Spatio-Temporal Analysis of Forest Cover Change in Kamrup District, Assam: A Remote Sensing and Gis Approach

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***Abstract*—This study assesses forest-cover change in Kamrup Rural District, Assam, from 1993 to 2023 using Landsat 5 and Landsat 8 imagery, GIS, and the Normalized Difference Vegetation Index. Forest ecosystems face growing pressure from human-induced disturbance and land-use change, with consequences for ecological integrity and socioeconomic well-being. By mapping vegetation change over three decades, the study identifies areas classified as afforestation and deforestation and examines how these opposing trends shape the district's land-cover patterns. The results indicate that vegetation gains have occurred alongside continued losses. This coexistence underscores why overall assessments alone may obscure local variation in forest-cover trajectories and why spatially explicit monitoring is essential. The findings highlight the ecological, socioeconomic, and environmental stakes of forest management and provide a basis for more targeted conservation and sustainable-development decisions in Kamrup Rural District.**

***Index Terms*—Afforestation, Deforestation, Remote Sensing, Vegetation, NDVI**

I. INTRODUCTION

Forests are essential to human well-being because they support ecological processes, social needs, and economic livelihoods (Sarun et al., 2026). As complex ecosystems, they sustain diverse plant and animal life while supporting people who depend on forest resources (Sarun et al., 2026). Their role in the global carbon cycle makes forest conservation especially consequential: forests can absorb carbon dioxide, but forest-sector activities also contribute approximately 17% of global greenhouse-gas emissions annually (Bellassen et al., 2009). Forests also help prevent soil erosion (Decocq et al., 2016). Taken together, these functions show that forest-cover change can affect not only biodiversity and livelihoods but also climate regulation and soil stability.

Human activity has transformed land cover across much of the Earth's surface (Song et al., 2018), often generating environmental conflicts and disrupting biogeochemical cycles (Jong et al., 2021) and temperature regimes (Dirmeyer et al., 2010). These changes are not merely shifts in land use: they can undermine ecosystem productivity and health at local, regional, and global scales. The growing pressures of land-use and land-cover change, air, water, and soil pollution, the loss of productive land, and biodiversity degradation therefore pose interconnected threats to ecosystem resilience (Kilic et al., 2004; Foster_JEcology_1992.Pdf, n.d.; Sherbinin et al., 2007).

Global deforestation is a major environmental challenge because it both releases carbon and weakens forests' capacity to store it, intensifying global warming. Its consequences extend beyond the loss of trees: forest destruction accelerates soil erosion, degrades ecosystems, and undermines environmental quality (Yasin et al., 2024). Because deforestation is a central form of land-use change, it also poses a direct threat to global biodiversity. The resulting degradation diminishes essential forest goods and services on which millions of people rely for subsistence and economic stability (Bora, 2022). Moreover, habitat fragmentation disrupts ecological corridors, isolating populations and potentially reducing the resilience of local plant and animal communities to climate-related stress (Hilty et al., 2020). Thus, deforestation is not simply a change in land cover; it can trigger interconnected ecological and socioeconomic impacts that reinforce the case for monitoring forest change and prioritizing conservation. Kamrup Rural, a district

in Assam, India, contains diverse ecosystems that provide important ecological and economic benefits. Yet its forest cover is under increasing pressure from land-use change and human activities. Rather than attributing degradation to particular groups, this study focuses on the documented pressures associated with shifting cultivation, agricultural expansion, and infrastructure development (Acharjee, 2014; Borpujari & Bora, 2021)(Kumar, 2017). These pressures make sustained monitoring essential: without reliable evidence of where and how forest cover changes, it is difficult to distinguish areas of loss from those of regeneration or to target conservation efforts effectively.

Remote sensing and GIS provide a systematic means of tracking these changes across time and space (Basumatary, 2022). Multi-temporal satellite imagery, image classification, and change analysis enable consistent assessment of forest-cover extent and distribution over successive periods (Forkuo & Frimpong, 2012). Such approaches have been used to examine deforestation patterns and the pace of forest change in tropical regions (Armenteras et al., 2005). Studies of Kamrup have also documented changes in forest cover and other land-use classes, demonstrating both the value of district-level analysis and the need for continued monitoring (Kumar, 2017). Integrating long-term satellite observations with landscape metrics can further show how fragmentation may leave forest patches susceptible to subsequent degradation (Mahapatra et al., 2025). This evidence can inform land-use policies intended to limit harm to regional biodiversity and ecosystem services (Badshah et al., 2024). Classifying forest areas as interior, edge, or patch can also help identify fragmented locations where habitat loss and ecological disturbance may be more pronounced (Ramachandra et al., 2023). Because peripheral forest zones are particularly susceptible to further degradation, identifying them can help prioritize monitoring and conservation interventions (Mahapatra et al., 2025).

Accordingly, this study uses multi-temporal NDVI maps to assess forest-cover change in Kamrup Rural District, Assam. NDVI measures vegetation greenness in satellite imagery, and comparisons across dates can reveal spatial patterns of vegetation change (Kalita & Baruah, 2026). This approach supports a consistent assessment of vegetation conditions and helps distinguish areas of denser and sparser vegetation over time (Bora et al., 2025). The resulting spatial baseline shows where vegetation has increased or declined and can inform forest monitoring and conservation priorities in the district (Bora et al., 2025).

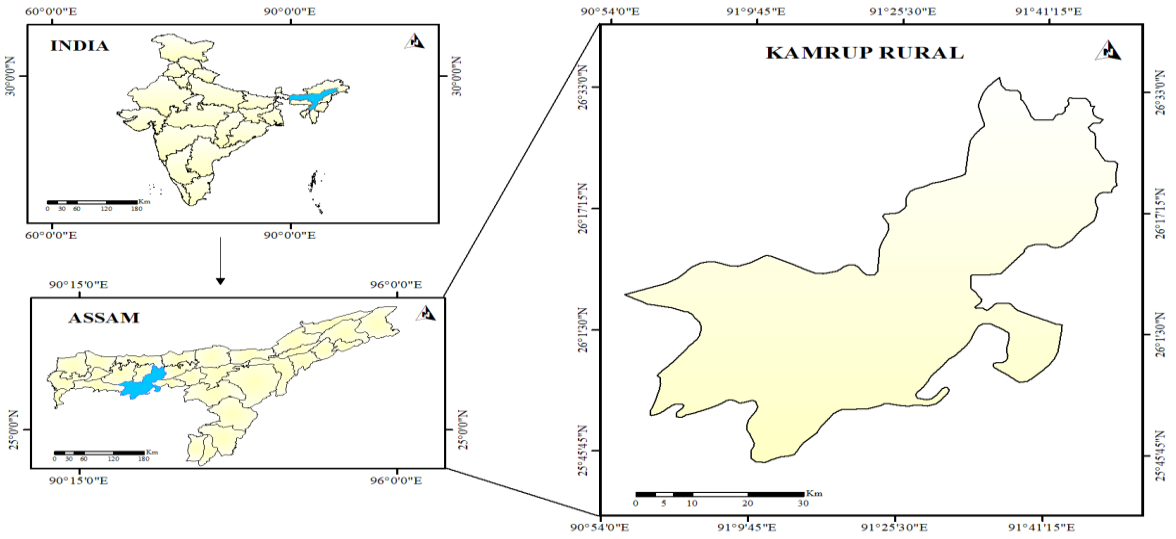
Against this backdrop, this research endeavors to delve into the decades-long dynamics of afforestation and deforestation in Kamrup Rural, Assam. By examining historical trends, identifying drivers of forest cover change, the study seeks to quantify and map the spatial extent of forest cover changes from 1993 to 2023 using remote sensing and GIS techniques so that it will be beneficial for the better conservation efforts in the region

II. STUDY AREA

Kamrup District is located between 25.46° and 26.49° N latitude and 90.48° and 91.50° E longitude. It is bordered by Udalguri and Baksa districts to the north, Meghalaya to the south, Darrang and Kamrup Metropolitan districts to the east, and Goalpara and Nalbari districts to the west. Established on 31 March 2003, the district has its administrative headquarters at Amingaon and covers approximately 2,740 km². According to the 2011 Census, its population was 1,517,542, and its literacy rate was 75.55%. The district comprises 1,027 villages administered through twelve revenue circles. Its main rivers are the Brahmaputra, Puthimari, Bornoi, Nona, Kulsi, Pagladiya, and Kalajal (Kamrup District | Government of Assam, India,). Its varied topography, from floodplains to rolling hills, supports a mosaic of ecosystems that are sensitive to human activity and seasonal hydrological changes.

Kamrup District has three main landform units: southern hills, central and western alluvial plains, and swampy areas along the Brahmaputra plains. Its humid subtropical climate features heavy rainfall, hot summers, and high humidity. Annual temperatures range from about 12 to 38°C. Winter daytime temperatures are generally 15–25°C and nighttime temperatures 8–15°C; summer daytime temperatures are 25–38°C and nighttime temperatures 15–25°C. Average annual rainfall is 1,752 mm, with a coefficient of variation of 15.3%; India Meteorological Department data report normal annual rainfall of 2,125.4 mm and 96.5 rainy days (Agriculture & Horticulture | Kamrup District | Government of Assam, India, n.d.). These varied

terrain and climate conditions provide context for interpreting vegetation patterns, as differences between dates may reflect both land-cover change and natural environmental variation (Kumar, 2017). Accordingly, this study uses multitemporal Landsat imagery and cloud masking to support reliable comparisons of forest cover over the three-decade study period (Huang et al., 2010). This approach examines forest-cover change in relation to human land-use shifts and hydro-climatic conditions without assuming either is the sole cause of observed patterns.



Study Area Map

Objective:

1 To quantify and map spatiotemporal changes in forest cover in Kamrup Rural, Assam, from 1993 to 2023 using multi-temporal satellite imagery and NDVI analysis.
2 To identify and examine the principal factors associated with forest-cover loss and regeneration in the study area.

III. DATABASE AND METHODOLOGY

This section outlines the multispectral data acquisition, preprocessing workflows, and classification algorithms employed to process multi-temporal Landsat imagery for the specified study period.

Database

This study integrates spatial and temporal datasets to assess forest-cover change in Kamrup Rural District, Assam. A digitized map of Assam provides the spatial reference for delineating the study area and locating the district. To enable comparison across the study period, Landsat 5 imagery acquired on 30 October 1993 and Landsat 8 imagery acquired on 4 December 2023 were selected. Both datasets have a 30-metre spatial resolution (Malatesta et al., 2018) and provide multispectral observations suitable for mapping vegetation and evaluating changes in forest cover. Together, these datasets establish the spatial and temporal basis for examining forest-cover dynamics in the district.

The details of the datasets used in this study are shown in Table 1.

Satellite	Sensor	Acquisition date	Path/row	Spatial resolution
Landsat 5	Thematic Mapper	30 October 1993	137/042	30 m
Landsat 5	Thematic Mapper	28 February 2009	137/042	30 m
Landsat 8	Operational Land Imager and Thermal Infrared Sensor	12 December 2023	137/042	30 m

Table 1: Acquired Satellite Images

Methodology

NDVI is calculated from the red and near-infrared bands to estimate vegetation abundance and compare images from different dates (Ehsan & Kazem, 2013). Comparing NDVI images helps identify where and how much vegetation has changed over time (Lyon et al., 1998).

The NDVI data layer is defined as:

NDVI = (NIR – R) / (NIR + R)

Here, NIR denotes reflectance in the near-infrared band, while R denotes reflectance in the red band. NDVI values range from −1 to +1; higher positive values generally correspond to greener, more abundant vegetation, whereas negative values are commonly associated with water, snow, clouds, and other non-vegetated surfaces (Ehsan & Kazem, 2013). As this study assesses changes in vegetation cover across Kamrup Rural, NDVI provides a consistent image-derived measure for comparing vegetation conditions across observation dates. Its widespread use in remote sensing reflects its capacity to quantify the contrast between near-infrared and red reflectance, a contrast associated with vegetation greenness (Huang et al., 2020).

Landsat imagery from 1993 and 2023 was used to assess vegetation change. Both datasets provide multispectral observations at 30-metre resolution, supporting consistent monitoring across the study area (Fung et al., 2023). For Landsat 5, bands 4 (near-infrared) and 3 (red) were used to calculate NDVI; for Landsat 8, bands 5 (near-infrared) and 4 (red) were used (Baqir et al., 2026). Higher NDVI values generally indicate denser green vegetation, while lower values may indicate sparse or absent vegetation (Ramachandra et al., 2012). Since NDVI measures vegetation greenness rather than forest cover directly, the results are interpreted as an indicator of vegetation change, not as a definitive measure of forest-class change.

The NDVI rasters were analyzed in ArcGIS to map vegetation-cover change across the study period. Reclassified rasters from different years were compared to identify transitions: vegetation changing to non-vegetation was coded as 0 (vegetation loss), and non-vegetation changing to vegetation was coded as 1 (vegetation gain). Areas with no change were classified separately. The resulting change rasters were converted to polygons to calculate the area and location of each transition. Because NDVI measures vegetation greenness rather than forest cover directly, the results are interpreted as vegetation-cover change, not definitive forest-class change.

Fig 2: Flow chart for the database and methodology

Acquired Satellite Images
(Landsat 5 (TM), Landsat 8 (DLI/TIRS)
Data pre-processing
Image Processing Analysis of Land-Use Change
Layer Stacking
Subset (Study Area)
Change detection of Forest Cover 1993, 2009, 2023.

Finally, the spatial intersection of these reclassified datasets enabled the calculation of net forest gain or loss across the three decades.

Spatial Analysis

IV. RESULT AND DISCUSSION

Forests play a crucial role in maintaining ecological balance and providing ecosystem services that support livelihoods, particularly in rural areas (Zhou et al., 2023). Their importance extends beyond biodiversity conservation: forests help protect soil and water, store carbon, and regulate the global carbon cycle (Anikwe & Ife, 2023). These functions make forest cover especially significant in Kamrup Rural; forests in India are known to limit soil erosion (Pandey et al., 2024) and moderate local microclimatic conditions (Zellweger et al., 2020). Assessing changes in forest cover is therefore essential not only for tracking vegetation extent but also for understanding potential changes in these locally and globally important ecosystem benefits.

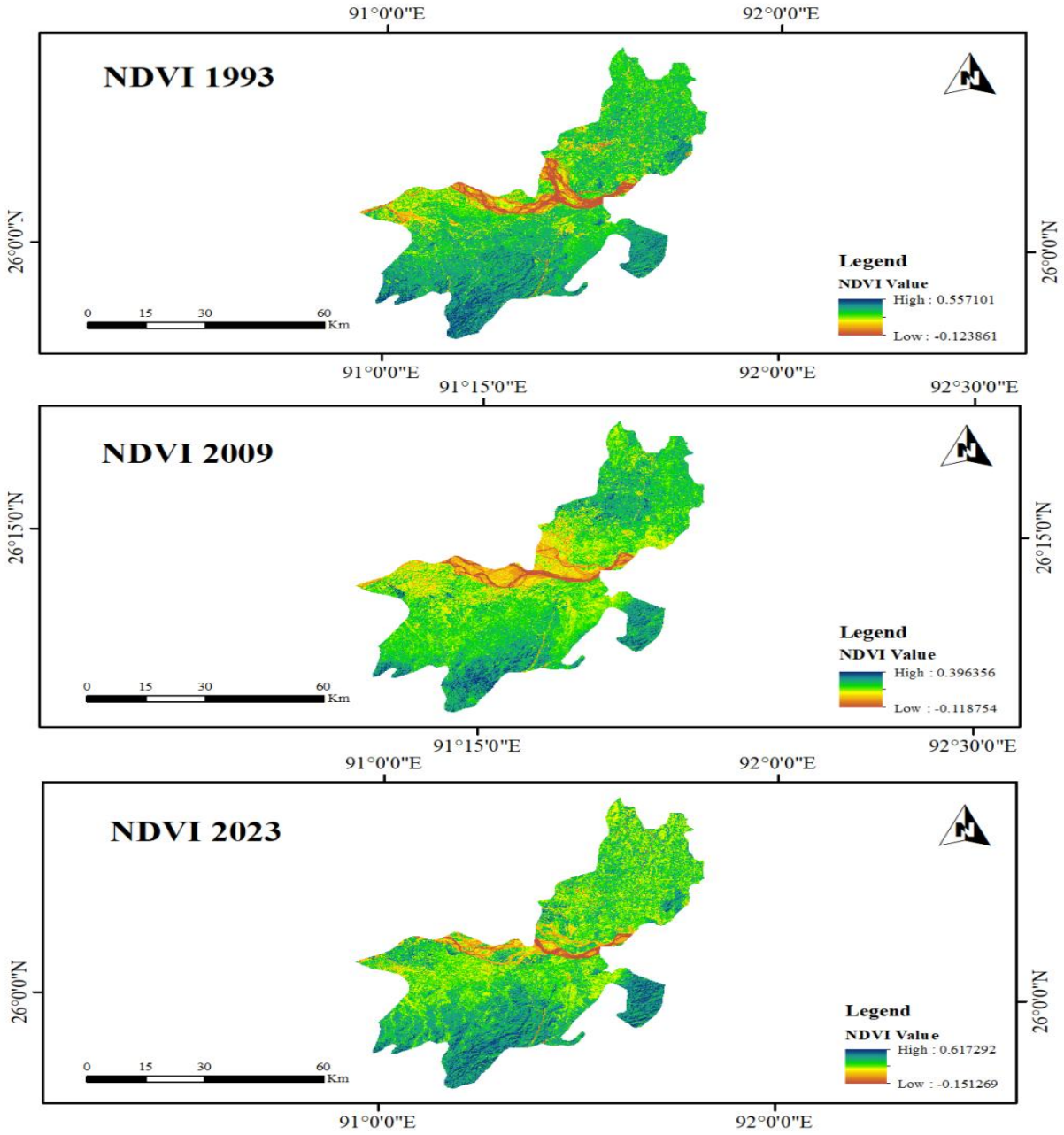


Figure 2. NDVI maps for 1993, 2009, and 2023

Vegetation Cover Changes in Kamrup Rural, Assam (1993-2023):

Forest-cover change is a dynamic process shaped by human activities, with consequences for ecosystem condition (Keith et al., 2022). In Kamrup Rural, comparison of vegetation patterns from 1993 to 2023 provides a basis for identifying where vegetation increased, declined, or remained relatively stable. The results indicate that these changes were uneven across the district: substantial areas shifted from vegetation to non-vegetation, while other areas showed vegetation gain. This spatial contrast suggests that gains in some locations did not offset losses elsewhere, underscoring the need to examine both the extent and distribution of change. Because the analysis uses NDVI as an indicator of vegetation greenness, these patterns are interpreted as vegetation-cover change rather than definitive evidence of forest-class change.

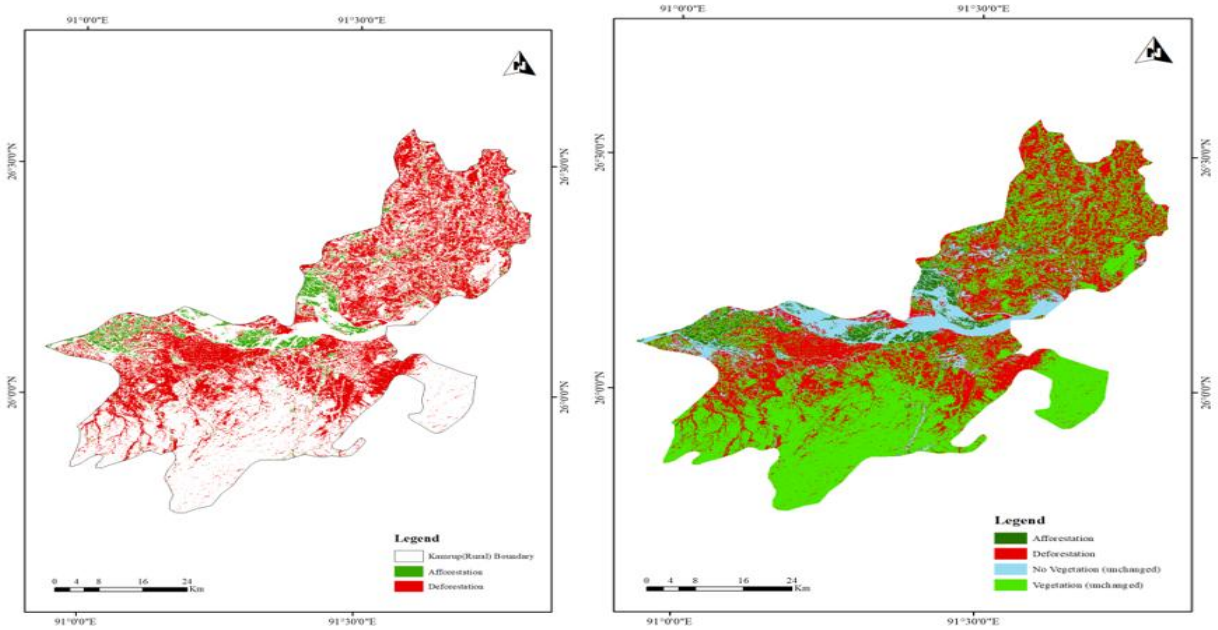


Fig 3: Changes of Forest Cover in Kamrup Rural (1993-2023)

Quantitative Analysis of Vegetation-Cover Change

The quantification of forest cover changes provides a comprehensive understanding of the magnitude and spatial extent of vegetation dynamics in Kamrup Rural. From 1993 to 2023, the area of no vegetation cover (unchanged) was determined to be 388.96 sq.km, indicating areas that remained devoid of significant vegetation throughout the study period. In contrast, the area undergoing afforestation amounted to 169.33 sq.km, highlighting regions where vegetation cover has increased over time. Conversely, deforested areas totaled 1062.08 sq.km, representing significant land conversion from forested to non-forested areas. Additionally, the area of unchanged vegetation cover was measured at 1538.85 sq.km, indicating regions where forest cover remained relatively stable over the study period.

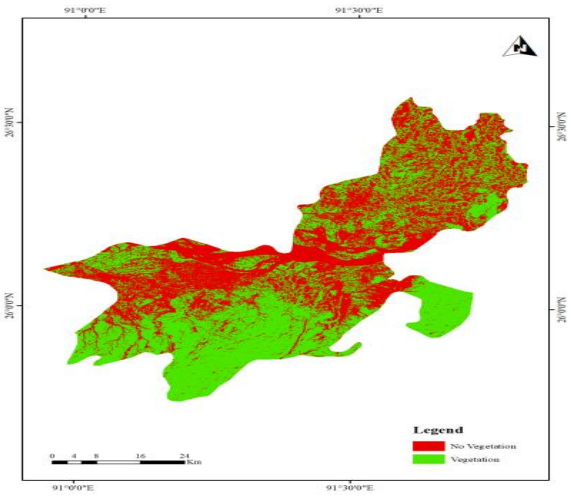
Change (1993-2023)	Area in sq. km	Percentage
No Vegetation to Vegetation (afforestation)	169.34	5.36
No Vegetation to No Vegetation(unchanged)	388.97	12.31
Vegetation to No Vegetation (deforestation)	1062.09	33.62
Vegetation to Vegetation (unchanged)	1538.85	48.71

Table 2: Transformation of vegetation from 1993 to 2023

Quantifying forest-cover change reveals the scale and spatial extent of vegetation dynamics in Kamrup Rural. Between 1993 and 2023, 388.96 sq. km remained without significant vegetation. Vegetation gain (afforestation) covered 169.33 sq. km. In contrast, 1062.08 sq.km changed from forested to non-forested land. A further 1538.85 sq. km remained under vegetation throughout the study period.

Forest Cover	Area in sq.km (1993)	Area in sq.km (2023)
No Vegetation	558.45	1451.40
Vegetation	2601.57	1708.51

Table 3: Change detection analysis of Kamrup Rural from 1993 to 2023



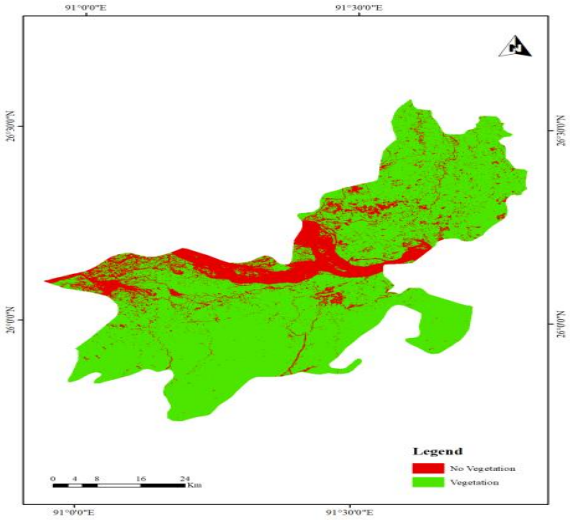


Fig 5: Vegetation And Non-Vegetation Mapping: Kamrup Rural, 1993 And 2023

Between 1993 and 2023, mapped vegetation loss in Kamrup Rural (1,062.09 sq. km) greatly exceeded vegetation gain (169.34 sq. km), resulting in a net decline of approximately 892.75 sq. km. Because the analysis is based on NDVI, this should be understood as a decline in vegetation cover, not definitive forest loss. The simultaneous occurrence of gains and losses highlights the need to consider their locations, not only district-wide totals. Agricultural expansion, infrastructure development, and natural disturbances are possible drivers, but this study did not establish their effects. Field data and long-term satellite monitoring could help identify and verify these drivers and inform targeted conservation and land-use policies. Community-based forest management and spatial monitoring may also help address vegetation loss while protecting catchments and wildlife habitats. Continued monitoring and collaboration among stakeholders are needed to balance development with ecological resilience (Bera et al., 2020).

V. CONCLUSION

This study used Landsat 5 and Landsat 8 imagery, the Normalized Difference Vegetation Index, and GIS techniques to assess forest-cover change in Kamrup District, Assam. The analysis identified areas of vegetation gain and loss over recent decades.

The findings demonstrate that remote sensing and GIS provide a valuable basis for monitoring forest-related change, but satellite-derived classifications alone cannot establish the condition or causes of change on the ground. Integrating these observations with field surveys and ground-based data can validate mapped vegetation patterns, improve assessment reliability, and help distinguish forest-cover change from other shifts in vegetation greenness. In Kamrup Rural District, this combined evidence can support more targeted decisions on forest conservation, restoration, and sustainable resource management

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