

Research Article

Land Use/Land Cover Change Detection Analysis Using Remote Sensing and GIS of Jaipur District, India

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Abstract

Rapid urbanization is reshaping land use and land cover (LULC) across many Indian cities and complicates sustainable urban planning. Jaipur, one of the fastest-growing cities of Rajasthan, has expanded considerably over recent decades, altering both its natural and built environments. This study examines the spatio-temporal pattern of LULC change in the Jaipur urbanizable area using multi-temporal Landsat imagery. Images from 2000, 2009 and 2017 were classified with a supervised Maximum Likelihood algorithm into six classes: built-up area, bare soil/fallow land, agricultural cropped land, natural vegetation, water body, and bare rock/hill surface. Change was then quantified through post-classification comparison, change matrices and dynamic degree. Between 2000 and 2017, built-up area more than doubled (+111.86%) and bare soil/fallow land rose by 45.48%, while agricultural cropped land and natural vegetation fell by 57.65% and 32.41%, respectively, pointing to rapid urban sprawl and land transformation. Classification accuracy was assessed using confusion matrices, overall accuracy and the Kappa statistic based on GPS field data. The results underline the need for sustainable urban development strategies and effective land management policies to curb the environmental impacts of unregulated growth in Jaipur. The study shows that remote sensing combined with GIS is a dependable means of monitoring urban LULC change and offers useful guidance for planners and policymakers.

Keyword

Land Use/Land Cover, Urbanization, Jaipur, Remote Sensing, GIS, Change Detection, Maximum Likelihood Classification, Urban Sprawl, Sustainable Development

1. Introduction

Land is the foundation of human life and sustains the activities on which survival and development depend [1]. Population growth and rising human activity have increased the pressure on this finite resource from agriculture, forestry, grazing, urban expansion and industry. When land is used carelessly or unsustainably, the consequences include unplanned urban growth, environmental degradation and the loss of productive farmland. Understanding land resources, and above all their

use and cover, is therefore essential for sound planning, management and regulation [2].

The LULC pattern of an area is the outcome of natural and socio-economic processes acting together over space and time (Opeyemi, 2006). The terms “land use” and “land cover” are often used as synonyms, but they describe different, closely linked ideas: land cover refers to the physical material present on the Earth’s surface, whereas land use refers to the human

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activities carried out on it [3].

LULC is never static, because natural processes and human interventions continually modify the Earth's surface. Change is driven by interacting socio-economic and biophysical factors such as economic growth, technological progress, demographic pressure and policy decisions. Studying LULC dynamics is therefore valuable: it supplies key inputs to agricultural, hydrological and ecological models and underpins sustainable development, land-use planning and natural resource management [4].

Measuring the trend, rate and magnitude of LULC change is nevertheless difficult, because change varies in space and time. Reliable knowledge of current LULC patterns, together with the ability to track how they evolve, is needed to use land optimally and to provide trustworthy data for predictive and simulation models.

Remote sensing technology has transformed LULC research since the 1980s. Earlier work relied mainly on conventional surveys and field observation, which were restricted to small, accessible areas and were expensive and slow, particularly for large urban regions [5]. Satellite remote sensing, by contrast, offers repeated coverage in digital form that can be processed efficiently within a Geographic Information System (GIS). This combination allows LULC change, and its relationship with population growth and other factors, to be detected and monitored more accurately.

Satellite images describe land use and land cover through the spectral signature of each pixel, that is, the type and amount of solar radiation reflected from the surface features it covers [6]. Visual and digital classification techniques applied within a GIS interpret these signatures and assign each pixel to an LULC category. Satellite data therefore provide a powerful means of analyzing LULC patterns and how they change over time.

This study analyzes the dynamics of LULC change in multi-temporal satellite images using GIS and remote sensing techniques. It maps and evaluates the LULC status of the Jaipur metropolitan region, with particular attention to the rate of land consumption and the growth of built-up area [7].

2. Study Area

This study focuses on Jaipur, the capital and largest city of Rajasthan, which lies in the eastern part of the state. Jaipur district is bordered by Sikar to the northwest, Alwar to the north and northeast, Dausa to the east, Tonk to the south, Ajmer to the southwest and Nagaur to the west. The study area is the Urbanizable Area (U1) of the Jaipur Development Authority (JDA) region, as defined in the Jaipur Master Plan–2025. Urban studies are usually limited to the Jaipur Municipal Corporation (JMC) boundary, but U1 was chosen here because the urban agglomeration now extends well beyond the municipal limits, and most recent LULC change is taking place in that outer zone [8].

The Jaipur urbanizable area spans roughly 945 km² and, according to the Master Development Plan–2025 (JDA), comprises 351 revenue villages within the municipal corporation territory. They are spread across several tehsils: Jaipur (117), Sanganer (162), Amber (40), Jamwa Ramgarh (14), Bassi (2), Phagi (11) and Chaksu (5). The region lies between latitudes 26°39'38.26" N and 27°04'67.66" N and between longitudes 75°36'36.59" E and 75°57'25.10" E. The Government of Rajasthan declared it a "Metropolitan Area" on 10 September 2010. Besides Jaipur city, the area includes surrounding towns, namely Renwal, Roopwas, Muhana, Ramchandrapura, Goner, Kalwar, Bindayaka, Bhankrota, Bilwa and Sinwae, which together add to the growing urban landscape.

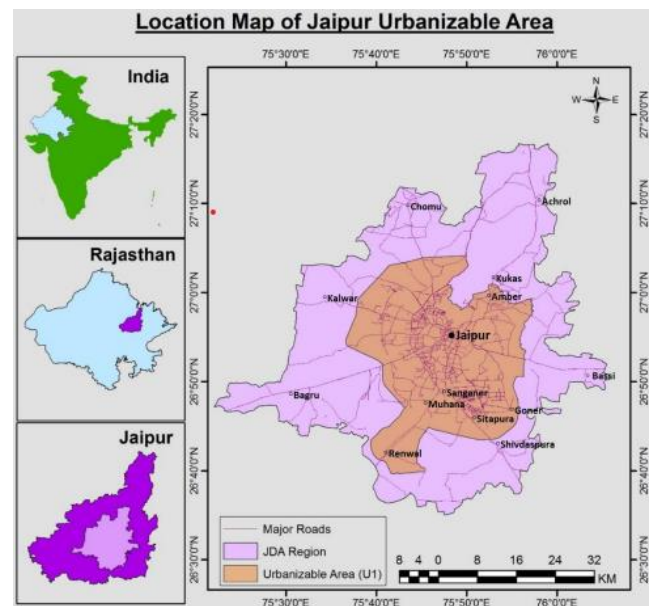


Figure 1. Location Map Of The Study Area.

3. Materials and Methods

Mapping LULC classes accurately from satellite imagery in a GIS environment is difficult because of mixed pixels, similar spectral responses among different surface features, and large areas of highly uniform cover [9]. To overcome these problems, LULC classes were identified by applying a supervised Maximum Likelihood Classification algorithm to radiometrically corrected Landsat land surface reflectance imagery [10].

Because LULC patterns vary unevenly in both space and time, studying their change requires time-series LULC datasets built from satellite images acquired on different dates. Images were selected mainly for low cloud cover (preferably below 10%) and for similar acquisition dates, which limits the effects of seasonal differences, sun angle, vegetation phenology and cropping patterns [11].

Three high-quality land surface reflectance images with suitable spatial and radiometric resolution were chosen to map and analyze LULC dynamics: one each from Landsat 5 TM,

Landsat 7 ETM+ and Landsat 8 OLI. They were downloaded as L1TP land surface reflectance products in GeoTIFF format from the USGS Earth Explorer portal (<http://earthexplorer.usgs.gov>).

In addition, a Digital Elevation Model (DEM) derived from Cartosat-1 stereo data supplied by the National Remote Sens-

ing Centre (NRSC), ISRO, was used to represent the topography of the region. The DEM was obtained in GeoTIFF format from the Bhuvan portal (<http://bhuvan-noeda.nrsc.gov.in>), uses geographic latitude–longitude coordinates at a 1 arc-second (~30 m) spatial resolution and is referenced to the WGS84 geoid [7]. This dataset served as the elevation reference for the study area.

Table 1. List Of Satellite Images Used For Land Cover Change Study And Their Specifications.

S No	Landsat Scene Identifier	WRS Path/Row	Sensor Identifier	Date Acquired	Image Quality	Scene Cloud Cover
1	LC81470412017055LGN00	147/041	OLI_TIRS	24/02/2017	9	0.01
2	LT51470412009033KHC00	147/041	5_TM	02/02/2009	9	0
3	LE71470412000049SGS00	147/041	7_ETM	18/02/2000	9	0

4. Change Detection

Understanding how land use and land cover change over time is essential for using land resources effectively and sustainably. Change detection in this study used multi-date satellite imagery [12]. A single-date image shows LULC only at one moment, whereas multi-date imagery allows conditions at different times to be compared and so reveals spatio-temporal change [13].

Following the framework of Macleod and Congalton (1998), four aspects of LULC change were examined:

- 1) Detecting whether change has occurred.
- 2) Measuring the areal extent of change.
- 3) Assessing the spatial pattern of change.
- 4) Identifying the nature and type of change.

The steps followed to map land cover and analyze its dynamics were as follows:

- 1) Delineating the boundary of the Urbanizable Area (U1) in ArcGIS and QGIS using SOI toposheets and the JDA Master Plan–2025.
- 2) Pre-processing the images: orthorectification (WGS84, UTM Zone 43), radiometric correction, and subsetting/mosaicking.
- 3) Choosing a suitable LULC classification scheme.
- 4) Supervised classification with the Maximum Likelihood algorithm, supported by visual interpretation and reference data.
- 5) Refining the classification with spectral indices (e.g., NDVI, NDWI) and thematic masks.
- 6) Validating on the ground and assessing accuracy with confusion matrices, overall accuracy and Kappa statistics based on GPS field data.
- 7) Comparing the classified maps after classification and detecting change with change matrices.

8) Analyzing the type and spatial pattern of LULC change.

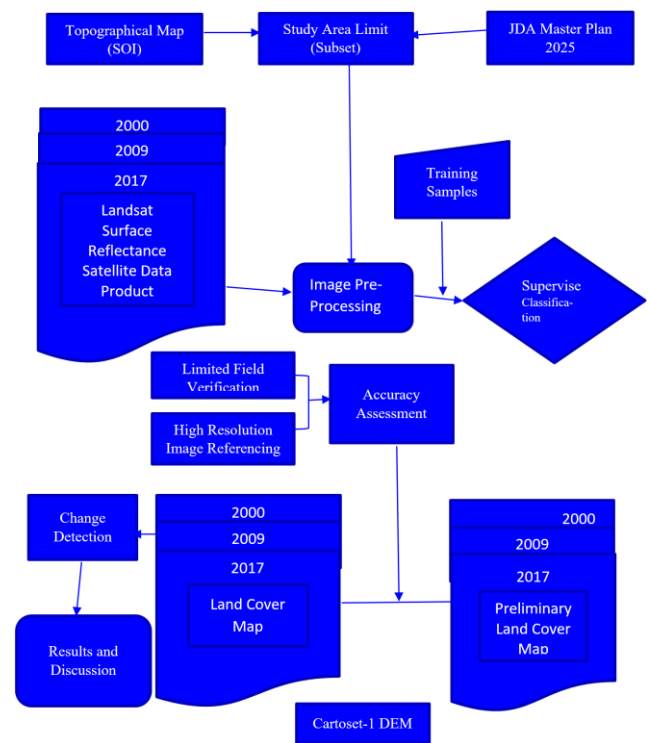


Figure 2. Flow chart of methodology for land use/land cover classification and change detection process.

5. Results and Discussion

LULC change detection results can be quantified in several ways. A basic approach is to tabulate the total change for each LULC class and examine how it trends over time [14].

LULC change was analyzed for 2000–2017 using an integrated remote sensing and GIS approach. The classified maps

for 2000, 2009 and 2017 appear in Figure 3, and Table 2 summarizes the classification results for the three years [15].

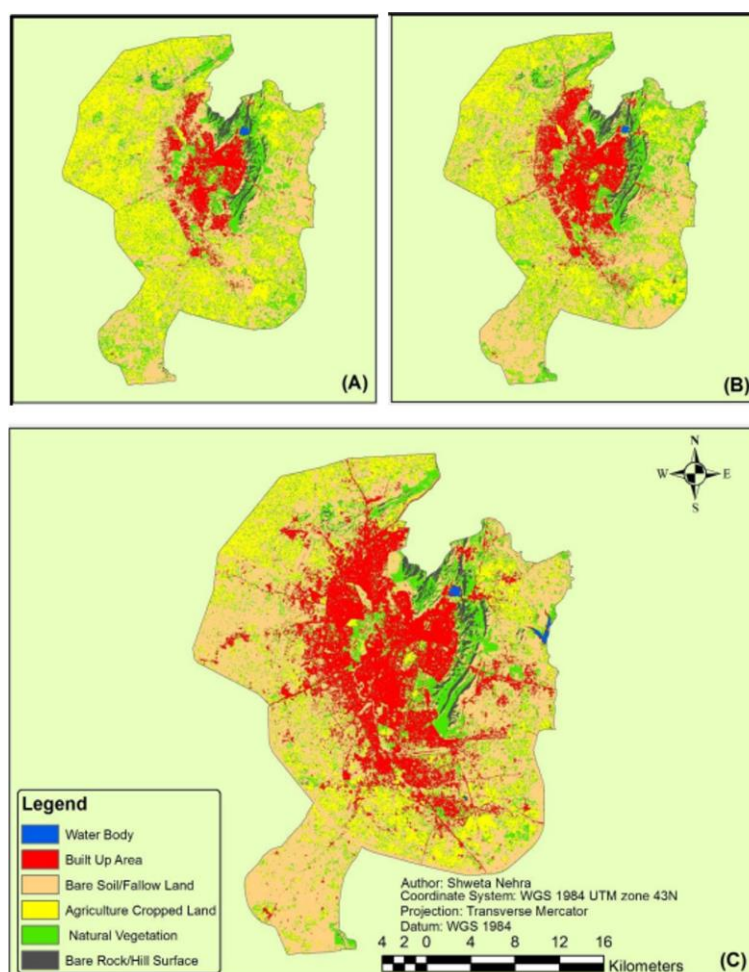


Figure 3. Comparison of classified map of the Jaipur urbanizable area obtained from different surface reflectance datasets (A) Landsat 7 ETM+, 2000 (B) Landsat 5 TM, 2009 and (C) Landsat 8 OLI, 2017.

Table 2. Area Statistics And Percentage Of The Land Use/Land Cover Classes For 2000, 2009 And 2017.

S No.	Land Cover	Year								
		2000			2009			2017		
		No. of Pixel	Area (Sq. Km)	Area (%)	No. of Pixel	Area (Sq. Km)	Area (%)	No. of Pixel	Area (Sq. Km)	Area (%)
1	Water Body	1417	1.28	0.13	1276	1.15	0.12	2082	1.87	0.20
2	Built Up Area	96770	87.09	9.21	130983	117.88	12.47	205019	184.52	19.52
3	Bare Soil/ Fallow Land	352235	317.01	33.54	430269	387.24	40.97	512428	461.19	48.79
4	Agriculture Cropped Land	326205	293.58	31.06	229046	206.14	21.81	138158	124.34	13.16
5	Natural Vegetation	245768	221.19	23.40	230281	207.25	21.93	166114	149.50	15.82
6	Bare Rock/ Hill Surface	25808	23.23	2.46	26339	23.71	2.51	24385	21.95	2.32
Total		1050203	945.18	100.00	1050203	945.18	100.00	1050203	945.18	100.00

LULC changed markedly over the 17-year period. Comparing the classes shows that built-up area and bare soil/fallow land grew substantially, while agricultural cropped land and natural vegetation declined sharply [16]. The other two classes, water body and bare rock/hill surface, varied only slightly.

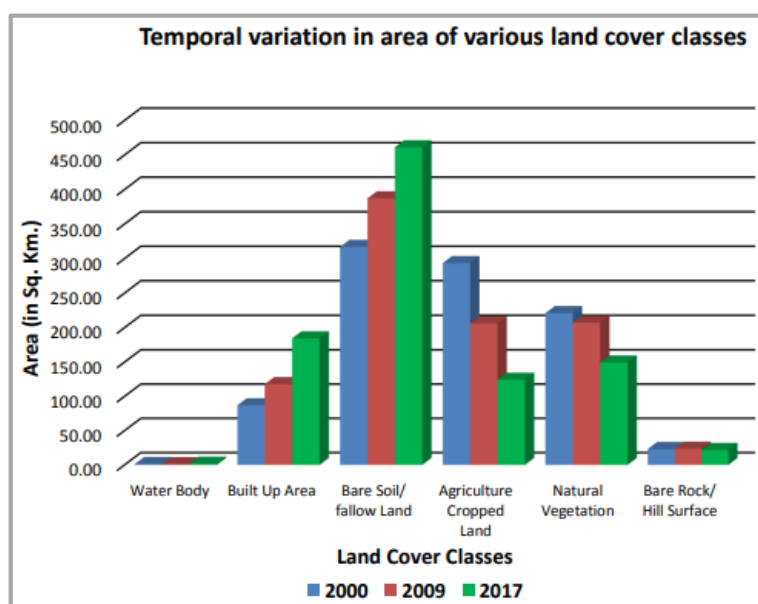


Figure 4. Temporal variation in area of various land use/ land cover classes in the study area.

Agricultural cropped land declined steadily, from 31.06% of the area in 2000 to 21.81% in 2009 and only 13.16% in 2017. Natural vegetation followed the same downward path, falling from 23.40% to 21.93% and then to 15.82%. Exposed rock/hill surface rose slightly from 2.46% to 2.51% between 2000 and 2009 and then dipped marginally to 2.32% in 2017 [17].

Water bodies, the smallest class in the region, changed little: they dipped from 0.13% to 0.12% between 2000 and 2009 and then rose to 0.20% of the total area in 2017.

6. Land Use/Land Cover Change

Water area decreased between 2000 and 2009 (percentage change -9.95%), owing to the continued shrinking of Mansagar Lake on the northeastern outskirts of the city [18]. From 2009 onward it grew, with a percentage change of $+63.17\%$, because a new reservoir was built near Mukandpura in the eastern part of the study area. Over the whole study period, the water body class grew by 46.93% , at a dynamic degree of 2.76 per annum (Chunxiao, Zhiming, and Nan 2000).

Table 3. LULC changes and dynamic degrees within the study area for the time span 2000-2009.

LULC Class	Area in km ²		Change in Area (km ²)	Percentage Change	Dynamic degree
	2000	2009			
Water Body	1.3	1.1	-0.1	-9.95	-1.11
Built Up Area	87.1	117.9	30.8	35.35	3.93
Bare Soil/fallow Land	317.0	387.2	70.2	22.15	2.46
Agriculture Cropped Land	293.6	206.1	-87.4	-29.78	-3.31
Natural Vegetation	221.2	207.3	-13.9	-6.30	-0.70
Bare Rock/Hill Surface	23.2	23.7	0.5	2.06	0.23

Table 4. LULC changes and dynamic degree within the study area for the time span 2009-2017.

LULC Class	Area in km ²		Change in Area (km ²)	Percentage Change	Dynamic degree
	2009	2017			
Water Body	1.1	1.9	0.7	63.17	7.90
Built Up Area	117.9	184.5	66.6	56.52	7.07
Bare Soil/fallow Land	387.2	461.2	73.9	19.09	2.39
Agriculture Cropped Land	206.1	124.3	-81.8	-39.68	-4.96
Natural Vegetation	207.3	149.5	-57.8	-27.86	-3.48
Bare Rock/Hill Surface	23.7	21.9	-1.8	-7.42	-0.93

Table 5. LULC changes and dynamic degree within the study area for the time span 2000-2017.

LULC Class	Area in km ²		Change in Area (km ²)	Percentage Change	Dynamic degree
	2000	2017			
Water Body	1.3	1.9	0.6	46.93	2.76
Built Up Area	87.1	184.5	97.4	111.86	6.58
Bare Soil/fallow Land	317.0	461.2	144.2	45.48	2.68
Agriculture Cropped Land	293.6	124.3	-169.2	-57.65	-3.39
Natural Vegetation	221.2	149.5	-71.7	-32.41	-1.91
Bare Rock/Hill Surface	23.2	21.9	-1.3	-5.51	-0.32

Built-up area grew by 35.35% between 2000 and 2009 and by 56.53% between 2009 and 2017, giving a cumulative increase of 111.86% over the 17 years [19].

This growth in built-up cover confirms that human activity is often the main driver of land cover change in the region [20]. It is also positively associated with population growth, which rose by almost the same proportion (118%) over the study period (Banthia 2001; Directorate of Census Operations-Rajasthan 2001; Master Development Plan-2025 JDA, n.d.), indicating that demographic factors play a major part in built-up expansion.

7. Spatial Analysis of Land Use/Land Cover Change

A central aim of change detection is to identify transitions between LULC classes, that is, which classes have turned into which. Post-classification comparison was carried out here by overlaying the 2000 and 2017 classified images pixel by pixel (Singh, 1989), which identifies the LULC type of every pixel at both dates [21].

A “from-to” change matrix was produced to quantify the nature and extent of the transformations: diagonal cells represent classes that did not change, and off-diagonal cells represent transitions between classes. The largest changes involved bare soil/fallow land, agricultural land and natural vegetation.

Water bodies grew from 1.3 km² to about 1.9 km², a net gain of roughly 0.6 km², mainly from bare soil/fallow land, with some loss to built-up area. Built-up area expanded by 97 km² between 2000 and 2017, mostly at the expense of bare soil/fallow land (58 km²), natural vegetation (24 km²) and agricultural land (15 km²). Small reverse transitions from built-up land to other classes were also found, probably owing to classification errors or spectral mixing in fringe areas [22].

Bare soil/fallow land was the dominant LULC class in the Jaipur urbanizable region (U1) throughout the study period. Between 2000 and 2017 it received about 153 km² from agricultural land and 104 km² from natural vegetation, while losing 58 km² to built-up area and 31 km² to natural vegetation. This points to a clear sequence of transitions from agriculture to bare soil/fallow land and then to built-up area, together with local exchange between bare soil and natural vegetation [3].

Agricultural land declined substantially: only 124 km² of

the original 294 km² remained in 2017, a net loss of 169.2 km². Natural vegetation also lost a net 72 km², mainly through conversion to bare soil and built-up land, although it received limited gains from agricultural and fallow land [5].

Bare rock/hill surface stayed largely stable during the study period, with only minor change.

Table 6. Cross-Tabulation “From - To” Change Matrix Showing Land Cover Change Between 2000 And 2017.

Land Cover Class - 2000	Land Cover Class - 2017						Grand Total
	Water Body	Built Up Area	Bare Soil/ Fallow Land	Agriculture Cropped Land	Natural Vegetation	Bare Rock/ Hill Surface	
Water Body	60.83%	20.47%	6.00%	3.81%	7.62%	1.27%	100.00%
Built Up Area	0.02%	90.54%	6.01%	0.22%	2.65%	0.57%	100.00%
Bare Soil/ Fallow Land	0.22%	22.84%	62.57%	5.18%	9.08%	0.12%	100.00%
Agriculture Cropped Land	0.04%	5.75%	52.94%	30.14%	11.11%	0.02%	100.00%
Natural Vegetation	0.12%	12.41%	38.97%	9.37%	38.04%	1.09%	100.00%
Bare Rock/ Hill Surface	0.13%	2.76%	3.79%	0.81%	12.63%	79.87%	100.00%
% of the Total area in 2017	0.20%	19.52%	48.79%	13.16%	15.82%	2.32%	100.00%

The spatial distribution of LULC change in the Jaipur urbanizable area (U1) differs markedly between regions: change was greatest in the western part and more moderate in the eastern and southern parts [23].

Little or no change occurred in the northern, mid-eastern

and extreme southern parts. The greatest change involved agricultural cropped land and bare soil/fallow land, whereas areas that were already built up and the hilly terrain showed little or no change between 2000 and 2017.

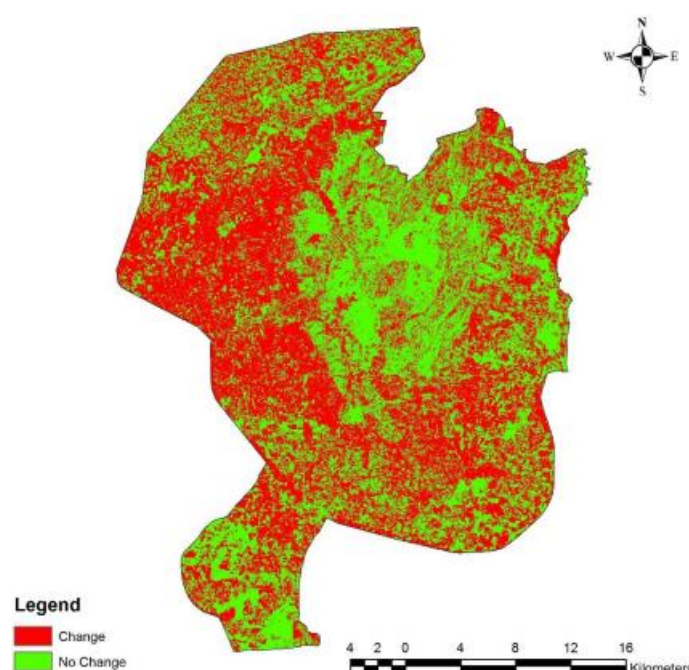


Figure 5. The spatial distribution of change occurred in land use/land cover of Jaipur Urbanizable Area (U1) from 2000 to 2017.

8. Conclusions

Remote sensing data were used to analyze the spatio-temporal changes in land use and land cover within the Jaipur urbanizable area. The study shows that satellite remote sensing delivers accurate and timely geospatial information for monitoring LULC dynamics in metropolitan areas [24]. The thematic maps produced indicate that combining supervised classification of Landsat land surface reflectance data with visual interpretation is an effective way to document LULC change.

Multi-temporal imagery from 2000, 2009 and 2017, analyzed in a GIS platform, shows rapid growth of both bare soil/fallow land and urban built-up area. The quantitative results give annual increases of +6.58% for built-up area and +2.68% for bare soil/fallow land, while cultivated agricultural land declined at an average of -3.39% per year. The most prominent transformation was the conversion of agricultural land into bare soil/fallow land and its subsequent change into built-up area. This trend is likely to persist given accelerating infrastructure development, tourism growth and population increase [25].

Urban expansion has been strongest on the western side of Jaipur, though recent growth is also visible in the northern, southern and southeastern sectors. More than 60% of the growth followed an extension pattern, whereas infill development was concentrated in the central and eastern parts of the city. Infilling has intensified in the urban core over time, leaving little developable land in central Jaipur [26].

The findings can help planners, policymakers and local authorities to improve land-use policy, anticipate infrastructure demand, identify future development hotspots and formulate sustainable regional development strategies. By combining change detection with spatial metrics, the study lays a firm foundation for future work on modeling and predicting urban growth. It also documents the substantial loss of natural vegetation and agricultural land to urbanization, which highlights the environmental cost of urban expansion and can raise public and policy awareness [27].

9. Scope for Future Work

Between 2000 and 2017, Jaipur's urban growth spread in all directions and added about 97 km² of built-up area, largely at the expense of natural vegetation, fertile agricultural land and bare soil. The environmental character of the urbanizable area has therefore changed substantially over 17 years, with major losses of productive cropland and natural ecosystems. To limit the adverse environmental effects of rapid urbanization, the present pattern of expansion should be regulated through effective land-use planning and management, which is also needed to prevent further land degradation and protect the remaining agricultural land.

The LULC information generated here can help researchers build robust urban growth models for the region, and planners,

policymakers and local authorities can use it to guide decisions and prepare for future urban development.

Future research should combine datasets of high spectral, spatial and temporal resolution with GIS and remote sensing techniques. Next-generation LiDAR and microwave satellite data can be used to build highly detailed Digital Surface Models (DSMs) and Digital City Models, improving the accuracy of change detection.

Further studies should also develop urban LULC models that incorporate socio-economic, ecological and geospatial factors to forecast future land-use patterns, with particular attention to the environmental consequences of urban expansion, such as land degradation and resource stress. Future work could also characterize urban volume and vertical growth, which optical remote sensing alone cannot capture effectively.

Abbreviations

DEM	Digital Elevation Model
DSM	Digital Surface Model
ETM+	Enhanced Thematic Mapper Plus
GIS	Geographic Information System
GPS	Global Positioning System
ISRO	Indian Space Research Organisation
JDA	Jaipur Development Authority
JMC	Jaipur Municipal Corporation
L1TP	Level-1 Precision and Terrain
LiDAR	Light Detection and Ranging
LULC	Land Use/Land Cover
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NRSC	National Remote Sensing Centre
OLI	Operational Land Imager
SOI	Survey of India
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
U1	Urbanizable Area of the JDA region
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
WRS	Worldwide Reference System

Author Contributions

Anshu Jain: Conceptualization, Formal Analysis, Resources, Writing – review & editing

Shailendra Jain: Data curation, Methodology, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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