Environment and Ecology 44 (3) 557—565, July—September 2026
Article DOI: https://doi.org/10.60151/envec/KJZG1402
ISSN: 0970-0420 (Print), ISSN: 3049-3625 (Online)

Monitoring of Land Use and Land Cover Changes in the Gai Sub-Watershed, NEI, Using GIS and Remote Sensing

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Received 27 February 2026, Accepted 18 June 2026, Published on 17 July 2026

ABSTRACT

The changes in land use and land cover significantly impact the environment in this watershed. This study utilizes Landsat satellite imagery from 2003, 2016, and 2024 to detect changes in the area. The supervised classification method is employed to analyse land cover changes in the Gai watershed. The land use and land cover classes are categorized into six types: agricultural land, built-up areas, forest, river/water bodies, scrubland, and others. Agricultural land and built-up areas are on the rise, along with forest and river areas, while other categories and scrubland are declining. Factors contributing to these changes include population growth, natural hazards, deforestation, and mining activities. Effective watershed management planning is essential for maintaining the environmental health and ecological balance and sustainable agricultural development of this area.

Keywords Change detection, LU/LC, GIS, Remote sensing.

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INTRODUCTION

Land use and cover change (LUCC) studies the changes to the surface of the land. Land cover is the natural cover of the land, like a forest. Land use represents the use of land for humans, such as agricultural land and commercial areas (Raj *et al*. 2024). The study of land-use and land-cover (LULC) changes is essential for understanding the environment and monitoring the degradation of natural resources, both in quality and quantity, on the Earth's surface. Climate, population growth, and natural hazards contribute to these changes. Both natural and anthropogenic factors play a role in land cover changes. Population growth is a significant factor driving changes in land cover, as the increasing built-up area results in a decrease in vegetation (Kafi *et al.* 2014). Identifying and understanding the patterns of LULC change is crucial for effective environmental management, including water management practices (Twisa and Buchroithner 2019).

Remote sensing methods give us useful ways to study environmental processes on a small and large scale. Satellite images enable rapid monitoring of the environment, particularly in areas that are inaccessible for field surveys due to topography, dense vegetation, or other local factors. Landsat images, with their suitable resolution, are effective for land cover mapping and change monitoring (Szabó *et al.* 2016). Change detection involves distinguishing differences in phenomena by observing them over different times, including the ability to assess temporal effects using a multi-temporal data set (Ahmed 2023). Many researchers have utilized satellite-based multispectral remote sensing data in GIS software to evaluate and monitor LULC changes (Patel *et al.* 2024, Mishra and Rai 2020, Hu *et al*. 2023, Hossain *et al.* 2023). This advanced technology is instrumental in mapping changes in land cover.

This study aims to visualize changes to apply the management plan to restoring natural resources and promoting sustainable management and development within the watershed. The findings of this paper will aid in identifying changes in natural resources, such as water, forests, and soil, to protect, conserve, and manage these resources, as well as our environment. To maintain these resources and achieve sustainable development, the government implements programs and policies.

MATERIALS AND METHODS

Study area

The Gai watershed extended between 27º26´0´´to 27º41´42´´N latitude to 94º34´1´´ to 94º42´19´´E longitude. The total area of this watershed is 139 square kilometres. The elevation variation range from 21 to 822 m and slope variation of this watershed is 0 to 69 degrees. Geomorphology of this study area falls under seven categories namely alluvial plain, flood plain, highly dissected hills and valleys, moderately dissected hills and valleys, mass wasting, piedmont slope, and water bodies. Soil taxonomy is also categorised into the five classes. Fig. 1 shows the location map of the study area.

Data collection

This study area was delineated using the Carto DEM of 30 m resolution (https://bhuvan.nrsc.gov.in) and Survey of India toposheet nos. 83I/6, 9, 10, and 11 of scale 1:50,000 (https://onlinemaps.surveyofindia.gov.in). In addition, 30-m resolution Landsat 8/9 satellite

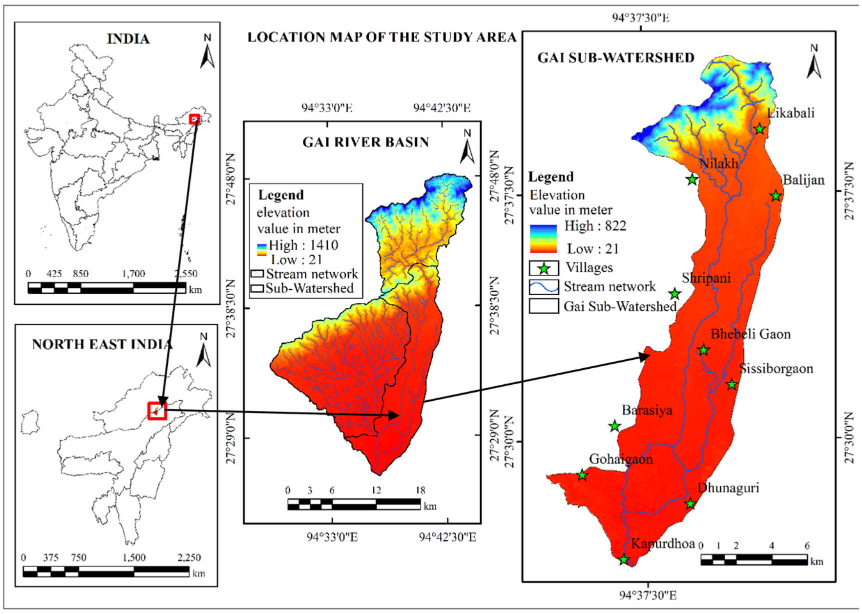

Fig: 1. Location map of the study area.

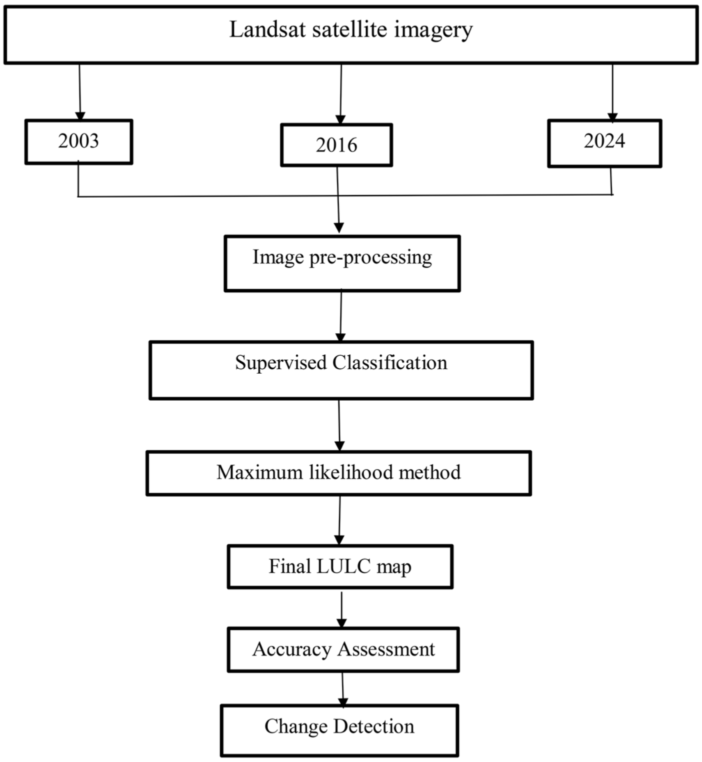

Fig. 2. Methodology of the study area.

images were used (https://earthexplorer.usgs.gov). Landsat satellite images of 2003 (Landsat 7) and 2016 and 2024 (Landsat 8/9) were downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov) to analyze land use and land cover (LULC) changes.

Methods

Landsat satellite images of 2003, 2016, and 2024 in the month of March were used for monitoring land use and land cover (LULC) changes in the Gai sub-watershed. The first step in processing all these images is image preprocessing, which improves image quality. The study area is classified using the supervised classification method for generating training samples and classifying the LULC classes. The LULC classes or training samples are further subjected to the maximum likelihood supervised classification method to produce the final map of LULC classes. The Arc toolbox is used to generate accuracy assessment points and a confusion matrix to evaluate the accuracy of these classifications and validate the results against ground truth data obtained from Google Earth Pro. Finally, the calculations of category-wise change detection are performed by intersecting LULC classes of 2003 to 2016 and 2016 to 2024. All processing steps were performed using ArcGIS 10.8 software. Fig. 2 shows the methodological flowchart of the study area.

RESULTS AND DISCUSSION

The evaluation and monitoring of land use and land cover (LULC) changes utilized satellite imagery from three years: 2003, 2016, and 2024. The study area was classified into six major categories: agricultural land, built-up area, forest, river/water bodies, scrubland, and an "others" category. The class-wise area for each year is presented in Table 1. Additionally, the LULC maps are shown in Figs. 3, 4, and 5.,

Change detection during 2003 – 2016

The assessment and identification of land use and

Table 1. Overall LULC class wise area.

SI. No.	LULC class	Area, 2003 km²	Area, 2003 %	Area, 2016 km²	Area, 2016 %	Area, 2024 km²	Area, 2024 %
1	Forest	22.83	16.37	21.98	15.76	21.17	15.18
2	River/Waterbodies	20.66	14.81	13.03	9.34	13.68	9.81
3	Agricultural land	48.35	34.67	52.77	37.83	59.68	42.79
4	Others	13.70	9.82	6.30	4.52	3.32	2.38
5	Built-up area	25.49	18.28	35.67	25.58	39.90	28.61
6	Marshy land	8.45	6.06	9.72	6.97	1.72	1.23
	Total	139	100.00	139	100.00	139	100.00

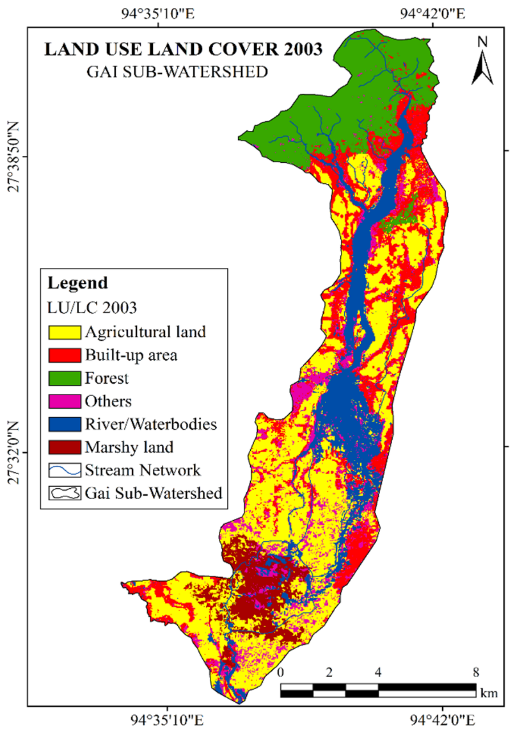

Fig. 3. Land use land cover map, 2003.

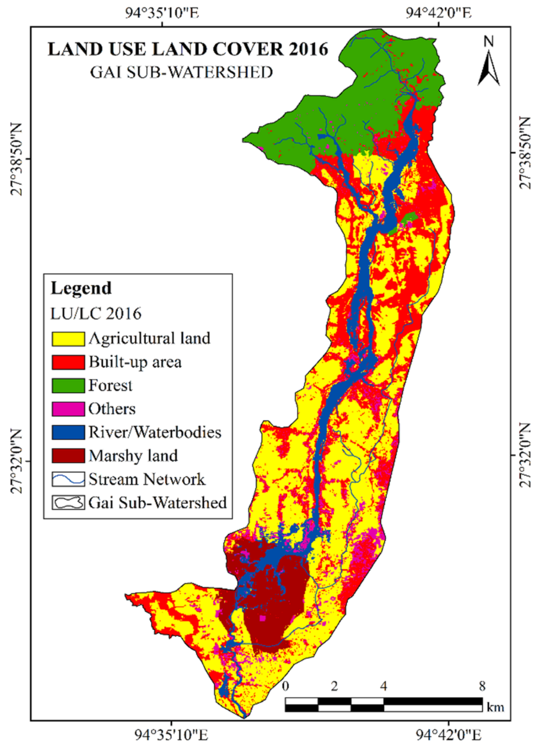

Fig. 4. Land use land cover map, 2016

land cover (LULC) changes from 2003 to 2016 reveal significant transformations across various classes. The expansion of settlements and the reduction of forest areas contributed to the conversion of forest land into agricultural land (0.08 km²), other areas (0.19 km²), and built-up areas (0.59 km²). In contrast, rivers and water bodies transitioned into agricultural land (7.50 km²), other categories (0.85 km²), and built-up areas (4.31 km²). Factors such as flooding and channel migration influenced these changes. During this period, the agricultural class within the watershed also underwent shifts, converting to river and water bodies (2.63 km²), other categories (2.02 km²), built-up areas (3.24 km²), and forest (0.01 km²). Natural hazards and the increase in settlements further contributed to the conversion of agricultural land into other categories and built-up areas. The "Others" category within the LULC area converted to 5.61 km² in agricultural land, 4.52 km² in built-up areas, and 1.33 km² in water bodies. Similarly, built-up areas transformed into rivers and water bodies (1.11 km²) and other categories (1.80 km²). marshy land also gave way to rivers and

Table 2. Change Detection (2003 - 2016), Gai Sub-Watershed.

Sl. No.	LULC Change (2003 - 2016)	Changed/Unchanged	Area in km^2	Area in %
1	Agricultural land - Agricultural land	Unchanged	38.10	27.32
2	Agricultural land - Built-up area	Changed	3.24	2.32
3	Agricultural land - Forest	Changed	0.01	0.01
4	Agricultural land - Others	Changed	2.02	1.45
5	Agricultural land - River/Waterbodies	Changed	2.63	1.89
6	Agricultural land - Marshy land	Changed	2.35	1.68
7	Built-up area - Built-up area	Unchanged	22.58	16.19
8	Built-up area - Others	Changed	1.80	1.29
9	Built-up area - River/Waterbodies	Changed	1.11	0.80
10	Forest - Agricultural land	Changed	0.08	0.06
11	Forest - Built-up area	Changed	0.59	0.42
12	Forest - Forest	Unchanged	21.97	15.75
13	Forest - Others	Changed	0.19	0.14
14	Others - Agricultural land	Changed	5.61	4.03
15	Others - Built-up area	Changed	4.52	3.24
16	Others - Others	Unchanged	2.24	1.61
17	Others - River/Waterbodies	Changed	1.33	0.95
18	River/Waterbodies - Agricultural land	Changed	7.50	5.38
19	River/Waterbodies - Built-up area	Changed	4.31	3.09
20	River/Waterbodies - Others	Changed	0.85	0.61
21	River/Waterbodies - River/Waterbodies	Unchanged	7.09	5.08
22	River/Waterbodies - Marshy land	Changed	0.90	0.65
23	Marshy land - Agricultural land	Changed	1.05	0.75
24	Marshy land - Others	Changed	0.06	0.04
25	Marshy land - River/Waterbodies	Changed	0.87	0.62
26	Marshy land - Marshy land	Unchanged	6.47	4.64
	Total		139	100

Table 3. Change Detection (2016 - 2024), Gai Sub-Watershed.

Sl. No.	LULC Change (2016 - 2024)	Changed/Unchanged	Area in km^2	Area in %
1	Agricultural land - Agricultural land	Unchanged	48.05	34.46
2	Agricultural land - Built-up area	Changed	0.68	5.29
3	Agricultural land - Forest	Changed	0.02	0.01
4	Agricultural land - Others	Changed	0.43	0.31
5	Agricultural land - River/Waterbodies	Changed	3.48	2.50
6	Agricultural land - Marshy land	Changed	0.05	0.04
7	Built-up area - Built-up area	Unchanged	32.32	18.07
8	Built-up area - Others	Changed	1.26	0.91
9	Built-up area - River/Waterbodies	Changed	2.09	1.50
10	Forest - Agricultural land	Changed	0.05	0.04
11	Forest - Built-up area	Changed	0.68	0.81
12	Forest - Forest	Unchanged	21.15	15.19
13	Forest - Others	Changed	0.10	0.19
14	Others - Agricultural land	Changed	2.15	1.55
15	Others - Built-up area	Changed	3.25	2.34
16	Others - Others	Unchanged	0.43	0.22
17	Others - River/Waterbodies	Changed	0.46	0.33
18	River/Waterbodies - Agricultural land	Changed	3.23	2.32
19	River/Waterbodies - Built-up area	Changed	2.80	2.09
20	River/Waterbodies - Others	Changed	0.26	0.18
21	River/Waterbodies - River/Waterbodies	Unchanged	6.56	4.70

Table 3. Continued.

Sl. No.	LULC Change (2016 - 2024)	Changed/Unchanged	Area in km²	Area in %
22	River/Waterbodies - Marshy land	Changed	0.18	0.13
23	Marshy land - Agricultural land	Changed	6.15	4.42
24	Marshy land - Others	Changed	0.76	0.54
25	Marshy land - River/Waterbodies	Changed	1.09	0.79
26	Marshy land - Marshy land	Unchanged	1.72	1.07
	Total		139	100

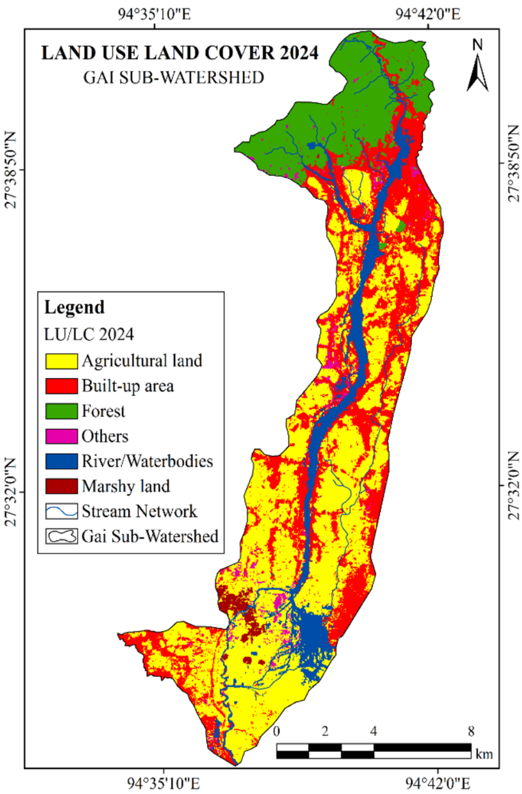

Fig 5. Land use land cover map, 2024.

other bodies of water (0.87 km²), other areas (0.06 km²), and agricultural land (1.05 km²). Table 2 and Fig. 6 show the change detection during 2003–2016. The observed transformations in the LULC classes indicate a shift in the watershed's characteristics, accompanied by a decline in environmental quality.

Change detection during 2016 – 2024

The change detection from 2016 to 2024 utilized Landsat satellite imagery. During this period, notable changes in the Land Use and Land Cover (LULC) classes were identified. Table 3 and Fig. 7 show the change detection during 2016–2024. The forest area decreased, converting into agricultural land by 0.05 km², other categories by 0.10 km², and built-up areas by 0.68 km². The area of rivers/water bodies was transformed into agricultural land (3.23 km²), other land (0.26 km²), marshy land (0.18 km²), and built-up areas (2.80 km²). Likewise, agricultural land was converted into river/water bodies (3.48 km²), other categories (0.43 km²), marshy land (0.05 km²), and built-up areas (0.68 km²). Factors such as flooding, siltation, and changes in river direction influenced these changes in both categories. Additionally, other classes transitioned into river/water bodies (0.46 km²), agricultural land (2.15 km²), and built-up areas

Table 4. Accuracy Matrix, 2003.

Sl. No.	LULC Class	Forest	Water-bodies	Agricultural land	Others	Built-up area	Marshy land	Total	User Accuracy	Kappa
1	Forest	12	0	0	0	0	0	12	1	0
2	Waterbodies	0	14	0	0	0	0	14	1	0
3	Agricultural land	0	0	32	0	2	0	34	0.94	0
4	Others	0	0	1	13	0	0	14	0.93	0
5	Built-up area	0	2	0	0	19	0	21	0.90	0
6	Marshy land	0	0	0	0	0	5	5	1	0
7	Total	12	16	33	13	21	5	100	0	0
8	Producer Accuracy	1	0.88	0.97	1	0.90	1	0	0.95	0
9	Kappa	0	0	0	0	0	0	0	0	0.94

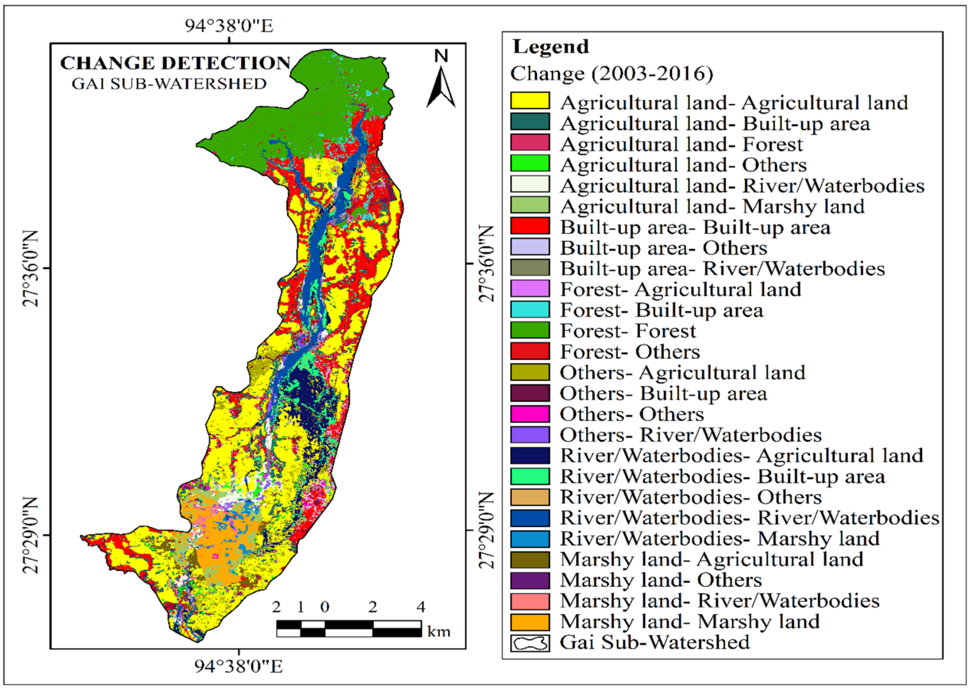

Fig. 6. Change detection map (2003-2016).

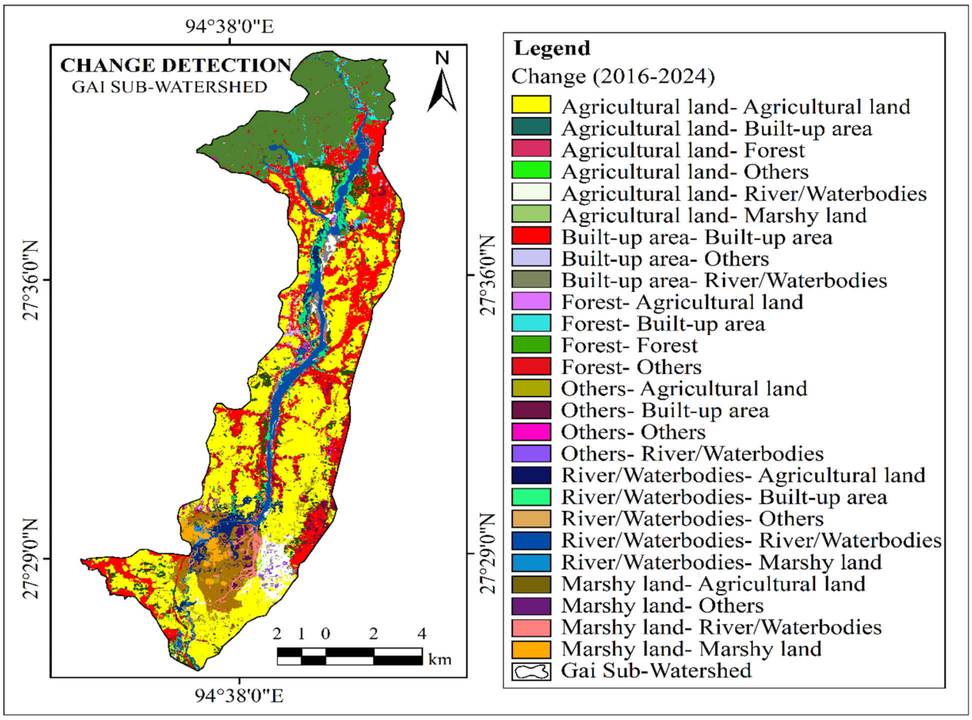

Fig. 7. Change detection map (2016-2024).

Table 5. Accuracy Matrix, 2016.

Sl. No.	LULC Class	Forest	Water-bodies	Agricultural land	Others	Built-up area	Marshy land	Total	User Accuracy	Kappa
1	Forest	13	0	0	0	0	0	13	1	0
2	Waterbodies	0	7	0	0	0	0	7	1	0
3	Agricultural land	0	0	33	0	1	0	34	0.97	0
4	Others	0	0	0	4	0	0	4	1	0
5	Built-up area	0	0	5	3	23	0	31	0.74	0
6	Marshy land	0	0	0	0	0	11	11	1	0
7	Total	13	7	38	7	24	11	100	0	0
8	Producer Accuracy	1	1	0.87	0.57	0.96	1	0	0.91	0
9	Kappa	0	0	0	0	0	0	0	0	0.88

Table 6. Accuracy Matrix, 2024.

Sl. No.	LULC Class	Forest	Water-bodies	Agricultural land	Others	Built-up area	Marshy land	Total	User Accuracy	Kappa
1	Forest	14	0	0	0	0	0	14	1	0
2	Waterbodies	0	12	0	0	0	0	12	1	0
3	Agricultural land	0	2	37	0	2	1	42	0.88	0
4	Others	0	0	0	0	1	0	1	0	0
5	Built-up area	0	1	0	0	29	0	30	0.97	0
6	Marshy land	0	0	0	0	0	1	1	1	0
7	Total	14	15	37	0	32	2	100	0	0
8	Producer Accuracy	1	0.8	1	0	0.91	0.5	0	0.93	0
9	Kappa	0	0	0	0	0	0	0	0	0.90

(3.25 km²). Built-up areas also shifted to river/water bodies (2.09 km²) and other categories (1.26 km²). The marshy land class changed into agricultural land (6.15 km²), other categories (0.76 km²), and river/water bodies (1.09 km²). Changes in LULC classes can be attributed to an increasing population, shifts in climatic parameters, and the occurrence of natural hazards, such as floods.

Accuracy assessment

For validating the LULC map, an accuracy assessment is crucial. It is impossible to validate the classification results without ground truth data. ArcGIS tools are utilized to generate 100 random accuracy assessment points, which are then verified in Google Earth Pro to identify the error matrix. The confusion errors are corrected to calculate the Kappa coefficient, allowing for a reliable determination of the LULC classes. This accuracy evaluation supports the validation of the LULC classification map for the study area. Details of the accuracy matrix are presented in Tables 4, 5, and 6.

CONCLUSION

This paper assesses changes in land use and land cover (LU/LC) using a supervised classification method. Geographic information systems and remote sensing techniques are essential tools for mapping and detecting changes in land cover. The primary causes of these changes include deforestation, mining, soil erosion, floods, population growth, and shifting cultivation. Agricultural land results from the conversion of built-up areas, forests, other types of land, rivers/water bodies, and scrubland. The built-up area is derived from the conversion of other types of land and river/water bodies. Forests are converted from agricultural land and built-up areas. Rivers/water bodies are converted to agricultural land, built-up areas, scrubland, and other uses. Scrubland is converted to agricultural land, while other areas include rivers and water bodies. These changes are impacting the watershed, leading to resource degradation and a decline in quality. Recently, environmental degradation has emerged as a critical issue, resulting in the reduction, pollution, and destabilization of our ecosystem. To achieve sustainable development, the conservation of natural resources is essential. Comprehensive watershed management planning and strategies should also be considered to effectively manage, protect, and conserve all resources available within the landscape.

ACKNOWLEDGMENTS

The author expresses gratitude to Nagaland University for the UGC Non-Net fellowship that facilitated the completion of this work, as well as to the supervisor and other individuals who contributed to the collection of field data.

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