Monitoring of Land Use and Land Cover Change Using Geoinformatics Techniques of Tosham Block; Haryana

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Abstract

This study analyses land use/ land cover changes in the Tosham block of Haryana between 1990 and 2025 using multi-temporal Landsat-5 and Landsat-8 satellite imagery. A supervised classification approach based on the Maximum Likelihood algorithm was implemented in QGIS to generate LULC maps and quantify spatio-temporal transformations in a heterogeneous semi-arid landscape. Results indicate a major restructuring of land use during the study period. In 1990, agriculture was the dominant class (31.4%), followed by sandy areas (28.9%) and fallow land (21.3%), while built-up land occupied only 3.4% of the total area. By 2025, agricultural land expanded markedly to 52.1% (an increase of 15,420.5 ha), and built-up land nearly doubled to 6.3% (an increase of 2,160.24 ha), reflecting agricultural intensification and growing urbanization. In contrast, fallow land decreased to 11.6% (−7,212 ha), sandy areas to 18.5% (−7,795 ha), and scrub land to 7.7% (−2,263.1 ha), indicating large-scale conversion of marginal and unused lands into cultivated and developed areas. Barren rocky terrain showed only minor change (−517.6 ha), whereas water bodies slightly increased (+206.96 ha), possibly due to improved water harvesting structures. The findings reveal strong anthropogenic influence on landscape transformation driven by irrigation development, population pressure, and infrastructure expansion. The study demonstrates the effectiveness of Landsat time-series data and GIS-based supervised classification for long-term LULC monitoring. It highlights the need for systematic land management strategies to balance agricultural growth and urban expansion with environmental conservation and sustainable resource use.

Keywords: *Land use/Land cover, Change, Classification, Remote sensing & GIS,*

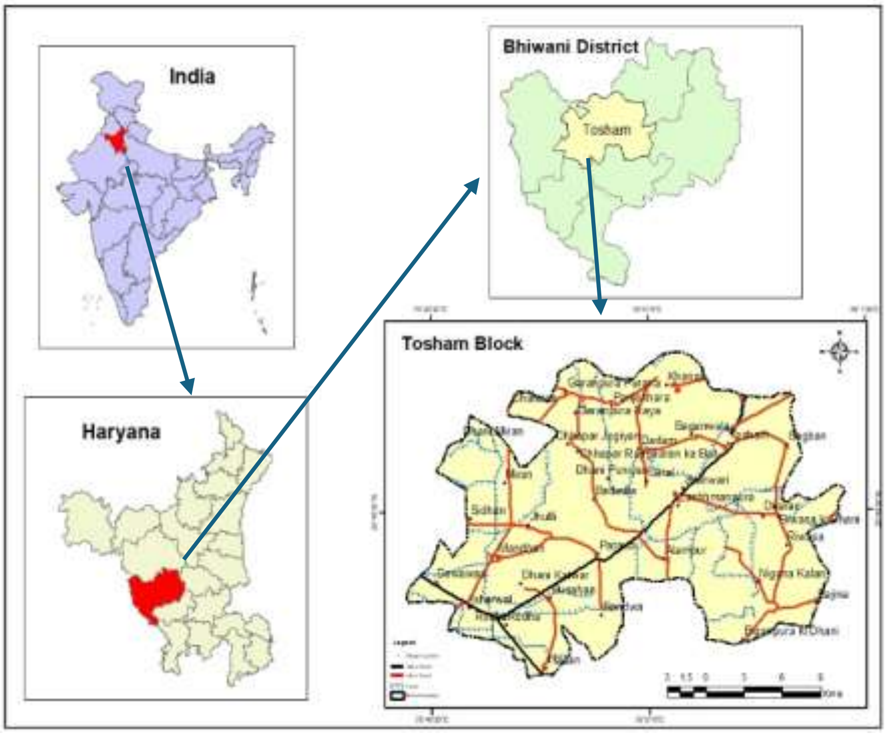
1. Introduction

Rapid population growth and intensified human activities are causing continuous changes in the land use/ land cover of the Earth. The increasing demand for housing, agriculture, industrial development, and transportation infrastructure has led to the large-scale conversion of forests and open lands into built-up areas. Land use/ land cover refers to the utilization of land for activities such as agriculture, conservation, development, recreation, wildlife habitats, and urban settlements, as well as the physical characteristics of the land surface. It represents the outcome of interactions between human activities and the natural environment at a specific location, influenced by climatic processes and socioeconomic dynamics. Land use/ land cover encompasses all living and non-living components present on the Earth's surface and is considered a vital asset of the earth system (Chughtai et al., 2021). The significance of land use arises from its dynamic interaction with the atmosphere, its role in regulating the hydrological cycle, and its influence on the surface energy balance, all of which are critical for understanding and predicting weather and climate processes. Vegetation, in particular, plays a crucial role in maintaining climatic stability through transpiration and carbon cycle regulation. It acts as a key interface among the atmosphere, hydrosphere, and lithosphere, thereby influencing ecological balance and environmental sustainability (Zhang et al., 2017; Ghorbanian et al., 2022). These transformations contribute to deforestation, loss of biodiversity, and overall environmental imbalance. Since land use and land cover are closely related and not mutually exclusive, the terms are often used interchangeably, as land use is inferred from land cover based on contextual evidence (Manonmani and Suganya, 2010). Land use/ land cover change has become a central component of contemporary strategies for natural resource management and environmental monitoring(Tiwari and Saxena, 2011). An improved understanding of land dynamics can be achieved through the systematic detection and assessment of land use/ land cover changes (Rawart and Kumar, 2015). In regions experiencing rapid and often undocumented land use changes, satellite-based observations provide objective, consistent, and reliable information on human utilization and transformation of the landscape. Moreover, the integrated use of satellite-based remote sensing (RS) and geographic information systems (GIS) has proven to be a robust, efficient, and cost-effective approach for monitoring land use/ land cover changes (Hathout, 2002; Lambin et. Al., 2003; Poyatos et. Al., 2003; Herold et. Al., 2003; Serra et. Al., 2008; López et. Al., 2013; Hazarika, et. Al., 2015). Remote sensing using satellite imagery facilitates the mapping of spatial distribution and temporal dynamics of environmental changes occurring across different regions (Torbick et al., 2016; Puno, 2018). A region's sustainability and development depend on continuous and accurate investigation of land use and land cover (LULC). Changes in LULC, particularly deforestation and urbanization, significantly influence global climate change (Li et al., 2022). Land use/ land cover changes have been widely recognized for their direct and indirect influences on multiple environmental components and processes (Patra et al., 2018). This study aims to analyze the patterns of land use/ land cover changes in a rapidly developing urban area of the Tosham Block, Bhiwani District, Haryana. The primary focus of the study is to identify and compare LULC classes using satellite imagery from the years 2006 and 2025 through the application of remote sensing and geographic information system (GIS) techniques.

2. Study area

The study area comprises the Tosham block, which is part of the Bhiwani district in the state of Haryana, India. Tosham is a rural Gram Panchayat located at the foothills of the Tosham Hill Range, which forms part of the Aravalli Mountain Range. Tosham is geographically located between 28°42′55″ N to 28°55′59″ N latitude and 75°39′11″ E to 76°00′21″ E longitude, covering an area of approximately 74500 hectares. The region has an average elevation of about 207 m (679 ft) above mean sea level. The study area experiences a dry climatic regime characterized by hot summers, cold winters, and a short monsoon season. The average temperature in the study area ranges from 3 °C to 45 °C, with high diurnal and seasonal temperature variations. During the summer months of June and July, hot, dust-laden winds locally known as loo blow from the Thar Desert of Rajasthan, intensifying arid conditions. The normal annual rainfall of the block is approximately 420 mm, most of which is received during the southwest monsoon season. Ecologically, the Tosham hill range represents an important biodiversity hotspot within the western–southern Haryana spur of the Northern Aravalli leopard wildlife corridor. The natural vegetation of the region is predominantly characterized by tropical thorn scrub and succulent species, adapted to arid and semi-arid conditions. Additionally, a variety of ephemeral plant species occur in the area, completing their life cycles within the short rainy season.

Figure 3.1: Location of study area



1. Materials and Methods

3.1 Materials- In this study, Landsat 5 Thematic Mapper (TM) satellite data for 1990 and Landsat 8 Operational Land Imager (OLI) data for 2025, downloaded from the USGS Earth Explorer, were used for land use/ land cover mapping and change detection analysis. The details of the satellite data utilized in this study are presented in table 3.1. The base map of the study area was extracted from Survey of India (SOI) topographic sheets at a scale of 1:50,000. Demographic information, such as district-wise population data, was obtained from the District Census Handbook published by the Census of India. Ground validation of the prepared LULC maps was carried out using GPS-based field survey samples collected in 2025.

Table 3.1: Details of the satellite data

Satellite	Sensor	Date	Spatial Resolution
Landsat - 5	TM	March 1990	30
Landsat - 8	OLI	March 2025	30

3.2 Methods- The present study is based on both primary and secondary data sources. An integrated approach combining Remote Sensing (RS) and Geographic Information System (GIS) techniques was adopted to analyze land use/ land cover dynamics. The study begins with data acquisition, involving the collection of multi-temporal Landsat satellite imagery. The acquired data were subjected to data preparation and image pre-processing, including layer stacking, image enhancement, and extraction of the study area boundary. These steps ensured radiometric consistency and enhanced visual interpretation for accurate image classification. The methodology involves supervised classification of multi-temporal satellite imagery to detect LULC changes between 1990 and 2025. Multi-temporal data are essential for examining land use transformations over extended periods. The primary objective of supervised classification in LULC mapping is to categorize different land cover features such as built-up land, agriculture land, fallow land, barren rocky area, sandy area, scrub land and waterbodies based on their spectral reflectance characteristics recorded by satellite sensors. In supervised classification, training sites are selected as representative samples of identified land cover types. These training sites are then used to develop spectral signatures that define numerical values for each land cover class based on their spectral attributes (Ramachandran and Reddy, 2017). The Maximum Likelihood (ML) algorithm, one of the most widely used supervised classification techniques, was employed for image classification (Jensen, 2005). This algorithm is based on probability theory and assumes that the training data for each class in each spectral band follow a normal distribution (Basukala et al., 2017). Following classification, thematic LULC maps were generated, and area statistics were calculated. Tables and graphs illustrating land cover changes were prepared using Microsoft Excel. A confusion matrix was generated to evaluate the classification accuracy, which formed the basis for accuracy assessment. Further, change detection analysis was carried out using the post-classification comparison method to identify spatial and temporal changes in LULC between 1990 and 2025. The overall methodological framework adopted in the present study is illustrated in figure 3.2.

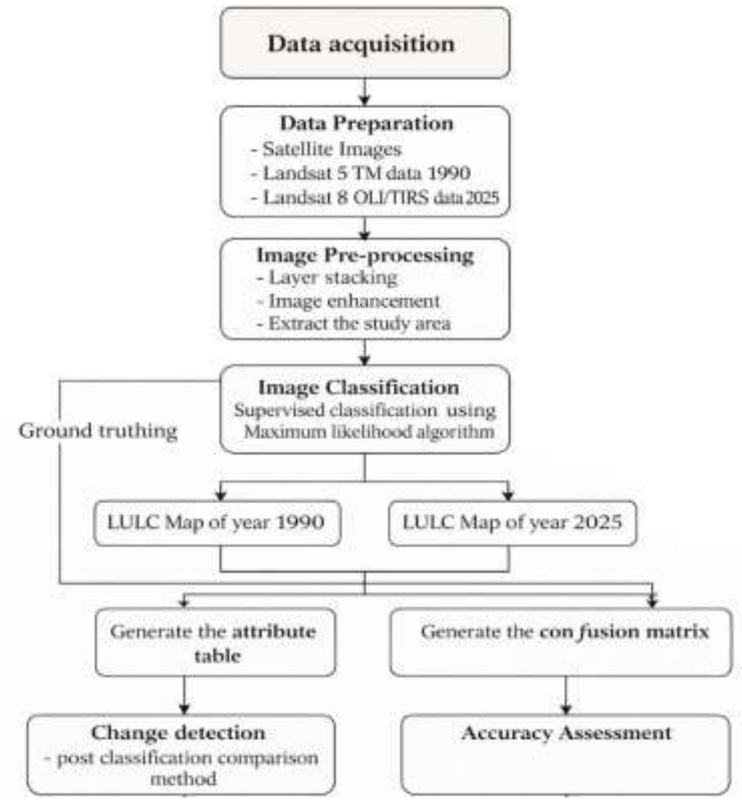


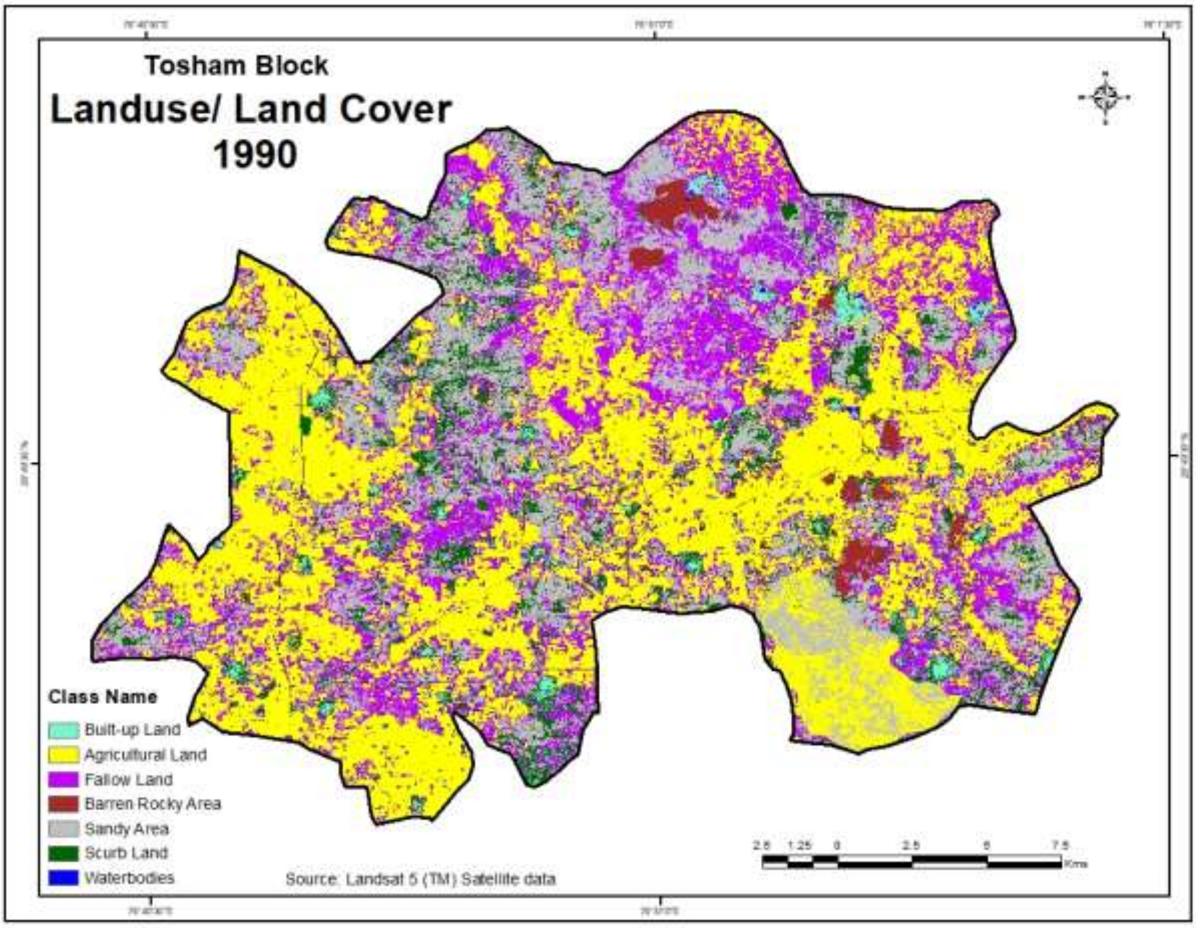
Figure 3.2: Methodological framework

4. Result

Land use/ land cover change represents one of the most extensive and perceptible transformations of the Earth's surface. Evaluating LULC changes across different spatial scales is essential for environmental conservation, natural resource management, land use planning, and sustainable development. The present study aims to examine land use/ land cover changes in the Tosham block, Haryana, over the period 1990–2025 using compatible, moderate-resolution Landsat satellite imagery. A supervised classification approach was employed for the classification and generation of LULC maps for the selected time periods. In this study, the supervised classification technique was applied to Landsat 5 and Landsat 8 satellite data to identify and classify various LULC categories, including built-up land, agricultural land, fallow land, barren rocky areas, sandy areas, scrubland, and water bodies. The details of the LULC categories considered in this study are presented below.

4.1 Land use/ Land cover (1990-2025) - Based on standard image interpretation elements such as tone, texture, shape, size, pattern, association, and site, visual interpretation of the Landsat imagery the land use/ land cover was carried out for both year. The land use/ land cover statistics for the Tosham block reveal substantial spatial transformations between 1990 and 2025 are presented in Tables 4.1. The total geographical area of the block remained constant at 74,500 ha, indicating that observed changes are due to internal land use conversions rather than boundary alterations. The land use/ land cover maps were prepared to identify and map the change details of the study area (Figures 4.1 and 4.2).

Figure 4.1: Land use/ Land cover of Tosham Block (1990)



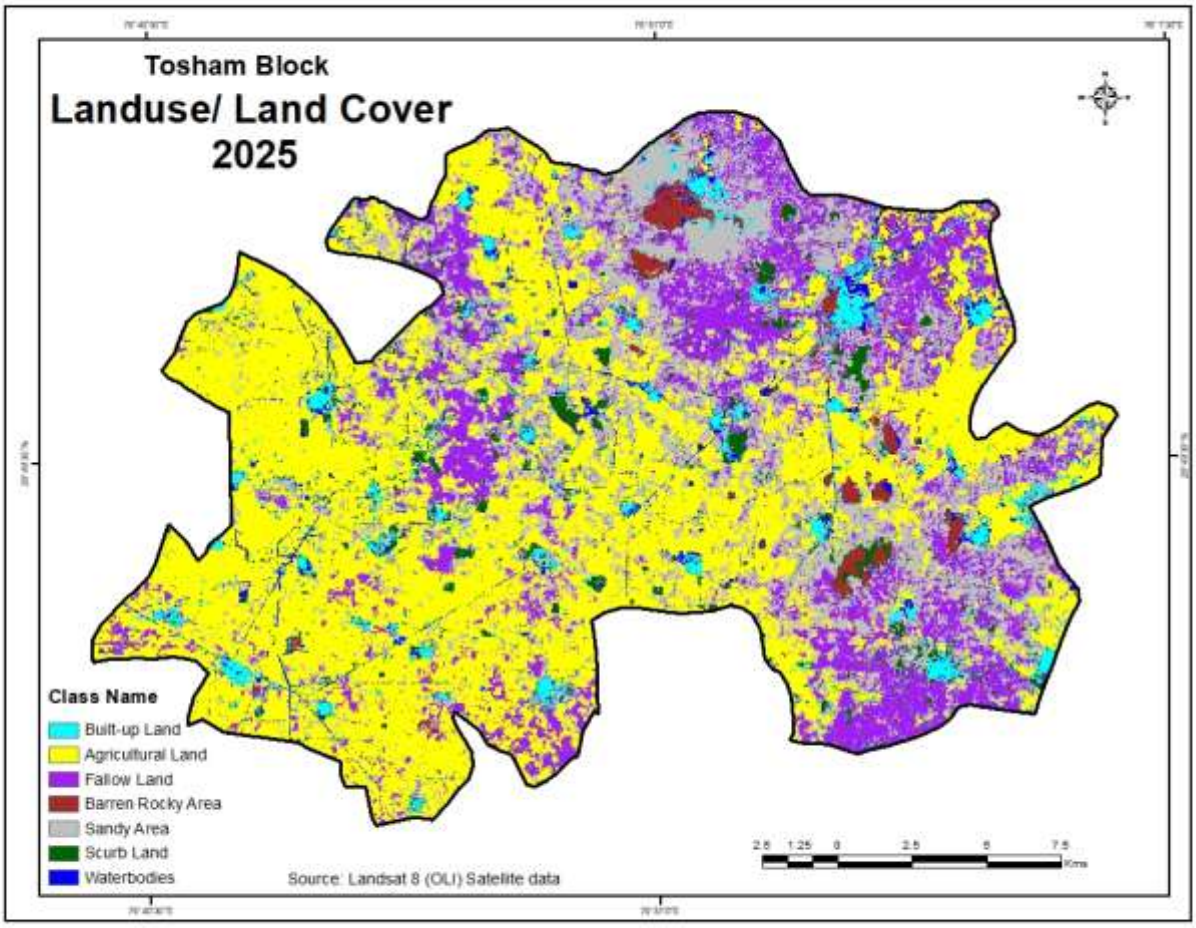


Figure 4.2: Land use/ Land cover of Tosham Block (2025)

Table 4.1: Land use/ Land cover of Tosham Block (2025)

Land use/ Land Cover classes	Area in Ha. (1990)	Area in % (1990)	Area in Ha. (2025)	Area in % (2025)
Built-up Land	2522.56	3.4	4682.8	6.3
Agriculture Land	23420.6	31.4	38841.1	52.1
Fallow Land	15863.2	21.3	8651.2	11.6
Barren Rocky Area	2177	2.9	1659.4	2.2
Sandy Area	21547.4	28.9	13752.4	18.5
Scrub Land	8006.1	10.7	5743	7.7
Waterbodies	963.14	1.3	1170.1	1.6
Total	**74500**	**100.0**	**74500**	**100.0**

Source: Landsat-5 (TM) and Landsat-8 (OLI) Satellite data

In 1990, agricultural land constituted the largest share of the total area (31.4%), followed by sandy area (28.9%) and fallow land (21.3%). Scrub land accounted for 10.7%, while built-up land occupied only 3.4% of the total area. Barren rocky areas and water bodies covered relatively smaller proportions, accounting for 2.9% and 1.3%, respectively. By 2025, a significant shift in land use pattern was observed. Agricultural land expanded substantially to 52.1% of the total area, indicating intensified agricultural activities. Built-up land nearly doubled, increasing from 3.4% to 6.3%, reflecting rapid urbanization and infrastructure development. In contrast, fallow land declined sharply to 11.6%, while sandy areas decreased to 18.5%, suggesting their conversion into cultivated or developed land. Scrub land also showed a reduction, covering 7.7% of the area in 2025. Minor changes were observed in barren rocky areas (2.2%) and water bodies, which increased slightly to 1.6%. In the present study comparison reveals a pronounced transformation of the landscape from fallow, sandy, and scrub lands toward agricultural and built-up land uses, highlighting increasing anthropogenic influence and changing land management practices in the Tosham block between 1990 and 2025.

4.2 Land use/ Land cover change from 1990-2025 - The land use/ land cover change distribution of the Tosham block for the years 1990 and 2025 is presented in table 4.2.

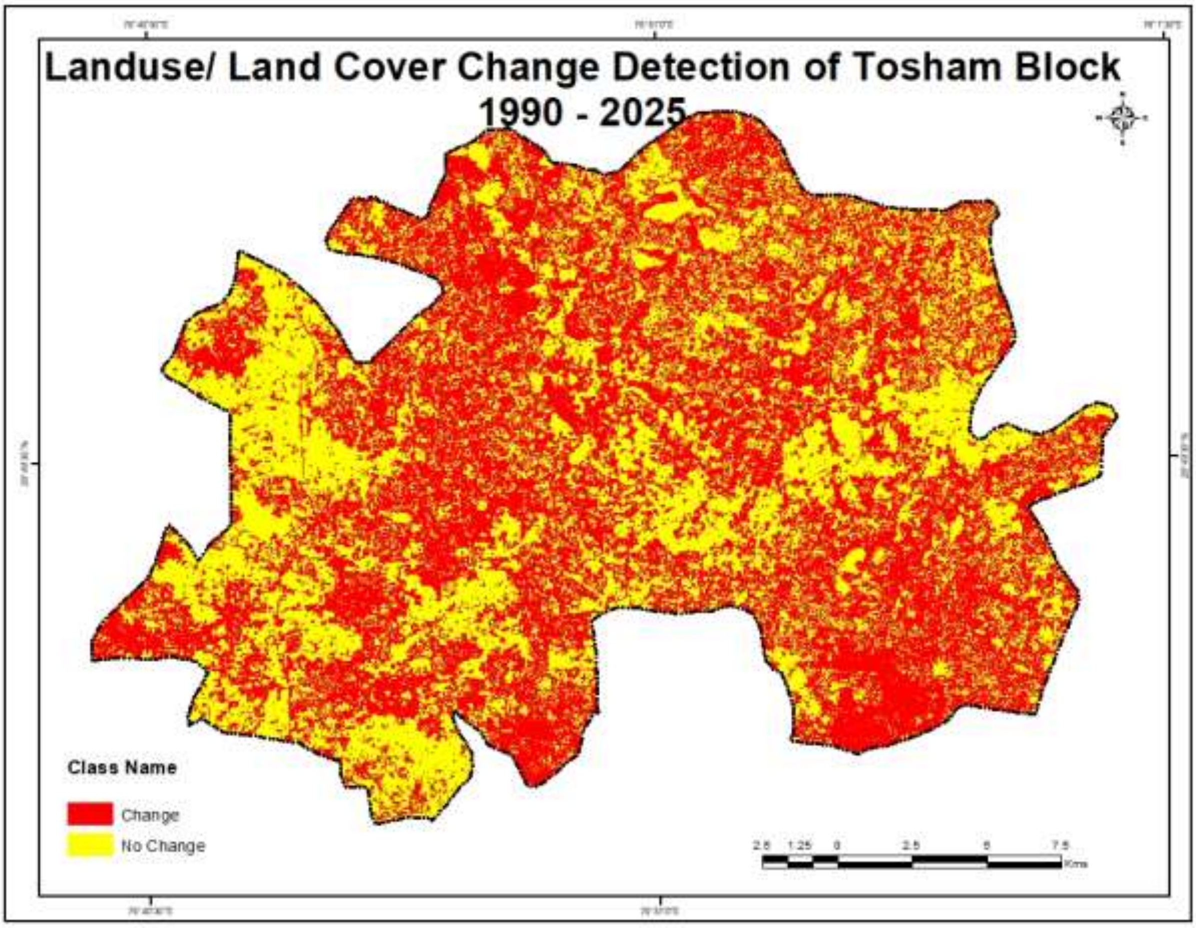
Table 4.2: Details of Land use/ Land cover change (1990- 2025)

Land use/ Land Cover classes	**Area in Ha. Change from 1990-2025**	**Area in % Change from 1990-2025**
Built-up Land	2160.24	2.9
Agriculture Land	15420.5	20.7
Fallow Land	-7212	-9.7
Barren Rocky Area	-517.6	-0.7
Sandy Area	-7795	-10.5
Scrub Land	-2263.1	-3.0
Waterbodies	206.96	0.3
Total	0	0

Source: Landsat-5 (TM) and Landsat-8 (OLI) Satellite data

In the table 4.2 it has been shown that agricultural land showed the most significant increase, expanding from 23,420.6 ha (31.4%) in 1990 to 38,841.1 ha (52.1%) in 2025, reflecting a net gain of 15,420.5 ha (20.7%). This increase suggests a large-scale conversion of fallow, sandy, and scrub lands into cultivated areas, possibly driven by agricultural intensification, irrigation development, and population pressure. Built-up land also increased markedly from 2,522.56 ha (3.4%) to 4,682.8 ha (6.3%), registering a net increase of 2,160.24 ha (2.9%). This expansion highlights ongoing urbanization, infrastructure development, and settlement growth in the Tosham block. In contrast, fallow land experienced a sharp decline from 15,863.2 ha (21.3%) in 1990 to 8,651.2 ha (11.6%) in 2025, resulting in a reduction of 7,212 ha (−9.7%). Similarly, sandy areas decreased substantially by 7,795 ha (−10.5%), indicating land reclamation and conversion into agricultural or other productive uses. Scrub land also declined from 8,006.1 ha (10.7%) to 5,743 ha (7.7%), showing a net loss of 2,263.1 ha (−3.0%), which may be attributed to anthropogenic activities such as agricultural expansion and mining. Barren rocky areas showed a minor reduction of 517.6 ha (−0.7%), suggesting limited transformation due to inherent terrain constraints. Conversely, water bodies exhibited a slight increase from 963.14 ha (1.3%) to 1,170.1 ha (1.6%), reflecting a net gain of 206.96 ha (0.3%), possibly due to the construction of small reservoirs, ponds, or improved water conservation measures.

Figure 4.3: Land use/ Land cover change of Tosham block (1990- 2025)



Source: Landsat-5 (TM) and Landsat-8 (OLI) Satellite data

Figure 4.3 illustrates the land use/ land cover change detection in the Tosham block between 1990 and 2025, derived using the post-classification comparison method. The map categorizes the study area into two classes i.e. change and no change. The areas marked in red represent zones where land use and land cover transformations have occurred during the study period, while areas shown in yellow indicate regions that remained unchanged. The spatial distribution of changes reveals that a substantial portion of the Tosham block has experienced significant LULC transformations over the last three and a half decades. The changes are widely distributed across the study area, indicating extensive human-induced modifications. The dominance of change pixels suggests a strong transition from fallow, sandy, scrub, and barren lands toward agricultural and built-up land uses, consistent with the quantitative LULC statistics. These changes may be attributed to factors such as agricultural expansion, population growth, infrastructure development, and land reclamation activities. Conversely, the areas showing no change are likely associated with stable land cover types, including rocky terrains and long-established land uses with limited anthropogenic intervention. Overall, the LULC change pattern in the Tosham block during 1990–2025 indicates a strong shift toward agricultural and built-up land, accompanied by a decline in fallow, sandy, scrub, and barren lands, reflecting intensified human intervention and changing land management practices.

4.3 Accuracy Assessment - Accuracy assessment is one of the most critical processes in land use and land cover classification, as it helps to validate and verify the classification results. In the present study, class-wise accuracy was evaluated, and user's accuracy, producer's accuracy, and overall accuracy were calculated. To assess the level of agreement between the classified map and reference data beyond chance. The Kappa coefficient was employed and range of Kappa coefficient values along with their corresponding strength of agreement has shown in table 4.3. Table 4.4 presents the error matrix for accuracy assessment of 2025 classification.

Table 4.3: Kappa coefficient range and its description

K-value	Strength of covenant
Strongly Disagree	<0.20
Disagree	0.20–0.40
Neither Agree nor Disagree	0.40–0.60
Agree	0.60–0.80
Strongly Agree	0.80–1.00

Source: Rwanga and Ndambuki (2017)

Table 4.4: Error matrix for accuracy assessment of 2025 classification

Reference Data									
Classified Data	**Built-up Land**	**Agriculture Land**	**Fallow Land**	**Sandy Area**	**Scurb Land**	**Barren Rocky Area**	**Waterbodies**	**RT**	**UA (%)**
Built-up Land	***8094***	17	128	256	987	10	5	9497	85
Agriculture Land	8	***22907***	82	15	2066	259	0	25337	90
Fallow Land	80	257	***14770***	30	29119	60	0	44316	65
Sandy Area	88	10	91	***14008***	450	79	2	14728	95
Scurb Land	80	211	1367	88	***57027***	81	0	58854	97
Barren Rocky Area	20	15	149	591	2011	***6682***	0	9468	71
Waterbodies	83	171	1	617	110	117	***545***	1644	63
CT	8453	23588	16588	15605	91770	7288	552	163844	
PA (%)	96	97	89	90	62	92	99		

Diagonal Italic numbers represent correctly classified samples for each LULC class
RT: row total; CT: column total; UA: user's accuracy; PA: producer's accuracy.
Sum of diagonal = 124033; Total = 163844
Overall accuracy = 75.7%.
Kappa coefficient (K) = .66

Table 4.4 presents the results of the accuracy assessment for the 2025 LULC classification. Out of a total of 163,844 reference points, 124,033 points were correctly classified, resulting in an overall accuracy of 78%. The user's accuracy was 85% for built-up land, 90% for agricultural land, 65% for fallow land, 95% for barren rocky areas, 96% for sandy areas, 71% for scrubland, and 63% for water bodies. The producer's accuracy was highest for water bodies (99%) and lowest for scrubland (97%). The Kappa coefficient value of 0.66 indicates a substantial level of agreement between the classified map and the reference data, reflecting a strong overall classification reliability. The study of land use/ land cover change has gained increasing importance in recent years due to the rapid transformation of natural landscapes by human activities. Over the past three decades, factors such as population growth, agricultural expansion, urbanization, industrial development, and mining activities have led to significant LULC changes in the Tosham Block of Haryana.

Conclusion

This study was conducted for the years 1990 and 2025 to assess the potential of Landsat-5 and Landsat-8 imagery for detecting land use/ land cover changes in the Tosham block of Haryana, a region characterized by heterogeneous land surfaces. Supervised classification using the Maximum Likelihood algorithm was applied in QGIS software to generate accurate LULC maps and to estimate and quantify spatio-temporal changes over the study period. The accuracy of the classified maps was evaluated using the Kappa coefficient, which revealed variations in classification accuracy among different LULC categories. Although multi-temporal Landsat data provide valuable insights for long-term LULC monitoring in tropical and sub-tropical regions. These changes have directly impacted soil fertility, water resources, forest cover, biodiversity, and the overall environmental balance of the region. Notably, there has been a substantial shift from agricultural land to built-up areas driven by urban and economic growth, along with alterations in natural features such as forests, water bodies, and barren lands due to intensified human intervention. This study aims to analyze the utilization and modification of land resources in the Tosham Block between 1990 and 2025, providing valuable insights for sustainable land management, spatial planning, and informed policymaking.

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