Remote Sensing-Based LULC Change Analysis for Forest Conservation in Painganga Wildlife Sanctuary

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Abstract

This study investigates the two decades of Land Use and Land Cover (LULC) dynamics in the Painganga Wildlife Sanctuary, located in Maharashtra, India, using multi-temporal satellite imagery and GIS techniques. Landsat data from the years 2004 to 2024 were used to classify the landscape into five major categories: Dense Forest, Deciduous Forest, Grassland, Barren Land, and Water Bodies. The supervised classification approach, specifically the Maximum Likelihood Classifier (MLC), was applied for accurate mapping. The results reveal significant spatial and temporal transformations in land cover patterns, including a marked decline in dense forest areas and a rise in barren and grassland regions. These changes indicate increasing anthropogenic pressure and possible forest degradation. Change detection analysis provided insights into the rate and extent of land transformation. This research demonstrates the importance of integrating remote sensing and GIS technologies for forest monitoring and management and highlights the urgent need for conservation interventions in the region.

Keywords: Land Use Land Cover(LULC),Geographic Information System(GIS),Maximum Likelihood Classifier(MLC).

Introduction

Forests are among the most vital ecosystems on the planet, providing essential ecological services such as carbon sequestration, biodiversity conservation, and climate regulation. However, they are increasingly under threat due to various anthropogenic activities, including deforestation, agricultural expansion, infrastructure development, and forest fires. Monitoring these changes is crucial for sustainable forest management and conservation planning.

Land Use and Land Cover (LULC) analysis serves as a fundamental approach to understanding the dynamics of landscape transformation over time. LULC change detection helps identify areas where natural vegetation has been altered, which can signal environmental degradation or human-induced pressure on ecosystems.

The use of Remote Sensing and Geographic Information System (GIS) has revolutionized environmental monitoring by providing spatially continuous and temporally consistent data. Satellite imagery enables researchers to monitor vast and inaccessible forested areas effectively and repeatedly, while GIS supports the integration, analysis, and visualization of spatial data for informed decision-making.

The Painganga Wildlife Sanctuary, located in the districts of Yavatmal in Maharashtra, is known for its dry deciduous forests dominated by teak and other native flora. In recent decades, the sanctuary has experienced growing pressure from encroachment, land conversion, illegal logging, and shifting cultivation practices, which may be contributing to forest degradation. A detailed LULC analysis of this region is essential to evaluate these impacts.

Objective

This research aims to analyze and quantify land use and land cover changes in the Painganga Wildlife Sanctuary from 2004 to 2024 using remote sensing and GIS techniques. The study intends to detect spatial and temporal patterns of change, assess the rate of forest degradation, and provide valuable insights for effective forest management strategies.

Study Area

The Painganga Wildlife Sanctuary is situated in the Yavatmal districts of Maharashtra, India. Geographically, it lies between 19°23' to 19°43' N latitude and 77°12' to 77°46' E longitude and covers a total area of approximately 450 square kilometers.

The sanctuary is named after the Painganga River, which flows along its boundary and supports various aquatic and terrestrial ecosystems. The terrain is gently undulating with the presence of minor hill ranges and valleys, making it ecologically diverse. The area is characterized by Southern Tropical Dry Deciduous Forests, predominantly composed of teak (Tectona grandis) along with species such as tendu (Diospyros melanoxylon), bel (Aegle marmelos), and bamboo (Dendrocalamus strictus).

The sanctuary plays a crucial role in the conservation of various wildlife species, including leopards, sloth bears, wild boars, deer species, and numerous avian and reptile species. However, it is also under increasing anthropogenic pressure due to illegal encroachment, timber extraction, livestock grazing, and seasonal forest fires.

The choice of this site for the study stems from its ecological importance and the visible changes in vegetation and land use over time. Assessing these changes is necessary to understand the landscape dynamics and support forest conservation efforts in the region.

Data and Methodology

Data Used

To analyze Land Use and Land Cover (LULC) changes in Painganga Wildlife Sanctuary over a 20-year period, the following satellite and ancillary data were used:

Data Source	Satellite	Sensor	Years	Spatial Resolution
USGS Earth Explorer	Landsat 5	Thematic Mapper (TM)	2004, 2007, 2011	30 meters
USGS Earth Explorer	Landsat 8	Operational Land Imager (OLI)	2019	30 meters
USGS Earth Explorer	Landsat 9	OLI-2	2024	30 meters
Survey of India	Topographic Maps	-	Reference base	-
Field Survey	GPS Points	-	Ground Truthing	-

Table No. 1: Satellite Data

Methodology

The workflow of the study involved the following steps:

Step 1: Image Preprocessing

- Downloaded Landsat images from USGS with <10% cloud cover
- Layer stacking and subsetting to the study area
- Radiometric and geometric correction (as required)

Step 2: Supervised Classification

- Applied Maximum Likelihood Classification (MLC) technique
- LULC categories classified:
  1. Dense Forest
  2. Deciduous Forest
  3. Grassland
  4. Water Bodies

5. Barren Land

Step 3: Accuracy Assessment

- Ground truth data collected during field visits and from high-resolution imagery
- Confusion matrix and Kappa coefficient used to evaluate classification accuracy

Step 4: Change Detection Analysis

- Conducted post-classification comparison
- Calculated area change (gain/loss) for each LULC class across the time periods
- Analyzed transition matrices to observe class conversions over time

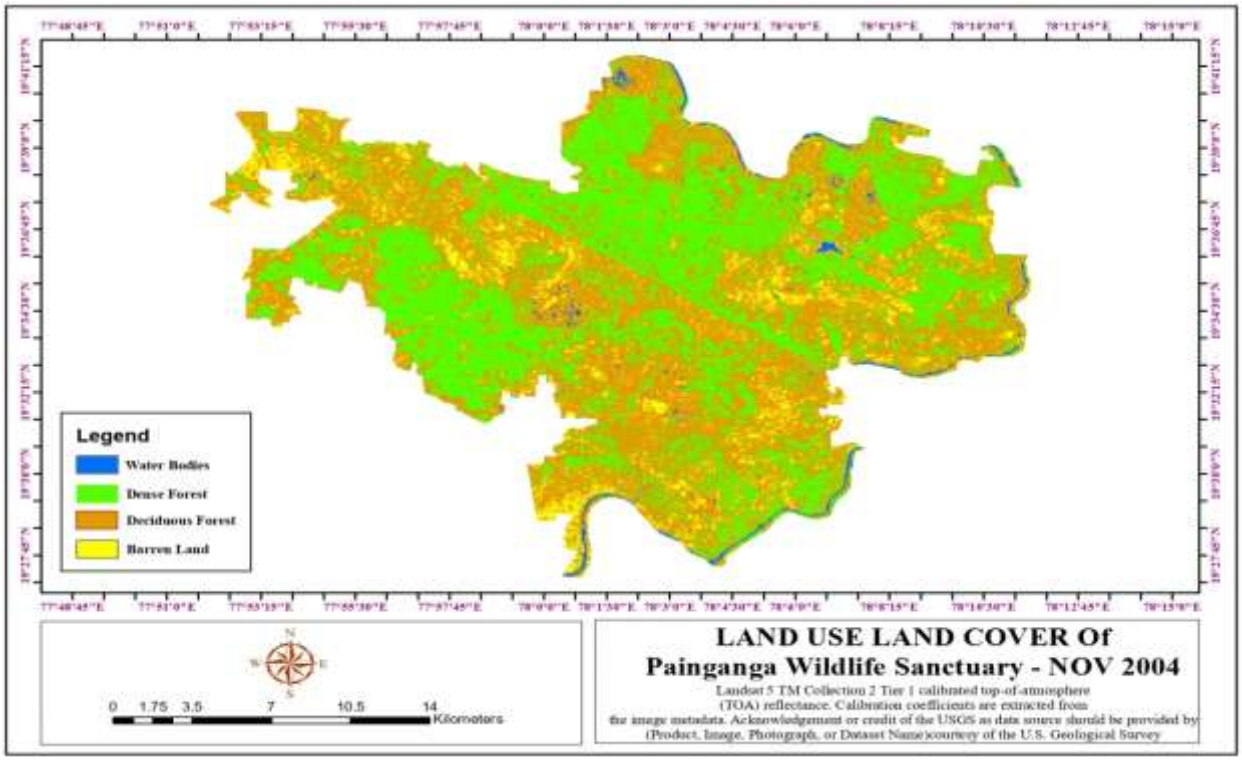
Result and Discussion

The LULC classification analysis as per shows in table no. 2 for the years 2004 and 2024 reveals notable transformations in the landscape of Painganga Wildlife Sanctuary over the past two decades. The study focused on four major land cover classes shows in map no.1&2: Dense Forest, Deciduous Forest, Barren Land, and Water Bodies

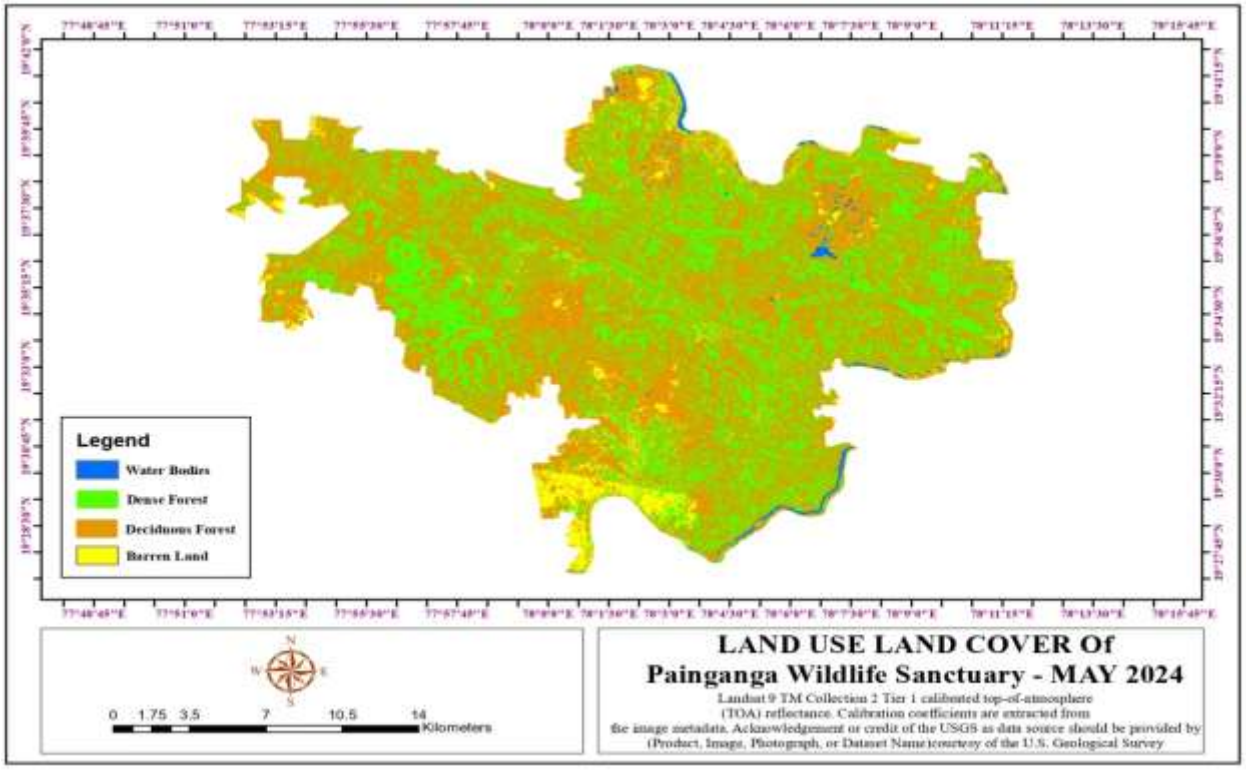
Key Observations:

Class	2004 (sq. km)	2024 (sq. km)	Change (sq. km)	Change (%)
Dense Forest	179.986	272.800	+92.814	20.21%
Deciduous Forest	226.902	167.556	-59.346	-12.93%
Barren Land	45.526	10.595	–34.931	–7.61%
Water Bodies	6.471	7.934	+1.463	0.32%

Table No. 2: Change Detection 2004 to 2024



Map No.1: LULC Nov 2004



Map No.2: LULC May 2024

Dense Forest:
There is a substantial increase of 92.814 sq. km (20.21%) in dense forest area, suggesting successful regeneration in certain zones. This could be attributed to afforestation efforts, natural regeneration, and stricter protection measures within the sanctuary's core areas.

Deciduous Forest:
A decline of 59.346 sq. km (–12.93%) is noted, which may indicate that parts of the deciduous forest have either become denser due to regrowth or been degraded due to anthropogenic disturbances, transitioning into scrub or barren land.

Barren Land:
The reduction of barren land by 34.931 sq. km (–7.61%) reflects a positive trend in landscape recovery. Previously degraded or fallow lands might have undergone ecological restoration or succession into vegetated forms.

Water Bodies:
An increment of 1.463 sq. km (0.32%) in water bodies may be a result of improved water retention structures, river flow conservation, or seasonal fluctuations during the post-monsoon image acquisition period.

Spatial analysis indicates that forest regrowth primarily occurred in the northern and central parts of the sanctuary, whereas forest degradation and loss of deciduous cover were concentrated around the fringes and near human habitation zones. The following factors may have influenced these trends:

- Afforestation programs and protection in buffer/core zones
- Encroachments and grazing pressure on the outer boundaries
- Climatic conditions, influencing forest regeneration and water body expansion
- Management interventions, including forest fire control and reforestation

Discussion

The findings indicate an overall positive trend in forest cover improvement, especially in dense forest areas, which may enhance the ecological stability of the sanctuary. However, the decline in deciduous forests highlights the need for targeted conservation efforts to protect biodiversity-rich transitional forest zones.

This study demonstrates the utility of Remote Sensing and GIS as robust tools for long-term LULC monitoring, offering critical insights for conservation planning, habitat management, and restoration of degraded zones in Painganga Wildlife Sanctuary.

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