Original Article
ISSN (Online): 3049-2319

ShodhSamajik: Journal of Social Studies
January-June 2025 2(1), 155-164

SPATIO-TEMPORAL DYNAMICS OF LAND USE AND LAND COVER IN KURUKSHETRA DISTRICT, HARYANA (2004–2024) A REMOTE SENSING AND GIS-BASED ANALYSIS

Pawan Kumar [1], Sunil Kumar [2]

[1] Research Scholar, Department of Geography, Tantia University, Sri Ganganagar, Rajasthan, India
[2] Professor and Dean, Faculty of Arts, Craft and Social Science, Tantia University, Sri Ganganagar, Rajasthan, India

Received 19 March 2025
Accepted 24 April 2025
Published 31 May 2025

DOI
10.29121/ShodhSamajik.v2.i1.2025.201

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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ABSTRACT

Land-use and land-cover (LULC) transformation is one of the significant indicators that represent the interaction of agriculture and environment under the influence of settlement expansion and infrastructure development. This study investigates the LULC dynamics in Kurukshetra District in Haryana in the period 2004-2024 using techniques of multi-temporal Landsat imagery, Remote Sensing and Geographic Information System (GIS). Supervised Maximum Likelihood Classification (MLC) was applied to Landsat 7 ETM+ and Landsat 8 OLI respectively to classify 2004 and 2024, respectively. The five main classes that were identified are Built-up Area, Cropland, Vegetation and Tree Cover, Water Bodies and Bare Land. The post-classification comparison techniques were used for quantifying the net change, gross gain and loss and changes occurring from one class to all other classes.

Cropland, at first, the most dominant land-cover class, declined by 148.04 km2 or 8.83 percent, from 1,220.09 km2 (72.79 percent) in 2004 to 1,072.05 km2 (63.96 percent) in 2024. Built-up Area, on the other hand, increased from 50.66 km2 (3.02 percent) to 129.55km2 (7.73 percent), with a net increase of 78.89 km2 . Vegetation and tree cover declined from 83.68 to 51.18 km2 and increased from 316.93 km2 to 417.66 km2 for Bare Land. Water Bodies varied only slightly, from 4.78 km2 to 5.69 km2. A total area of 574.31 km2 or 34.26 percent of the district underwent transformation from one class to another class. The most important changes identified are Cropland-Bare Land, then Bare Land-Cropland. In turn this reflects significant agricultural seasonality. There was a direct Cropland to Built-up conversion of an area of 41.47 km2. From the analysis it can be concluded that Kurukshetra is mainly still an agricultural area, although settlement and infrastructure development have increased a lot.

Keywords: Land use and Land Cover, Change Detection, Landsat, Remote Sensing, GIS, Cropland, Built-up Expansion, Transition Matrix

1. INTRODUCTION

The land is the physical basis of agriculture, settlements, infrastructure, organizations, commercial development, plant and animal life and hydrological systems. The way that land is being utilised or what is growing on top of it has a fundamental influence on the interaction between people's activities and the environment. Fast expansion of settlements, of infrastructure, increasing intensity of agricultural land use and vegetation changes will alter the regional land Lambin et al. (2001), Turner et al. (2007).

RS and GIS are important tools in the study of these changes. Satellite imagery provides frequent and spatially continuous observations and, with GIS, can carry out classification, measurement, comparison and interpretation of multi-temporal land-surface data. In particular, the Landsat programme enables large area long-term investigation due to its multispectral observations with a 30 m spatial resolution providing adequate detail to monitor major LULC categories Jensen (2015), Lillesand et al. (2015).

Change detection can be achieved using several methods such as spectral differencing and post-classification comparison Singh (1989), Lu et al. (2004). Post-classification comparison can be useful as each image is initially classified separately and then corresponding pixels are compared. It not only allows the amount of change of a category to be measured, but also the origin and direction of change.

The scale of spatial coverage of human modifications to Earth's land surface may be unparalleled throughout history. Land cover changes (the biophysical state of the Earth's land surface) and land use changes (the purpose or intention human agents have for the biophysical state of the land surface) are argued to be among the most important Turner et al. (1990), Lambin et al. (1999).

Such an approach is particularly relevant in intensive agricultural landscapes. Agricultural fields may appear as Cropland when standing vegetation is present but as Bare Land after harvesting, ploughing or during a fallow period. Consequently, all Cropland Bare Land transitions should not automatically be interpreted as permanent agricultural abandonment. In contrast, conversion from Cropland to Built-up Area generally represents a more persistent functional transformation.

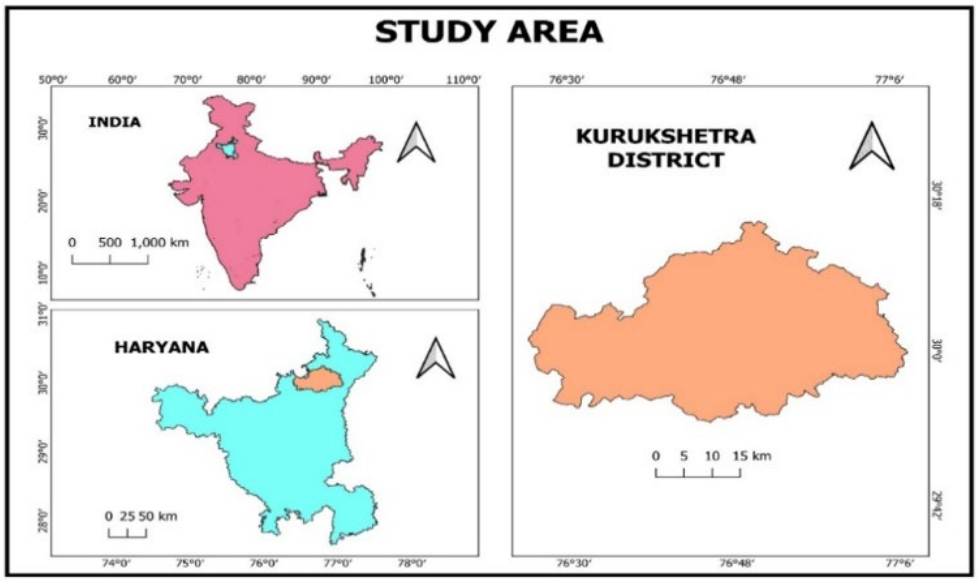
The district of Kurukshetra is chosen with the view to have a setting with a high agricultural potential and dynamic growth in terms of settlements, transport infrastructure and institutional development for such analysis. It has been demonstrated in previous studies that the district has a strong agrarian character, though the district displays a considerable diversity in the landcover composition of various parts. The current study compares the LULC pattern of Kurukshetra District at the beginning and at the end of a two-decade period and tries to figure out the main transition pathways that have led to the changes witnessed.

2. STUDY AREA

Kurukshetra District is in the north-eastern part of Haryana, lying in the Indo-Gangetic alluvial plain. The official geographical area of the district was noted to be approximately 1,676 km2 (i.e. the raster-based analytical area used for analysis in this study was 1,676.1375 km2. The plains are level, with fertile alluvial soils and a large irrigation network. Hence agriculture is the major land use, wheat and paddy making the core of the cropping system. Groundwater is extensively used as agricultural irrigation.

The largest built-up area is found in the Kurukshetra-Thanesar urban complex, other centres include Shahabad, Pehowa, Ladwa and many smaller villages. The district is of considerable religious, administrative, cultural and commercial significance. Areas of natural vegetation occur mainly in the form of plantations, orchards, agroforestry, trees in institutional premises, along roads and canals and in village groves. Standing-water bodies such as ponds and canals occur but are fairly small in extent.

Map 1



Map 1 Location of Kurukshetra District, Haryana
Sources: Computed by researcher through QGIS

3. MATERIALS AND METHODS

3.1. SATELLITE DATA AND IMAGE PROCESSING

As two satellite datasets for the initial and final years of the time period are needed, Landsat 7 ETM+ imagery for the year 2004 is used (baseline) and Landsat 8 OLI imagery for 2024 as latest time. Landsat Collection 2 Level-2 Surface Reflectance products are chosen because they are atmospherically corrected and can be used for quantitative land-surface analysis.

Visible, Near-Infrared and Shortwave-Infrared bands were used. Image processing and analysis were carried out using software: QGIS 3.40.9 and Semi-Automatic Classification Plugin 8.5.0 (Congedo, 2021). All raster datasets are stored in the WGS 84 / UTM Zone 43N (EPSG:32643) coordinate system with a spatial resolution of 30 m X 30 m. This means that each pixel represents 900 m2 or 0.0009 km2. The false-colour and SWIR-sensitive composites will be analysed for discrimination purposes of vegetation, Cropland, Built-up Area and exposed surfaces.

3.2. CLASSIFICATION

A conventional five-class classification scheme was used.

Sr. No	LULC category
1	Built-up Area
2	Cropland
3	Vegetation
4	Water Bodies
5	Bare Land

Sources: Compiled by researcher from various standard resources.

Each satellite image also had regions of Interest created and individually trained. These were then classified using Supervised Maximum Likelihood Classification to identify which LULC class each pixel was most likely to belong to.

The classifications were assessed by comparing visually to multispectral composites. Only clearly systematic errors were corrected. Special care was taken to detect any spectral similarity between low-density Built-up Area and Bare Land or harvested agricultural surfaces and exposed soil.

3.3. ACCURACY ASSESSMENT AND CHANGE DETECTION

The independent-validation samples were used to evaluate the classification accuracy. Overall accuracy of the map of 2004 is 98.15 percent and the corresponding Kappa coefficient is 0.9574. For the map of 2024, Overall Accuracy amounts to 96.86 percent and the Kappa value equals 0.9406, demonstrating a good thematic accuracy.

The persistence, gain, loss and class-to-class transformation were then calculated using the pair of final output maps as the before and after classification.

4. RESULTS

4.1. LULC DISTRIBUTION

Table 1

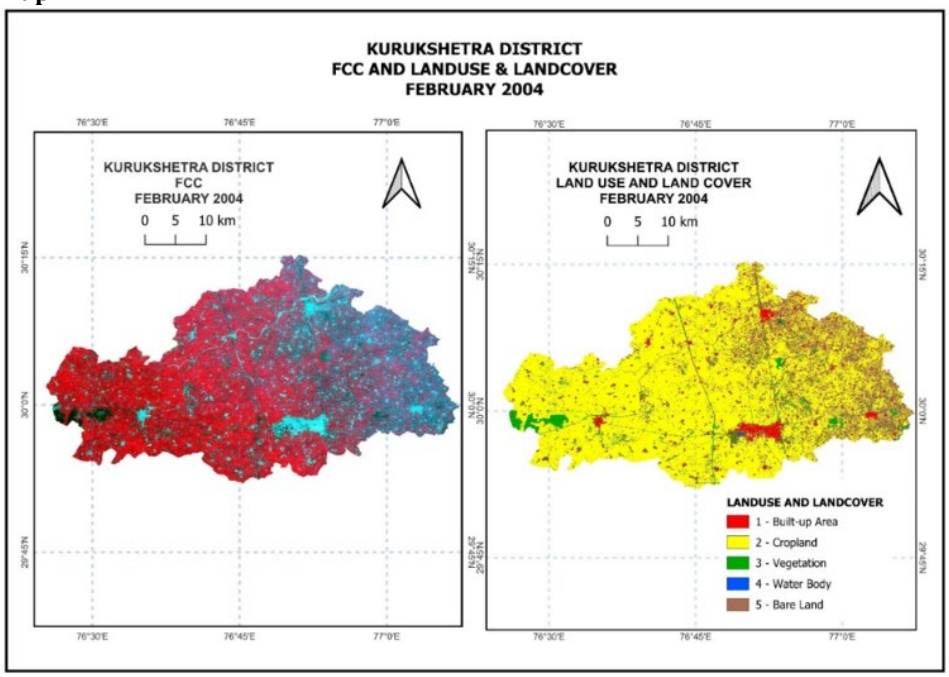
Table 1 LULC pattern of Kurukshetra District 2004 and 2024.

LULC category	2004 Area in km²	2004 percent	2024 Area in km²	2024 percent	Change area in km²	change percent
Built-up area	50.66	3.02	129.55	7.73	78.89	4.71
Cropland	1,220.09	72.79	1,072.05	63.96	-148.04	-8.83
Vegetation and Tree Cover	83.68	4.99	51.18	3.05	-32.5	-1.94
Water Bodies	4.78	0.29	5.69	0.34	0.91	0.05
Bare Land	316.93	18.91	417.66	24.92	100.73	6.01
Total	1,676.14	100	**1,676.14**	**100**		

Source: Calculated by researcher from satellite image analysis.

The findings show a significant transformation of the district landscape with cropland still remaining the most frequent class but decreasing by 148.04 km2 or 12.13 percent of its original area. Built-up Area had increased by 78.89 km2 or a relative increase of 155.71 percent so the built-up extent that the map represented in 2024 was approximately 2.56 times that of 2004. Vegetation & Tree Cover fell (by 32.49 km2 or 31.78 percent) between 2004 to 2024. Water Bodies had a relatively small percentage increase in 0.91 km2 as their original area was small.

Map 2



Map 2 LULC Patterns in 2004
Sources: Computed by researcher through QGIS

Diagram 1

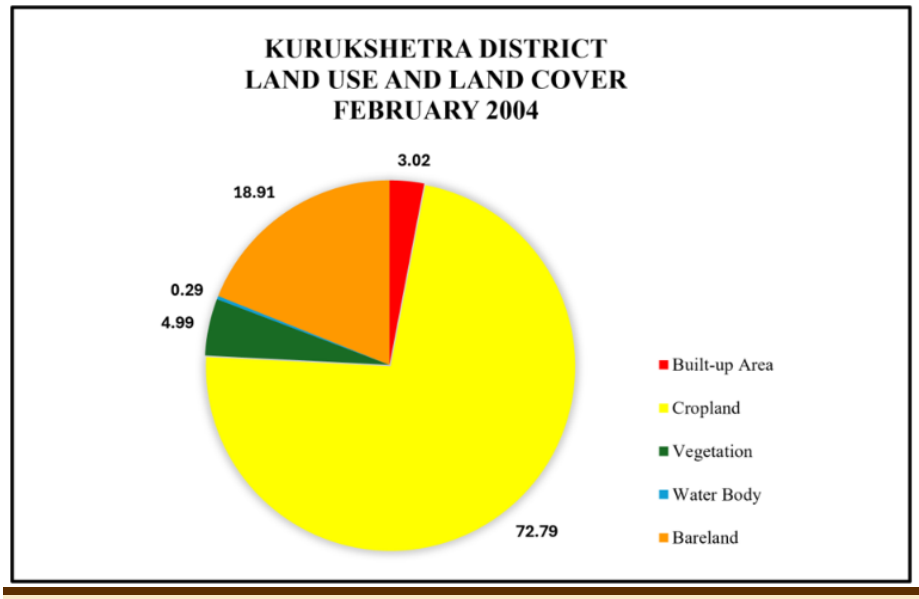
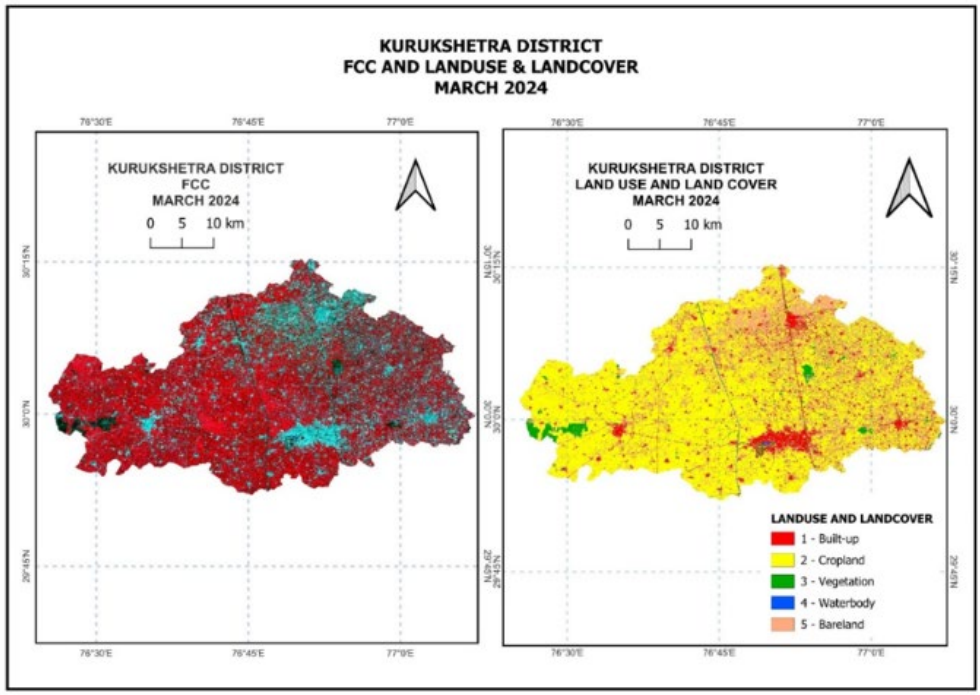


Diagram 1 LULC in 2004
Sources: Computed by the researcher.

Map 3



Map 3 LULC in 2024
Sources: Computed by researcher through QGIS

Diagram 2

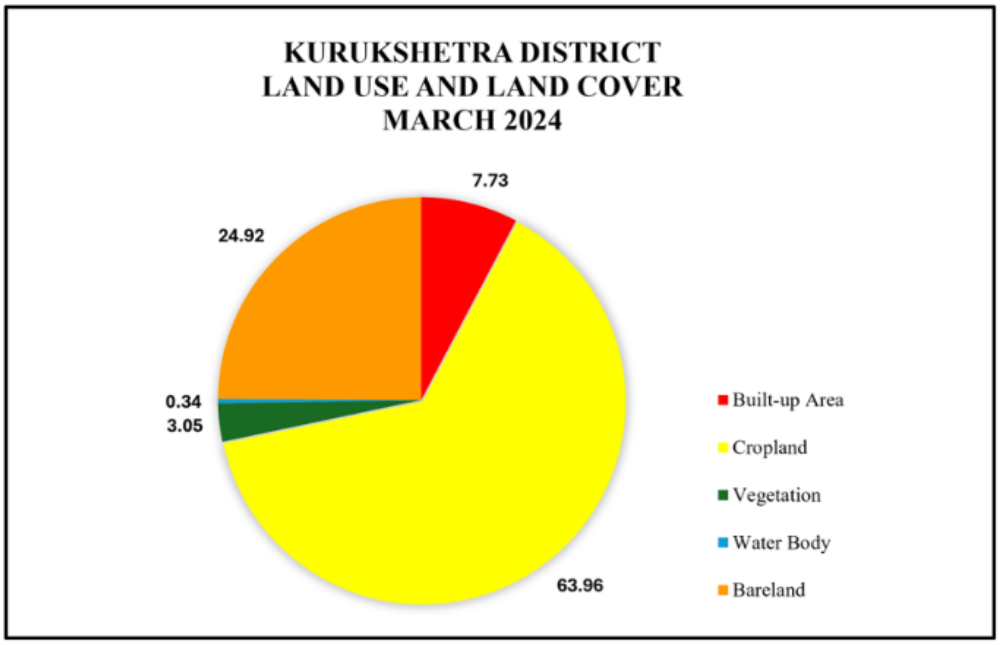


Diagram 2 LULC in 2024
Sources: Computed by the researcher.

4.2. PERSISTENCE AND CHANGED AREA

This means that after classification, 1,101.83 km2, which constitutes 65.74 percent of the district, has been assigned to one LULC category in both endpoint maps. The balance of 34.26 percent 574.31 km2, however, fell within a different category in 2024. This does not imply that one-third of the district had been irrevocably converted from one use to another, but it should also be acknowledged that a large proportion of the difference found in the classification was from Bare Land and Cropland classes dependent to the level of cultivation in the area.

4.3. CLASS TO CLASS TRANSITION

Table 2

Table 2 LULC transition matrix, 2004 and 2024 (km2)

	Built-up	Cropland	Vegetation	Water	Bare Land	2004 Total
Built-up	30.76	6.74	0.83	0.33	13.13	**50.66**
Cropland.	41.47	915.96	12.48	0.69	249.5	**1,220.09**
Vegetation	7.88	26.67	24.46	0.98	23.69	**83.68**
Water Bodies	0.78	0.34	0.34	1.87	1.45	**4.78**
Bare Land	49.79	122.35	13.07	1.82	129.9	**316.93**
2024 Total	**129.55**	**1,072.05**	**51.18**	**5.69**	**417.66**	**1,676.14**

Sources: Calculated by researcher

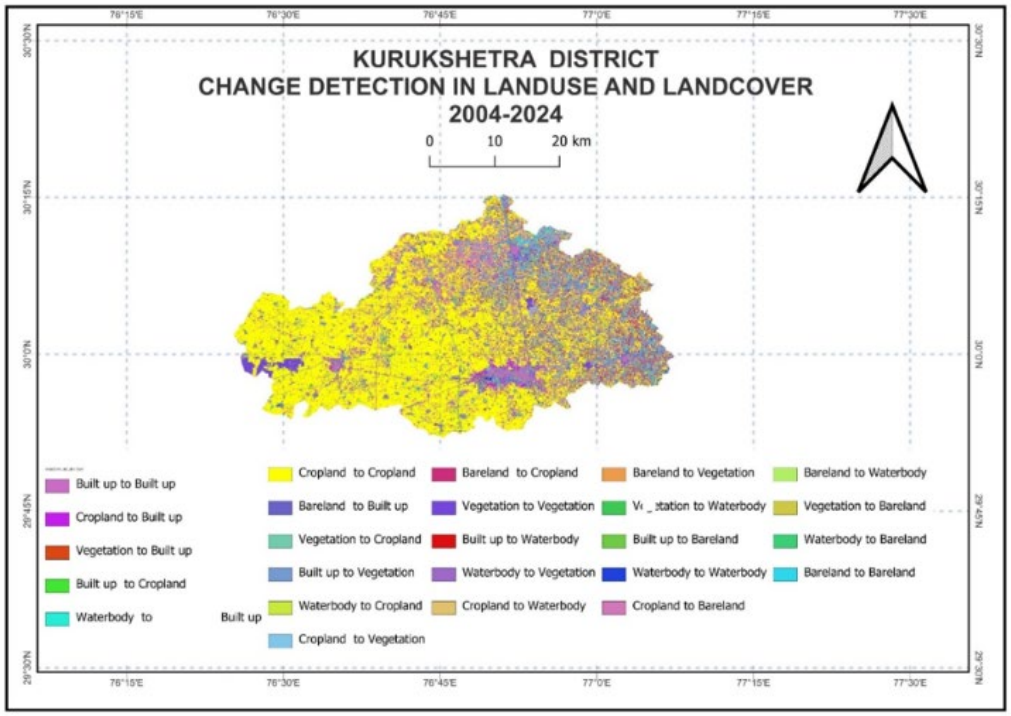
The most significant shift occurred in the form of Cropland to Bare Land. A considerable amount of Bare Land to Cropland also moved between these two time states. These complementary instances suggest substantial dynamism across the agricultural regions studied. The two main sources of the additional Built-up Area were Bare Land and Cropland, with Vegetation 7.88 km2 also being part of it.

5. DISCUSSION

5.1. GROWTH OF THE BUILT-UP AREA

The most obvious directional transformation is the expansion of Built-up area. The growth from 50.66 km2 to 129.55 km2 indicates a significant growth of settlements and constructed surfaces. The Built-up class includes cities, towns, villages, roads, institutions etc., and the increase witnessed therefore should not be understood to be attributable to processes of urbanization alone. The direct transformation of 41.47 km2 Cropland into Built-up Area is significant. This is because such changes tend to last longer than the typical seasonal shifts seen within various agricultural land types. Also, 49.79 km2 Bare Land transformed into Built-up area points to development occurring on open, exposed ground, perhaps also near existing settlements. These suggest that agriculture was increasingly in competition with the growth of settlement.

Map 4



Map 4 LULC change During 2004-2024
Sources: Computed by researcher through QGIS

5.2. REDUCTION IN CROPLAND AND SUBSTITUTION OF CROPLAND WITH BARE LAND

Cropland in the district is decreased from 1,220.09 km2 in 2004 to 1,072.05 km2 by 2024, but is still predicted to take up almost two-thirds of the total LULC. The most significant result, however, was the amount of Cropland-Bare Land interchange. Cropland-Bare Land interchange was 249.50 km2 whilst Bare Land-Cropland was 122.35 km2. This mutual movement suggests that Bare Land is not simply representing abandoned or degraded land. The different times when a field may be harvested, ploughed, in some fallow state, covered by crop residue and affected by changes in moisture levels throughout the seasons may mean that it looks like Bare Land on one date and Cropland on another.

Nevertheless, the area decrease in Cropland does not simply translate to a loss of farmland, which will more accurately reflect structural agricultural change should be measured by its direct conversion to Built-up Area.

5.3. VEGETATION DYNAMICS

During the period, Vegetation and Tree Cover decreased from 83.68 km2 to 51.18 km2. From the transition matrix, we found that 26.67 km2 vegetation turns into cropland, 23.69 km2 vegetation becomes bare land and 7.88 km2 vegetation turns into built-up area. However, the Vegetation class includes various types of managed tree cover such as plantations, orchards, agroforestry, roadside vegetation, etc. Therefore, the decline seen in this map should not be assumed to be deforestation but may, in fact, represent harvesting of plantations, a change in

canopy condition (e.g. dead trees), conversion to cultivation or loss of managed trees.

5.4. BARE LAND AND WATER BODIES

Bare Land also has increased in area to a large proportion, although the meaning of this is heterogeneous including not just temporary agricultural surfaces, also includes vacant plots, exposed soil, open land associated with construction and therefore is not necessarily indicative of land degradation. The smallest class was Water Bodies, although the absolute increase is less than 1 km2. As water bodies are surface water only (i.e. can be seen spectrally), this should not be assumed to be a measure of actual available water, as this does not include irrigation or groundwater supply.

In brief, the extent of the *build-up area increased from 50.66 km² in 2004 to 129.55 km² in 2024,* which indicates that the proportion of its share *increased from 3.02 percent to 7.73 percent*. The net outcome difference was *78.89 km² or 4.71 percent*. The *loss of cropland of 148.04 km², reduced from 1,220.09 km² in 2004 to 1,072.05 km² in 2024*. This was likely to have resulted in a reduction in the percentage share of the district's total area, *from 72.79 percent to 63.96 percent.* The *net loss in cropland was 148.04 km² or 8.83 percentage* point reduction. The areal extent of *vegetation and trees cover reduced from 83.68 km² in 2004 to 51.18 km² in 2024*. Such increase seemed to have led to a net decrease in its share in the city *from 4.99 percent to 3.05 percen*t or a *loss of 32.50 km² or 1.94 percent points*. *The water bodies marginal increased from 4.78 km² in 2004 to 5.69 km² in 2024.* The net percentage of area gained or *net area increased was 0.34 percent to 0.29 percent, which incremented to 0.05 percent and 0.91 km².* While the *bare land in 2004 covered an area of 316.93 km², it has increased to 417.66 km² in the year 2024.* Therefore, this change in area results in 24.92 percent share of the total area, showing a difference in area *100.73 km² and 6.01 percent.*

6. CONCLUSION

This analysis shows that there have been considerable changes in the LULC of the Kurukshetra District from 2004 to 2024. About 34.26 percent of it lies within a different endpoint category while 65.74 percent remains within the same classification. Although Cropland was still the major class the area decreased by 148.04 km2. The highest directional increase was seen for Built-up Area where the area increased by 78.89 km2 (155.71percent). Bare Land increased by 100.73 km2 and a decrease was seen for Vegetation (32.49 km2). Water Bodies remained relatively stable in absolute terms.

The transition analysis indicates the highest identified flow in Cropland-Bare Land, though this flow is much counterbalanced and shows the significance of agricultural seasonality. Therefore, although remotely sensed LULC transition does show a functional change, not all transitions reflect a permanent change. A more long-term change has to do with the extension of the settlement, with an especially large area of 41.47 km2 and 49.79 km2 Bare Land being converted into Built-up Area.

For this survey, Kurukshetra is essentially an area of agriculture in 2024, although there has been substantial reorganization of its landscape in the past twenty years. Therefore, monitoring of settlement expansion, preservation of quality farmland and correct use of new land surfaces, plus regular geospatial monitoring should be of key consideration to its planning.

CONFLICT OF INTERESTS

None .

ACKNOWLEDGMENTS

None.

REFERENCES

Jensen, J. R. (2015). Introductory Digital Image Processing: A Remote Sensing Perspective (4th ed.). Pearson.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., et al. (2001). The Causes of Land-Use and Land-Cover Change: Moving Beyond the Myths. Global Environmental Change, 11(4), 261–269. https://doi.org/10.1016/S0959-3780(01)00007-3

Lillesand, T. M., Kiefer, R. W., and Chipman, J. W. (2015). Remote Sensing and Image Interpretation (7th ed.). Wiley.

Lu, D., Mausel, P., Brondízio, E., and Moran, E. (2004). Change Detection Techniques. International Journal of Remote Sensing, 25(12), 2365–2401. https://doi.org/10.1080/014311603100013986

Singh, A. (1989). Digital Change Detection Techniques Using Remotely Sensed Data. International Journal of Remote Sensing, 10(6), 989–1003. https://doi.org/10.1080/01431168908903939

Turner, B. L., II, Lambin, E. F., and Reenberg, A. (2007). The Emergence of Land Change Science for Global Environmental Change and Sustainability. Proceedings of the National Academy of Sciences, 104(52), 20666–20671. https://doi.org/10.1073/pnas.0704119104