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Spatio-Temporal Analysis Of Land Use And Land Cover Changes In Aurangabad (Chh. Sambhajinagar) City, Maharashtra, India (2002–2022) Using Rs And Gis

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ABSTRACT
This study analyzes the changes in land use and land cover (LULC) in Chh. Sambhajinagar city, Maharashtra, India, over 20 years from 2002 to 2022, using Geographical Information Systems (GIS) and remote sensing techniques. The analysis was carried out using Survey of India topographic maps along with satellite data from IRS LISS-III and PAN sensors. Based on field surveys, geographical characteristics, and image interpretation, the study area was classified into eight LULC categories. A comparative assessment revealed a substantial increase in built-up areas, accompanied by a marked decline in agricultural land, water bodies, and dense forest cover. These changes are primarily attributed to rapid urbanization and population growth in the region during the study period.
Keywords: *Land Use, Land Cover, Urbanization, Remote Sensing, GIS, Chh. Sambhajinagar, India, Spatio-Temporal Analysis*

1. INTRODUCTION

Urban environments are undergoing rapid transformations driven by both natural processes and human activities, leading to significant environmental degradation and associated impacts on human health. Understanding changes in LULC is crucial for sustainable planning, efficient utilization of natural resources, and effective environmental management (Bikis et al. 2025; Debele and Beketie 2025; Pushpalatha et al. 2025). Traditional methods such as demographic surveys, censuses, and field-based environmental assessments are often insufficient for addressing complex environmental issues, as they struggle to handle large, multidisciplinary datasets (Alqurashi and Alharbi 2025; Das et al. 2025; Rajkumari and Hussain 2025; Wathore et al. 2025). Advancements in remote sensing and Geographical Information Systems (GIS) have revolutionized the way LULC changes are studied and monitored. Remote sensing provides continuous, up-to-date spatial information, enabling the detection of land surface dynamics over time (Alawode et al. 2025; Roy and Roy 2010; Selmy et al. 2023). When integrated with GIS, these technologies offer powerful tools for capturing, storing, analyzing, and visualizing spatial data, thereby supporting decision-making and development planning (Alqurashi and Alharbi 2025; Mashala et al. 2023; Rane et al. 2023). In recent decades, remote sensing and GIS have been widely applied across various fields, including agriculture, environmental monitoring, and ecosystem assessment. Several researchers have highlighted the importance of LULC studies due to their profound effects on ecological balance, vegetation dynamics, and socio-economic conditions (Arpitha, Harishnaika, and Ahmed 2025; Saleem et al. 2024; Selmy et al. 2023; Seyam, Haque, and Rahman 2023; Tahir et al. 2025). The present study area, Chh. Sambhajinagar, has experienced rapid urbanization and industrialization over the past two decades, accompanied by a significant rise in population. These factors have contributed to extensive land transformation, making it essential to analyze and quantify LULC changes to guide sustainable urban development and resource management (Kayte 2014; Masroor et al. 2022). The LULC maps provide essential information about the earth's surface, including vegetation, water bodies, urban structures, and other natural features. Although the terms LULC are often used interchangeably, they represent distinct concepts. Land cover refers to the physical and biological cover on the earth's surface, such as forests, agricultural fields, water, bare soil, or urban infrastructure. Mapping and identifying land cover are critical for global environmental monitoring, natural resource management, and sustainable planning. It also establishes a baseline for detecting temporal changes and preparing thematic maps (Belay, Melese, and Senamaw 2022; Mishra, Rai, and Rai 2020). In contrast, land use describes the purpose or function for which land is utilized, such as agriculture, settlement, industrial development, or recreational activities. Accurate information on land use is essential for monitoring current patterns and tracking changes over time, which supports effective decision-making in urban and rural planning (Gribb and Czerniak 2015; Mirkatouli, Hosseini, and Neshat 2015; Nedd et al. 2021). Over the years, remote sensing technologies have become indispensable for LULC mapping due to their ability to capture data quickly, cost-effectively, and with high spatial and temporal accuracy (Gülci, Wing, and Akay 2025). When integrated with Geographic Information Systems (GIS), these technologies provide robust tools for analyzing land use patterns, modeling future scenarios, and supporting sustainable development strategies (Chatrabhuj et al. 2024; Darem et al. 2023; Sharma et al. 2024). In the present study, LULC changes were investigated in Chh. Sambhajinagar and parts of Maharashtra, to assess the extent and dynamics of land transformation over two decades. These regions have been experiencing recurrent environmental challenges, including drought, hailstorms, and erratic rainfall, which further emphasize the need for systematic monitoring and resource management. The primary aim of this study is to detect, map, and quantify the LULC changes in the urban area of Chh. Sambhajinagar between 2002 and 2022 using satellite imagery and topographic maps. Specifically, the study focuses on preparing LULC maps for the years 2002 and 2022, quantifying the spatial and temporal changes that have occurred over this two-decade period, and analyzing the patterns and trends of these changes to identify the key driving factors. Furthermore, the research seeks to determine the extent of inter-class transitions between different LULC categories, providing valuable insights for urban planning, environmental management, and sustainable development initiatives in the region.

2. MATERIALS AND METHODS

2.1 Study Area

The study area, Chh. Sambhajinagar city, is a rapidly developing metropolitan region located in the Maharashtra state of India and has been identified as one of the upcoming smart cities under India's urban development initiatives. Geographically, the city lies at approximately 19.88°N latitude and 75.33°E longitude, with an average elevation of 572 meters above sea level and a total area of 123 km^2 (GoI 2012; A. Kale et al. 2020) (Figure 1). Aurangabad named after the Mughal emperor Aurangzeb, serves as the administrative headquarters of the Aurangabad Division and the Marathwada region (Garg et al. 2016). In 2023 state government renames it as Chh. Sambhajinagar. It is popularly known as the "City of Gates" due to its numerous historical gateways and monuments. The city is a major cultural and tourism hub, surrounded by UNESCO World Heritage Sites such as the Ajanta and Ellora Caves and other significant landmarks like the Bibi Ka Maqbara, often referred to as the "Mini Taj Mahal." In recent years, study region has undergone rapid urbanization, industrialization, and population growth, emerging as a key industrial and educational center. It was recently declared the "Tourism Capital of Maharashtra", reflecting its growing economic and cultural importance. By population, it is the fifth-largest city in Maharashtra, following Mumbai, Pune, Nagpur, and Nashik. However, this accelerated urban growth has led to profound transformations in land use patterns, including the expansion of built-up areas, encroachment on agricultural lands, and a decline in natural ecosystems such as forests and water bodies. Chh. Sambhajinagar has a semi-arid climate, characterized by hot summers, mild winters, and erratic monsoons. The region receives an average annual rainfall of 700–800 mm, primarily during the southwest monsoon season (June–September) (Deshmukh and Deshpande 2020; A. B. Kale, Bandela, and Kulkarni 2018; Masroor et al. 2022) However, rainfall distribution is highly variable both spatially and temporally, often leading to droughts and water scarcity. In recent years, hailstorms and unseasonal rains have become increasingly common, adversely impacting agriculture and local livelihoods. These climatic stresses, combined with urban sprawl, have intensified land degradation and the loss of natural vegetation (Ch et al. 2020; Huchhe and Bandela 2024; Khetwani and Singh 2020). The study area is dominated by black cotton soils (regur) with high moisture retention, underlain by Deccan Trap basalt formations, which form important groundwater aquifers. Historically covered with dry deciduous forests and grasslands, the region has undergone extensive land transformation due to agriculture and rapid urbanization, resulting in fragmented vegetation, shrinking water bodies, and expanding built-up areas (Gupta et al. 2011). These changes highlight the urgent need for systematic monitoring and assessment of LULC dynamics. Therefore, Chh. Sambhajinagar and its adjoining areas provide a critical case study for evaluating the spatio-temporal impacts of urbanization on natural resources, offering insights that can guide sustainable urban planning, environmental management, and climate resilience strategies.

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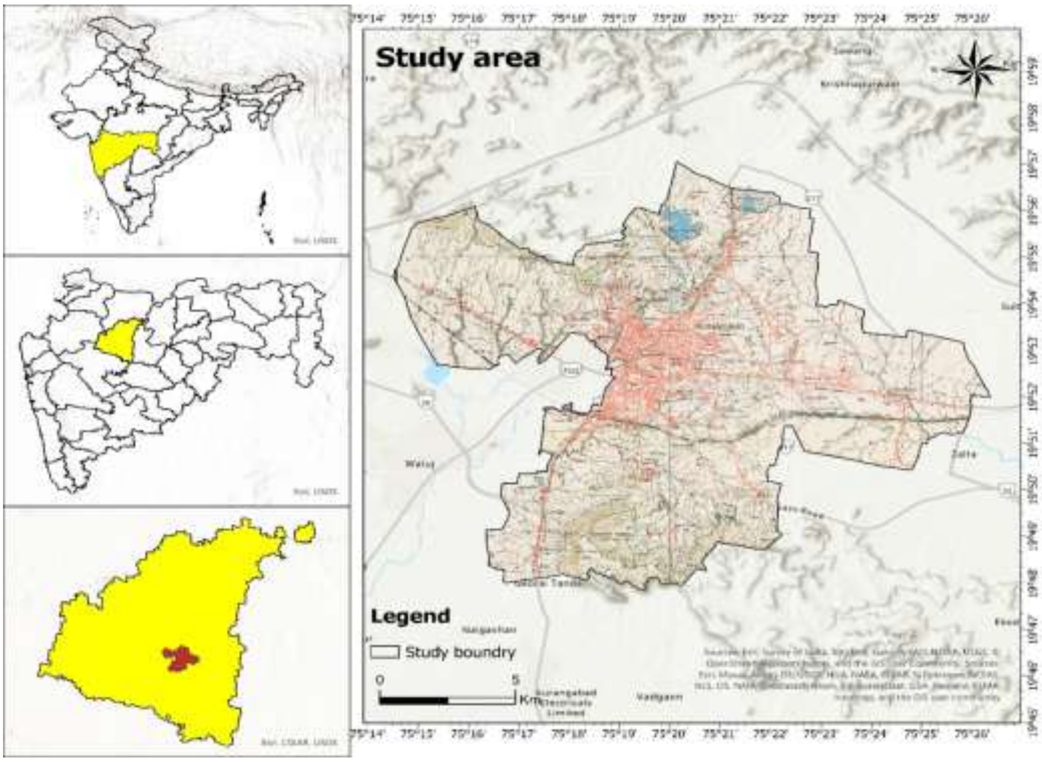

Figure 1. Map showing the spatial location and topographic features of Chhatrapati Sambhajinagar city and surrounding region.

2.2 Data Sources and Image Preprocessing for LULC Mapping and Change Detection

The data used in this study include a digital topographic map from 1976 at a 1:50,000 scale, and satellite imagery from IRS-P6 LISS-III and Landsat 7 ETM+ sensors. These datasets were used to generate LULC maps for the years 2002 and 2022. The base map of the study area was prepared using the Survey of India topographic sheet 46 P/12 at a 1:50,000 scale. Image preprocessing and interpretation were carried out using ERDAS Imagine 2019, a satellite image processing software. A False Color Composite (FCC) was created using the layer stacking option in the spectral toolbox to enhance the visual distinction between various land cover features. The study area was extracted by applying the subsetting tool, and the images were saved as Area of Interest (AOI) files for further analysis. These processed datasets were then used for classification and change detection to assess spatio-temporal changes in LULC (Figure 2).

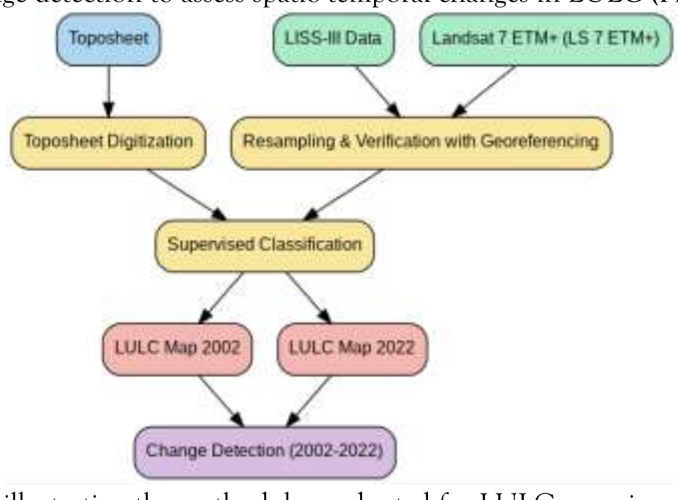

Figure 2. Flowchart illustrating the methodology adopted for LULC mapping and change detection (2002–2022).

3. RESULT & DISCUSSION

3.1 Land Use/Land Cover (LULC) Changes between 2002 and 2022

Figure 3 and Figure 4 depict the spatial distribution of LULC classes for the years 2002 and 2022, respectively, within the Chh. Sambhajinagar urban region. In 2002, the area was predominantly covered by barren land (54.01%), followed by vegetation (31.33%), urban settlements (14.30%), and a very small fraction of water bodies (0.36%) (Table 1). The LULC map for 2002 (Figure 3) clearly shows that most urban settlements were concentrated in the central part of the study area, surrounded by extensive vegetation and agricultural lands. By 2022, significant changes in LULC patterns were observed (Figure 4). The urban area expanded dramatically to 35.68%, showing more than a 2.5-fold increase over two decades. This growth has primarily occurred at the expense of agricultural and vegetated land, which decreased from 31.33% to 19.49%. Barren land also reduced to 43.84%, indicating ongoing land conversion for construction and infrastructure development (Table 1.2). Water bodies showed a slight increase from 0.36% to 0.99%, mainly due to the development of artificial reservoirs and water storage structures.

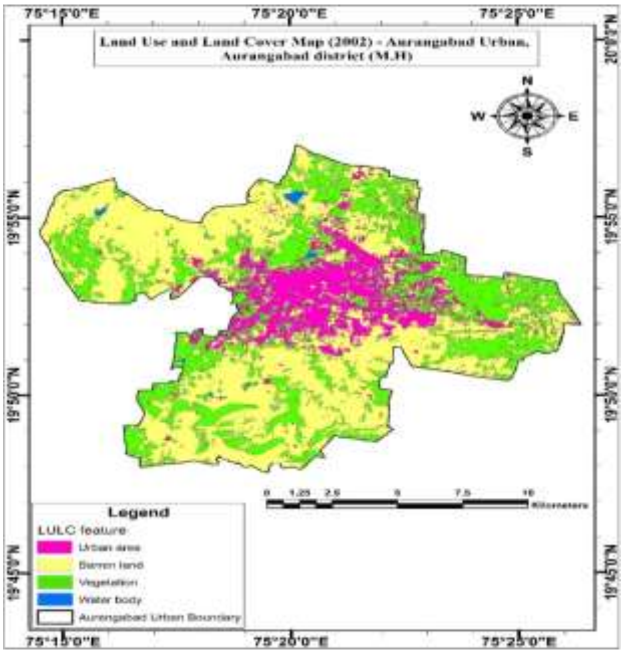

Figure 3. LULC map of Chh. Sambhajinagar urban area for the year 2002.

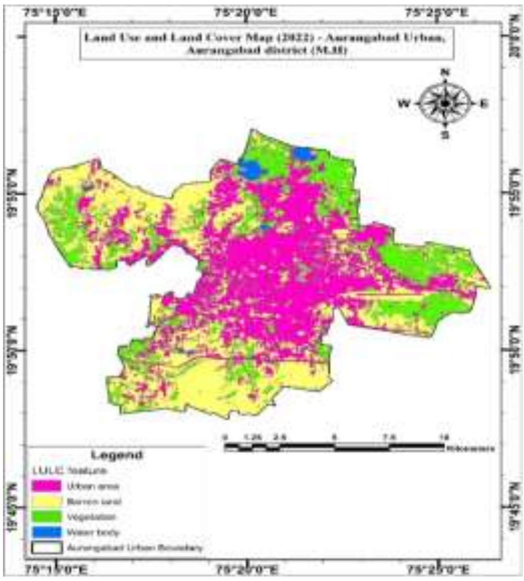

Figure 4. LULC map of Chh. Sambhajinagar urban area for the year 2022.

Table 1. LULC classification, percentage distribution, and inter-class transitions for Chh. Sambhajinagar urban area between 2002 and 2022

FID	LULC_2002	Area_2002	Percentage of area	LULC_2022	Area_2022	Percentage of area
0	**Barren land**	96.8	54.0	**Barren land**	78.6	43.8
1	**Urban area**	25.7	14.3	**Urban area**	64.0	35.7
2	**Vegetation**	56.2	31.3	**Vegetation**	35.0	19.5
3	**Water body**	0.7	0.4	**Water body**	1.8	1.0

	Total	179.3	100.0	**Total**	179.3	100.0

The Digital Elevation Model (DEM) in Figure 5 shows the elevation profile of the Chh. Sambhajinagar urban area, ranging from 528 m to 849 m above sea level. Urban expansion is largely concentrated in low-lying regions, which are more accessible and favorable for development, while elevated areas remain less developed, retaining some natural vegetation cover.

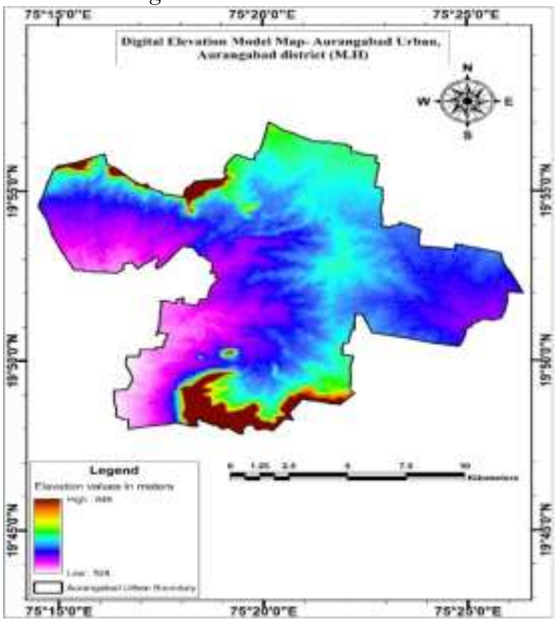

Figure 5. Digital Elevation Model (DEM) of Chh. Sambhajinagar urban area showing elevation variation.

3.2 Change Detection Analysis (2002–2022)

Table *2* presents the inter-class transitions of LULC in Chh. Sambhajinagar urban area between 2002 and 2022. The analysis highlights significant transformations driven by rapid urbanization, agricultural decline, and environmental pressures over the two-decade study period. The most notable transition occurred from barren land to urban area, covering 32.57 km², indicating rapid infrastructure development and expansion of settlements. A considerable portion of vegetated land (9.75 km²) was also converted to urban land, reflecting the encroachment of built-up areas into green and agricultural zones. This transition emphasizes the direct impact of population growth and industrialization on natural land resources. Vegetated areas experienced a net loss, with 20.29 km² shifting to barren land, suggesting degradation of agricultural fields and deforestation caused by unsustainable land practices and climatic factors such as drought. Only 25.58 km² of vegetation remained stable throughout the period, indicating limited conservation of green spaces. Water bodies showed a slight increase in overall area, with 0.67 km² of barren land and 0.14 km² of urban land being converted into water-covered regions. This positive change is likely due to the construction of artificial reservoirs or water management projects. However, some water bodies were also lost, with 0.04 km² converted to barren land and 0.06 km² to urban use, reflecting encroachment and pollution. The urban area remained relatively stable in its core, with 21.57 km² of land consistently classified as urban in both years, indicating densification rather than outward sprawl in certain central parts of the city.

Table 2. Change detection matrix showing inter-class transitions of LULC between 2002 and 2022 in Chh. Sambhajinagar urban area.

FID	FID_Diss_1	LULC_2002	Area_2002	FID_Diss_1	LULC_2022	Area 2022	Change name	Area change
0	0	Barren land	96.8	0	Barren land	78.6	Barren land-Barren land	55.36
1	0	Barren land	96.8	1	Urban area	64.0	Barren land-Urban area	32.57
2	0	Barren land	96.8	2	Vegetation	35.0	Barren land-Vegetation	8.16
3	0	Barren	96.8	3	Water	1.8	Barren land-	0.67

		land			body		Water body	
4	1	Urban area	25.7	0	Barren land	78.6	Urban area-Barren land	2.85
5	1	Urban area	25.7	1	Urban area	64.0	Urban area-Urban area	21.57
6	1	Urban area	25.7	2	Vegetation	35.0	Urban area-Vegetation	1.09
7	1	Urban area	25.7	3	Water body	1.8	Urban area-Water body	0.14
8	2	Vegetation	56.2	0	Barren land	78.6	Vegetation-Barren land	20.29
9	2	Vegetation	56.2	1	Urban area	64.0	Vegetation-Urban area	9.75
10	2	Vegetation	56.2	2	Vegetation	35.0	Vegetation-Vegetation	25.58
11	2	Vegetation	56.2	3	Water body	1.8	Vegetation-Water body	0.47
12	3	Water body	0.7	0	Barren land	78.6	Water body-Barren land	0.04
13	3	Water body	0.7	1	Urban area	64.0	Water body-Urban area	0.06
14	3	Water body	0.7	2	Vegetation	35.0	Water body-Vegetation	0.07
15	3	Water body	0.7	3	Water body	1.8	Water body-Water body	0.49

The findings from Table 2 highlight the rapid urbanization and land transformation that occurred between 2002 and 2022. The most significant change is the conversion of 32.57 km² of barren land to urban area, indicating large-scale infrastructure development driven by population growth and industrialization. Additionally, 9.75 km² of vegetated land transitioned to urban use, reflecting the steady encroachment of settlements into agricultural and forested areas. This pattern demonstrates the intense pressure on natural resources caused by expanding urban boundaries. Vegetation experienced a substantial net loss, with 20.29 km² converted to barren land, a clear sign of deforestation, agricultural land degradation, and the impacts of recurring droughts in the region. Only 25.58 km² of vegetated land remained stable during the study period, emphasizing the urgent need for conservation strategies to protect the remaining green spaces. Water bodies showed a slight overall increase, with 0.67 km² of barren land and 0.14 km² of urban land converted into water-covered areas, likely due to the creation of artificial reservoirs and water management initiatives. However, there were localized losses where 0.04 km² of water bodies became barren land and 0.06 km² were converted to urban uses, indicating encroachment and pollution of natural water sources. Interestingly, 21.57 km² of urban land remained classified as urban throughout the two decades, demonstrating core urban densification, where the population increased within existing built-up areas rather than only outward sprawl. This densification highlights the dual nature of urban growth in Chh. Sambhajinagar—both vertical expansion and horizontal sprawl.

3.3 Image Classification

The classification of LULC maps was performed using a supervised classification method in ERDAS Imagine 2013. Training sets (signatures) were created for known land cover types, including water bodies, built-up areas, vegetation, agricultural land, and wasteland. Each pixel in the imagery was compared with these training signatures and assigned to the most probable class, while pixels that did not match any category were grouped as unclassified. To ensure accuracy, ground truth verification was conducted, and misclassified pixels were corrected using the Recode tool. The final classification identified five major LULC classes:

a) Water bodies
b) Agricultural land
c) Built-up area

d) Fallow/non-agricultural land
e) Grassland/wasteland

This step was essential for ensuring reliable change detection analysis, providing a consistent baseline for comparing land cover changes between the two time periods (2002 and 2022).

3.4 Change Detection Analysis

Change detection was carried out to quantify and interpret temporal changes in LULC between 2002 and 2022. Using cross-tabulation in ERDAS Imagine 2013, a change matrix was produced to identify gains, losses, and inter-class transitions across different land cover categories.

The results revealed clear patterns of urban expansion, significant vegetation loss, and slight improvement in water resources. The substantial increase in built-up areas corresponds to population growth and economic development, while the sharp decline in vegetation reflects environmental degradation and the loss of ecosystem services. These findings are crucial for urban planners, policymakers, and environmental managers, providing actionable insights for designing sustainable development strategies.

3.5 Environmental Implications

The rapid conversion of vegetation and agricultural land to urban areas has significant environmental and socio-economic consequences, including:

- Reduction in groundwater recharge due to impervious surfaces replacing natural, permeable landscapes.
- Loss of biodiversity and green cover, which increases vulnerability to climate change impacts.
- Higher risk of urban flooding, as low-lying areas become densely populated and natural drainage systems are disrupted.
- Urban heat island effects, caused by the concentration of concrete and built-up surfaces.

Although there has been a slight increase in water bodies, largely due to artificial reservoirs and conservation initiatives, these efforts are insufficient given the growing water demand in this semi-arid region. Immediate policy interventions are necessary to strike a balance between urban growth and environmental sustainability, ensuring that future development does not compromise ecological health.

4 CONCLUSION

This study analyzed the spatio-temporal dynamics of LULC in Chh. Sambhajinagar urban area between 2002 and 2022 using remote sensing and GIS technologies. The results clearly demonstrate substantial transformation in land cover patterns over the two decades. The built-up area increased dramatically (from 14.30% to 35.68%), primarily at the expense of vegetation and agricultural lands, which declined sharply during the same period. A slight increase in water bodies was observed, attributed to artificial reservoirs and water management initiatives, though these efforts remain insufficient to meet the region's growing demand. The change detection analysis revealed that the most significant transition was the conversion of barren land to urban area, covering 32.57 km^2, followed by the conversion of vegetation to urban use (9.75 km^2). These trends highlight the rapid pace of urbanization and its direct impact on natural resources. This research confirms that integrating GIS and remote sensing techniques provides a reliable, cost-effective approach for monitoring urban growth and environmental change. The findings are valuable for urban planners, environmental managers, and policymakers, offering crucial insights for sustainable development strategies. Immediate policy interventions are needed to control unplanned urban expansion, conserve remaining green spaces, and manage water resources effectively. By quantifying and mapping LULC changes, this study contributes to a better understanding of how rapid urbanization affects ecological balance. It underscores the need for sustainable urban planning, particularly in semi-arid regions like Chh. Sambhajinagar, where natural resources are highly vulnerable to human-induced pressures.

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