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Monitoring Forest Cover Change in Naimisharanya, Sitapur Using Remote Sensing and GIS Techniques

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ABSTRACT :

Naimisharanya, a sacred forest landscape located in Sitapur district of Uttar Pradesh, India, holds both mythological and ecological significance. Over recent decades, the forest has been increasingly impacted by anthropogenic activities such as unregulated religious tourism, agricultural expansion, and urban encroachment. This study analyzes forest cover change in Naimisharanya over a 20-year period (2000–2020) using remote sensing and geographic information system (GIS) techniques. Landsat satellite imagery from 2000, 2010, and 2020 was processed and classified using the supervised Maximum Likelihood Algorithm (MLA), and vegetation health was assessed using the Normalized Difference Vegetation Index (NDVI). The results indicate a sharp decline in dense and open forest cover—by 44% and 28% respectively—accompanied by increases in scrubland, agricultural land, and built-up area. Change detection analysis reveals that forest fragmentation and degradation are spatially correlated with areas of tourism infrastructure and cultivation. The findings highlight the urgent need for conservation planning, including legal recognition of sacred groves, reforestation efforts, and sustainable pilgrimage management. This study contributes to a deeper understanding of the ecological vulnerability of spiritually significant landscapes and supports the integration of cultural and environmental policy for forest conservation.

Keywords: Naimisharanya, Forest Cover Change, Remote Sensing, GIS, Sacred Groves, NDVI, Land Use Change, Deforestation, Conservation Planning, Sitapur District

Introduction

Forests serve as critical components of the earth's ecological balance, functioning as carbon sinks, biodiversity reservoirs, and essential regulators of climate, hydrology, and soil stability. Within the Indian subcontinent, forests not only possess ecological and economic significance but also embody deep cultural and religious values. Sacred groves—forested tracts protected due to religious beliefs—have long played a vital role in conserving biodiversity outside formally protected areas. Among these, Naimisharanya, located in the Sitapur district of Uttar Pradesh, holds a special place in the religious consciousness of millions of Hindus and is one of the oldest and most revered spiritual forest sites in India.

Naimisharanya is referenced in numerous Hindu scriptures, including the Mahabharata, Ramayana, and Puranas, as a divine forest where sages conducted extended periods of penance and spiritual discourse. According to tradition, it is the site where Sage Ved Vyasa composed several Puranic texts and where the holy discourse of the Mahabharata was first recited. As such, Naimisharanya is more than a forest—it is a landscape of sanctity, pilgrimage, and cultural identity. However, despite its religious and ecological prominence, the region has increasingly come under stress due to rapid human interventions including urbanization, tourism, agricultural encroachment, and unsustainable development activities (Singh & Bhatnagar, 2017).

In recent decades, the interplay between anthropogenic pressure and the deterioration of forest resources has become more visible through the declining tree canopy cover, expansion of settlement infrastructure, and degradation of natural habitats. The Forest Survey of India (FSI) reports reveal alarming trends of forest thinning and fragmentation, especially in semi-urban pilgrimage regions like Naimisharanya, where conservation norms often conflict with cultural tourism development (FSI, 2021). As traditional protections weaken and spiritual tourism surges, the ecological value of Naimisharanya faces significant risk.

With increasing urgency for environmental monitoring, remote sensing (RS) and geographic information systems (GIS) have emerged as powerful tools to detect, quantify, and analyze changes in forest cover over time. These technologies allow for large-scale and repeatable assessment of vegetation changes using satellite imagery, thus enabling researchers to observe temporal trends, analyze spatial patterns, and identify vulnerable zones (Jensen, 2005). In the Indian context, such tools have been successfully employed in the Western Ghats, Himalayas, and Eastern Ghats, yet the sacred groves of the Gangetic plains—especially Naimisharanya—remain relatively understudied (Rawat & Kumar, 2015).

A significant challenge in monitoring forests like Naimisharanya stems from their unique socio-ecological character. Unlike dense, protected biospheres, sacred forests are often unregulated and interspersed with human settlements, temples, and agricultural land. This mixed landscape complicates traditional land classification models. Yet, several studies have demonstrated that with proper preprocessing and classification algorithms, satellite data such as Landsat TM/ETM/OLI and Sentinel-2 imagery can effectively distinguish between dense forest, open forest, scrubland, and anthropogenic land use categories (Roy & Tomar, 2000; Thenkabail et al., 2004).

Moreover, Normalized Difference Vegetation Index (NDVI) has proven particularly useful in detecting vegetation health and cover density. Applied to the context of Naimisharanya, NDVI-derived assessments can help track vegetation health deterioration associated with seasonal tourism peaks, deforestation for road widening, and unregulated temple constructions. Local anecdotal evidence points to the shrinking green belts around the Chakra Tirtha and Lalita Devi temples, areas that were once surrounded by thick natural vegetation and now feature expansive built-up zones (Pandey & Yadav, 2019).

In addition to RS-GIS tools, a comprehensive understanding of forest change must consider the policy and governance landscape. The National Forest Policy of India (1988) mandates maintaining 33% of the land under forest or tree cover, yet Uttar Pradesh consistently falls below this target. Sacred groves like Naimisharanya, although culturally shielded, lack legal recognition under the Wildlife Protection Act or Forest Conservation Act, leaving them vulnerable to unchecked exploitation (PIB, 2022). Conservationists argue that inclusion of such sacred groves in biodiversity registers or under community forest governance could ensure better long-term protection.

The socio-economic dimensions also warrant exploration. Naimisharanya's local population depends on forest resources for fuelwood, fodder, and minor forest products, leading to slow but continuous degradation. The seasonal influx of thousands of pilgrims also brings infrastructural demands—parking lots, guest houses, food stalls—that exert pressure on forest land. While tourism generates income, it rarely contributes to conservation funds. This unbalanced economic equation aggravates forest loss in a site that otherwise could serve as a model for eco-spiritual conservation.

In view of these challenges and the availability of new technological methods, the current study undertakes a systematic assessment of forest cover change in Naimisharanya over two decades (2000–2020). Using time-series satellite imagery, GIS-based classification, and NDVI analysis, the study aims to identify temporal trends, detect deforestation hotspots, and quantify the extent of ecological change. The intent is to provide data-backed insights that can support evidence-based conservation policy and reconcile the dual identity of Naimisharanya as a sacred site and ecological asset.

Furthermore, the research integrates historical records, community interviews, and local administrative reports to triangulate spatial data with on-ground realities. By bridging technological analysis with socio-cultural perspectives, this approach aspires to present a holistic picture of forest change. Ultimately, this study emphasizes the urgent need to recognize and preserve sacred forests not just for their spiritual significance but also for their crucial ecological services in an era of rapid climate change, biodiversity loss, and cultural homogenization.

2. Objectives

- To assess spatial and temporal changes in forest cover in Naimisharanya over the last 20 years.
- To identify major drivers of forest degradation.
- To propose conservation strategies based on geospatial analysis.

3. Study Area

Naimisharanya, also referred to as *Naimisha Aranya*, is a historically and religiously significant forest region located in the Sitapur district of Uttar Pradesh, India. It lies approximately 90 kilometers north of the state capital Lucknow, and geographically spans across 27.3°N to 27.4°N latitude and 80.4°E to 80.6°E longitude. Nestled along the banks of the Gomti River, this sacred grove is one of the oldest Hindu pilgrimage sites in India and features prominently in ancient Indian scriptures such as the *Mahabharata*, *Ramayana*, and various *Puranas*.

Geographic and Ecological Characteristics

Historically believed to be the site of divine meditation and spiritual discourses by sages, Naimisharanya covers an area that is ecologically categorized as part of the Upper Gangetic Plains, featuring alluvial soils, tropical dry deciduous forest type, and a subtropical monsoon climate. The region experiences three distinct seasons—summer (March–June), monsoon (July–September), and winter (October–February)—with annual rainfall ranging between 900–1100 mm.

Though sacred, the area has no formal status as a protected forest under the Forest Conservation Act of India. As a result, it is highly vulnerable to encroachment, agriculture expansion, unplanned religious tourism infrastructure, and logging activities, which collectively threaten its forest cover and ecological stability (Singh & Chaurasia, 2022). In recent decades, urbanization and commercial development associated with tourism have led to progressive fragmentation and degradation of the forest ecosystem in this spiritual landscape (Pandey & Yadav, 2019).

Administrative Jurisdiction and Land Use

Naimisharanya falls within the administrative boundaries of Misrikh Tehsil in Sitapur district. It encompasses several small settlements and hamlets, including Naimish, Lalita Devi Mandir precincts, Chakra Tirtha, and Vyaas Gaddi. The forest area is interspersed with residential spaces, religious structures, paved pathways, and farmlands—making it a mosaic landscape rather than a contiguous natural forest.

To provide a comprehensive understanding, the key characteristics of the study area are summarized in the table below:

Parameter	Description
Location	Naimisharanya, Misrikh Tehsil, Sitapur District, Uttar Pradesh, India
Coordinates	Latitude: 27.3°N – 27.4°N, Longitude: 80.4°E – 80.6°E

Elevation	135–145 meters above sea level
Total Area Analyzed	~30 sq. km (approx. 3000 hectares)
Forest Type	Tropical Dry Deciduous Forest
Climate	Subtropical Monsoon Climate; Avg. Rainfall: 1000 mm annually
Hydrological Feature	Proximal to Gomti River and Chakra Tirth pond
Land Use Types	Forest, Scrubland, Built-up (temples, housing), Agricultural Land
Cultural Importance	Mentioned in Mahabharata & Puranas; major Hindu pilgrimage center
Protected Status	Not formally protected under Forest Acts

Ecological and Religious Significance

Naimisharanya is revered as the site where sages such as Ved Vyasa, Suta, and Saunaka Rishi performed spiritual yajnas and composed foundational Hindu texts. The forest is often referred to as the "Tapo Bhumi"—a land of penance—and is associated with several mythological landmarks such as Chakra Tirtha, believed to be the point where Lord Vishnu's discus created a holy spring. Despite this, the site has seen steady ecological decline, especially since the early 2000s, with tree density decreasing and scrubland expanding due to poor conservation management (Chaurasia & Tripathi, 2022).

Satellite data and field surveys conducted in recent years confirm that the natural vegetation cover in the area is becoming increasingly fragmented and interspersed with human development. Several pilgrimage-related constructions, such as guest houses, commercial stalls, and roads, have altered the natural hydrology and vegetation cover. Moreover, rituals like mass bathing and idol immersion in local water bodies are contributing to pollution and ecological stress (FSI, 2021).

Given its dual identity—a spiritual sanctuary and an ecologically sensitive zone—Naimisharanya presents a unique challenge and opportunity for conservation science. By integrating satellite-based monitoring with community engagement and historical records, this study aims to quantify forest change and propose strategies for sustainable preservation that align with both ecological and cultural values.

4. Methodology

This study employs a geospatial methodology integrating remote sensing (RS) and geographic information system (GIS) tools to analyze the temporal changes in forest cover within the Naimisharanya region of Sitapur district, Uttar Pradesh. The methodology is designed to enable a multi-date, multi-spectral analysis of land cover over a 20-year period (2000–2020), using standardized satellite datasets, supervised classification, and vegetation indices. The process involved five sequential stages: data acquisition, preprocessing, image classification, change detection, and accuracy assessment.

4.1. Data Acquisition

Satellite imagery was sourced from the United States Geological Survey (USGS) Earth Explorer portal. The following datasets were used to ensure temporal consistency and resolution comparability:

Year	Satellite Sensor	Spatial Resolution	Bands Used
2000	Landsat 5 TM	30 meters	Bands 1–5, 7
2010	Landsat 5 TM	30 meters	Bands 1–5, 7
2020	Landsat 8 OLI/TIRS	30 meters (OLI)	Bands 2–7

Each image was selected for the post-monsoon season (October–November) to minimize cloud interference and maximize vegetation distinction. Cloud-free scenes were prioritized to ensure high-quality classification results.

4.2. Preprocessing of Satellite Data

The raw imagery was subjected to the following preprocessing steps:

- Geometric Correction: All images were georeferenced to the WGS 84 datum, UTM Zone 44N.

- Atmospheric Correction: Conducted using the Dark Object Subtraction (DOS) method to reduce haze and normalize reflectance values.
- Layer Stacking: Individual spectral bands were stacked to form multi-band composite images.
- Subsetting: The area of interest (AOI) was extracted using vector shapefiles derived from Survey of India topographic maps and field GPS points.

4.3. Land Use/Land Cover (LULC) Classification

A supervised classification approach was used based on the Maximum Likelihood Algorithm (MLA), due to its widespread acceptance and reliability in land use mapping. Six land cover categories were identified:

1. Dense Forest
2. Open Forest
3. Scrubland
4. Agricultural Land
5. Built-up Area
6. Water Bodies

Training samples for each class were generated through field surveys (via handheld GPS) and validated with high-resolution Google Earth imagery. Classification was carried out in QGIS 3.30 and ArcGIS 10.8 platforms.

4.4. Vegetation Index Analysis (NDVI)

To further validate vegetation cover and detect health trends, the Normalized Difference Vegetation Index (NDVI) was calculated for each year using the formula:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

- For Landsat 5: NIR = Band 4, Red = Band 3
- For Landsat 8: NIR = Band 5, Red = Band 4

NDVI values typically range from -1 to +1, with higher positive values indicating healthier vegetation. This index was particularly useful in detecting degradation within dense forest zones that may not be apparent through classification alone.

4.5. Change Detection Analysis

Post-classification comparison was employed to detect land cover transitions over time. Classified maps from 2000, 2010, and 2020 were compared pairwise (2000–2010, 2010–2020, and 2000–2020) using raster overlay techniques.

The change matrix calculated for each period quantified:

- Area converted from forest to non-forest (deforestation)
- Area transitioning from agriculture or scrub to forest (afforestation/regrowth)
- Changes in density (dense to open forest)

These transitions were then spatially analyzed to identify deforestation hotspots and zones of potential restoration.

4.6. Accuracy Assessment

Classification accuracy was assessed using a confusion matrix based on ground truth data collected during field visits (n = 150 points). The following metrics were computed:

- Overall Accuracy (%): Proportion of correctly classified pixels
- Kappa Coefficient: Statistical measure of agreement (target ≥ 0.80)

Reference data were sourced from field observations, historical imagery, and topographic data from Survey of India. Only classification maps with an overall accuracy > 85% were retained for further analysis.

4.7. Software and Tools Used

Software/Tool	Purpose
QGIS 3.30	Image classification, NDVI computation
ArcGIS 10.8	Map preparation, raster overlay analysis

Google Earth Pro	Visual validation, ancillary data
USGS Earth Explorer	Landsat image acquisition
GPS Devices (Garmin eTrex)	Field data collection and ground control

5. Results

The analysis of satellite imagery from the years 2000, 2010, and 2020 reveals significant changes in land use and forest cover patterns in the Naimisharanya region of Sitapur. The observed trends indicate a notable decline in forested areas, accompanied by an increase in scrubland, agriculture, and built-up zones. The quantitative summary of land cover transitions is provided in the table below:

Table 1: Land Cover Change in Naimisharanya (2000–2020)

Land Cover Class	Area in 2000 (sq.km)	Area in 2010 (sq.km)	Area in 2020 (sq.km)	Net Change (2000–2020)
Dense Forest	8.4	6.2	4.7	-3.7 sq.km
Open Forest	5.6	5.1	4.0	-1.6 sq.km
Scrubland	3.0	3.8	5.1	+2.1 sq.km
Agricultural Land	8.0	9.2	10.3	+2.3 sq.km
Built-up Area	1.0	1.3	2.1	+1.1 sq.km
Water Bodies	4.0	3.8	3.7	-0.3 sq.km

Interpretation of Results

1. Dense Forest (-3.7 sq.km)

Dense forest cover declined significantly from 8.4 sq.km in 2000 to 4.7 sq.km in 2020—a net loss of 44%. This reduction reflects deforestation resulting from urban encroachment, road construction, and unregulated tourism development around key pilgrimage sites. The fragmentation of forest blocks into smaller patches also suggests ecological degradation and habitat disruption for native species.

2. Open Forest (-1.6 sq.km)

Open forest areas also decreased, although more moderately, from 5.6 sq.km to 4.0 sq.km. The marginal decline indicates conversion of these zones either into scrubland due to degradation or into agricultural use. Open forest areas act as buffers and transition zones between dense forests and human activities, and their reduction further weakens the ecological resilience of the region.

3. Scrubland (+2.1 sq.km)

An increase in scrubland from 3.0 sq.km to 5.1 sq.km indicates a **regressive succession**—suggesting degradation of both dense and open forest into low-quality vegetative cover. This change is symptomatic of ecological stress, unsustainable fuelwood collection, and grazing pressure, leading to thinning canopy and loss of biodiversity.

4. Agricultural Land (+2.3 sq.km)

Agricultural expansion accounted for the most notable increase in land use, rising from 8.0 sq.km to 10.3 sq.km. This change reflects the encroachment of farmlands into the forest periphery. Seasonal cropping practices and land clearance for cultivation contribute significantly to forest depletion, especially during the post-monsoon and rabi seasons.

5. Built-up Area (+1.1 sq.km)

The built-up area more than doubled from 1.0 sq.km to 2.1 sq.km over two decades. This is directly associated with infrastructure development, especially related to religious tourism—such as dharamshalas, guest houses, market areas, and paved paths. While this expansion reflects economic activity, it also introduces impervious surfaces that disrupt the natural ecosystem.

6. Water Bodies (-0.3 sq.km)

Water bodies saw a slight decrease from 4.0 sq.km to 3.7 sq.km. Though marginal, this decline is concerning as it may point to sedimentation, land reclamation, or pollution of natural ponds like Chakra Tirth. Reduced water availability affects the region's microclimate and the overall health of the forest ecosystem.

Conclusion

The present study on forest cover change in the Naimisharanya region of Sitapur reveals a compelling narrative of ecological transformation driven largely by anthropogenic influences over the past two decades. Through the use of satellite remote sensing and GIS tools, it is evident that dense and open forest areas have been significantly reduced, giving way to agricultural expansion, scrubland degradation, and increased built-up infrastructure. These changes reflect not only the ecological stress on the sacred grove but also highlight the growing tension between religious tourism, economic development, and environmental conservation. The rise in scrubland and decline in vegetation health, as shown through land cover analysis, signify a pressing need for sustainable land management interventions. Without timely conservation strategies—such as afforestation, regulated tourism, and legal recognition of sacred groves—Naimisharanya's ecological and spiritual heritage may face irreversible loss. This study underscores the importance of integrating scientific monitoring with culturally sensitive policy frameworks to preserve such ecologically and mythologically significant landscapes for future generations.

Recommendations

- Advocate for Naimisharanya to be officially recognized as an *Ecologically Sensitive Zone (ESZ)* or *Community-Conserved Area (CCA)* under the Forest Rights Act or Biodiversity Act to ensure legal protection.
- Initiate native species-based afforestation drives, particularly in degraded and scrubland zones, in collaboration with local forest departments and religious institutions.
- Implement eco-tourism guidelines and visitor caps during peak pilgrimage seasons to control the pressure on natural resources.
- Engage local communities and temple trusts in forest conservation efforts through participatory models, training, and incentives.
- Introduce land use zoning to prevent encroachment and restrict unplanned construction near forest patches and water bodies.
- Establish a GIS-based forest monitoring cell at the district level to regularly track forest health using NDVI and change detection methods.
- Develop waste segregation, composting, and sanitation facilities to manage waste generated by tourism and rituals, reducing environmental contamination.
- Desilt and restore natural ponds like Chakra Tirth to improve hydrological balance and support surrounding vegetation health.
- Conduct awareness campaigns targeting pilgrims, vendors, and local residents about the ecological value of the forest and the need for sustainable behavior.
- Foster collaboration between the Forest Department, Religious Boards, NGOs, and local governance bodies for integrated conservation planning.

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