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Mapping Urban Land Transformation in Dehradun City, Uttarakhand, India (2001-2025): A Remote Sensing and Land Transformation Analysis

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Abstract: ***The modern world is the absolute example of an urbanized world. The pace of urbanization keeps on constantly varying the physical dimension of an urban area, changing the spatial distribution of its built-up area, green cover and various other land use classes. The present research examines the transformation in the urban land use pattern in Dehradun city, Uttarakhand, from 2001 to 2025, using multi-temporal satellite data and remote sensing as well as GIS technology. Landsat satellite data acquired from USGS (earthexplorer.usgs.gov), was used to prepare LULC maps for two study years. The LULC classes were categorised as built-up area, agriculture, Barren Land and vegetation. The results indicate an increase in built-up area from 63.0675 km^2 in 2001 to 112.5495 km^2 in 2025, whereas the vegetated area declined from 67.73 km^2 in 2001 to 38.103 km^2 in 2025. The kappa coefficient of 0.81 for 2001 and 0.88 for 2025 shows the reliability of the generated LULC maps. The Land transformation matrix quantifies the class-to-class transitions. The findings provide a geospatial foundation for comprehending the transforming land cover of Dehradun city over the study period and contributes to proper urban land use planning.***

Keywords: Urban Land Transformation, LULC, Land Transformation Matrix, GIS, Dehradun city

1. Introduction

The Urban Population all over the world has increased expeditiously from 751 million in 1950 to 4.2 billion in 2018(United Nations, 2025). The rate at which urban areas are growing swiftly, this era is called the era of urbanization (Gupta, 2013). Almost 522 million people live in urban areas in India and the number of the urban dwellers is estimated to increase further (United Nations, 2025). The increase in the urban population demands the land for accommodation and various other uses, leading to expansion of built-up area, replacing the vegetated and agricultural land. Urbanization leads to the turning of agricultural land to impervious surface (Ministry of Housing and Urban Affairs, 2022). The growing city, despite being an indicator of economic growth, generally has poor impact on its ecological health (Gaur & Singh, 2023). Dehradun, the capital city of Uttarakhand, has undergone tremendous increase in its urban population after the formation of Uttarakhand State(B. Agarwal et al., 2018) The study of land use and land cover is central component of the urban policies in the contemporary world (Kaul & Sopan, 2012). Land cover is the apparent physical characteristic of an area like forest, water body, barren land etc., while land use is the human utilization of an area for its own good like residential area, commercial area, agricultural land etc. Despite changing the physical dimension of an area, the changes in Land use and Land cover lead to the degradation of the ecological health of a city (A. Agarwal et al., 2019) The most efficient way to assess the change in the land use land cover is through remote sensing and GIS, using satellite imagery (Kumar et al., 2020). Spatial and temporal observation of the earth's surface through satellite data has become important to study the man's interaction with its natural environment (Kaul & Sopan, 2012). The monitoring of spatial growth patterns of a city has become significant for urban planners to analyse its land surface dynamics (Roy & Roy, 2010).

The present study is based on analysing and monitoring the change in the Land use Land Cover of Dehradun city from 2001 to 2025. It further tries to understand the transition from one land use class to another using the land cover transformation matrix, using geospatial techniques.

2. Study Area

Dehradun city is the capital city of Uttarakhand, India. It was recognised as capital, post the formation of the state of Uttarakhand in 2000. It lies in the central part of Doon Valley, bounded by lesser Himalayas in the north and Shiwalik hills in the south. Dehradun city is located on the fertile land near the Himalayan foothills, in north-western part of Uttarakhand, in Northern India (P. Gupta & Goyal, 2014) The spatial extent of the study area is as- Latitude: 30.228124°N to 30.421258°N, Longitude: 77.930881°E to 78.136338°E. Dehradun has a humid subtropical climate with distinct seasons. It is located in Garhwal region of the state. Its altitude is approximately 410-700 meters above mean sea level. The total area of Dehradun city, under the jurisdiction of Dehradun Municipal Corporation is 185.481 km^2.

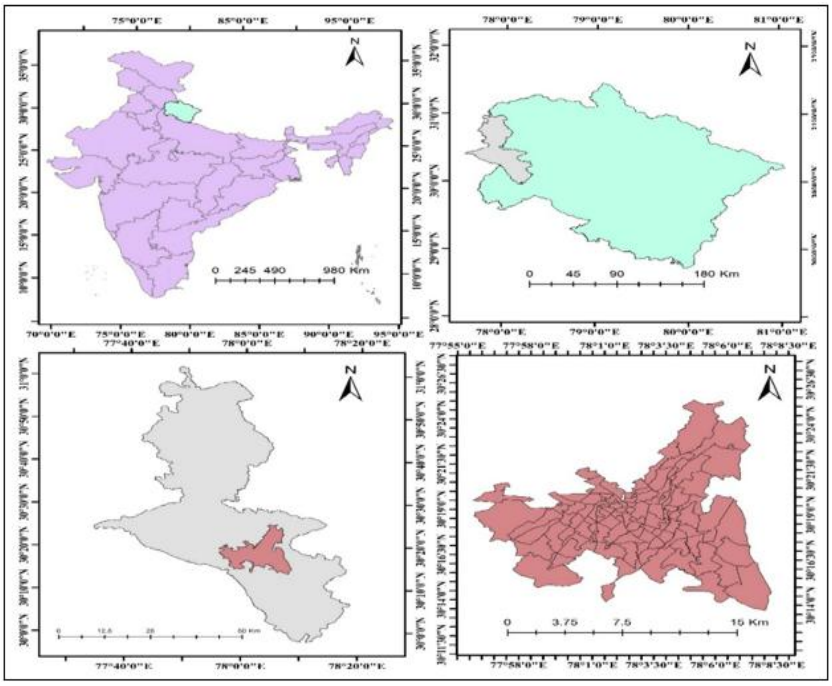


Figure 1: Locational Map of Dehradun City

3. Database and Methodology

Synoptic view of the urban area is necessary to study the urban growth and expansion; therefore, satellite data has been acquired for analysis (K. Gupta, 2013). The spatial data relating to land use land cover of an area is required to determine the qualitative as well as quantitative variations in land use and land cover (Roy & Roy, 2010). The multi-spectral satellite images poses to have great potential in analysing, monitoring, mapping the changes in the various land use categories (Fazal & Ali, 2022) To analyse the change in the land use and land cover for Dehradun over a period of time, Landsat satellite images were downloaded from USGS-United States Geological Survey (earthexplorer.usgs.gov) for the year 2001 as well as 2025. For 2001, Landsat 7ETM+ satellite imagery and for 2025 Landsat 8OLI/TIRS satellite imagery was utilized. The details of the satellite imageries used for the study is given in table no. 1. The Municipal Boundary map was taken from the office of Dehradun Municipal Corporation. The obtained imageries were then processed in GIS software. The Maps generated were extracted to the study area.

Table 1: Specifications of the Satellite Data used for the LULC analysis

Specifications	2001	2025
Date Acquired	30/12/2001	24/12/2025
WRS Path	146	146
WRS Row	039	039
Sensor	ETM+	OLI/TIRS
Satellite	7	8
Spatial Resolution	30m	30m

The satellite data used, was projected to the WGS 84/UTM Zone 44N coordinate system for both the years 2001 and 2025. The Band composite image was generated using the required spectral bands. The resultant composite image was then used for the supervised classification. The classification method used for the categorization of the Land use Land Cover classes is the maximum likelihood classification (MLC) algorithm. The required training samples were taken from the False Color Composite (FCC) image. The four LULC classes have been identified for both the years (2001&2025) namely- Built-up area, Barren land, Agriculture and Vegetation. For accuracy assessment, random accuracy points were taken and compared with the reference dataset in the google earth software, besides, confusion matrix for both the years was generated as well as overall accuracy, producers' accuracy and kappa coefficient was calculated. The change in LULC from 2001 to 2025 was examined by comparing the LULC maps prepared for both the years. The area occupied by each LULC class was calculated for both the years, change detection was done using the equation as:

- Change in Area = $Area_{2025} - Area_{2001}$
- % Change = $\frac{Area_{2025} - Area_{2001}}{Area_{2001}} \times 100$

The assessment of the transition from one land use class to another land use class is crucial, to understand the pattern and nature of change. In order to study this transition of one land use class to another, land cover transformation matrix was created from 2001 to 2025.

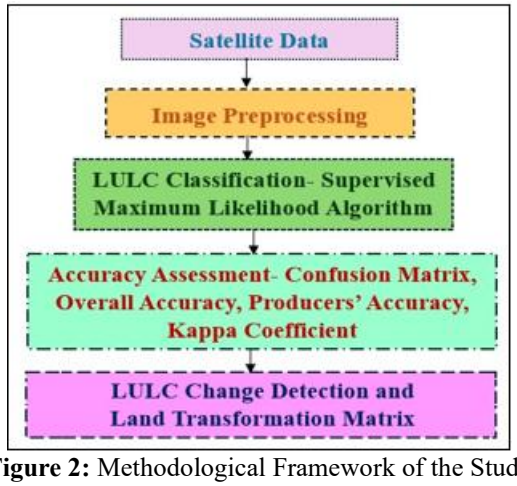


Figure 2: Methodological Framework of the Study

4. Result and Discussion

The geospatial techniques plays a significant role in studying the urban expansion and change in LULC (Jana et al., 2020). The remote sensing technology is useful to analyse the pattern of urban growth and establish the trend in the change of urban growth over time (K. Gupta, 2013). The analysis assesses the change in the spatial distribution of the various land use categories in Dehradun city over the period from 2001 to 2025.

In 2001, the dominant land use category was vegetation and built-up area, with fair share of Agriculture land as well. The built-up area occupied the core of the city, while agriculture land and vegetation almost surround it. The major land use category is vegetation having 67.7376 km^2 of area in the city. The built-up area of the city in 2001 is 63.0675 km^2. The area under agriculture and barren land was 35.6301 km^2 and 19.0458 km^2 respectively.

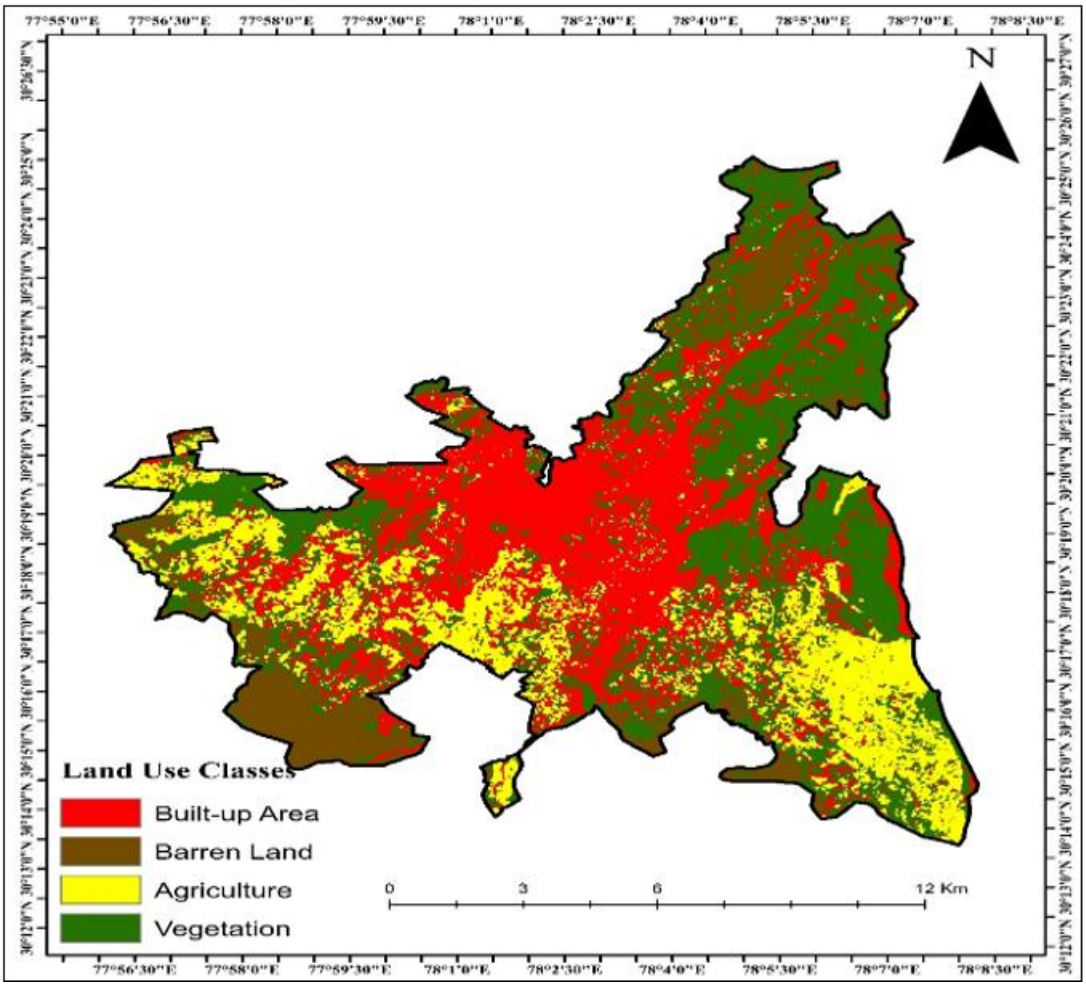
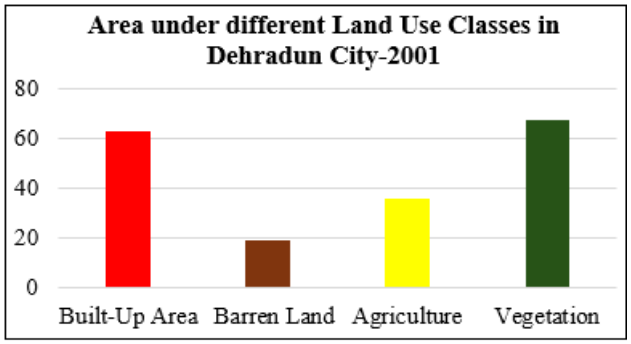


Figure 3: Land Use Land Cover map of Dehradun city in 2001

Land Use Class	Area km^2
Built-Up Area	63.0675
Barren Land	19.0458
Agriculture	35.6301
Vegetation	67.7376
Total Area	185.481



Accuracy Assessment of LULC for 2001: For accuracy assessment, accuracy points were taken randomly and compared with the reference dataset on google earth pro. The confusion matrix was used to evaluate the reliability of the LULC Map of Dehradun city for 2001. The kappa coefficient was also calculated to assess the agreement between the classified maps and the reference data. The kappa coefficient for 2001 LULC map is 0.806737, which indicate almost perfect agreement, and strongly reliable data.

LULC Classes	Built-up Area	Barren Land	Agriculture	Vegetation	Total	User's Accuracy
Built-up Area	26	1	0	3	30	0.866667
Barren Land	1	27	2	1	31	0.870968
Agriculture	1	0	7	2	10	0.7
Vegetation	0	0	3	26	29	0.896552
Total	28	28	12	32	100	0
Producer's Accuracy	0.928571	0.964286	0.583333	0.8125	0	0.86

In 2025, there is an apparent decline of vegetation cover as well as the agriculture land, whereas built-up area increased enormously. The built-up area expanded almost two-fold over the study period, pushing the agriculture land and vegetation to the periphery. The area under built-up in 2025 is 112.5495 km^2, having high density at core of the city. The vegetation cover has area of 38.1033 km^2. The agriculture and barren land have area as 29.8233 km^2 and 5.0049 km^2 respectively.

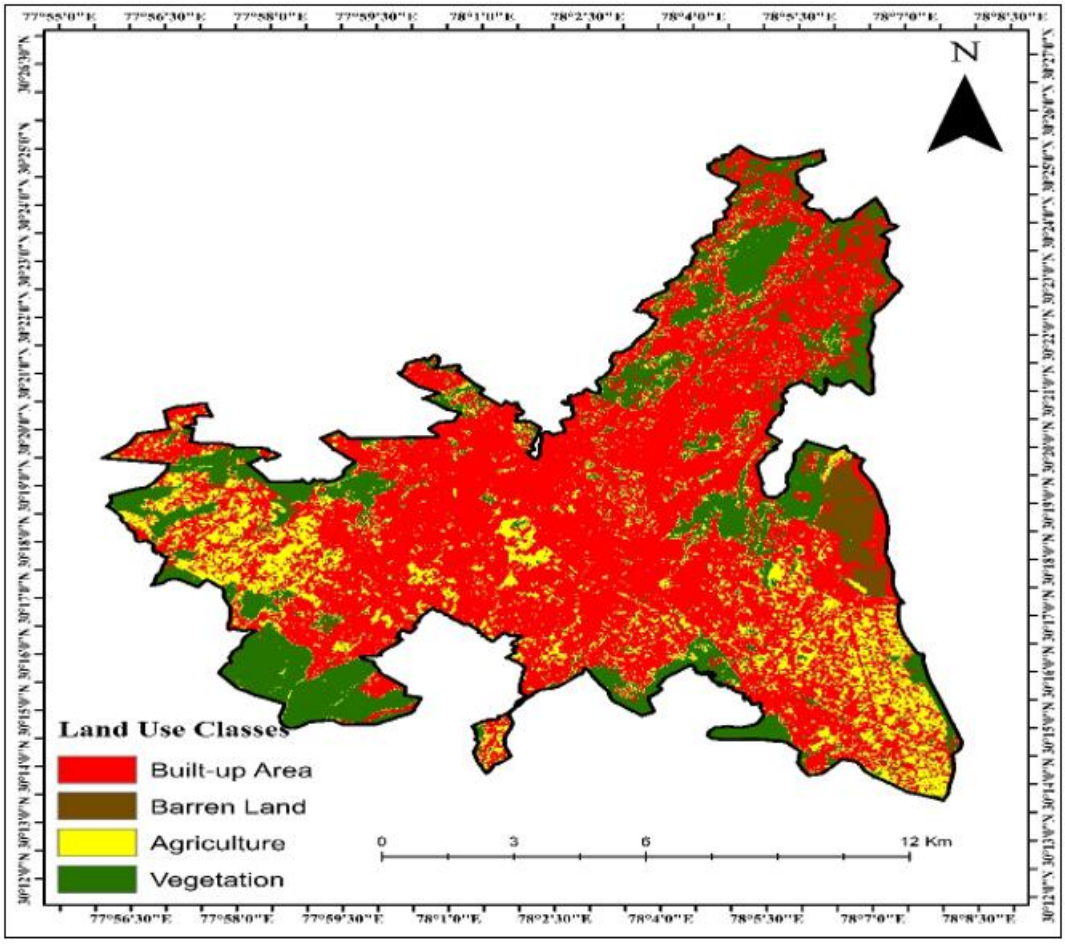
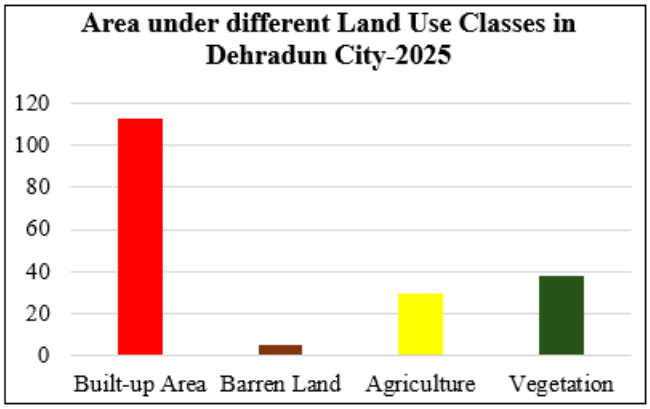


Figure 4: Land Use Land Cover Map of Dehradun City in 2025

Land Use Class	Area_km^2
Built-up Area	112.5495
Barren Land	5.0049
Agriculture	29.8233
Vegetation	38.1033
Total Area	185.481



Accuracy Assessment of LULC for 2025: For accuracy assessment, accuracy points were taken and compared to the ground truth point using google earth pro. The confusion matrix was used to evaluate the reliability of the LULC Map

of Dehradun city for 2025. The kappa coefficient was also calculated to assess the agreement between the classified maps and the reference data. The kappa coefficient for 2025 LULC map is 0.879904, which indicate perfect agreement, and strongly reliable data.

Land use classes	Built-up Area	Barren Land	Agriculture	Vegetation	Total	User's Accuracy
Built-up Area	65	0	3	2	70	0.928571
Barren Land	0	14	0	0	14	1
Agriculture	0	0	14	0	14	1
Vegetation	0	0	1	1	2	0.5
Total	65	14	18	3	100	0
Producer's Accuracy	1	1	0.777778	0.333333	0	0.94

LULC Change Detection:

The change in the area under different LULC classes is explicit. The exponential change in the area under built-up from 2001 to 2025 is alarming, as it has expanded enormously, at the cost of other land use classes (agriculture, vegetation and barren land). The maximum area transitioned under built-up land use classes, and jumped almost two folds. The vegetation class declined over the study period, so does the agriculture and barren land. Over the period of time the built-up area has pushed the agriculture and vegetation land to the periphery. The change in the urban land use area brings the attention of urban planners to the proper policy formulation imbibing the environment conservation and promotion of urban green spaces in the city (Turaga et al., 2020).

Table 2: Statistics of the Area change (km^2) under LULC classes in Dehradun city (2001-2025)

Land Use Class	Area 2001 (km^2)	Area 2025 (km^2)	Area Change	% Area Change
Built-Up Area	63.0675	112.5495	49.482	78.45879415
Barren Land	19.0458	5.0049	-14.0409	-73.72176543
Agriculture	35.6301	29.8233	-5.8068	-16.29745636
Vegetation	67.7376	38.1033	-29.6343	-43.74867134

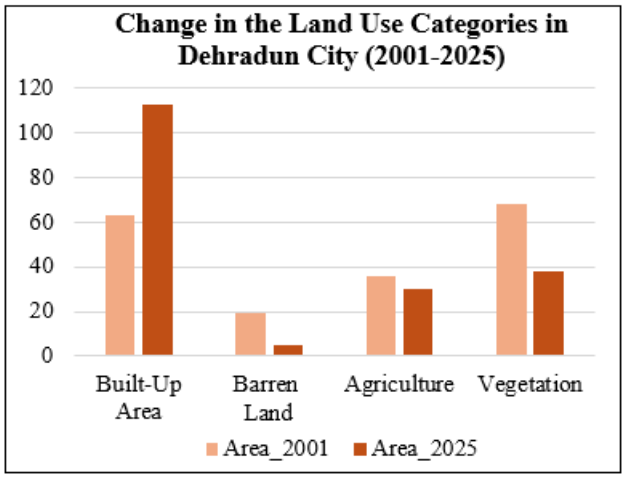


Figure 5: Area change in Dehradun City (2001-2025)

Class to Class Transition and Land Transformation Matrix:

Land transformation matrix studies the magnitude of transition between individual land use classes over the period of time. Land transformation matrix is used to study the inter class transitions among various classes in Dehradun city from 2001 to 2025. The matrix quantifies the area converted from one class to another and provides a detailed understanding of the changing land use pattern. Insights into the matrix shows that the three classes namely vegetation, agriculture and barren land have transitioned in built-up area over time. Only the area under built-up class has increased drastically at the cost of other three classes. The decline in the remaining three classes: agriculture, vegetation and barren land is alarming, and should be the prime concern of the urban planners.

Table 3: Land Transformation Matrix of Dehradun city (2001-2025)

Land-use Class	Built-up (2025)	Barren Land (2025)	Agriculture (2025)	Vegetation (2025)	Total Area (km2)
Built-up (2001)	55.86	0.61	5.13	1.35	62.95
Barren Land (2001)	1.42	0.01	0.77	16.51	18.71
Agriculture (2001)	21.96	0.08	13.10	0.67	35.81
Vegetation (2001)	34.66	4.17	9.33	19.51	67.67
Total Area (km2)	113.90	4.87	28.33	38.04	185.14

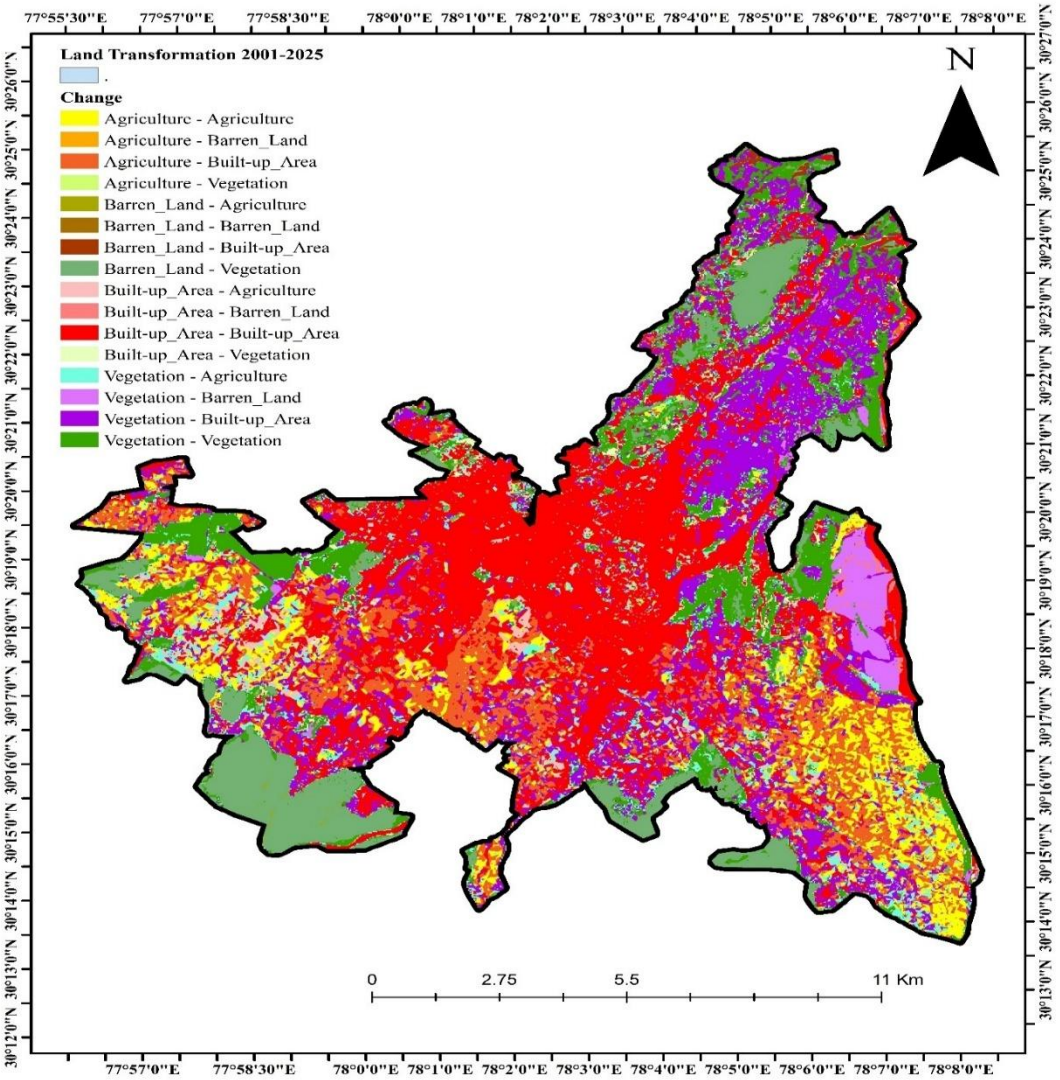


Figure 6: Land Transformation of LULC classes in Dehradun city (2001-2025)

5. Conclusion

The paper studied the urban land transformation of Dehradun city from 2001 to 2025, using the geospatial techniques. The analysis of satellite data and mapping of the LULC of the study area gave synoptic overview about the apparent changes in the land use classes over the study period. The results evidently show that there is exponential increase in the built-up area in Dehradun city over the period of time. The area under built-up has jumped from 63.0675 km^2 in 2001 to 112.5495 km^2 in 2025. This enormous change in the built-up area is alarming and should be a primary focus of the urban planners. This increase in the urban impervious land is at the cost of agriculture and vegetation area. The area under vegetation has declined from 67.73 km^2 in 2001 to 38.103 km^2 in 2025. The decline in the vegetation cover of Dehradun city from 2001 to 2025 warrants special attention on the sustainable approach to urban planning and inculcating the Urban Green Spaces in the urban policy formulation (Haq, 2011). The core of the city has been occupied by urban concrete land, pushing the agriculture and vegetation to the periphery. Keeping in view the continuous increase in the urban concrete land and declining green cover, the conservation of the remaining green cover should be the main concern of the urban policy formulation (Ministry of Urban Development, 2014).

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