Adepoju *et al*., 2023; Olofsson *et al*., 2020). Recent advances in geospatial technologies, machine learning, and satellite-based monitoring have improved the detection and mapping of forest cover changes across tropical ecosystems (Ologunde *et al*., 2025). Forest land cover studies in Nigeria continue to demonstrate increasing forest degradation (Chunwate *et al*., 2025; Aniramu *et al*., 2026). Recent forest monitoring studies conducted in different ecological zones of Nigeria have also pointed out the growing importance of remote sensing and GIS approaches for sustainable environmental management and conservation planning (Anule *et al*., 2026).

Several studies have reported declines in forest cover within forest reserves in southwestern Nigeria (Aigbokhan, 2018; Akinyemi, 2019). Prior studies conducted in Shasha Forest Reserve have demonstrated that poor forest management techniques, urbanization, and agricultural growth all contribute to forest degradation (Adeyemi *et al*., 2021; Alo *et al*., 2020). To comprehend the scope and development of these changes, however, regular observation is required.

Therefore, this study used remotely sensed data and GIS tools to analyze changes in land-use and land-cover in Shasha Forest Reserve, Osun State, Nigeria, between 1987 and 2023. The objectives were to create classified land use and land cover maps for 1987, 2002, and 2023, measure changes in the main land cover classes during the course of the study, calculate the amount and percentage of forest cover change, and evaluate the reserve's annual rate of deforestation.

Materials and methods

Study area: Shasha Forest Reserve is situated in Osun State, Nigeria, between latitudes 6°58′N and 7°10′N and longitudes 4°20′E and 4°32′E (Figure 1). The reserve was established in 1925, and is located in the humid tropical rainforest zone, which has a climate with significant yearly rainfall and high humidity. The study area's rainfall distribution is bimodal, peaking in June–July and September–October. The average annual temperature is roughly 27 °C, and the average annual rainfall is between 1200 and 1450 mm. The reserve contains several economically and ecologically important tree species, including *Milicia excelsa*, *Afzelia africana*, *Terminalia africana*, *Mansonia altissima*, *Tectona grandis*, and *Gmelina arborea*. (Akinyemi *et al*., 2021; Femi *et al*., 2023) Like many forest reserves in Nigeria, Shasha Forest Reserve has experienced increasing stress from agricultural activities, settlement expansion, and logging.

Data collection: Landsat satellite imagery for the years 1987, 2002, and 2023 was obtained from the United States Geological Survey (USGS) Earth Resources Observation and Science (EROS) database. The datasets included Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 9 Operational Land Imager (OLI) imagery. The Landsat imagery used represents a 36-year interval for evaluating long-term land cover changes within the forest reserve. Recent studies have incorporated multi-temporal Landsat imagery due to its reliability for long-term environmental monitoring and its compatibility with GIS-based spatial analysis (Zhu *et al*., 2019; Chunwate *et al*., 2025; Friedl *et al*., 2022).

Image pre-processing: The acquired Landsat satellite imagery was processed in ArcGIS environment. Geometric correction and georeferencing were carried out using the Universal Transverse Mercator (UTM) projection system referenced to the WGS 84 datum. False-color composite images were generated to improve the distinction between land cover categories. Bands 4, 3, and 2 were used for Landsat TM and ETM+ imagery, while bands 7, 5, and 4 were used for Landsat OLI imagery (Temitope and Oyebamiji, 2020). (Landsat 4-5 TM and Landsat 7 ETM+ bands and their uses, 2016) The study area was subsequently extracted from the full imagery through subsetting procedures.

Land cover classification: A supervised classification approach was applied using the Maximum-Likelihood Algorithm. Training samples representing the major land cover classes were selected through region of interest (ROI) polygons. Four land cover classes were identified as built-up area, dense forest, sparse vegetation, and water bodies. The Maximum Likelihood Algorithm was selected because of its effectiveness in dealing with complex land cover categories with similar spectral signatures (Pal and Mather, 2003). Supervised maximum likelihood classification has been widely applied in land cover studies due to its robustness and ability to effectively classify heterogeneous tropical landscapes (Phiri and Morgenroth, 2017).

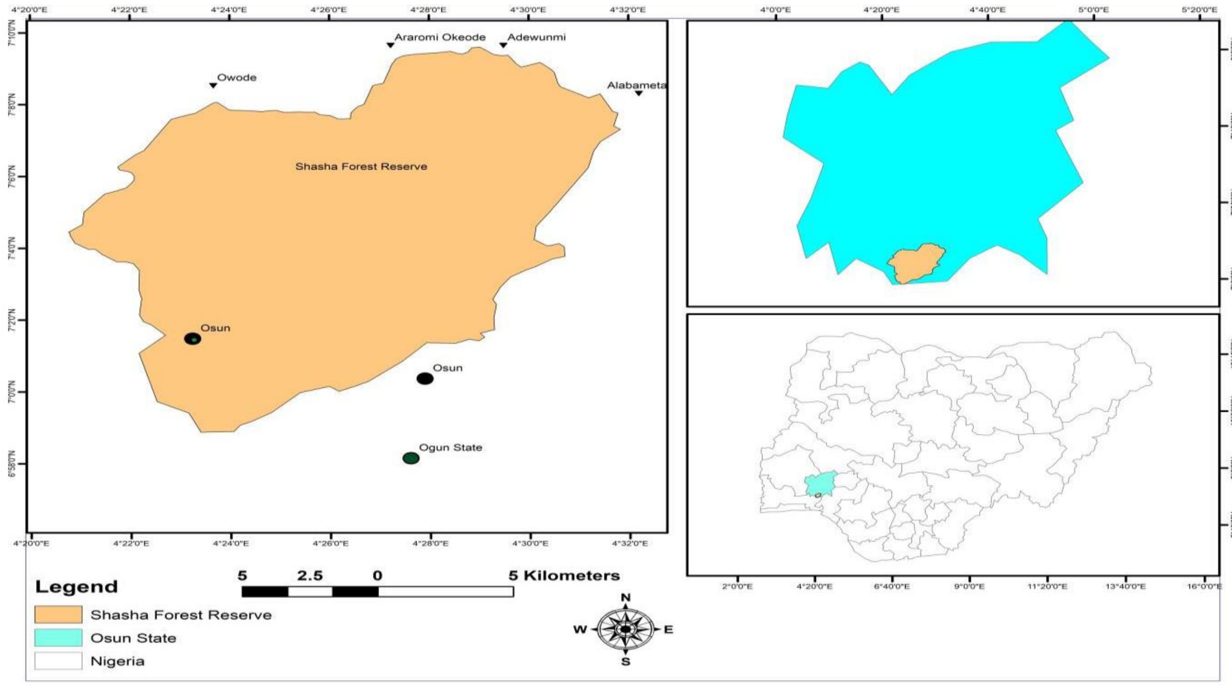

Figure 1: Map of Shasha Forest reserve in Osun State, Nigeria

Change detection analysis: Post-classification change detection algorithms were used to evaluate changes between study years. Change matrices were generated to determine transitions between land cover classes for 1987-2002 and 2002-2023 (Adesioye and Owoh, 2016). Post-classification comparison methods are commonly used in multi- temporal change detection studies because they allow direct identification of transitions between land cover classes (Singh, 1989; Hussain *et al*., 2013). The combination of supervised classification methods with post-classification change detection continues to be one of the most widely accepted approaches for evaluating land cover changes in tropical forest environments (Njoku *et al*., 2026).

The magnitude of change was calculated as:

$$\text{Magnitude of Change} = \text{previous year} - \text{initial year}$$

$$\text{Percent of Change} = \frac{Magnitude\ of\ Change}{Sum\ of\ Change} * 100$$

Annual rate of deforestation (t) was calculated using the formula proposed by Puyravaud (2003).

$$r = \frac{1}{T2 - T1} * ln\frac{A2}{A1}$$

where A1 and A2 are the forest cover at time T1 and T2, respectively.

Data analysis: Spatial analysis and image processing were carried out using ArcGIS 10.8 and ENVI software. Microsoft Excel was used for statistical summaries, chart generation, and result tabulation. (ArcGIS for Excel: Aggregate Features, 2023)

Results

Classified maps of Shasha forest reserve for 1987, 2002, and 2023: Four land cover classes were identified within Shasha Forest Reserve during this study: built-up area, dense forest, sparse vegetation, and water bodies. Dense forest remained the dominant land cover class throughout the study period; however, a consistent decline in forest area was observed between 1987 and 2023. Built-up areas expanded considerably during the same period, indicating increasing anthropogenic activities within and around the reserve. Figures 2, 3, and 4 show the classified map of Shasha Forest Reserve for the years 1987, 2002, and 2023, respectively. The classified images show the four land cover classes identified from the Landsat images, with the dense forest covering a larger percentage in the two periods under the study.

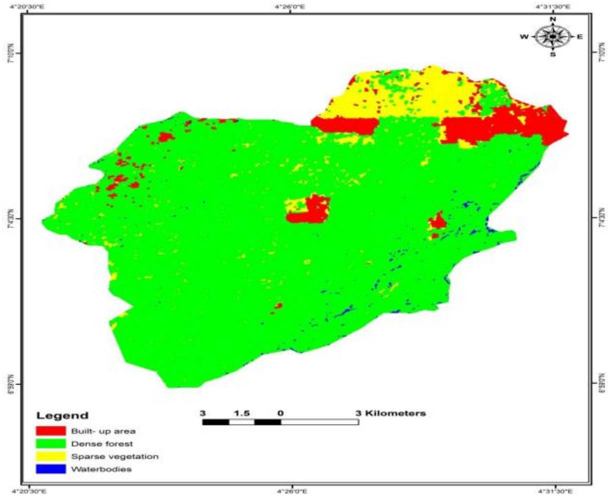

Figure 2: Land-use/land-cover classification map of Shasha Forest Reserve for 1987.

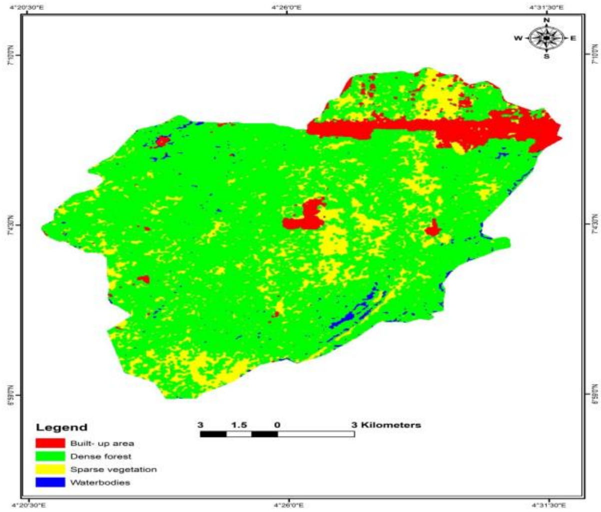

Figure 3: Land-use/land-cover classification map of Shasha Forest Reserve for 2002

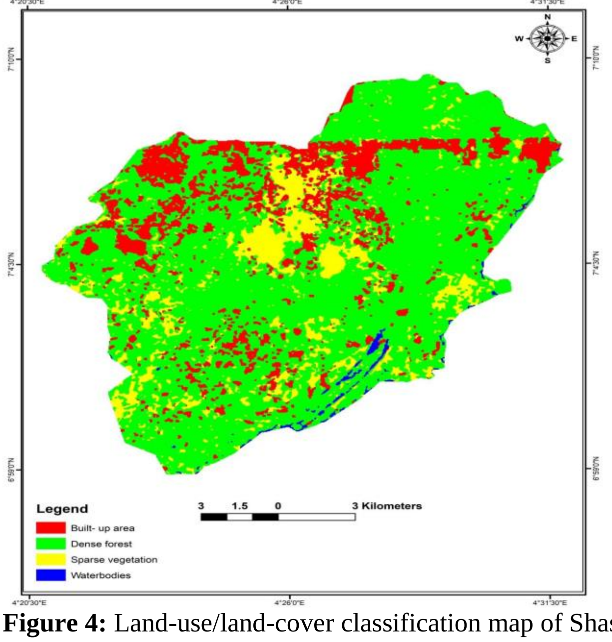

Figure 4: Land-use/land-cover classification map of Shasha Forest Reserve for 2023**.**

Land cover change between 1987 – 2002 and 2002 – 2023: Dense forest cover declined from 185.13 km² in 1987 to 164.42 km² in 2002, representing a loss of approximately 20.71 km². During this period, portions of dense forest were converted to built-up areas, sparse vegetation, and water bodies. Built-up areas increased slightly from 18.61 km² to 19.39 km², (Table 1) while sparse vegetation expanded substantially from 23.55 km² to 41.87 km². Within 1987 and 2023, dense forest decreased from 185.13 km² to 152.19 km², corresponding to a total loss of 32.94 km². Built-up area expanded significantly from 18.61 km² to 49.18 km². Sparse vegetation increased from 23.54 km² in 1987-30.59 km² in 2023, while water bodies decreased from 6.91 km²-2.25 km².

Table 1: Class statistics results: 1987, 2002, 2023

Land cover types	1987 (Km^2)	2002 (Km^2)	2023 (Km^2)
Built-up area	18.61	19.38	49.18
Dense forest	185.13	164.42	152.19
Sparse vegetation	23.54	41.86	30.58
Water bodies	6.91	8.53	2.24

Magnitude and percentage of change: The largest positive land cover change observed during the study period occurred in built-up areas, which increased by 30.56 km² between 1987 and 2023. Dense forest recorded the largest decline, with a reduction of 32.94 km² (Table 2).

Table 2: Magnitude of change detected for each land cover type of Shasha Forest Reserve for 1987, 2002 and 2023

Land cover types	1987-2002 (Km^2)	2002-2023 (Km^2)	1987-2023 (Km^2)
Built-up area	0.77	29.79	30.56
Dense forest	-20.70	-12.23	-32.94
Sparse vegetation	18.32	-11.27	7.04
Water bodies	1.61	-6.28	-4.66

The percentage change analysis showed that dense forest declined by 14.06% between 1987 and 2023. In contrast, the built-up area increased by 13.05% during the same period (Figure 5).

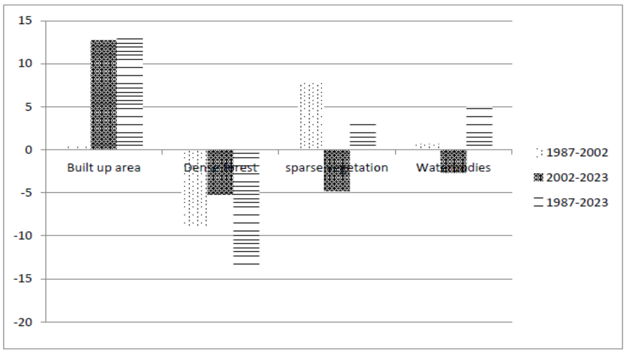

Figure 5: Percentage of change in land cover areas in Shasha Forest Reserve

Annual rate of deforestation: The annual rate of dense forest deforestation indicated forest decline throughout the study period. The annual deforestation rate between 1987 and 2002 was estimated at -0.79, while the annual rate between 1987 and 2023 was -0.54 (Figure 6).

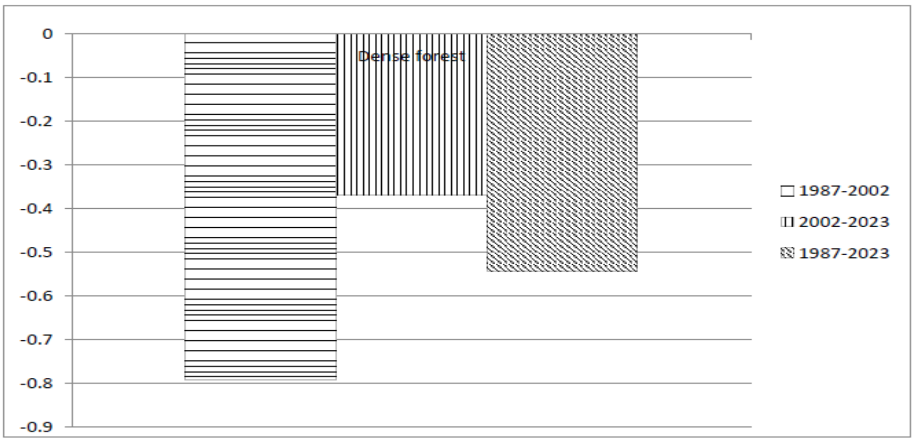

Figure 6: Annual rate of change/ deforestation of dense forest area in Shasha Forest Reserve

Discussion

The findings of this study indicate substantial land-cover transformation in Shasha Forest Reserve over the last three decades. The most change observed was the reduction in dense forest area, along with the expansion of built-up areas.

According to Orimoogunje *et al*. (2009) and Curtis *et al*. (2018), agricultural practices and human settlement are posing a growing danger to forest reserves throughout tropical Africa, which is consistent with the study's findings about the decrease in thick forest area. Similar research carried out in Nigerian forest reserves has connected increased human activity in protected areas and poor implementation of conservation regulations to forest degradation (Adepoju *et al*., 2023). Similar trends of decreasing forest acreage and growing built-up areas have lately been documented in a number of Nigerian locations, demonstrating the pervasive impact of human activity on protected forest ecosystems (Orimoogunje, 2014; Ologunde *et al*., 2025; Aniramu *et al*., 2026). Meyfroidt *et al*. (2010) found that around 61% of the world's tropical forests were changed to other land use and land cover types between 2000 and 2005. Similarly, Africa has the highest rate of deforestation of any continent. This is corroborated by Rodríguez-Veiga *et al*. (2025) and Owolabi (2019). If current land-use trends continue, recent GIS modeling studies have also predicted ongoing forest loss in numerous Nigerian forest areas (Enoh *et al*., 2026). These results support the need for more robust forest protection laws, sustainable land management techniques, and ongoing GIS technology-based environmental monitoring.

Increased human activity within and around the forest reserve is indicated by the growth in built-up areas between 1987 and 2023. These actions frequently worsen the loss of forests and interfere with natural processes (Enoh *et al*., 2026; Muteya *et al*., 2025; Ologunde *et al*., 2025). Sparse vegetation first increased between 1987 and 2002, then decreased between 2002 and 2023. Land clearing, farming, and reforestation initiatives in some areas of the forest reserve may be associated with this tendency (Popoola, 2017). This outcome is consistent with the study conducted by Oates *et al*. (2014), which found that between 2002 and 2014, there was a general increase in the size of forest area throughout that period.

Forest ecosystems are crucial for hydrological stability and watershed preservation. Water availability may be impacted by ongoing forest degradation (Jones *et al*., 2009).

The yearly rates of deforestation show that the reserve's forest cover decrease is still a problem. A combination of multi-temporal satellite imagery and spatial analysis provided valuable information on the extent of change. The use of remotely sensed data in combination with GIS-based analysis continues to provide reliable data for evaluating long-term environmental change and facilitating sustainable forest management decisions (Wulder *et al*., 2019). The findings highlight the need for enforcement against illegal logging, promotion of conservation-based agriculture, and community participation in forest management may help reduce degradation in Shasha Forest Reserve.

Conclusion

This study evaluated land-use and land-cover changes in Shasha Forest Reserve, Osun State, Nigeria, between 1987 and 2023 using remote sensing and GIS techniques. Analysis showed major changes within the reserve over the 36-year study period.

Dense forest cover declined considerably, while built-up areas increased significantly. Sparse vegetation and water bodies also showed noticeable changes over time. The results indicate increasing anthropogenic activities in the forest reserve. Stronger enforcement of forest protection policies and conservation-focused land management are crucial to preserving the remaining forest resources in Shasha Forest Reserve.

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