https://doi.org/10.26565/2410-7360-2026-64-30

UDC 911.52:528.8:004.9

Forest Cover Changes in Marat Longri Patradisa Longnit Forest Complex of Karbi Anglong District, North East India

Parag Jyoti Kashyap[1], https://orcid.org/0000-0003-4273-841X, e-mail: kashyapparagjyoti@gmail.com
PhD Student, Department of Geography

Sahana Bose[1], https://orcid.org/0000-0003-2108-9297, e-mail: sahanadona@gmail.com
PhD, Assistant Professor, Department of Geography

[1] *Assam University, Diphu Campus, Assam, India*

ABSTRACT

Purpose. This study analyzes the spatio-temporal dynamics of forest cover in the Marat Longri–Patradisa–Longnit Forest Complex (MLPL), Karbi Anglong district, Assam, over the period 1994–2024. The forest complex is an ecologically significant landscape in Northeast India, supporting rich biodiversity and serving as a critical habitat for several threatened species. The objectives were to quantify changes in major forest types, examine land use and land cover (LULC) transitions, assess anthropogenic drivers of forest degradation, and evaluate their implications for biodiversity conservation, particularly for the Western Hoolock Gibbon (Hoolock hoolock).

Methodology. Multi-temporal satellite imagery, including Landsat 4–5 TM (1994 and 2004) and BHUVAN LISS IV (2014 and 2024), was used for the analysis. All images were radiometrically and geometrically corrected to ensure temporal consistency. The study area was classified into seven LULC categories: Semi-Evergreen Forest, Moist Mixed Deciduous Forest, Scrub Forest, Degraded Forest, Agricultural Land/Shifting Cultivation, Built-up Areas, and Water Bodies. Pixel-based supervised classification and post-classification change detection were performed using ArcGIS 10.3. Classification accuracy was evaluated using Producer Accuracy, User Accuracy, Overall Accuracy, and Kappa statistics.

Results. The results indicate a significant decline in Semi-Evergreen Forest and Moist Mixed Deciduous Forest, accompanied by notable increases in Degraded Forest, Scrub Forest, Agricultural Land/Shifting Cultivation, and Built-up Areas. These changes reflect increasing anthropogenic pressures, including shifting cultivation, illegal and selective logging, agricultural expansion, infrastructure development, and settlement growth. The classified maps achieved high accuracy, with average User Accuracy ranging from 90.64% to 96.53% and Kappa values between 0.81 and 0.93, confirming the reliability of the classification. The observed forest changes have intensified habitat fragmentation, reduced canopy connectivity, and degraded habitat quality for forest-dependent wildlife.

Scientific novelty and practical significance. This study presents a comprehensive long-term assessment of forest cover dynamics in the MLPL Forest Complex and demonstrates the ecological consequences of landscape transformation. By linking forest cover change with biodiversity conservation, particularly the conservation of the Western Hoolock Gibbon, the findings provide a scientific basis for sustainable forest management, restoration of degraded forests, regulation of shifting cultivation, and strengthened community-based conservation initiatives to enhance ecological resilience in Northeast India.

ARTICLE INFO

Manuscript received
30 September 2025

Revised manuscript received
6 November 2025

Manuscript accepted
25 May 2026

Available online
30 May 2026

Keywords:

Forest cover change, Remote sensing, GIS, Hoolock Gibbon, Habitat fragmentation, Karbi Anglong, Northeast India, Land use and land cover (LULC), Biodiversity conservation.

Introduction

Forest cover changes have now emerged as a critical environmental issue at the global level and even in India, with ongoing large-scale changes in forest extent and composition remodeling landscapes and ecosystems [1, 2]. Though land use and forest cover are frequently employed synonymously, they express different meanings in natural resource management and environmental monitoring [3, 4]. Forest cover describes the physical extent and spatial distribution of vegetation, especially tree canopies, on the surface of the Earth, whereas land

In cites: Kashyap Parag Jyoti, Bose Sahana (2026). Forest Cover Changes in Marat Longri Patradisa Longnit Forest Complex of Karbi Anglong District, North East India. *Visnyk of V. N. Karazin Kharkiv National University, Series Geology. Geography. Ecology*, (64), 395–404. https://doi.org/10.26565/2410-7360-2026-64-30

© Parag Jyoti Kashyap, Sahana Bose, 2026
This work is licensed under a Creative Commons Attribution 4.0 International License

use describes human land use and management activities like agriculture, habitation, and infrastructure development [5, 6]. Forested cover change in India has been driven by rapid population increase, expansion in agriculture, urban expansion, and enhanced demand for natural resources [7, 8]. These anthropogenic forces, combined with infrastructural growth and shifting cultivation patterns, have resulted in extensive deforestation and forest degradation in various regions [9, 10]. The importance of research on forest cover change became apparent during the mid-1970s, and by the mid-1980s scientists realized that forests played a crucial role as sources and sinks of carbon, highlighting their impact on the global carbon cycle and climate balance [11, 12].

Forest cover change is currently identified as one of the most significant drivers of global and regional environmental change [13, 14]. Knowledge of the spatial and temporal patterns of forest cover is thus critical for successful land resource management and conservation planning [15, 16]. The pattern and pace of forest cover change, however, differ considerably among Indian regions [17].

In Northeast India, where forest ecosystems harbor exceptional biodiversity and many indigenous communities, forest cover change has been especially significant [18, 19]. Complex socio-ecological interactions, where traditional shifting cultivation, population pressure, and development activities together determine forest dynamics, are the characteristics of the region. Studies revealed that these changes impact natural resources, agricultural productivity, economic development, and ecological stability directly or indirectly [20, 21].

Therefore, forest cover change analysis is imperative to ensure effective monitoring, evaluation, conservation, and planning [22, 23]. Human activities have drastically changed the forested ecosystems of Northeast India over the decades [24]. As forest cover includes both natural and human-altered vegetation, it is crucial to have a holistic knowledge of its dynamics for effective decision-making, ecosystem restoration, and sustainable forest resource management [25, 26].

The Karbi Anglong district is especially significant for the purpose of forest protection in Assam. It is the most extensive district in the state by surface area and has the highest percentage of forest cover [27, 28]. The district consists of a number of different forest complexes, and among them the Marat Longri–Patradisa–Longnit Forest Complex is particularly significant. This forest complex is rich in flora and fauna and is one of the most under-scientifically unexplored areas in Assam. It is the largest habitat area (around 52%) of the endangered Western Hoolock Gibbon (Hoolock hoolock), and also provides shelter to the maximum population of Asian Elephants in Northeast India [29]. Therefore, analyzing forest cover dynamics in this region is of critical importance.

In this context, the object of the study is the forest cover of the Marat Longri–Patradisa–Longnit Forest Complex. The subject of the study is the spatio-temporal changes in forest cover and land use/land cover patterns from 1994 to 2024. The main purpose of the study is to assess changes in forest cover, identify the major anthropogenic drivers responsible for these changes, and evaluate their implications for biodiversity conservation, with particular emphasis on the canopy-dependent Western Hoolock Gibbon (Hoolock hoolock).

1. Materials and Methods

Study Area

The Marat Longri–Patradisa–Longnit Forest Complex is situated in the Karbi Anglong district of Assam (Figure 1). It lies between the geographical coordinates of 93°08′E to 93°30′E longitude and 25°45′N to 26°10′N latitude, covering a total area of approximately 802 sq. km. The complex comprises seven major Reserve Forests (R.F.) and District Council Reserve Forests (D.C.R.F.), namely Meyungdisa (D.C.R.F.), Disama (R.F.), Kaki (R.F.), Englongkiri (D.C.R.F.), Patradisa (R.F.), Longnit (R.F.), and Khonbamon (D.C.R.F).

Data Source

The study employed multi-temporal satellite datasets, including Landsat 4–5 TM C2 L2 imagery from 1994 and 2004, and BHUVAN LISS IV imagery from 2014 and 2024, sourced from the USGS Earth Explorer and NRSC BHUVAN platforms, respectively. The Landsat images had a spatial resolution of 30 m, while the LISS IV data offered a finer resolution of 5.8 m. All datasets were acquired in TIFF format and processed using ArcGIS 10.3. Before analysis, radiometric and geometric corrections were applied to reduce sensor-related noise, atmospheric distortions, and spatial inaccuracies, thereby ensuring spatial precision and spectral consistency across all time periods.

To maintain uniformity among datasets and ensure reliable temporal comparisons, image resampling was conducted to reconcile differences in spatial resolution. Seven categories were delineated: Semi-Evergreen Forest, Mixed Moist Deciduous Forest, Scrub Forest, Degraded Forest, Agricultural Land/Shifting Cultivation, Built-up Areas, and Water Bodies. All images were geo-referenced to the WGS 84 coordinate system using the UTM Zone 46N projection. False Color Composite (FCC) images were generated to aid in visual interpretation. The study boundary of the Marat Longri–Patradisa–Longnit Forest

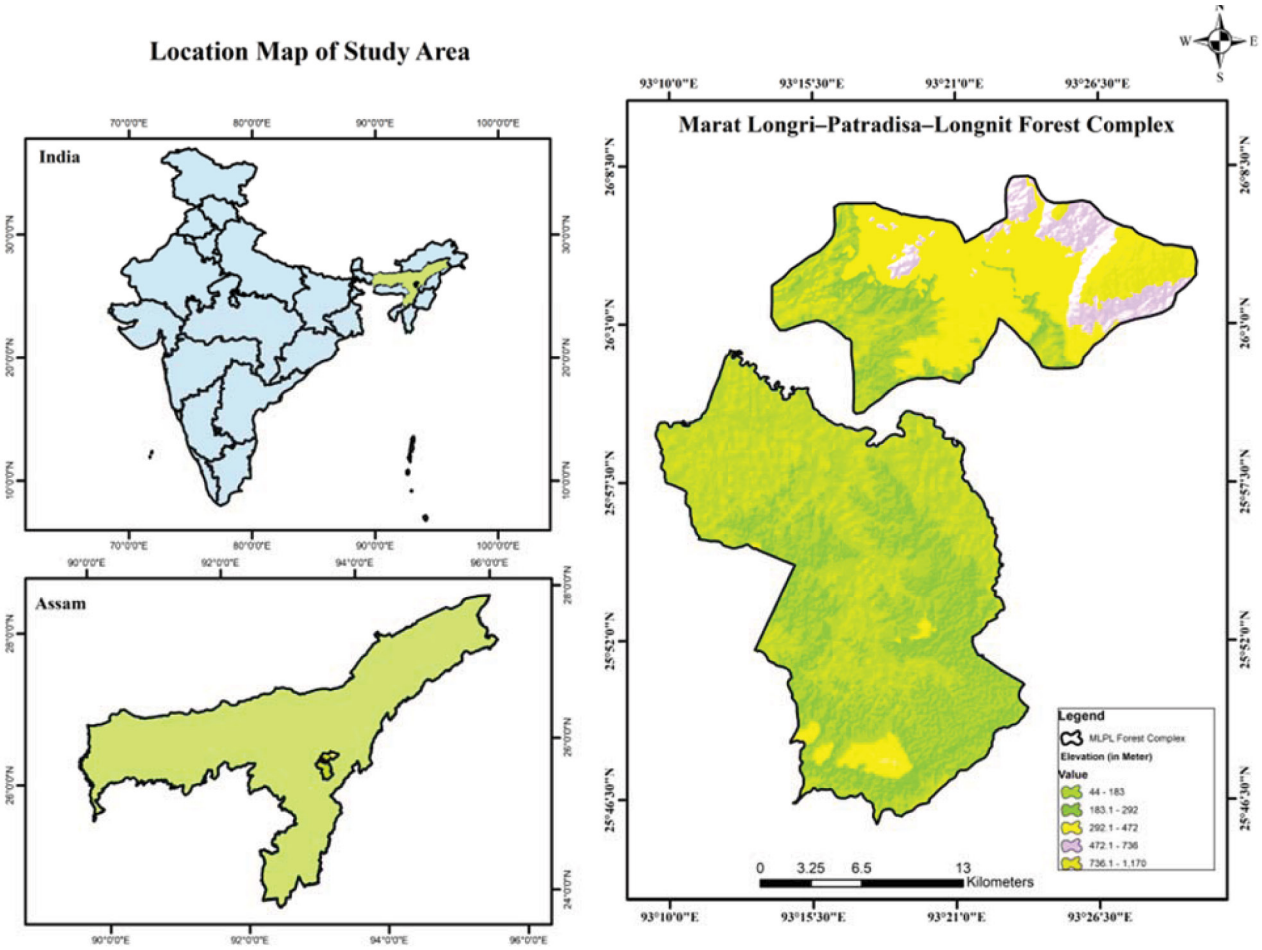

Fig. 1. Location map of Study Area

Complex was defined using Survey of India Toposheets (Nos. 83G/1, 83G/5, 83F/4, and 83F/8; scale 1:50,000). Finally, pixel-based supervised classification techniques were employed to generate forest cover maps for each time period.

Satellite data information:

A post-classification change detection approach was applied using a change matrix to assess and quantify temporal variations in forest cover. The matrix depicts the transitions among different forest cover categories across the study period from 1994 to 2024. The magnitude of change for each forest cover class was computed using the following equation:

$$ti = t_1 - t_2 \quad (1)$$

Where, ti signifies the degree of change in classes i, t_1 denotes the base image, and t_2 denotes the most recent image.

The following formula was used to calculate the percentage change for each forest cover category:

$$Pci = (t_1 - t_2)/t_2 \times 100 \quad (2)$$

Where, t_2 represents the most recent image, t_2 represents the base image and Pci represents the percentage of change in class i [30].

Accuracy assessment is a vital component of image classification, ensuring the dependable detection, interpretation, and evaluation of changes [31]. To accomplish this, the classified results were validated using the original mosaic, Google Earth imagery, and GPS-based reference points. A confusion matrix was generated by superimposing the classified forest cover map onto ground truth data to evaluate its accuracy. Various statistical measures such as overall accuracy, Kappa coefficient, producer's accuracy, and user's accuracy were calculated [30]. The computation of these accuracy indices followed

Table 1

Satellite Data information

Sensor	Resolution (in m.)	Path/Row/orbit/Scene Number	Data format	Acquisition time	Purpose
LANDSAT 4-5	30	136/42	Geotiff	27/11/1994	Forest Cover Analysis
LANDSAT 4-5	30	136/42	Geotiff	08/02/2004	Forest Cover Analysis
LISS 4	5.8	014649011200053	Geotiff	14/02/2014	Forest Cover Analysis
LISS 4	5.8	036801011200053	Geotiff	10/01/2024	Forest Cover Analysis

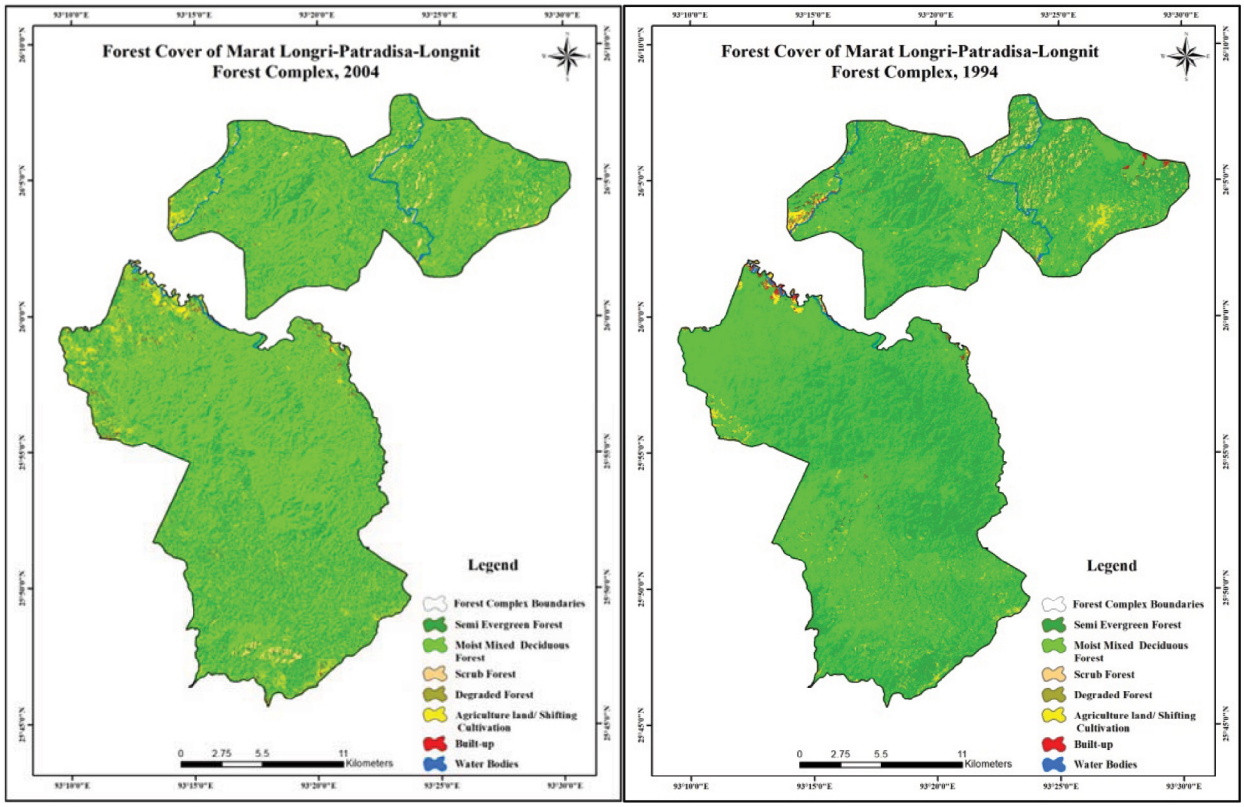

Fig. 2. Forest Cover of MLPL Forest Complex 1994 and 2004

the methodologies described by Islami et al. (2022) and Garg et al. (2016) [32, 33].

Producer accuracy:

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category (The Column Total)}} \times 100 \quad (3)$$

User Accuracy:

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category (The Row Total)}} \times 100 \quad (4)$$

Overall Accuracy:

$$\frac{\text{Total number of correctly classified pixels}}{\text{Total number of pixels in the matrix table}} \times 100 \quad (5)$$

Kappa Coefficient:

$$\frac{N\sum_{i}^{r=1} x_{ii} - \sum_{i}^{r=1} (x_{i+} * x+i)}{N^2 - \sum_{i}^{r=1} (x_{i} + * x+i)} \quad (6)$$

Where, r is the matrix's number of rows, xii denotes the total number of pixels in row i and column i that were correctly classified, and xi+ and x + i denote the marginal sums of row i and column i.

Result and Analysis

The temporal assessment of forest cover and land use changes in the Marat Longri–Patradisa–Longnit Forest Complex from 1994 to 2024 reveals substantial alterations across various land cover classes (Table 2). The results indicate a consistent decline in dense forest categories, accompanied by a marked expansion of degraded, scrub, and human-modified areas over the three decades (Figure 2 and 3).

The Semi-Evergreen Forest category declined markedly from 285.03 sq. km in 1994 to 158.40 sq. km in 2024, representing a net loss of 126.63 sq. km. This substantial reduction indicates large-scale deforestation and canopy thinning, primarily driven by shifting cultivation, logging, and other anthropogenic pressures. Similarly, the Moist Mixed Deciduous Forest cover decreased from 297.90 sq. km to 248.26 sq. km over the same period, suggesting ongoing degradation and conversion of late-successional forest stands into secondary or disturbed forest types. In contrast, both Scrub Forest and Degraded Forest classes exhibited significant expansion. The scrub forest area increased from 82.09 sq. km in 1994 to 120.44 sq. km in 2024, while degraded forest expanded from 41.20 sq. km to 122.31 sq. km. These increases reflect continued ecological deterioration and the replacement of dense canopy forests with fragmented, low-quality vegetation indicating a shift toward secondary succession stages.

The Agriculture and Shifting Cultivation area grew moderately, from 32.52 sq. km in 1994 to 46.10 sq. km in 2024, emphasize the persistent dependence of local communities on forest resources for subsistence agriculture. Likewise, the Built-up area expanded sharply from 27.87 sq. km to 71.10 sq. km, reflecting increased settlement growth, infrastructure development,

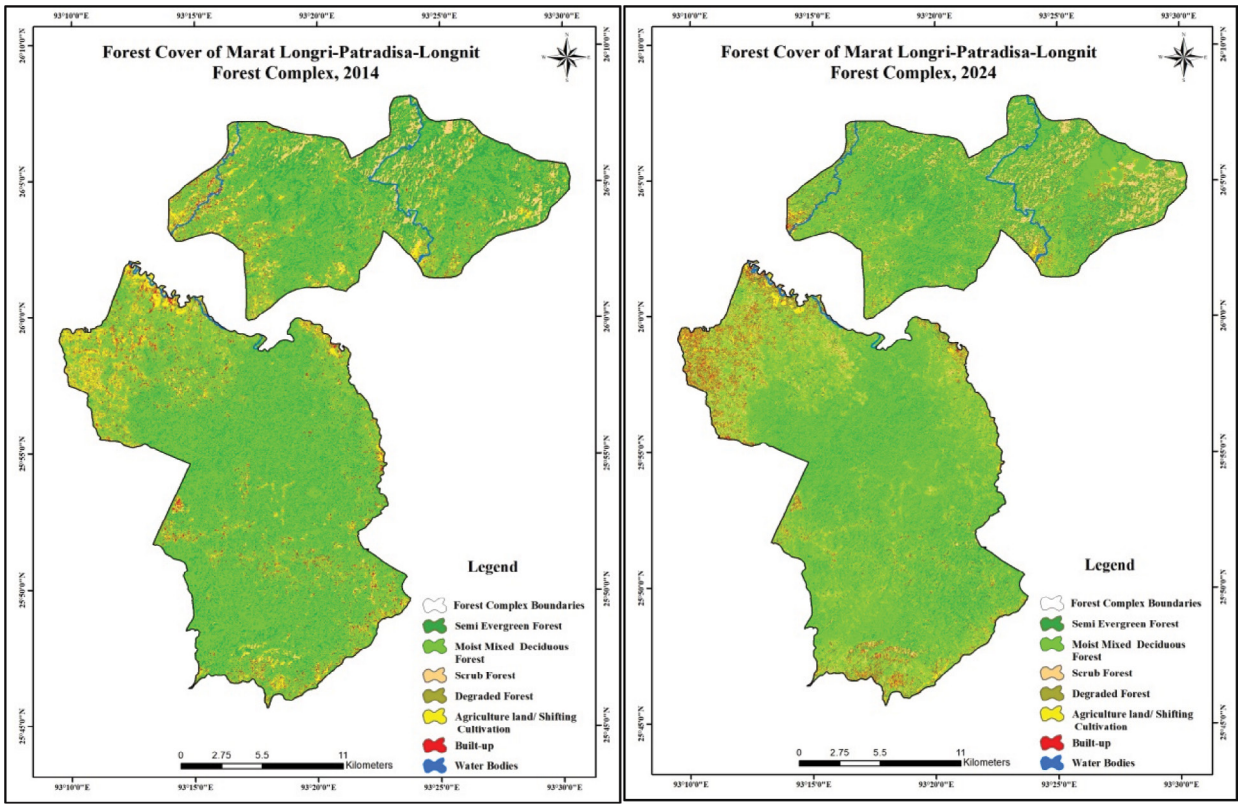

Fig. 3. Forest Cover of MLPL Forest Complex 2014 and 2024

and human encroachment into forested regions. In contrast, the Water Bodies category remained relatively stable throughout the study period, maintaining an average area of approximately 34.8 sq. km, which suggests minimal hydrological change within the complex.

The analysis reveals a consistent pattern of forest loss and landscape transformation across the study period. The combined area of dense forests (Semi-Evergreen and Moist Deciduous) declined from 582.93 sq. km in 1994 to 406.66 sq. km in 2024, indicating a net loss of 176.27 sq. km of forest cover. While this decline highlights an intensifying trend of deforestation, the concurrent expansion of degraded forest, scrubland, and built-up areas emphasize growing anthropogenic stress on the ecosystem. These transformations carry significant ecological consequences, particularly for canopy-dependent species such as the Western Hoolock Gibbon (Hoolock hoolock), which rely on contiguous forest cover for their survival and movement.

2. Discussion

The spatiotemporal analysis of land use and forest cover changes in the Marat Longri–Patradisa–Longnit Forest Complex for the period 1994–2024 presents a clear trend of ecological transformation characterized by increasing deforestation and habitat fragmentation. The quantitative trends summarized in Table 3 and Figure 4 clearly show a steady reduction in dense forest classes especially

Table 2

Area of different classified forest cover classes in the Marat Longri–Patradisa–Longnit Forest Complex

Classes	1994 (Area in km²)	2004 (Area in km²)	2014 (Area in km²)	2024 (Area in km²)
Semi Evergreen Forest	285.03	243.05	176.58	158.4
Moist Mixed Deciduous	297.9	295.66	268.1	248.26
Scrub Forest	82.09	93.39	103.92	120.44
Degraded Forest	41.2	66.39	108.27	122.31
Agriculture land/ Shifting Cultivation	32.52	38.29	45.92	46.1
Built-up	27.87	29.89	63.83	71.1
Water Bodies	34.81	34.75	34.8	34.81
Total	801.42	801.42	801.42	801.42

Table 3

Forest Cover changes of MLPL Forest Complex 1994-2024

Forest Cover Class	1994 Area in (%)	2004 Area in (%)	2014 Area in (%)	2024 Area in (%)	Change (1994–2004)	Change (2004–2014)	Change (2014–2024)
Semi-Evergreen Forest	35.57	30.33	22.03	19.76	–5.24	–8.29	–2.27
Moist Mixed Deciduous	37.17	36.89	33.45	30.98	–0.28	–3.44	–2.48
Scrub Forest	10.24	11.65	12.97	15.03	+1.41	+1.31	+2.06
Degraded Forest	5.14	8.28	13.51	15.26	+3.14	+5.23	+1.75
Agriculture/Shifting Cultivation	4.06	4.78	5.73	5.75	+0.72	+0.95	+0.02
Built-up	3.48	3.73	7.96	8.87	+0.25	+4.23	+0.91
Water Bodies	4.34	4.34	4.34	4.34	–0.01	+0.01	+0.00

Semi-Evergreen Forests and Moist Mixed Deciduous Forests paired with the continuous increase of degraded and scrubland categories.

The Semi-Evergreen Forest category underwent the sharpest loss, decreasing from 35.56% in 1994 to 19.76% in 2024. The 15.80% loss accounts for widespread canopy loss and deforestation due to anthropogenic factors of shifting cultivation, logging, and land clearing for settlement and agriculture. As with Moist Mixed Deciduous Forests, which decreased from 37.17% to 30.98%, this indicates continued conversion of mature forest stands into secondary growth or disturbed terrain. The steepest fall in both forest categories was between 2004 and 2014, which is a time most likely to be marked by increased human activity and uncontrolled land conversion. On the other hand, Scrub Forest and Degraded Forest classes experienced a sharp rise during the study period. Scrub Forests grew from 10.24% in 1994 to 15.03% in 2024, whereas Degraded Forests grew from 5.14% to 15.26%. These trends indicate that previously dense forests are experiencing successional regression, whereby canopy loss and soil loss have resulted in dense cover of poor-quality vegetation. This trend is consistent with other research in tropical and sub-tropical forest habitats of Northeast India [34, 35], where such processes of degradation have been attributed to expanding human habitation and resource use. The Built-up and Agriculture/Shifting Cultivation categories also expanded, reflecting increasing human encroachment and reliance on forest products for survival. The Built-up category more than doubled from 3.48% to 8.87% representing accelerated settlement growth and infrastructure development. Agricultural and shifting cultivation areas grew comparatively modestly, indicating ongoing livelihood dependency on land use. These patterns altogether hint at growing anthropogenic alteration of the environment, sometimes at the cost of ecological health. Conversely, Water Bodies class showed minimal variation, with a mean of 4.3% of the total area over the study period. This stability indicates that hydrological conditions have not been significantly affected by the changing land use in the surrounding areas, although localized effects on water quality and flow regimes cannot be eliminated.

3. Accuracy Assessment

Accuracy testing of the forest cover classification for the period 1994-2024 shows good reliability

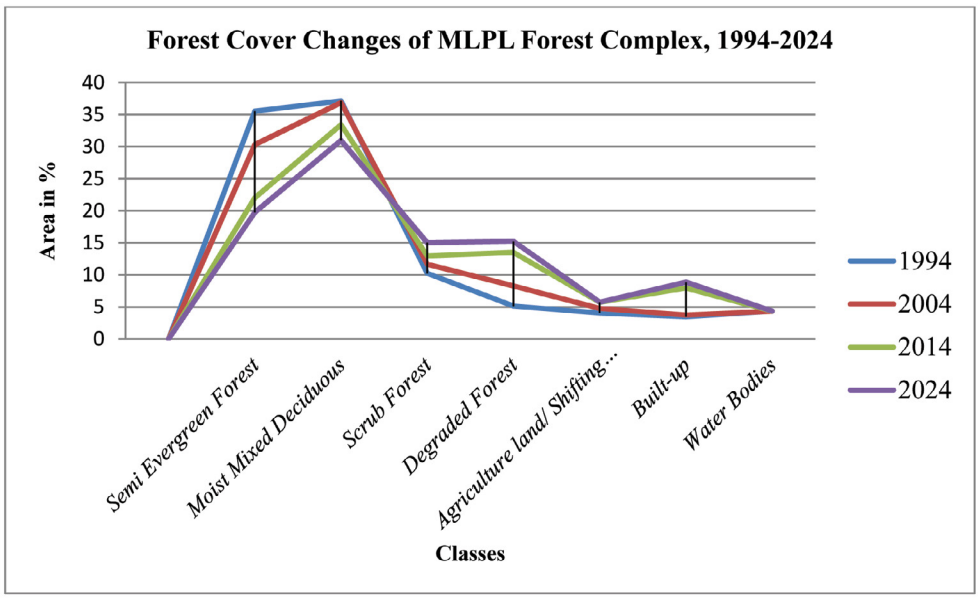

Fig. 4. Forest Cover changes of MLPL Forest Complex 1994-2024

Table 4

Accuracy assessment of forest cover classification in the Marat Longri–Patradisa–Longnit Forest Complex from 1994 to 2024, showing Producer Accuracy, User Accuracy, average User Accuracy, and estimated Kappa statistics for each year

Classes	1994 Producer Accuracy	1994 User Accuracy	2004 Producer Accuracy	2004 User Accuracy	2014 Producer Accuracy	2014 User Accuracy	2024 Producer Accuracy	2024 User Accuracy
Semi Evergreen Forest	92.11%	96.86%	94.97%	98.85%	98.64%	96.18%	94.72%	85.93%
Moist Mixed Deciduous Forest	96.35%	97.85%	93.12%	98.37%	92.44%	97.89%	92.60%	98.88%
Scrub Forest	94.25%	82.55%	97.89%	95.97%	96.67%	98.72%	90.97%	94.89%
Degraded Forest	99.12%	91.23%	98.45%	98.94%	99.78%	88.49%	99.77%	68.73%
Agricultural land/ Shifting Cultivation	98.97%	99.87%	92.88%	93.88%	99.73%	98.87%	97.72%	97.31%
Built-up	98.44%	87.55%	99.87%	98.72%	90.55%	82.72%	69.95%	89.78%
Water Bodies	78.45%	99.52%	97.82%	90.99%	92.75%	94.65%	75.89%	97.97%
Overall Accuracy	93.91		96.53		93.36		90.64	
Kappa statistics	0.88		0.93		0.87		0.81	

of the results (Table 4). Overall user accuracy varied from 90.64% (2024) to 96.53% (2004), with high consistency between the classified maps and reference data. The related Kappa statistics that take into account agreement by chance ranged from 0.81 to 0.93, corroborating further the quality of the classifications. Small decreases in user accuracy as well as Kappa in 2014 and 2024 indicate enhanced spectral confusion among classes, which is primarily due to anthropogenic land use changes as well as heterogeneity of the landscape. Collectively, these measures confirm the trustworthiness of the satellite-based forest cover maps for the four decades.

4. Conclusion

The spatio-temporal evaluation of the changes in the forest cover during the period of 1994-2024 within the Marat Longri–Patradisa–Longnit Forest Complex shows significant ecological changes driven mainly by human activities. The result reflects a significant reduction in Dense forest categories—particularly Semi-Evergreen and Moist Mixed Deciduous Forests—coupled with a significant increase in Degraded Forests, Scrub Forests, and Built-up lands. These together represent an increasing deforestation pattern, habitat degradation, and fragmentation of the landscape.

The consistent rise in degraded and human-modified land categories indicates more rigorous shifting cultivation, timber removal, agricultural encroachment, and settlement expansion, all of which have greatly altered the natural structure and composition of the vegetation. Even though the area of Water Bodies has exhibited negligible fluctuation, the mass-scale conversion of dense forests to degraded areas is a major threat to the ecological integrity and diversity of the region.

These changes in landscape have serious implications for canopy-associated species like the Western Hoolock Gibbon (Hoolock hoolock), which relies on unbroken forest cover for its existence, mobility, and reproduction. Habitat loss trend highlights the imperative of adopting sustainable forest management, participatory conservation initiatives, and policy initiatives that align local livelihoods with ecological conservation.

In short, the study highlights a relentless pattern of forest decline that, if not addressed, would lead to irreparable ecological harm. Immediate measures addressing reforestation, connectivity of habitats, and peoples' awareness are crucial for saving the existing forests and improving the long-term ecological resilience of the Marat Longri–Patradisa–Longnit Forest Complex.

Внесок авторів: всі автори зробили рівний внесок у цю роботу
Конфлікт інтересів: автори повідомляють про відсутність конфлікту інтересів
Декларація про використання генеративного штучного інтелекту: Автори не використовували інструменти генеративного штучного інтелекту (GenAI) при написанні статті. Автори несуть повну відповідальність за зміст та цілісність публікації.

Author Contributions: All authors have contributed equally to this work
Competing interests: The authors declare no competing interests
Declaration of use of generative artificial intelligence: The authors did not use generative artificial intelligence (GenAI) tools when writing the article. The authors retain full responsibility for the content and integrity of the publication.

Подяка. Автори висловлюють подяку Спеціальному головному охоронцю лісів (Spl. PCCF), Карбі Англонг, Ассам, і Автономній раді Карбі Англонга за надання дозволу на проведення досліджень в охоронюваних територіях. Ми висловлюємо щиру подяку кафедрі географії Ассамського університету за їхню постійну підтримку під час навчання. Автори також хочуть висловити свою щиру вдячність доктору Пранджіту Кумару Сарма, доценту кафедри географії коледжу Мангалдай, за його щедре керівництво та підтримку.

Acknowledgement. The authors gratefully acknowledge the Special Principal Chief Conservator of Forest (Spl. PCCF), Karbi Anglong, Assam, and the Karbi Anglong Autonomous Council for granting permission to conduct research in the protected areas. We extend our sincere thanks to the Department of Geography, Assam University, for their continuous support during the study. The authors also wish to express their heartfelt appreciation to Dr. Pranjit Kumar Sarma, Associate Professor, Department of Geography, Mangaldai College, for his generous guidance and support.

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ

1. Kaur, H., Tyagi, S., Mehta, M., & Singh, D. (2023). Time series (2001/2002–2021) analysis of Earth observation data using Google Earth Engine (GEE) for detecting changes in land use land cover (LULC) with specific reference to forest cover in East Godavari Region, Andhra Pradesh, India. *Journal of Earth System Science*, 132(2), 86. https://doi.org/10.1007/s12040-023-02099-w
2. Pasha, S. V., & Dadhwal, V. K. (2024). National analysis on variations in estimates of forest cover dynamics over India (2001–2020) using multiple techniques and data sources. *Spatial Information Research*, 32(4), 451–461. https://doi.org/10.1007/s41324-024-00570-4
3. Liu, Y., Liu, R., Qi, L., Chen, J., Dong, J., & Wei, X. (2024). Global mapping of fractional tree cover for forest cover change analysis. *ISPRS Journal of Photogrammetry and Remote Sensing*, 211, 67–82. https://doi.org/10.1016/j.isprsjprs.2024.03.019
4. Santoro, A., Piras, F., Fiore, B., Bazzurro, A., & Agnoletti, M. (2024). Forest-cover changes in European Natura 2000 sites in the period 2012–2018. *Forests*, 15(2), 232. https://doi.org/10.3390/f15020232
5. Hussain, K., Mehmood, K., Anees, S. A., Ding, Z., Muhammad, S., Badshah, T., & Khan, W. R. (2024). Assessing forest fragmentation due to land use changes from 1992 to 2023: A spatio-temporal analysis using remote sensing data. *Heliyon*, 10(14). https://doi.org/10.3390/land11111889
6. Kombate, A., Folega, F., Atakpama, W., Dourma, M., Wala, K., & Goïta, K. (2022). Characterization of land-cover changes and forest-cover dynamics in Togo between 1985 and 2020 from Landsat images using Google Earth Engine. *Land*, 11(11), 1889. https://doi.org/10.3390/land11111889
7. Zhang, X., Zhao, T., Xu, H., Liu, W., Wang, J., Chen, X., & Liu, L. (2023). GLC_FCS30D: The first global 30-m land-cover dynamic monitoring product with a fine classification system from 1985 to 2022 using dense time-series Landsat imagery and continuous change-detection method. *Earth System Science Data*, 15, 5407–5432. https://doi.org/10.5194/essd-16-1353-2024
8. Voigt, C., Hernandez-Aguilar, K., Garcia, C., & Gutierrez, S. (2019). Predictive modeling of future forest cover change patterns in southern Belize. *Remote Sensing*, 11(7), 823. https://doi.org/10.3390/rs11070823
9. Bhat, Y., Nandy, S., Das, K., Tamang, M., Padalia, H., Nath, A. J., & Singh, R. P. (2024). Vegetation disturbance and regrowth dynamics in shifting cultivation landscapes. *Scientific Reports*, 14, 28324. https://doi.org/10.1038/s41598-024-78089-9
10. Das, P., Behera, M. D., Barik, S. K., & Mudi, S. (2025). Earth observation for monitoring of shifting cultivation. In *Sustainable Development Perspectives in Earth Observation* (pp. 201–216). Elsevier. https://doi.org/10.1016/B978-0-443-14072-3.00013-7
11. Sohl, T. L., & Sleeter, B. M. (2012). Role of remote sensing for land-use and land-cover change modeling. In *Remote Sensing of Land Use and Land Cover* (pp. 225–239). Springer. https://doi.org/10.1201/b11964-18
12. Mehmood, K., Anees, S. A., Rehman, A., Tariq, A., Liu, Q., Muhammad, S., & Hatamleh, W. A. (2024). Assessing forest cover changes and fragmentation in the Himalayan temperate region: Implications for forest conservation and management. *Journal of Forestry Research*, 35(1), 82–96. https://doi.org/10.1007/s11676-024-01734-6
13. Lambin, E. F. (1999). Monitoring forest degradation in tropical regions by remote sensing: Some methodological issues. *Global Ecology and Biogeography*, 8(3–4), 191–198. https://doi.org/10.1046/j.1365-2699.1999.00123.x

REFERENCES

1. Kaur, H., Tyagi, S., Mehta, M., & Singh, D. (2023). Time series (2001/2002–2021) analysis of Earth observation data using Google Earth Engine (GEE) for detecting changes in land use land cover (LULC) with specific reference to forest cover in East Godavari Region, Andhra Pradesh, India. *Journal of Earth System Science*, 132(2), 86. https://doi.org/10.1007/s12040-023-02099-w
2. Pasha, S. V., & Dadhwal, V. K. (2024). National analysis on variations in estimates of forest cover dynamics over India (2001–2020) using multiple techniques and data sources. *Spatial Information Research*, 32(4), 451–461. https://doi.org/10.1007/s41324-024-00570-4
3. Liu, Y., Liu, R., Qi, L., Chen, J., Dong, J., & Wei, X. (2024). Global mapping of fractional tree cover for forest cover change analysis. *ISPRS Journal of Photogrammetry and Remote Sensing*, 211, 67–82. https://doi.org/10.1016/j.isprsjprs.2024.03.019
4. Santoro, A., Piras, F., Fiore, B., Bazzurro, A., & Agnoletti, M. (2024). Forest-cover changes in European Natura 2000 sites in the period 2012–2018. *Forests*, 15(2), 232. https://doi.org/10.3390/f15020232
5. Hussain, K., Mehmood, K., Anees, S. A., Ding, Z., Muhammad, S., Badshah, T., & Khan, W. R. (2024). Assessing forest fragmentation due to land use changes from 1992 to 2023: A spatio-temporal analysis using remote sensing data. *Heliyon*, 10(14). https://doi.org/10.3390/land11111889
6. Kombate, A., Folega, F., Atakpama, W., Dourma, M., Wala, K., & Goïta, K. (2022). Characterization of land-cover changes and forest-cover dynamics in Togo between 1985 and 2020 from Landsat images using Google Earth Engine. *Land*, 11(11), 1889. https://doi.org/10.3390/land11111889
7. Zhang, X., Zhao, T., Xu, H., Liu, W., Wang, J., Chen, X., & Liu, L. (2023). GLC_FCS30D: The first global 30-m land-cover dynamic monitoring product with a fine classification system from 1985 to 2022 using dense time-series Landsat imagery and continuous change-detection method. *Earth System Science Data*, 15, 5407–5432. https://doi.org/10.5194/essd-16-1353-2024
8. Voigt, C., Hernandez-Aguilar, K., Garcia, C., & Gutierrez, S. (2019). Predictive modeling of future forest cover change patterns in southern Belize. *Remote Sensing*, 11(7), 823. https://doi.org/10.3390/rs11070823
9. Bhat, Y., Nandy, S., Das, K., Tamang, M., Padalia, H., Nath, A. J., & Singh, R. P. (2024). Vegetation disturbance and regrowth dynamics in shifting cultivation landscapes. *Scientific Reports*, 14, 28324. https://doi.org/10.1038/s41598-024-78089-9
10. Das, P., Behera, M. D., Barik, S. K., & Mudi, S. (2025). Earth observation for monitoring of shifting cultivation. In *Sustainable Development Perspectives in Earth Observation* (pp. 201–216). Elsevier. https://doi.org/10.1016/B978-0-443-14072-3.00013-7
11. Sohl, T. L., & Sleeter, B. M. (2012). Role of remote sensing for land-use and land-cover change modeling. In *Remote Sensing of Land Use and Land Cover* (pp. 225–239). Springer. https://doi.org/10.1201/b11964-18
12. Mehmood, K., Anees, S. A., Rehman, A., Tariq, A., Liu, Q., Muhammad, S., & Hatamleh, W. A. (2024). Assessing forest cover changes and fragmentation in the Himalayan temperate region: Implications for forest conservation and management. *Journal of Forestry Research*, 35(1), 82–96. https://doi.org/10.1007/s11676-024-01734-6
13. Lambin, E. F. (1999). Monitoring forest degradation in tropical regions by remote sensing: Some methodological issues. *Global Ecology and Biogeography*, 8(3–4), 191–198. https://doi.org/10.1046/j.1365-2699.1999.00123.x

14. Yuh, Y. G., N'Goran, K. P., Kross, A., Heurich, M., Matthews, H. D., & Turner, S. E. (2024). Monitoring forest cover and land use change in the Congo Basin under IPCC climate change scenarios. *PLOS ONE*, 19(12), e0311816. https://doi.org/10.1371/journal.pone.0311816
15. Adepoju, M. O., Millington, A. C., & Tansey, K. T. (2006). Land use/land cover change detection in metropolitan Lagos (Nigeria): 1994–2002. In *ASPRS 2006 Annual Conference*, Reno, Nevada (pp. 1–5).
16. Sarkissian, A. J., & Kutia, M. (2024). Sustainable forest management under climate change conditions—A focus on biodiversity conservation and forest restoration. *Frontiers in Forests and Global Change*, 7, 1533425. https://doi.org/10.3389/ffgc.2024.1533425
17. Singh, A. M., & Devi, K. R. (2016). Land use and land cover change detection of fringe areas of Imphal City, Manipur, India. *IOSR Journal of Humanities and Social Science*, 21(2), 09–16. https://doi.org/10.9790/0837-21220916
18. Guria, R., Mishra, M., Baraj, B., Goswami, S., Santos, C. A. G., da Silva, R. M., & Bhutia, K. D. O. (2024). Examining the drivers of forest cover change and deforestation susceptibility in Northeast India using multicriteria decision-making models. *Environmental Monitoring and Assessment*, 196(11), 1098. https://doi.org/10.1007/s10661-024-13172-2
19. Devi, A. R., & Shimrah, T. (2022). Assessment of land use and land cover and forest fragmentation in traditional landscape in Manipur, Northeast India. *International Journal of Environmental Science and Technology*, 19(10), 10291–10306. https://doi.org/10.1007/s13762-021-03712-5
20. Mahato, R., Nimasow, G., Nimasow, O. D., & Bushi, D. (2021). Assessing the tropical forest cover change in northern parts of Sonitpur and Udalguri District of Assam, India. *Scientific Reports*, 11, 11170. https://doi.org/10.1038/s41598-021-90560-5
21. Nguyen, A., Kovyazin, V., & Pham, C. (2025). Application of remote sensing and GIS in monitoring forest cover changes in Vietnam based on natural zoning. *Land*, 14(5), 1037. https://doi.org/10.3390/land14051037
22. Rawat, K. S., Kumar, S., & Garg, N. (2024). Statistical comparison of simple and machine learning-based land use and land cover classification algorithms: A case study. *Journal of Water Management Modeling*. https://doi.org/10.14796/JWMM.H524
23. Negassa, M. D., Mallie, D. T., & Gemeda, D. O. (2020). Forest cover change detection using geographic information systems and remote sensing techniques: A spatio-temporal study on Komto Protected Forest priority area, Ethiopia. *Environmental Systems Research*, 9, 1. https://doi.org/10.1186/s40068-020-0163-z
24. Sarma, P. K., Sarma, K., Nath, K. K., Talukdar, B. K., Huda, M. E., & Baruah, B. (2016). Analysis of land use/land cover changes and its future implications in Garo Hill region of Meghalaya: A geo-spatial approach. *IJIREM*, 3(1), 2350–0557.
25. Saikia, A. (2013). *Over-exploitation of forests: A case study from North East India.* Springer. https://doi.org/10.1007/978-3-319-01408-1
26. Ritse, V., Basumatary, H., Kulnu, A. S., Dutta, G., Phukan, M. M., & Hazarika, N. (2020). Monitoring land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India. *Environmental Monitoring and Assessment*, 192(11), 711. https://doi.org/10.1007/s10661-020-08674-8
27. Le Moine, R. (2012). The land use cover changes from 1992 to 2011 in Karbi Anglong, Assam, India.
28. Datta, P., & Bose, S. (2020). Assessing the changes in climate extremes over Karbi Anglong district of Assam, North-East India. *Spatial Information Research*, 28(5), 547–558. https://doi.org/10.1007/s41324-020-00312-2
29. Biswas, J., Taro, R., Das, J., & Rabha, A. (2016). *A conservation action plan for the Western Hoolock Gibbon (Hoolock hoolock) in Karbi Anglong, Assam.* Primate Research Centre NE India. ISBN: 978-93-5258-060-6
30. Nath, N., Sahariah, D., Meraj, G., Debnath, J., Kumar, P., Lahon, D., & Kanga, S. (2023). Land use and land cover change monitoring and prediction of a UNESCO World Heritage Site: Kaziranga eco-sensitive zone using cellular automata-Markov model. *Land*, 12(1), 151. https://doi.org/10.3390/land12010151
31. Das, S., & Sarkar, R. (2019). Predicting the land use/land cover change using Markov model: A catchment-level analysis of the Bhagirathi-Hugli River. *Spatial Information Research*, 27, 439–452. https://doi.org/10.1007/s41324-019-00251-7

14. Yuh, Y. G., N'Goran, K. P., Kross, A., Heurich, M., Matthews, H. D., & Turner, S. E. (2024). Monitoring forest cover and land use change in the Congo Basin under IPCC climate change scenarios. *PLOS ONE*, 19(12), e0311816. https://doi.org/10.1371/journal.pone.0311816
15. Adepoju, M. O., Millington, A. C., & Tansey, K. T. (2006). Land use/land cover change detection in metropolitan Lagos (Nigeria): 1994–2002. In *ASPRS 2006 Annual Conference*, Reno, Nevada (pp. 1–5).
16. Sarkissian, A. J., & Kutia, M. (2024). Sustainable forest management under climate change conditions—A focus on biodiversity conservation and forest restoration. *Frontiers in Forests and Global Change*, 7, 1533425. https://doi.org/10.3389/ffgc.2024.1533425
17. Singh, A. M., & Devi, K. R. (2016). Land use and land cover change detection of fringe areas of Imphal City, Manipur, India. *IOSR Journal of Humanities and Social Science*, 21(2), 09–16. https://doi.org/10.9790/0837-21220916
18. Guria, R., Mishra, M., Baraj, B., Goswami, S., Santos, C. A. G., da Silva, R. M., & Bhutia, K. D. O. (2024). Examining the drivers of forest cover change and deforestation susceptibility in Northeast India using multicriteria decision-making models. *Environmental Monitoring and Assessment*, 196(11), 1098. https://doi.org/10.1007/s10661-024-13172-2
19. Devi, A. R., & Shimrah, T. (2022). Assessment of land use and land cover and forest fragmentation in traditional landscape in Manipur, Northeast India. *International Journal of Environmental Science and Technology*, 19(10), 10291–10306. https://doi.org/10.1007/s13762-021-03712-5
20. Mahato, R., Nimasow, G., Nimasow, O. D., & Bushi, D. (2021). Assessing the tropical forest cover change in northern parts of Sonitpur and Udalguri District of Assam, India. *Scientific Reports*, 11, 11170. https://doi.org/10.1038/s41598-021-90560-5
21. Nguyen, A., Kovyazin, V., & Pham, C. (2025). Application of remote sensing and GIS in monitoring forest cover changes in Vietnam based on natural zoning. *Land*, 14(5), 1037. https://doi.org/10.3390/land14051037
22. Rawat, K. S., Kumar, S., & Garg, N. (2024). Statistical comparison of simple and machine learning-based land use and land cover classification algorithms: A case study. *Journal of Water Management Modeling*. https://doi.org/10.14796/JWMM.H524
23. Negassa, M. D., Mallie, D. T., & Gemeda, D. O. (2020). Forest cover change detection using geographic information systems and remote sensing techniques: A spatio-temporal study on Komto Protected Forest priority area, Ethiopia. *Environmental Systems Research*, 9, 1. https://doi.org/10.1186/s40068-020-0163-z
24. Sarma, P. K., Sarma, K., Nath, K. K., Talukdar, B. K., Huda, M. E., & Baruah, B. (2016). Analysis of land use/land cover changes and its future implications in Garo Hill region of Meghalaya: A geo-spatial approach. *IJIREM*, 3(1), 2350–0557.
25. Saikia, A. (2013). *Over-exploitation of forests: A case study from North East India.* Springer. https://doi.org/10.1007/978-3-319-01408-1
26. Ritse, V., Basumatary, H., Kulnu, A. S., Dutta, G., Phukan, M. M., & Hazarika, N. (2020). Monitoring land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India. *Environmental Monitoring and Assessment*, 192(11), 711. https://doi.org/10.1007/s10661-020-08674-8
27. Le Moine, R. (2012). The land use cover changes from 1992 to 2011 in Karbi Anglong, Assam, India.
28. Datta, P., & Bose, S. (2020). Assessing the changes in climate extremes over Karbi Anglong district of Assam, North-East India. *Spatial Information Research*, 28(5), 547–558. https://doi.org/10.1007/s41324-020-00312-2
29. Biswas, J., Taro, R., Das, J., & Rabha, A. (2016). *A conservation action plan for the Western Hoolock Gibbon (Hoolock hoolock) in Karbi Anglong, Assam.* Primate Research Centre NE India. ISBN: 978-93-5258-060-6
30. Nath, N., Sahariah, D., Meraj, G., Debnath, J., Kumar, P., Lahon, D., & Kanga, S. (2023). Land use and land cover change monitoring and prediction of a UNESCO World Heritage Site: Kaziranga eco-sensitive zone using cellular automata-Markov model. *Land*, 12(1), 151. https://doi.org/10.3390/land12010151
31. Das, S., & Sarkar, R. (2019). Predicting the land use/land cover change using Markov model: A catchment-level analysis of the Bhagirathi-Hugli River. *Spatial Information Research*, 27, 439–452. https://doi.org/10.1007/s41324-019-00251-7

32. Islami, F. A., Tarigan, S. D., Wahjunie, E. D., & Dasanto, B. D. (2022). Accuracy assessment of land use change analysis using Google Earth in Sadar Watershed Mojokerto Regency. *IOP Conference Series: Earth and Environmental Science*, 950, 012091. https://doi.org/10.1088/1755-1315/950/1/012091
33. Garg, R., Kumar, A., Prateek, M., Pandey, K., & Kumar, S. (2022). Land cover classification of spaceborne multifrequency SAR and optical multispectral data using machine learning. *Advances in Space Research*, 69(4), 1726–1742. https://doi.org/10.1016/j.asr.2021.06.028
34. Tripathi, R. S., Roy, A., Kushwaha, D., Lalnunmawia, F., Lalnundanga, L. H., Lalnunzira, C., & Roy, P. S. (2016). Perspectives of forest biodiversity conservation in Northeast India. *Journal of Biodiversity, Bioprospecting and Development*, 3(2), 1–9. https://doi.org/10.4172/2376-0214.1000157
35. Hazarika, N., Das, A. K., & Borah, S. B. (2015). Assessing land-use changes driven by river dynamics in chronically flood-affected Upper Brahmaputra plains, India, using RS-GIS techniques. *The Egyptian Journal of Remote Sensing and Space Science*, 18(1), 107–118. https://doi.org/10.1016/j.ejrs.2015.02.001

32. Islami, F. A., Tarigan, S. D., Wahjunie, E. D., & Dasanto, B. D. (2022). Accuracy assessment of land use change analysis using Google Earth in Sadar Watershed Mojokerto Regency. *IOP Conference Series: Earth and Environmental Science*, 950, 012091. https://doi.org/10.1088/1755-1315/950/1/012091
33. Garg, R., Kumar, A., Prateek, M., Pandey, K., & Kumar, S. (2022). Land cover classification of spaceborne multifrequency SAR and optical multispectral data using machine learning. *Advances in Space Research*, 69(4), 1726–1742. https://doi.org/10.1016/j.asr.2021.06.028
34. Tripathi, R. S., Roy, A., Kushwaha, D., Lalnunmawia, F., Lalnundanga, L. H., Lalnunzira, C., & Roy, P. S. (2016). Perspectives of forest biodiversity conservation in Northeast India. *Journal of Biodiversity, Bioprospecting and Development*, 3(2), 1–9. https://doi.org/10.4172/2376-0214.1000157
35. Hazarika, N., Das, A. K., & Borah, S. B. (2015). Assessing land-use changes driven by river dynamics in chronically flood-affected Upper Brahmaputra plains, India, using RS-GIS techniques. *The Egyptian Journal of Remote Sensing and Space Science*, 18(1), 107–118. https://doi.org/10.1016/j.ejrs.2015.02.001

Зміни лісового покриву в лісовому комплексі Марат Лонгрі Патрадіса Лонгніт округу Карбі Англонг, Північно-Східна Індія

Параг Джйоті Кашьяп[1], https://orcid.org/0000-0003-4273-841X, e-mail: kashyapparagjyoti@gmail.com
аспірант, кафедра географії

Сахана Бозе[1], https://orcid.org/0000-0003-2108-9297, e-mail: sahanadona@gmail.com
д. філософії, доцент, кафедра географії

[1] *Університет Ассама, кампус Діпху, Ассам, Індія*

АНОТАЦІЯ

Метою дослідження є аналіз просторово-часової динаміки лісового покриву в лісовому комплексі Марат Лонгрі–Патрадіса–Лонгніт (MLPL) в окрузі Карбі Англонг (Ассам, Індія) протягом 1994–2024 рр. Комплекс є важливим осередком біорізноманіття Північно-Східної Індії та середовищем існування багатьох рідкісних видів. Дослідження спрямоване на оцінку змін основних типів лісів, трансформації землекористування, впливу антропогенних чинників на деградацію лісів та наслідків цих процесів для збереження біорізноманіття, зокрема західного Хулоцького гібона. Використано супутникові знімки Landsat 4–5 TM за 1994 і 2004 рр. та BHUVAN LISS IV за 2014 і 2024 рр. Після попередньої обробки територію класифіковано за сімома категоріями землекористування та земного покриву: напіввічнозелені, вологі змішані листяні, чагарникові та деградовані ліси, сільськогосподарські угіддя, забудовані території й водойми. Для аналізу застосовано контрольовану піксельну класифікацію та післякласифікаційне виявлення змін у ArcGIS 10.3. Достовірність результатів оцінено за показниками точності виробника, користувача, загальної точності та статистикою Каппа. Результати засвідчили суттєве скорочення площ напіввічнозелених і вологих змішаних листяних лісів та одночасне збільшення площ деградованих і чагарникових лісів, сільськогосподарських угідь і забудованих територій. Це свідчить про посилення антропогенного впливу, пов'язаного з вирубуванням лісів, розвитком сільського господарства, інфраструктури та поселень. Класифікація характеризувалася високою точністю: середня точність користувача становила 90,64–96,53 %, а статистика Каппа – 0,81–0,93. Виявлені зміни призвели до фрагментації середовищ існування та погіршення умов для видів, залежних від лісових екосистем. Дослідження є комплексною довгостроковою оцінкою динаміки лісового покриву MLPL і демонструє необхідність сталого управління лісами, відновлення деградованих ділянок, регулювання змінного землеробства та посилення природоохоронних заходів для збереження біорізноманіття й підвищення екологічної стійкості регіону.

ІНФОРМАЦІЯ ПРО СТАТТЮ :

Manuscript received
16 October 2025

Revised manuscript received
16 December 2025

Manuscript accepted
25 May 2026

Available online
30 May 2026

Ключові слова:

зміна лісового покриву, дистанційне зондування, ГІС, Хулоцький гібон, фрагментація середовища існування, Карбі Англонг, Північно-Східна Індія.