Assessment of Land Use and Land Cover Dynamics in the Rural-Urban Fringe of Hisar City

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KEYWORDS

Urban-rural fringe, Land use land cover change, Geospatial technology, Hisar, Urbanization.

ABSTRACT

Rapid urbanization in Hisar city has significantly impacted the peri-urban areas, known as the urban-rural fringe (URF), where the boundaries between urban and rural landscapes are becoming increasingly indistinct. This study investigates land use/land cover (LULC) changes in Hisar's fringe areas, focusing on how the land has transformed over time. By utilizing geospatial technologies, we analyzed LULC changes through digital image processing and supervised machine learning classification applied to Landsat data from 2003, 2013, and 2023. The results reveal notable changes: barren land decreased by 28.2 sq km, while built-up areas expanded by 248.1 sq km in the inner fringe and 69.7 sq km in the outer fringe. Vegetation increased by 15.1 sq km in the inner fringe, but declined by 14.32 sq km in the outer fringe. Both water bodies and forested areas experienced substantial reductions, with losses of 15.5 sq km and 40 sq km in the inner fringe, and 39.12 sq km and 147.07 sq km in the outer fringe, respectively. These transformations indicate broader socio-economic and environmental shifts, emphasizing the need to understand the causes and consequences of urbanization for effective land management. The study highlights the importance of continuous monitoring of LULC changes to inform sustainable planning and development in the fringe area of Hisar city.

Introduction

The impact of urbanization on the rural-urban fringe (RUF) is significant and multifaceted, influencing both the environment and the socio-economic landscape. The rural-urban fringe, also known as the peri-urban area, is the transition zone between urban and rural environments, where urban development and rural landscapes coexist and often compete for space and resources. The expansion of urban areas often leads to the conversion of agricultural land, forests, and natural landscapes into built-up environments. This shift in land use can reduce the availability of fertile land for farming, impacting food production and local agriculture (Seto et al., 2012). Urban sprawl may lead to fragmented land use patterns, where agricultural land is interspersed with industrial, residential, and commercial developments, complicating land management and sustainability. Urbanization brings an increase in impervious surfaces like roads, buildings, and parking lots, which contribute to soil erosion, reduced water infiltration, and higher flood risks (Alemu et al., 2024). Deforestation, habitat destruction, and the decline of wetlands in peri-urban areas can lead to a loss of biodiversity and ecological balance (Alam et al., 2019). Pollution from urban areas, including air, water, and soil contamination, can spread into the rural-urban fringe, negatively affecting agriculture and public health.

The growing demand for housing, infrastructure, and industries in peri-urban zones often encroaches on agricultural land. Farmers may be forced to adapt by intensifying agricultural practices, leading to overuse of resources such as water, fertilizers, and pesticides, which can degrade soil quality and reduce long-term productivity. On the other hand, urbanization can also lead to more demand for locally sourced food and urban agriculture, providing new economic opportunities for rural areas if managed well (Oyinloye et al., 2021). Urbanization of the fringe zone often leads to shifts in the socio-economic structure. Rural communities may experience rising land prices, increased migration to urban areas for jobs, and changes in local employment patterns. While urban areas offer economic opportunities, the pressure on infrastructure and social services (like healthcare, education, and sanitation) often leads to challenges in managing growing populations (Un-Habitat, 2016). The influx of people and businesses into peri-urban zones can also create conflicts over land ownership, resource usage, and governance, potentially exacerbating inequalities between urban and rural populations. The demand for water, energy, and other resources in urbanizing areas often outstrips supply, putting additional pressure on rural areas that may already be facing resource scarcity (Li et al., 2021). Competition for land and resources in the rural-urban fringe can lead to environmental stress, further exacerbating challenges related to sustainable development and resource management. Urbanization often results in improved infrastructure such as roads, electricity, and communication networks in peri-urban areas, potentially raising living standards and enhancing access to services for rural populations. However, inadequate or poorly managed urban expansion can strain public services, leading to overcrowding, insufficient waste management, and traffic congestion in the rural-urban fringe.

The rural-urban fringe is often a melting pot of rural traditions and urban lifestyles. The migration of rural populations to peri-urban areas can lead to shifts in cultural practices, family structures, and local governance. Urban lifestyles may influence rural communities, leading to shifts in agricultural practices, social norms, and even consumption patterns, which could impact traditional knowledge and local customs. Land use and land cover (LULC) changes play a significant role in shaping landscapes, determining URF and influencing various aspects of human activities and environmental sustainability. These changes are crucial for understanding the dynamics of urbanization, agricultural expansion, and environmental impacts (Goldewijk & Ramankutty (2004); Alam et al., 2019; Pabi, 2007). Evaluating LULC is essential for addressing environmental issues such as unregulated development, loss of agricultural lands, destruction of wetlands, and wildlife habitats (Alam et al., 2019). LULC change is a complex phenomenon influenced by biophysical and socio-economic factors (Arsanjani, 2012).

These factors encompass long-term climatic shifts, geomorphological and ecological processes, alterations in vegetation cover and landscape structures, climate variability, and the greenhouse effect (Rindfuss et al., 2004; Arsanjani, 2012). Land use (LU) refers specifically to the human modification and application of land for economic purposes (Turner et al., 1994; Sohl, 2012). LU reflects the actions taken to shape the land cover and the resulting economic benefits derived. Land cover (LC), in contrast, refers to the continuous natural characteristics of the Earth’s surface, such as vegetation, rocks, soil, water and human-made structures (Molder, 2011).

A rapid increase in population and the consequent escalated anthropogenic activities are the core cause of giving rise to a wide variety of alterations in LULC changes (Lambin et al., 2001). The changes are so profound and penetrative that when different elements of such changes are combined globally, they show considerable ecological implications (Lambin et al., 2001). The availability and distribution of various biotic and abiotic resources influenced by LULC changes provide an example of these implications. Additionally, LU classes, defined by human activities on the LC, are closely linked to population distribution, making them effective indicators for demographic and related studies (Linard et al., 2010).

The conversion of agricultural land to urban uses is transforming agricultural production, social structures, and land markets in peri-urban areas, highlighting the need to balance urban development with agricultural sustainability. However, the expansion of urban areas directly impacts available agricultural land, potentially affecting food production and agricultural activities in cities (Oyinloye et al., 2021). This transformation of LC due to urbanization can have profound effects on the natural conditions of the landscape (Salvati & Zitti, 2007). On contrary, it has also been observed that land degradation in certain regions can be mitigated by factors such as increasing woodland cover and reducing human pressure and agricultural intensification (Gebreyesus et al., 2022). Information on existing LU is essential for planning optimal utilization of land (Chaudhary 2003; Clevers et al. 1999; Dhawan 2017; Gupta and Roy 2012; Hooda et al. 1992; Hussin and Shaker 1995). The physical results of past human activity, such as vegetation clearance, etc., are included within the concept of LU changes. Land and soil are precious natural resources and are nature's gift to the humankind. The prosperity of a country depends on the richness of these resources.

In a country like India, where the population pressure on land is high, rational utilization of the land resources assumes great importance for the optimal and sustained production with minimum hazards. Essentially, this will mean proper utilization of land and soil. These resources, however, have been most recklessly used by humans in the past to extract more and more from them. This has caused rapid deterioration and degradation of lands. The land resources are limited, as the total geographical area is fixed. Land is, therefore, scarce in supply. It is irreplaceable and not reproducible. While the land is finite, the population dependent on land and its needs are infinite (Narumalani et al. 2004; Reid et al. 2000; Kuemmerle et al. 2006). These have been increasing with time. Per capita availability of the resources, therefore, has been declining. One of the prime requisites for better LU is information on existing LU and the distribution of settlement, forest, agricultural land, barren land, etc., and they are important to determine land use policy, planning of transportation, and communication services, etc. The present LU is the result of different causes which are related to landforms, soil conditions, irrigation facilities, marketing, communication and transport, and socioeconomic conditions (Yang and Liu 2005; Yonas et al. 2013; Meyfroidt and Lambin 2008). Information regarding changes in LULC has become a primary and crucial constituent of research to produce strategies for assessment and evaluation of environmental changes as well as management of natural resources to encourage sustainable use and development (Twisa and Buchroithner, 2019).

Earlier there were many methods to analyze LULC changes but there was limitation also like time consuming methods, the applicability for small area and many such limitations. But nowadays with the help of Remote sensing (RS) and Geographic Information System (GIS) the scenario has changed and this have been acknowledged as crucial and influential tools for evaluation of environmental changes over varied spatial and temporal scales (Dewan and Corner, 2013). The applicability of using spaceborne imagery to measure LULC changes has been demonstrated by several researchers (Twisa and Buchroithner, 2019). RS and GIS are exceptional at mapping and identifying changes in LULC and LST (Aboelnour and Engel, 2018; Malik et al., 2020). Remote sensing data allows researchers to understand and predict these landscape transformations. The multifaceted impacts of LULC changes encompass a wide range of issues.

These includes reduced provisioning services: food, fiber, and timber production, increased disease risks, elevated atmospheric gasses contributing to climate change, diminished biodiversity, life support functions, and agrobiodiversity, soil degradation and altered freshwater hydrology, agricultural water use, and coastal zones (Alemu et al., 2024). Understanding LU changes is crucial for sustainable urban planning, as it provides insights into impervious surface coverage, tree canopy cover, and other land surface dynamics that influence urban development (DeFries & Bounoua, 2004). Therefore, the impact of LU change extends to ecosystem services, with consequences for agriculture, settlement patterns, and economic activities (Aziz et al., 2020). Rapid LU expansion driven by urbanization poses challenges for sustainability and necessitates effective land management policies (Chaka & Oda, 2019).

The rapid pace of urbanization in developing countries presents a complex phenomenon with both opportunities and challenges (Un-Habitat, 2016). While cities offer the potential for economic growth, improved living standards, and social mobility, the speed and scale of urban expansion often create significant strains on infrastructure and social services. In developing countries like Ethiopia, agriculture, the mainstay of the economy (FAO, 2016), is a key driver of LULC change. Ethiopia's agricultural expansion has significantly altered natural landscapes, including forests and grasslands bordering cultivated and grazing areas (Lambin et al., 2003). There are various studies at world level related to LULC change detection or their trends. Urbanization is a significant phenomenon in India, characterized by the expansion of urban areas and the transformation of rural landscapes into peri-urban zones. The URF represents the interface between urban and rural environments, exhibiting diverse LU patterns and socio-economic dynamics (Sengupta, 2017). Since independence, the urban population of India has consistently risen, displaying a growth rate surpassing the national average population growth rate. However, the extent of urbanization varies significantly among states and union territories, exhibiting intra-state disparities as well.

Haryana stands out as one such state with elevated urbanization levels, registering 34.88% (Census of India, 2011), notably higher than the national average of 31.16%. This escalating urbanization trend in Haryana is primarily driven by city expansion, ribbon development, and leapfrogging urban sprawl (Shekhar & Shekhar, 2021). Although there have been various studies in Hisar city, Haryana about LULC change detection but the status of LULC changes of urban and rural periphery fringe of Hisar city in Haryana, India remained undocumented. Land is the basic and most important resource in Haryana, as it is true for nearly all other states of the country (Kumar 2017; Kushwaha and Oesten 1995; Ram and Singh 1995; Rani 2017; Toleti 1995). In Haryana, rapid population expansion has led to the excessive utilization of natural resources. A complex interplay of biophysical processes and socioeconomic factors shapes LULC patterns across space and time (FAO, 2016). This study addresses this knowledge gap by analyzing spatiotemporal patterns and key drivers of LULC changes over a 20-year period (2003–2023) for the urban and rural fringe of Hisar, Haryana. This research also aims to assess to identify the key drivers of these changes. Understanding these LULC dynamics is critical for informing the development and implementation of sustainable natural resource management strategies in Hisar city. The present work focus on the evaluation of trends and patterns of the urbanization in Hisar city and its impact on the urban-rural fringe areas. The study also inculcates the assessment of the changes in the LULC in the in the fringe area. Furthermore, the outcomes of this research will provide valuable insights to decision-makers, enabling them to comprehend the extent of changes in the study area and make informed decisions based on these findings.

Study Area

The study area encompasses the Hisar city and its fringe area, spanning latitudes from 28°53'04.500" to 29°49'01.500" N and longitudes from 75°13'01.500" to 76°18'01.500" E

(Figure 1), covering an area of 3,983 square kilometers. The city of Hisar is situated in the west-central part of Haryana and is one of the largest urban centers in the state. It borders Rohtak to the east, Fatehabad to the west, Jind to the north, and Bhiwani to the south. Hisar serves as the administrative hub of the district, classified as a Class-I city with a population of 307,024. Located in the alluvial plains of the Ghaggar-Yamuna basin, Hisar is a significant agricultural center in Haryana, known for producing wheat, cotton, and pulses, which play a vital role in the state's agricultural economy (Kumar at al., 2019). Further the area has been divided into 2 fringes: Urban Fringe and Rural Fringe. For the delineation of the rural-urban fringe of Hisar city following indicators/determinants (Ratio of non-agricultural workers, Population growth, Population density, Literacy, Sex ratio etc. are used. Total 81 villages are considered for the current study out of which 60 are in rural fringe and 21 are in urban fringe. The rural-urban fringe is a transitional zone outside the city with mixed characteristics of both rural and urban areas. It represents an area between purely urban characteristics and primary rural activities. It shows cultural developments influenced by urban area, with a sense of traditional rural attributes. Thus, with the help of pre-decided indicators/variables, the extent of the rural-urban fringe of the Hisar city is determined (Table 1).

Table 1: Distribution of Villages, Area, and Population in Rural-Urban Fringe Zones of Hisar.

Rural-Urban Fringe Zones	**Number of Villages**	**Area in Hectare (2011)**	**Population in 2011**
Primary Fringe	21	38896	143398
Secondary Fringe	60	67308	207005
Total	81	106204	350403

This fringe area extends from highly urbanized municipal limits to agricultural dominants rural areas. Overall, Hisar district, nestled in the fertile plains of Haryana, India, possesses a rich history, agricultural significance, and burgeoning industrial development. Hence, current research work is effort to monitor its positive growth trajectory, ensuring sustainability and provision of adequate resources for the current population.

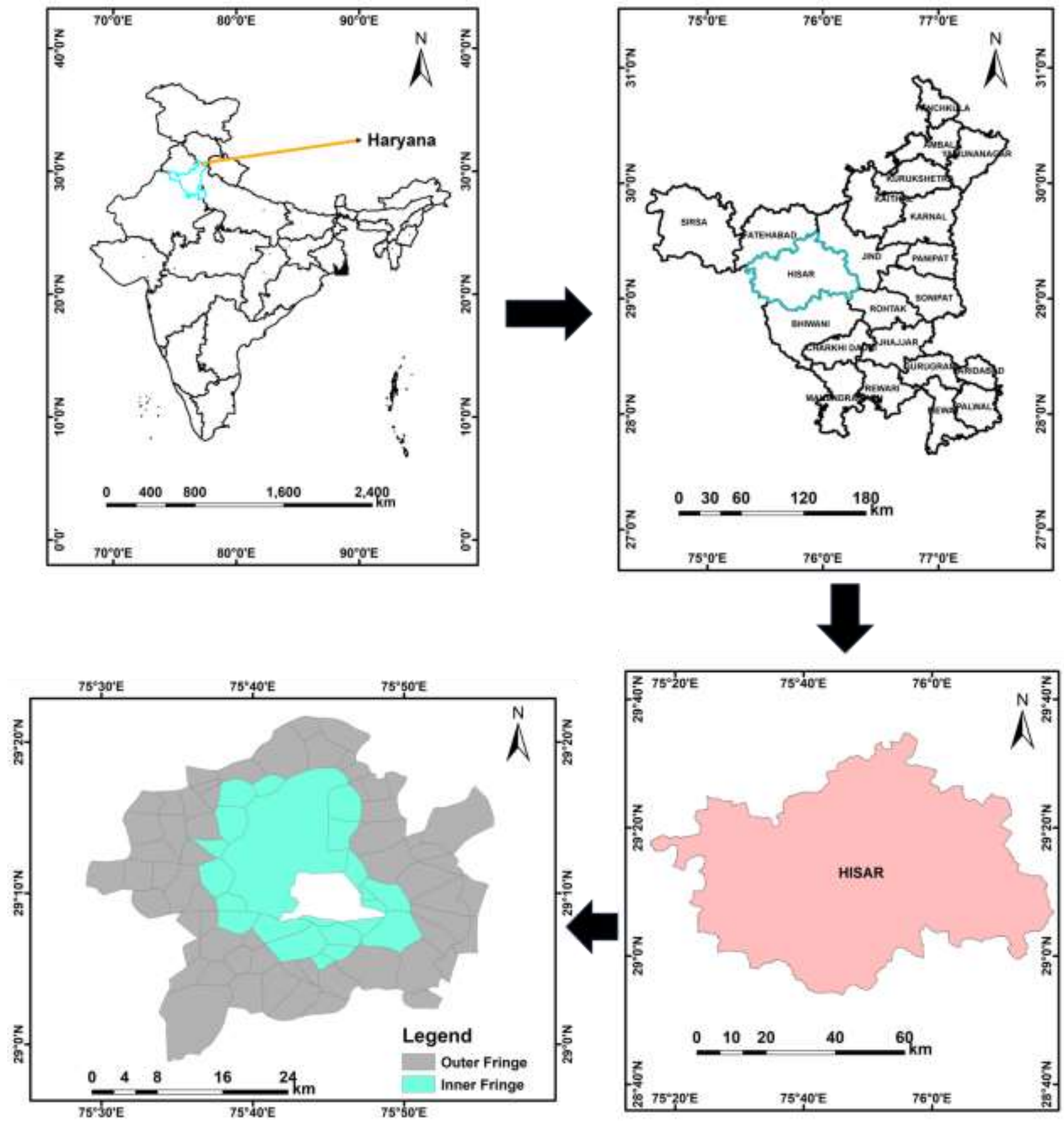
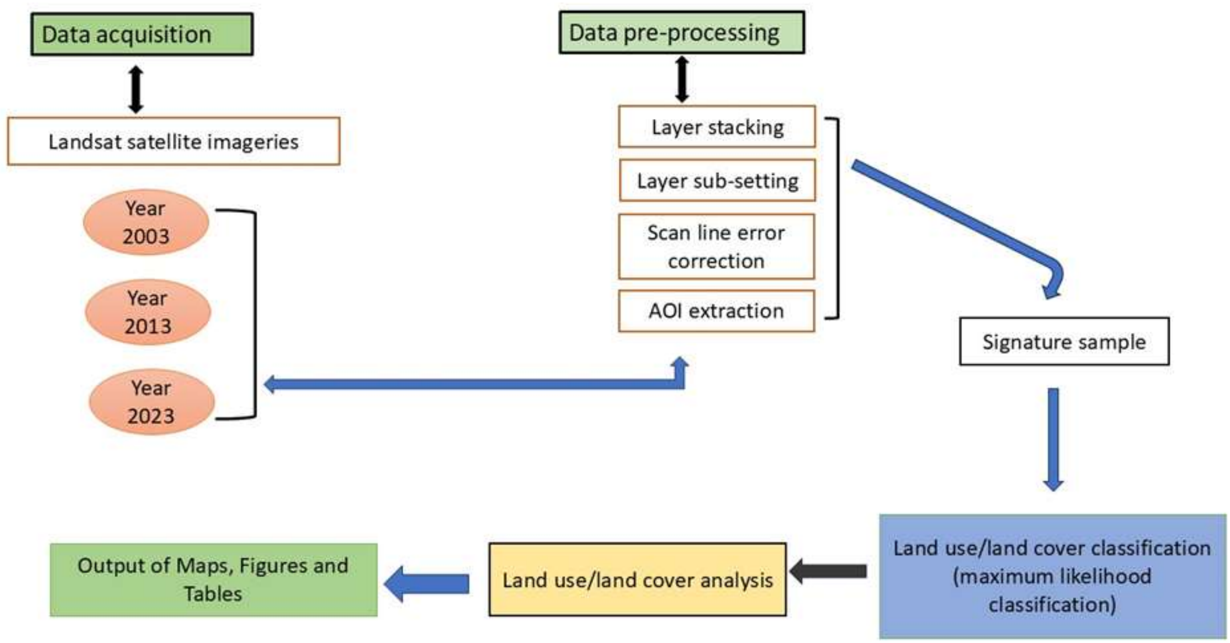


Figure 1: Representation of the study area.

Material and Methods

Geospatial technology plays a vital role in understanding urbanization and its impacts on land use and land cover (LULC). By integrating coarse and fine spatial resolution satellite sensors, this technology effectively monitors LULC changes driven by activities such as deforestation in tropical regions and urban expansion (Lambin et al., 2003). The application of geospatial technologies has been instrumental in mapping urban land cover using remotely sensed imagery coupled with machine learning classifiers (Kamusoko, 2021). Remote sensing, in particular, is recognized for its capacity to provide detailed and accurate land-use information essential for urban planning and management (Herold et al., 2002). The analysis of Landsat time-series data has proven pivotal in tracking LULC changes, especially in the context of rapid urbanization and climatic variations (Zaidi et al., 2017). Moreover, geospatial tools contribute significantly to sustainable land use planning by offering insights into land utilization patterns. These tools enable the detection of LULC changes, providing valuable data for promoting sustainable development and informed decision-making (Sonowal & Thakuriah, 2022; Sharma et al., 2021).



This study utilizes geospatial technologies to analyze the trends and patterns of land use and land cover (LULC) in the rural urban fringe of Hisar city. The spatial data for this analysis is derived from the Landsat series, with pre-harvest months selected for accuracy. The study examines LULC dynamics within the region using primary data acquired from Landsat satellites with a spatial resolution of 30 meters. To generate LULC maps for the study area, satellite data from multiple periods were employed, including Landsat 7 ETM+ (October) and Landsat 8 OLI/TIRS (December). Data for the years 2003, 2013, and 2023 were sourced from the U.S. Geological Survey, as detailed in Table 2. This approach ensures a comprehensive temporal analysis of LULC changes across the study area.

Table 2: Different data sources used for the current study.

Satellite & Sensor	**Bands**	**Year**	**Month**	**Path & Row**	**Procured From**
Landsat 7	1, 2, 3, 4, 5, 7	2003	October	147, 40	https://earthexplorer.usgs.gov/
Landsat 8	1, 2, 3, 4, 5, 7	2013,2023	December	147, 40	https://earthexplorer.usgs.gov/

The downloaded satellite images with scan line errors were corrected using the "Landsat Toolbox" in ArcGIS 10.8. The correction process involved utilizing the "Fix Landsat 7 Scanline Errors" tool after adding the toolbox to the software. Georeferencing and digitization of shapefiles were also performed using ArcGIS 10.8 to prepare the study area for analysis. The study area was segmented into urban and rural fringe zones to facilitate a detailed examination of the spatial distribution of land use and land cover (LULC). After isolating the area of interest through clipping, signature samples were generated for five primary LULC categories: vegetation, barren land, built-up area, waterbody, and forest. A supervised classification technique, known for its effectiveness in remote sensing and image analysis, was applied to categorize the LULC types. This method involves training a classification algorithm with pre-labeled data samples representing different land cover classes, enabling the algorithm to identify and classify similar patterns across the entire image. For this study, supervised classification using the maximum likelihood algorithm was applied to Landsat satellite imagery from 2003, 2013, and 2021. Over 200 signature samples were assigned across the five categories to ensure accurate classification. The classification tool in ArcGIS 10.8 was employed to generate LULC maps for the study area. This approach facilitated the precise identification and mapping of land cover types, enabling a temporal analysis of changes in land use patterns across urban and rural zones. The results were analyzed using various techniques to compute percentages and detect changes in LULC over the study period. Additionally, an accuracy assessment was conducted for the most recent image, yielding an overall accuracy of 89.16% and a kappa statistic of 0.86. These metrics confirm the reliability and validity of the classification process, ensuring that the study provides robust insights into LULC dynamics in the region.

Results and Discussion

Land Use and Land Cover (LULC) mapping is a critical tool for land resource studies, regional planning, and management. It plays a significant role in identifying and monitoring land degradation and its associated impacts. In this study, LULC mapping was conducted to meet the research objectives, utilizing a supervised classification approach on satellite imagery to categorize land into five broad classes: vegetation, barren land, built-up area, waterbody, and forest. The analysis spans a 22-year period, from 2003 to 2023, focusing on the dynamic changes in LULC within Hisar city. The data reveals notable transformations among land cover classes, showcasing shifts in land use types and the extent of these changes. To ensure accuracy, the classifications were validated through extensive field surveys. The area statistics for each LULC category are presented in Tables 3 and 4 for the inner fringe, and Tables 5 and 6 for the outer fringe.

The study area was divided into inner and outer fringe zones based on the previously discussed statistical framework. The primary results of the analysis include detailed LULC maps and post-processed calculations of area changes for each land cover class. This research specifically examines the LULC changes in Hisar district over three key years: 2003, 2013, and 2023. The findings highlight significant alterations across all five primary categories, reflecting the evolving patterns of land use within the district over the studied period. These insights contribute to a deeper understanding of land dynamics, offering valuable information for planning and management efforts aimed at sustainable development in the region.

Table 3: Land use/ Land cover under different category in inner fringe for the year of 2003, 2013, 2023

Sr. No.	**LU/LC Classes**	**2003**		**2013**		**2023**	
		Area (sq. km)	**Area (%)**	**Area (sq. km)**	**Area (%)**	**Area (sq. km)**	**Area (%)**
1	Vegetation	122.6	37%	130.8	39%	137.7	41%
2	Barren land	97.4	29%	84.71	25%	69.2	21%
3	Built-up	18.6	6%	58.3	17%	88.3	26%
4	Water bodies	24.9	7%	19.6	6%	9.4	3%
5	Forest	70.6	21%	41.7	12%	30.6	9%
	Total	**334.11**	**100%**	**334.11**	**100%**	**334.11**	**100%**

The table 3 illustrates the dynamic shifts in Land Use and Land Cover (LULC) classes in the study area over a 20-year period (2003–2023). The analysis is based on five primary LULC classes: vegetation, barren land, built-up areas, water bodies, and forest, highlighting notable trends and changes in land distribution.

Vegetation: Area covered by vegetation increased from 122.6 sq. km (37%) in 2003 to 137.7 sq. km (41%) in 2023, showing a steady rise in vegetation cover by approximately 12.3% over the 20-year period. This increase may be attributed to afforestation efforts, changes in land use policies, or natural succession in certain areas.

Barren Land: The area of barren land significantly decreased from 97.4 sq. km (29%) in 2003 to 69.2 sq. km (21%) in 2023, marking a reduction of around 28.9%. This decline indicates potential land reclamation or urban and agricultural expansion into previously barren areas.

Built-Up Areas: The built-up area exhibited a dramatic increase, expanding from 18.6 sq. km (6%) in 2003 to 88.3 sq. km (26%) in 2023. This 375.3% increase highlights the rapid urbanization in the region, likely driven by population growth and economic development.

Water Bodies: Water body coverage showed a significant decline from 24.9 sq. km (7%) in 2003 to 9.4 sq. km (3%) in 2023, representing a loss of approximately 62.3%. The reduction may be due to over-extraction of water resources, encroachment, or climatic factors such as prolonged droughts.

Forest: Forest cover reduced considerably from 70.6 sq. km (21%) in 2003 to 30.6 sq. km (9%) in 2023, reflecting a decline of 56.7%. This loss may result from deforestation, land conversion for agriculture or urban expansion, and inadequate reforestation efforts.

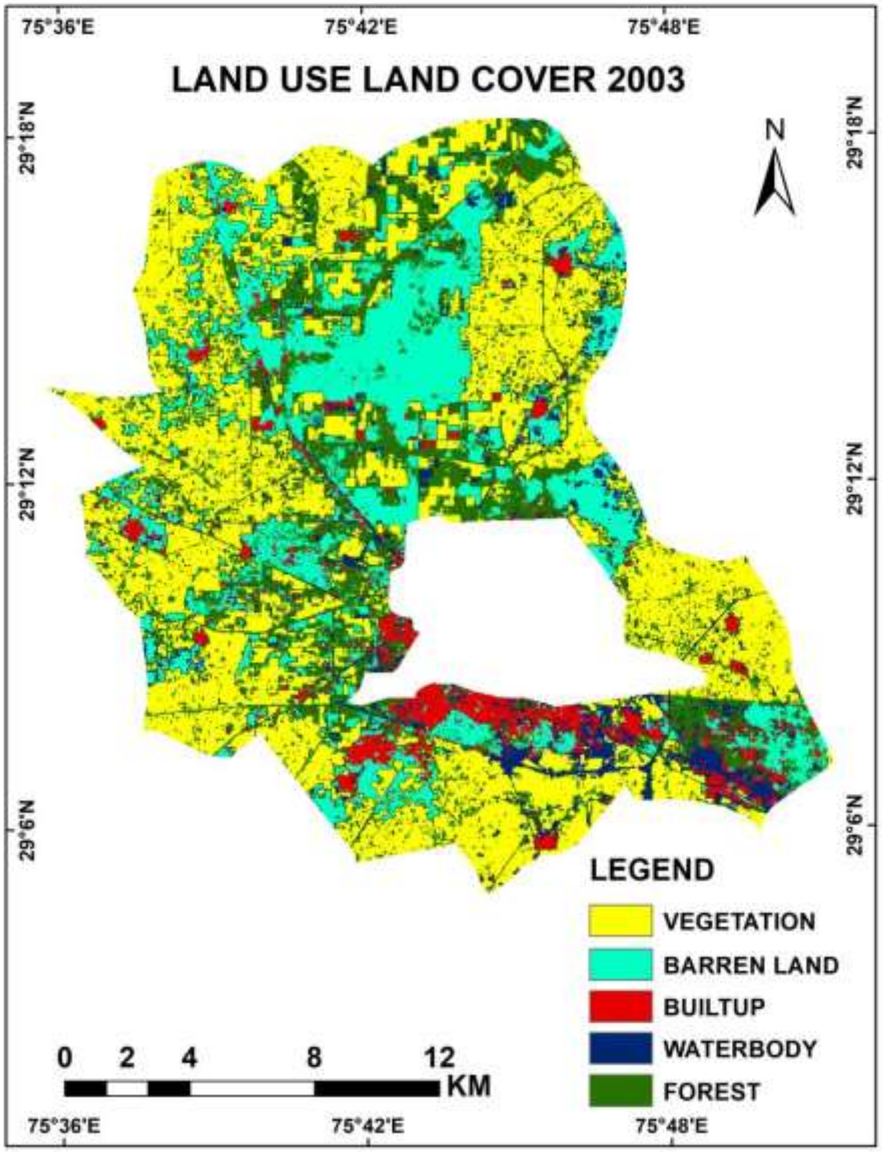


Figure 3: Land use land cover of inner fringe of Hisar for year 2003.

An intriguing scenario is discerned from the LULC map of urban fringe in 2003. The map shows that vegetation holds the largest land in urban fringe during 2003 **(Figure 3**). It occupies approximately 122 sq kms of land. A higher demand of agriculture products in the city leads to the expansion of vegetative land around the urban area. It is also interesting to know that built up land covers only 18 sq kms of land in urban fringe and stands at last in term of having the total area. Barren land also holds a significant portion of land surface in the urban fringe as it occupies the about 100 sq kms of land surface in 2003. However, only 70 sq kms of land area is engrossed by forest cover. Water bodies also found in the urban fringe expanded on about 25 sq kms of land which is only 7% of the total land area of the urban fringe. The water bodies are mainly founded near by the built-up area and non-existence of a river channel explains the low area under water bodies.

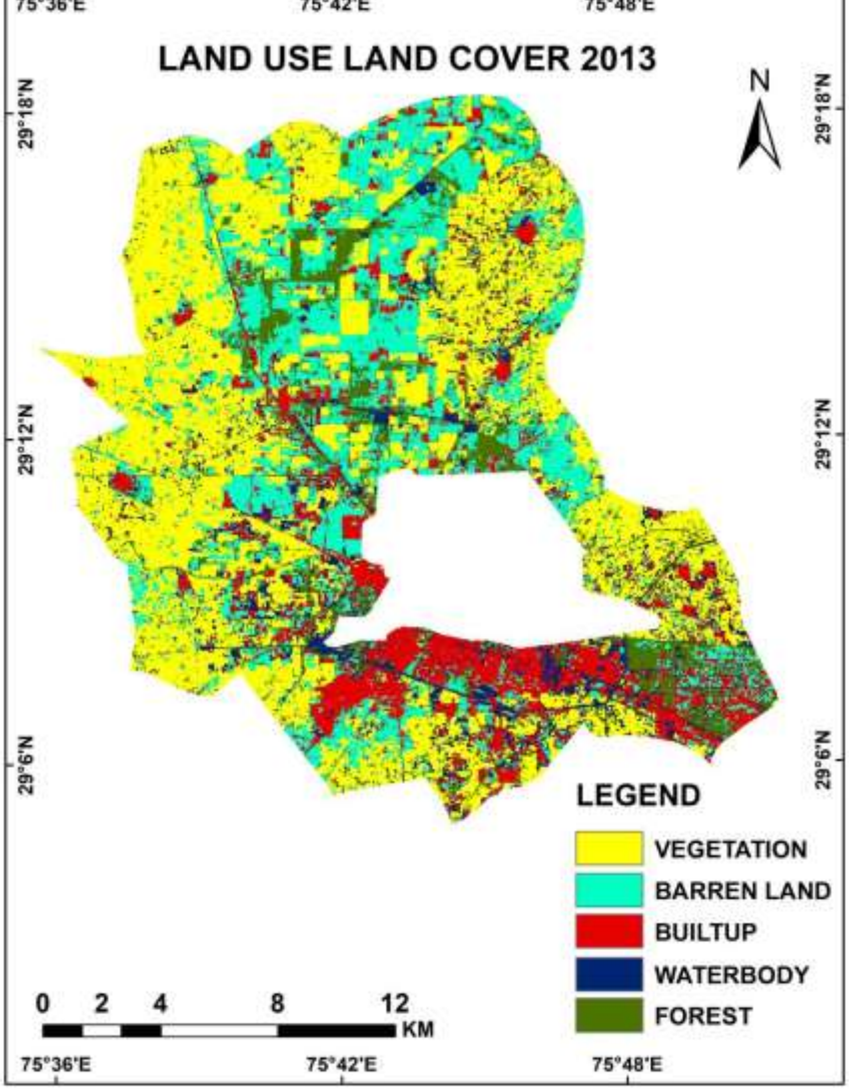


Figure 4: Land use land cover of inner fringe of Hisar for year 2013.

Figure 4 shows that the LULC pattern of urban fringe has changed drastically from 2003 to 2013. Only two categories show expansion in the total area in the urban fringe. They are built up area and vegetation. Although vegetation shows expansion in the total area but the expansion is very low as it expanded only 2%. However, built up area increased significantly as it occupies the approximately 58 sq kms of total land. Built up area holds only 6% of the total land in 2003 and increased up to 17% till 2013. The lowest land holder is now the water bodies which occupies only 6% land of the total urban fringe with holds on the about 20 sq kms of land surface. Barren land and forest area also declined in the urban fringe. The steady growth of population with migration and natural population growth in cities leads the demand of agriculture products as well as industrial products resulted in the expansion of vegetation and built-up land.

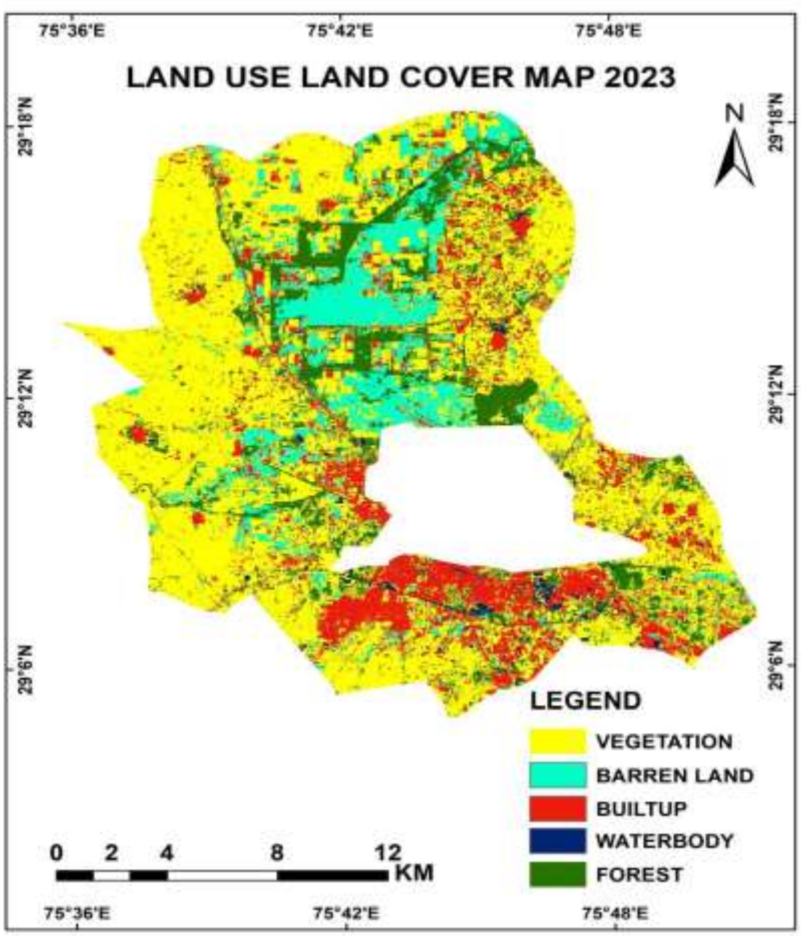


Figure 5: Land use land cover of inner fringe of Hisar for year 2023.

With a slight increase, vegetation successfully maintains its first place in term of having highest land surface in 2023 also (Figure 5). Now, it occupies approximately 138 sq km of land which is about 41% of the total land surface of the urban fringe. Notably, water bodies also stand at last and decreased up to 3% with having only about 10 sq kms of land in urban fringe. High consumption of water and population pressure on land leads to this decline. Forest area also declined in the urban fringe and holds only about 30 sq kms of land surface that is only 9% of the total land of urban fringe. Barren land also decreases as it occupies only 21% of the total land of the urban fringe (Table 3). It is interesting to know that built up area again shows a significant expansion in the urban fringe and holds approximately 70 sq kms of land in urban fringe which makes it the second largest land holding category which constitute about 26% of the total land surface of urban fringe. Population growth leads to the expansion of built-up area as the population expands, there is an increased demand for housing, commercial spaces, and infrastructure, leading to the conversion of land previously used for vegetation and agriculture (Manju Sharma & Vipin Kumar, 2023).

Table 4: Change in area (sq. km) of different land use/land cover classes of inner fringe for year 2003-2023.

Sr. No.	LU/LC Classes	Area in 2003	Area in 2023	Change in area
1	Vegetation	122.6	137.7	15.1
2	Barren land	97.4	69.2	-28.2
3	Built-up	18.6	88.3	69.7
4	Water bodies	24.9	9.4	-15.5
5	Forest	70.6	30.6	-40
	Total	**334.11**	**334.11**	

The table 4 provides a comparative analysis of LULC changes in the study area over a 20-year period, highlighting the differences in land cover for five key categories and the resulting changes in area

Vegetation: Area Change: Increased from 122.6 sq. km in 2003 to 137.7 sq. km in 2023, showing a net gain of 15.1 sq. km. Implications: This growth may be attributed to improved land management practices, afforestation, or recovery of abandoned agricultural land.

Barren Land: Area Change: Decreased from 97.4 sq. km in 2003 to 69.2 sq. km in 2023, resulting in a net loss of 28.2 sq. km. Implications: The decline in barren land suggests its conversion into built-up areas or vegetation, reflecting land reclamation efforts or urban expansion.

Built-Up Areas: Area Change: Increased significantly from 18.6 sq. km in 2003 to 88.3 sq. km in 2023, with a substantial gain of 69.7 sq. km. Implications: This dramatic rise indicates rapid urbanization and infrastructure development, driven by population growth and economic activities.

Water Bodies: Area Change: Reduced from 24.9 sq. km in 2003 to 9.4 sq. km in 2023, representing a net loss of 15.5 sq. km. Implications: The significant reduction raises concerns about water resource management, potentially linked to over-extraction, encroachment, or climatic factors.

Forest : Area Change: Declined from 70.6 sq. km in 2003 to 30.6 sq. km in 2023, showing a sharp decrease of 40 sq. km. Implications: The loss of forest cover highlights deforestation for agriculture, urban expansion, or other anthropogenic activities, posing challenges for biodiversity and climate regulation.

Land use land cover change of outer fringe area of Hisar City

In 2003, forest occupied the largest land surface in outer fringe of the study area (**Figure 6**). It consists approximately two hundred and ninety-seven square kms of land surface. A significant amount of land is engrossed in vegetation as vegetation holds approximately 154 sq kms of land surface. Vegetation land distributed all over the area especially around the built-up land. Green revolution and globalization policies favors the expansion of vegetation land all around the state and the study area is no exception. Barren land placed at third in term of consisting a significant amount of land surface under the category. It constitutes approximately 116 sq kms of land in the outer fringe. It is notable that although barren land also found in the north eastern and north western part of the fringe area however it is significantly spread in the southwestern part of the fringe area in this time period. The built-up area is very low in 2003 as it constitutes only approximately 28 sq kms in the outer fringe. Although the built-up area is low but it is distributed all over the fringe area. Approximately seventy-four sq kms of land is absorbed by water bodies in the outer fringe area.

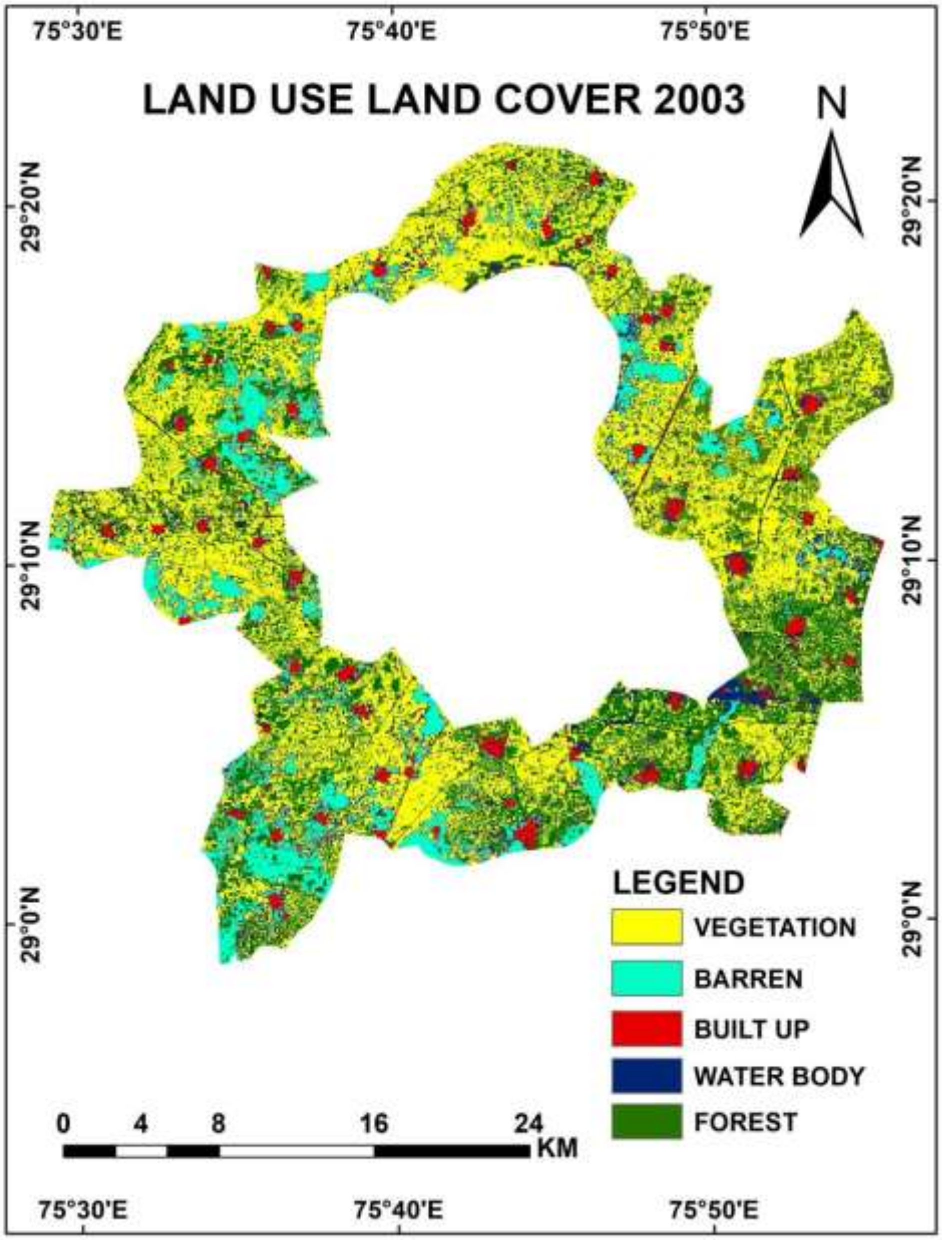


Figure 6: Land use land cover of outer fringe of Hisar for year 2003.

The map shows that there are significant changes in the land use land cover of outer fringe till 2013 time period (Figure 7). The most noteworthy change is observed in the forest category of land use land cover as forest area decreased up to 181 sq kms. It indicates that about one hundred sq kms of land is deprived of forests to use for other purposes. Vegetation made a significant increase and placed at first with having about 291 sq kms of land into the vegetation. An interesting increment in the vegetation land is can be seen in the western part of the fringe as showed in the map. The expansion of irrigation facilities leads the path to convert the barren land into the vegetative land to overcome the demand of food grains as well as other agricultural products. Although having a downfall, forests is the second largest land use category in the outer fringe in 2013. Barren land and water body shows decline in amount of land occupied in 2013. Built area also shows increase in the amount of land engrossed. Increase in population is the main reason for expansion of built-up area. It is notable that till this time period built up area got almost doubled the amount from previous time period. However, it still occupied the least area in comparison to other land use land cover categories and thus placed at last in the land use land cover classes.

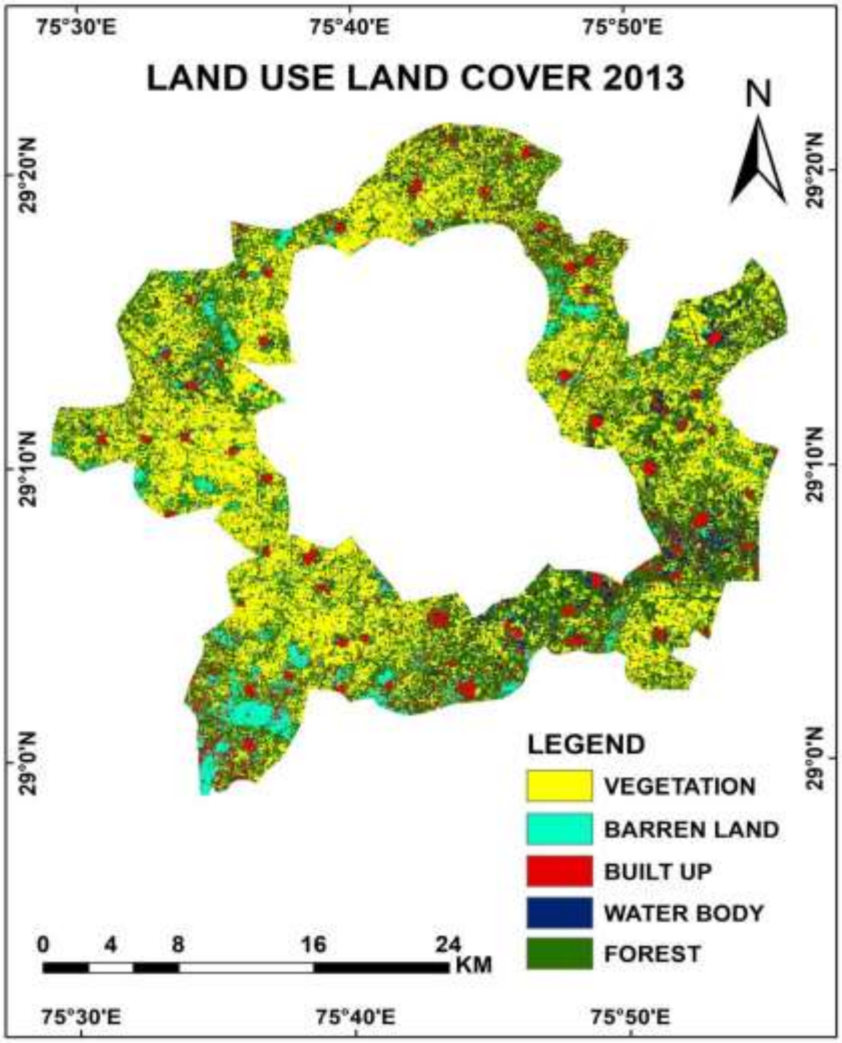


Figure 7: Land use land cover of outer fringe of Hisar for year 2013.

A significant change in land use land cover is observed from the Figure 8. It is clear that built up area made a huge increase as it is significantly occupied the eastern and south eastern parts of the outer fringe. Shockingly, it occupied about 300 sq kms of the total land surface and also placed at first in term of having the largest area as compared to other classes. A blast of population demands the increase in residential facilities and expansion of industries and service sector also increase with population growth. In this way, population growth leads the way of expansion in built up area in the outer fringe. While the decrease in area of land is observed in the waterbodies. Waterbodies decreased up to 35 sq kms in the outer fringe which is an alarming rate. An interesting scenario is observed in land use in this time as vegetation decreased more rapidly than the forests in during this time. Forest area lost only approximately thirty sq. kms however the vegetation decreased in a significant amount of about one hundred sq. kms of land. Barren land also decreased till now and it constitute about the sixty-eight sq. kms of land surface in outer fringe in 2023.

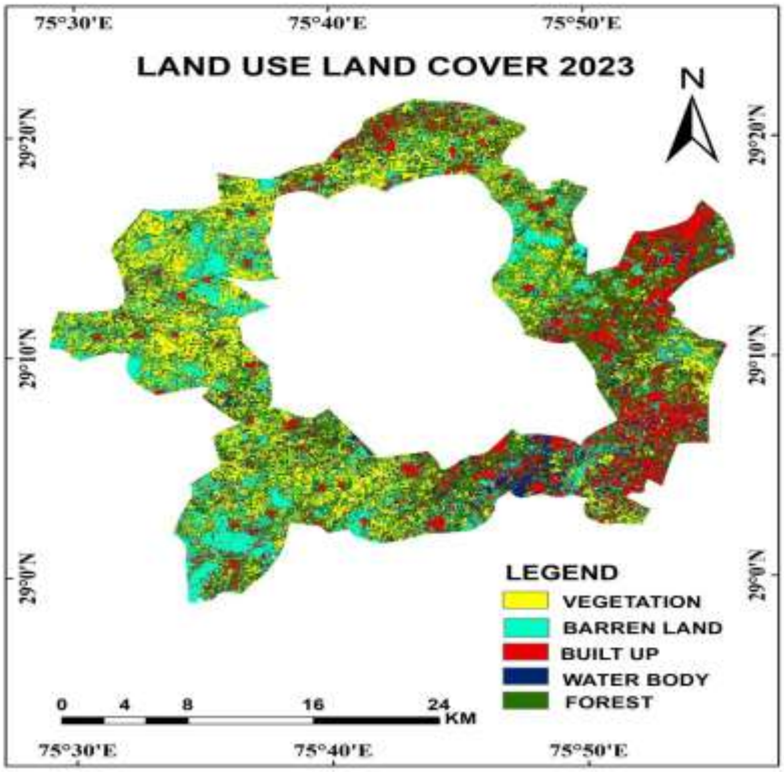


Figure 8: Land use land cover of outer fringe of Hisar for year 2023.

The table 5 provides a comparative analysis of Land Use and Land Cover (LULC) changes across three timeframes—2003, 2013, and 2023—illustrating shifts in land use patterns within the study area.

Vegetation 2003: Occupied 154.55 sq. km (23%) of the total area. 2013: Increased significantly to 291.21 sq. km (43%), showing a notable gain during this decade. 2023: Reduced to 140.23 sq. km (21%), reversing previous gains. Trend: Vegetation fluctuated, indicating land management changes or urban expansion affecting green cover.

Barren Land 2003: Covered 116.52 sq. km (17%). 2013: Decreased to 75.93 sq. km (11%), and further reduced to 68.93 sq. km (10%) by 2023. Trend: Consistent decline suggests reclamation for agriculture, urban development, or vegetation growth.

Built-Up Areas: 2003: Occupied 28.33 sq. km (4%). 2013: Expanded to 50.49 sq. km (8%) and further surged to 276.43 sq. km (41%) by 2023. Trend: A dramatic increase underscores rapid urbanization, population growth, and infrastructure development over two decades.

Water Bodies: 2003: Spanned 74.95 sq. km (11%). 2013: Declined slightly to 72.34 sq. km (11%), and further dropped to 35.83 sq. km (5%) by 2023. Trend: Steady decline indicates challenges in water resource management, possibly due to urban encroachment or climatic factors.

Forest: 2003: Accounted for the largest share at 297.58 sq. km (44%). 2013: Reduced significantly to 181.96 sq. km (27%), and further decreased to 150.51 sq. km (22%) by 2023. Trend: The consistent reduction reflects deforestation, urban expansion, or agricultural activities impacting

forest resources.
Overall Trends:
Urban Expansion: Built-up areas increased more than ninefold between 2003 and 2023, primarily at the expense of vegetation, forests, and barren land.
Environmental Degradation: Declines in water bodies and forest cover highlight significant environmental challenges, emphasizing the need for sustainable resource management.
Vegetation Dynamics: The fluctuation in vegetation cover suggests the impact of urban sprawl and changes in agricultural practices.
Land Reallocation: The steady decline in barren land reflects land transformation for urban and semi-urban uses.

Table 5: Land use/ Land cover under different category in outer fringe for the year of 2003, 2013, 2023

Sr. No.	**LULC Classes**	**2003**		**2013**		**2023**	
		Area (sq. km)	**Area (%)**	**Area (sq. km)**	**Area (%)**	**Area (sq. km)**	**Area (%)**
1	Vegetation	154.55	23%	291.21	43%	140.23	21%
2	Barren land	116.52	17%	75.93	11%	68.93	10%
3	Built-up	28.33	4%	50.49	8%	276.43	41%
4	Water bodies	74.95	11%	72.34	11%	35.83	5%
5	Forest	297.58	44%	181.96	27%	150.51	22%
	Total	**671.93**	**100%**	**671.93**	**100%**	**671.93**	**100%**

The table 6 summarizes the significant changes in LULC classes over two decades (2003–2023) within the study area. The data highlights notable transformations across vegetation, barren land, built-up areas, water bodies, and forests.

Vegetation: 2003: Covered 154.55 sq. km. 2023: Reduced to 140.23 sq. km, a net decrease of 14.32 sq. km. Trend: The loss in vegetation could be attributed to urban expansion or conversion to agricultural and built-up land.

Barren Land: 2003: Occupied 116.52 sq. km. 2023: Declined sharply to 68.93 sq. km, a loss of 47.59 sq. km. Trend: Indicates reclamation of barren land for urban development or agricultural purposes.

Built-Up Areas: 2003: Spanned 28.33 sq. km. 2023: Expanded dramatically to 276.43 sq. km, a staggering increase of 248.1 sq. km. Trend: Reflects rapid urbanization, infrastructure development, and population growth, significantly transforming the landscape.

Water Bodies 2003: Occupied 74.95 sq. km. 2023: Reduced to 35.83 sq. km, a loss of 39.12 sq. km. Trend: The decline in water bodies suggests challenges such as urban encroachment, water resource mismanagement, and potential climate change impacts.

Forest: 2003: Constituted the largest share at 297.58 sq. km. 2023: Shrunk to 150.51 sq. km, a significant loss of 147.07 sq. km. Trend: Deforestation due to urban sprawl, agricultural expansion, and industrial development has drastically reduced forest cover.

Table 6: Change in area (sq. km) of different land use/land cover classes of outer fringe for year 2003-2023.

Sr. No.	**LULC Classes**	**Area in 2003**	**Area in 2023**	**Change in area**
1	Vegetation	154.55	140.23	-14.32
2	Barren land	116.52	68.93	-47.59
3	Built-up	28.33	276.43	248.1
4	Water bodies	74.95	35.83	-39.12
5	Forest	297.58	150.51	-147.07
	Total	**671.93**	**671.93**	

Area covered under vegetation category is 122.6 sq. km in year 2003, which increased by 15.1 sq. km in year 2023 in inner fringe (**Table 3**, **4**). Total area under barren land category is 97.4 sq. km in 2003 and which is decreased by 28.2 sq. km in year 2023 in inner fringe. Total area under built up category is 18.6 sq. km in year 2003, and it increased by 69.7 sq. km in year 2023 in inner fringe. Area covered under water body category is 24.9 sq. km in year 2003, which decreased by 15.5 sq. km in year 2023 in inner fringe. Area covered under forest category is 70.6 sq. km in year 2003, which decreased by 40 sq. km in year 2023 in inner fringe Area covered under vegetation category in outer fringe is 154.55 sq. km in year 2003, which decreased by 14.32 sq. km in year 2023 (**Table 5, 6**). Urban expansion has transformed undeveloped and agricultural land into built-up areas, reflecting the shift from agricultural use to urban or industrial development. Total area under barren land category in outer fringe is 116.52 sq. km in 2003 and which is decreased by 47.59 sq. km in year 2023. This shift reflects the growing use of previously undeveloped land for agriculture, driven by the demand for increased agricultural production in Hisar, Haryana. Total area under built up category in outer fringe is 28.33 sq. km in year 2003, and it increased by 248.1 sq. km in year 2023 due to increased population and demand for more urbanized area.

Area covered under water body category in outer fringe is 74.95 sq. km in year 2003, which decreased by 39.12 sq. km in year 2023. This suggests the drying or drainage of water bodies, leading to their colonization by plants. Area covered under forest category in outer fringe is 297.58 sq. km in year 2003, which decreased by 147.07 sq. km in year 2023. The conversion of forest land into built-up areas due to urban sprawl also suggests increased afforestation or natural regrowth of vegetation in previously open spaces.

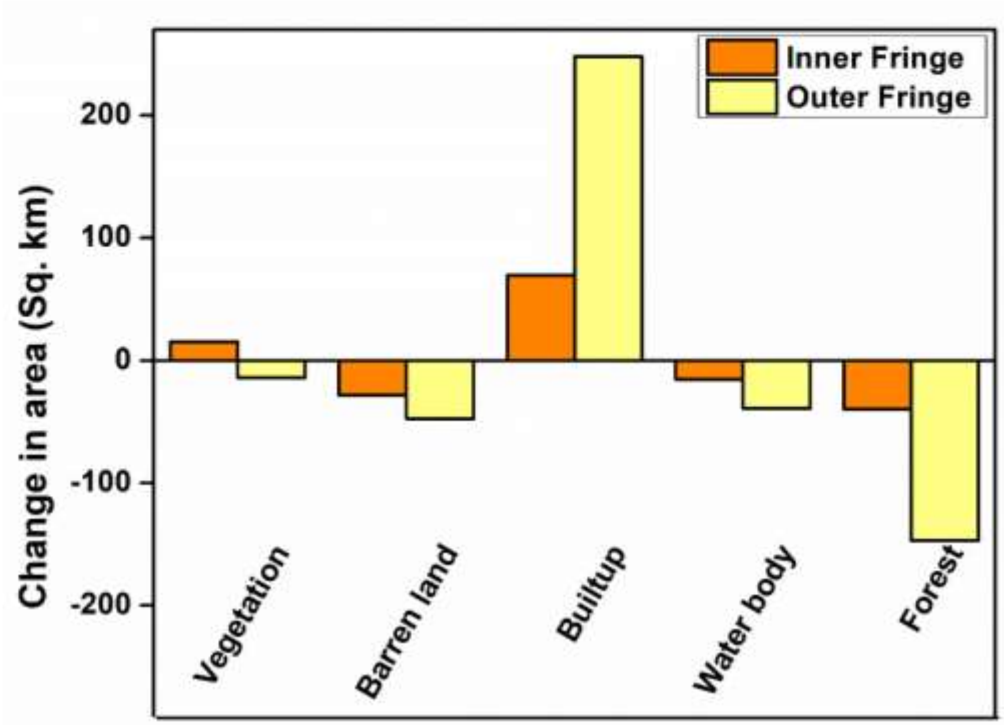


Figure 9: Percentage change of land use and land cover classes in Rural Urban Fringe of Hisar City 2003-2023.

Urban sprawl and uncontrolled urban growth have become major concerns worldwide. Numerous studies across different regions have shown that sprawl is primarily driven by population growth and push factors that trigger migration to nearby cities. It initially occurs on agricultural, vegetated, and open lands within a city, then extends to the periphery to meet the increasing demand for land. This expansion leads to significant changes in LULC, compromising the environment and undermining regional sustainability by reducing crop production and forest resources. The analysis of land use and land cover changes in Hisar district from 2003 to 2023 reveals significant transformations. Key trends include the conversion of barren land, forests, and cropland into built-up areas, indicating urban expansion and agricultural intensification. Additionally, there is a notable reversal of some built-up and cropland back into barren land or vegetation, reflecting dynamic land management practices and shifting environmental conditions. Understanding these changes is essential for effective planning and promoting sustainable development in the region. However, the built-up area in the outer fringe of Hisar has also grown significantly more than in the inner fringe (**Figure 9**). This expansion in the outer areas can be attributed to factors such as suburbanization, infrastructure development, industrial and commercial growth, and overcrowding in the inner fringe. In contrast, it has been observed that built-up density has increased more in the core areas of the city, consistent with the findings of Manju Sharma and Vipin Kumar (2023).

Conclusion

The study on land use and land cover (LULC) changes over three distinct periods (2003, 2013, and 2023) in the outer and inner fringe areas reveals significant shifts driven primarily by population growth, agricultural demands, and urban expansion. In the outer fringe, forests initially dominated the landscape in 2003, occupying around 297 sq km. However, by 2013, forest cover had decreased to 181 sq km, losing approximately 100 sq km to other land uses, reflecting a broader trend of deforestation and land conversion. Vegetation, conversely, increased significantly, rising to 291 sq km by 2013, facilitated by improved irrigation and agricultural expansion. Despite these shifts, barren land and water bodies saw a reduction in area, while built-up areas nearly doubled from 28 sq km to 58 sq km, driven by increased population and infrastructure needs. By 2023, the most striking transformation was the expansion of built-up areas, which surged to 300 sq km, overtaking all other land use types. This change highlights the rapid pace of urbanization and industrial growth, particularly in the eastern and southeastern parts of the outer fringe. The decrease in vegetation and water bodies raises environmental concerns, indicating the pressure of development on natural resources.

In the inner fringe, a different yet related pattern emerged. Vegetation was the most prevalent land use in 2003, with around 122 sq km, supported by the demand for agricultural produce in nearby urban areas. Built-up areas were minimal, covering just 18 sq km. Over the decade leading to 2013, vegetation maintained its dominance, although with only a modest increase. The most notable change was the rise in built-up areas, which expanded significantly to 58 sq km, driven by urban population growth and the need for housing and services. Barren land and forest areas both saw reductions, while water bodies decreased slightly, indicating increased land use competition. By 2023, vegetation retained its leading position, covering 138 sq km, yet built-up areas continued to grow to 70 sq km, now constituting 26% of the inner fringe. The continuous decline in water bodies and forests, along with increased urban infrastructure, underscores the environmental challenges posed by urbanization.

Thus, LULC analysis highlights a clear trend of expanding built-up areas, driven by population growth and industrialization, at the expense of natural and agricultural lands. This shift raises concerns about sustainable development, the preservation of natural resources, and the need for balanced urban planning to mitigate the environmental impacts of unchecked urban sprawl.

Conflict of Interest: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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