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Change in the Forest Cover of the Tikri Reserved Forest Area of Gonda district in Uttar Pradesh: A Land Use / Land Cover Analysis

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Abstract

This study examines changes in forest cover within the Tikri Reserved Forest area, located in the eastern part of Gonda district of Uttar Pradesh. Data from Landsat-7 and Landsat-8 satellites, obtained from the USGS, were analyzed through Supervised Image Classification and the Normalized Difference Vegetation Index (NDVI) to assess changes in forest cover and vegetation health from 2010 to 2020. The analysis reveals a reduction in forest area by 670 hectares over the decade (2010-2020) and a decline in vegetation health, as indicated by decreasing NDVI values. The highest NDVI value in 2010 was 0.59 which reduced to 0.45 in 2020. These changes are attributed to illegal logging activities, often facilitated by corrupt practices among forest officials, and the overexploitation of forest resources to meet local demands. To mitigate further degradation and enhance forest health, the study advocates for stricter enforcement of conservation laws and more effective forest management practices.

Keywords: Tikri Reserved Forest; Remote Sensing; GIS; Forest Cover Change; Normalized Difference Vegetation Index (NDVI); LULC

1 Introduction

Forests are essential to human civilization, providing fundamental resources such as food, clothing, and shelter. Historically, humans have interacted with nature, shaping it in both positive and negative ways. As populations grew, the increased demand for resources led to the over-exploitation of forests and other natural resources, creating imbalances in ecosystems [(1)]. Initially, human activities were relatively balanced, as resources were used sustainably to meet immediate needs with preserving them substantially for future generations. However, contemporary practices prioritize profit over sustainability, resulting in significant environmental degradation and threatening future generations [(2)].

The interaction between humans and nature is complex, encompassing both beneficial and detrimental impacts. In ancient societies, while humans did alter their environment, they also engaged in practices that allowed for natural regeneration. This balance has been disrupted in modern times by extensive exploitation driven by economic motives.

This unsustainable exploitation highlights the urgent need for effective monitoring and management of natural resources to ensure that current needs are met while preserving resources for future [1,2].

Monitoring and evaluating changes in land use and land cover (LULC) is critical for sustainable resource management. Advances in satellite imagery, such as Landsat-7 Enhanced Thematic Mapper (ETM+) and Landsat-8 OLI/TIRS, have revolutionized the study and monitoring of various earth surface phenomena, including forest degradation and aggradation [3]. Satellite imageries offer high spectral, spatial, and temporal resolution, enabling precise analysis of environmental changes.

LULC analysis is a powerful tool for studying changes on earth's surface. It relies on satellite imagery to track changes over time. Land cover refers to the physical materials on the surface of the earth such as vegetation, water bodies, and bare soil, while land use pertains to the purpose for which the land is utilized, such as agriculture or recreation [4].

In the context of forest management, the Indian Forest Act of 1927 defines Reserved Forests as areas designated by the State Government with restricted access, where local people are prohibited from entering unless authorized by a Forest Officer. This study focuses on the Tikri Reserved Forest area, which has not been extensively studied for over a century, except for historical records like the 'Gonda: A Gazetteer' from 1905.

Although there has been research on botanical aspects of forests, such as the floristic assessment by Singh et al. in 2016 [5], there is a notable gap in the literature concerning forest cover assessment in the Tikri Reserved Forest. To address this gap, this study aims to quantify the changes in forest cover over the decade of 2010 to 2020. This study seeks to evaluate how the area of the Tikri Reserved Forest has altered from 2010 to 2020, determining whether there has been an increase or decrease in forest cover. Additionally, it aims to analyze changes in vegetation density using the Normalized Difference Vegetation Index (NDVI), providing insights into the health and vitality of the forest's vegetation over this period.

2 Materials and Methods

2.1 Study area

The focus of this study is the Tikri Reserved Forest, situated in the Gonda district of Uttar Pradesh, India. Gonda district lies in the eastern part of Uttar Pradesh, constating a part of ancient Avadh Region. This study specifically examines the Tikri Reserved Forest area, not the entire district. The geographic coordinates of Gonda district lies between 26°46' to 27°26' north latitude and 81°30' to 82°36' east longitude. The district is bordered by Basti district to the east, Bahraich district to the west, Balrampur district to the north, and Faizabad (now Ayodhya) & Barabanki districts to the south. The study area map is shown in Figure 1.

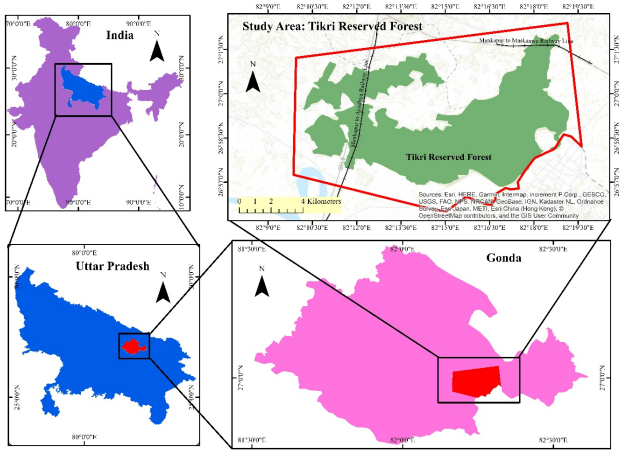

Fig. 1. Study area map depicting Tikri Reserved Forest Area
Source: Created by author.

Gonda district is divided into sixteen blocks, with the Tikri Reserved Forest spanning four blocks namely Mankapur, Chhapiya, Nawabganj, and Wazirganj. The Tikri Reserved Forest, also known as Nawabganj Forest, features a gentle slope towards the south and east. It is drained by the Chamnai and Manwar rivers, as well as other watercourses such as the Sujoi Nala. The soil is predominantly sandy loam, approximately two meters deep, with clay soil found in swamps and depressions.

The forest is largely covered with inferior Sal trees, interspersed with species such as Asaiva, Dhau, and Mahua. Scattered throughout the forest are a few large trees, including Mahua, Banyan, and Pipal. A narrow stretch of grassland is present along the river. Major forest products include Mahua timber, Mahua flowers, fuel for cooking, thatching materials, and Baib grass. Despite its status as a Reserved Forest, local communities have continuously relied on the forest for their basic needs. This paper aims to investigate changes in the forest cover of the Tikri Reserved Forest over the past decade (2010-2020).

2.2 Data source

To quantify changes in forest cover, this study employs LULC analysis using satellite imagery. The analysis utilizes Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and Landsat-8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) C1 Level-1 imagery. Satellite images for the years 2010, 2015, and 2020 was used to cover a ten-year period. These images were obtained from the United States Geological Survey (USGS) Earth Explorer website (https://earthexplorer.usgs.gov/). The dataset used in this study includes images with a spatial resolution of 30 meters and less than 10%

Table 1. Key features of satellite imageries used in the study

Satellite	Sensor	Acquisition date	Bands used	Spatial Resolution	Processing
Landsat-7	Enhanced Thematic Mapper (ETM+)	17-02-2010	Visible (B1, B2, B3) NIR (B4) SWIR (B5, B7) TIR (B5)	30 m	Level-1
Landsat-8	Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	11-03-2015 05-02-2020	Visible (B2, B3, B4) NIR (B5) SWIR-1 (B6) SWIR-2 (B7)	30 m	Level-1

cloud cover. Key features of the datasets are summarized in Table 1 below.

2.3 Analysis

2.3.1 Supervised Classification of Satellite Imagery

In LULC analysis, the supervised classification method is utilized to classify satellite imagery into land cover groups. This process involves several key steps. Initially, satellite data is imported into GIS software. The satellite image is then processed by combining multiple spectral bands using the composite tool available in the image analysis option in ArcGIS.

Following the creation of the composite image, training samples are provided. These samples are specific pixel values associated with different LULC classes, selected and verified by examining the composite image's bands. Once the training samples are made, the 'Supervised Image Classification' option in ArcGIS is used to classify the entire satellite image into various LULC classes based on these samples [6].

2.3.4 Normalized Difference Vegetation Index (NDVI

The NDVI is employed to measure vegetation density by assessing the difference between Near-Infrared (NIR) and red light, where vegetation reflects NIR and absorbs red light. The NDVI is calculated using the formula:

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

NDVI values range from -1 to +1, with higher values indicating denser vegetation and lower values suggesting less denser vegetation [7].

For this study, NDVI values were calculated for the years 2010, 2015, and 2020 to assess changes in vegetation density over the decade.

3 Result and Discussion

The LULC map indicates a decline in forest cover over the studied period. The key findings of the study are summarized below:

3.1 Change in land cover

The study analyzed four LULC classes: waterbody, agriculture, settlement, and forest. The total area covered by these classes was 14,364 hectares. The distribution of these classes has shifted over the past decade, as illustrated in the accompanying graphs. The percentage share of forest has declined from 54.4% in 2010 to 49.8% in 2020 (Figure 2).

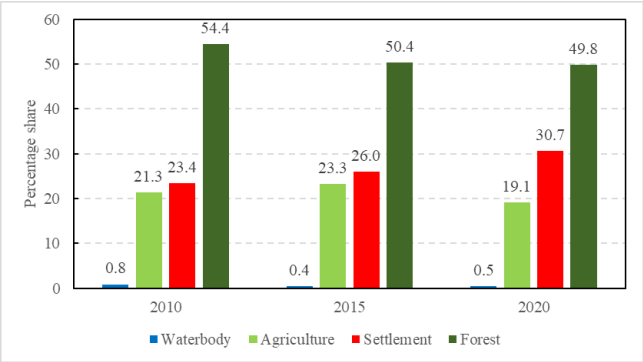

Fig. 2. Percentage share of land cover in Tikri Reserved Forest area (2010-2015) Source: Authors own elaboration.

The forest cover within the Tikri Reserved Forest area was 7,821 hectares in 2010. This area decreased to 7,236 hectares in 2015 and further reduced to 7,151 hectares in 2020. The most significant decline occurred between 2010 and 2015, with a loss of 585 hectares. From 2015 to 2020, the forest cover decreased by 85 hectares. Overall, the forest cover reduced by 670 hectares from 2010 to 2020. Settlement areas increased significantly, expanding by 369 hectares from 2010 to 2015 and by 674 hectares from 2015 to 2020, resulting in a total increase of 1,043 hectares over the decade (Table 2).

Waterbody area decreased by 68 hectares between 2010 and 2015 but increased by 11 hectares between 2015 to 2020. Overall, there was a net reduction of 57 hectares in waterbodies over the decade. Agricultural areas expanded by 284 hectares from 2010 to 2015 but subsequently decreased by 600 hectares from 2015 to 2020. The net change over the decade shows a decrease of 316 hectares in agricultural land. The LULC change can be visualized through Figure 3.

Table 2. Change in LULC in TikriReserved Forest are (2010-2020)

LULC Type	Area in hectares			Absolute change		
	2010	2015	2020	2010-2015	2015-2020	2010-2020
Waterbody	122	54	65	-68	11	-57
Agriculture	3060	3344	2744	284	-600	-316
Settlement	3361	3730	4404	369	674	1043
Forest	7821	7236	7151	-585	-85	-670
Total	**14364**	**14364**	**14364**	**0**	**0**	**0**

Source: Authors own calculations using Landsat data.

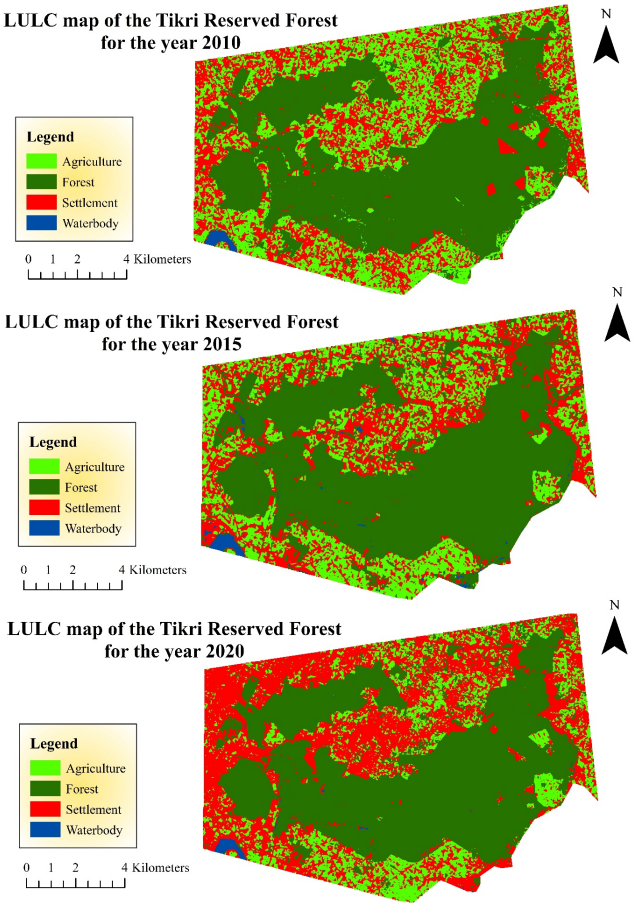

Fig. 3. Change in the LULC of the Tikri Reserved Forest area (2010-2020)

3.2 Change in NDVI

The analysis of the NDVI over the decade (2010-2020) indicates that the upper limit of NDVI value of 0.59 in 2010 declined to 0.45 in 2020 signalling a decrease in the healthy vegetation in Tikri Reserved Forest during the study period (Figure 4).

3.3 Causes of changing patterns of LULC

The observed decline in forest cover can be attributed to several factors. Wealthy individuals, including politicians, often engage in illegal timber trade, frequently in collusion with corrupt forest officials. Additionally, fires caused by burning agricultural residue in nearby fields can spread to and damage the forest. Despite its designation as a reserved forest, enforcement of protective measures is inadequate, with officials sometimes accepting bribes and ignoring illegal activities. Local communities who rely on the forest for their livelihoods contribute to deforestation as they harvest resources for personal use. Furthermore, increased demand for forest products may drive individuals to cut down timber for sale. Lastly, the increasing population drives higher demand for housing, leading to further deforestation to accommodate new construction. This trend is evident in the LULC maps, which show that expanding settlement areas correspond with shrinking forest cover[8,9].

4 Conclusion and Recommendations

This study highlights a substantial decline in forest cover within the Tikri Reserved Forest, with a reduction of 670 hectares over the past decade (2010-2020). During the same period, settlement areas have expanded, while agricultural land has shown fluctuating trends, increasing from 2010 to 2015 and then decreasing from 2015 to 2020. The NDVI analysis indicates that the vegetation density deteriorated evident from higher NDVI value dropping from 0.59 in 2010 to 0.45 in 2020. This decline signifies a significant reduction in vegetation health.

To address the problem of decreasing forest cover and enhance forest health, several measures are essential. First, there must be a rigorous enforcement of forest protection laws to prevent illegal activities. Additionally, stringent actions should be taken against those involved in illegal timber trade, ensuring that individuals engaged in such activities are held accountable. It is also crucial to allow local communities access to forest resources under regulated conditions to meet their needs while supporting conservation efforts. Finally, regular patrolling and accountability measures should be implemented to address any corruption among forest officials

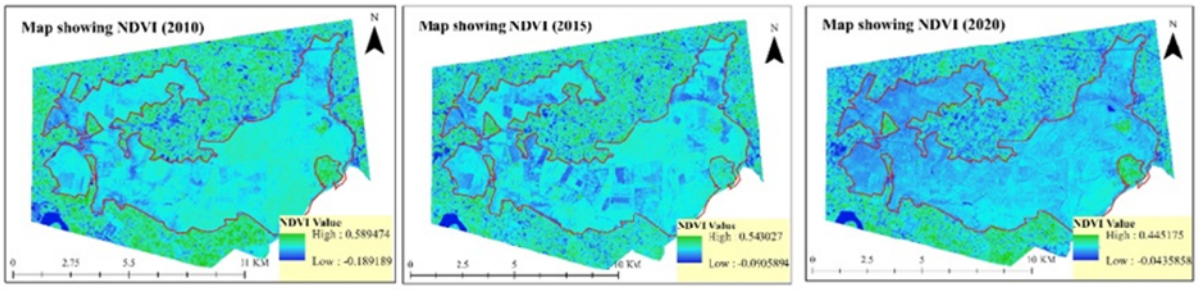

Fig. 4. Change in NDVI of Tikri Reserved Forest Area (2010-2020) Source: Created by author.

who may be complicit in illegal exploitation. By adopting these strategies, it is possible to halt further degradation and promote the sustainable management and recovery of forest areas.

5 Acknowledgements

Not applicable

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