

# Analysing Changing Dynamics of LULC of Madlauda Block by Utilizing Sentinel-2 Satellite Imagery

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## ABSTRACT

*Land use/land cover (LULC) change analysis has become essential for understanding landscape transformation, environmental sustainability, and resource management in rapidly developing agrarian regions. Madlauda Block of Panipat District, Haryana, represents an intensively cultivated rural landscape experiencing increasing pressure from agricultural expansion, settlement growth, and infrastructure development. Monitoring these changes is necessary for sustainable land management and planning. The present study analysed the changing dynamics of LULC in Madlauda Block using multi-temporal Sentinel-2 satellite imagery. The major objectives of the study were to map the LULC pattern of the block, examine spatial and temporal changes over time, identify major land transformation trends, and assess the growth of built-up areas and decline of natural land cover. The study also aimed to understand how agricultural dominance has evolved under increasing human pressure. Multi-temporal Sentinel-2 imagery for the years 1994, 2009, and 2025 were used for analysis. Satellite data were downloaded from open-access repositories and pre-processed through atmospheric correction, image mosaicking, and clipping to the study area boundary. Supervised classification techniques were applied to classify land use categories into agriculture, vegetation, built-up land, sand, and water bodies. Post-classification comparison and change detection techniques were used to identify spatial transformations and quantify area changes. The results revealed that agriculture remained the dominant land use throughout the study period, covering more than two-thirds of the total geographical area. Built-up land increased significantly, indicating rapid settlement expansion and infrastructure growth. Vegetation cover declined sharply, reflecting pressure from agricultural intensification and human activities. Water bodies showed fluctuations, with an increase in the earlier period followed by a decline, suggesting hydrological stress and land conversion. Sand areas exhibited minor variations.*

**Keywords:** Land Use/Land Cover (LULC), Change Detection, Sentinel-2 Imagery

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## INTRODUCTION

Rapid population growth, agricultural intensification, infrastructure development, and urban expansion significantly altered land surfaces, particularly in the intensively cultivated regions of northern India. Monitoring these changes had therefore become essential for evaluating ecological stability, soil productivity, and sustainable land management (Lambin et al., 2003; Turner et al., 2007). Land transformation and urban expansion; however, the moderate spatial resolution limited the detection of micro-level changes (Weng, 2012). The launch of the European Space Agency's Sentinel-2 mission marked a significant advancement in earth observation by providing multispectral imagery with 10-meter spatial resolution and a high revisit frequency, enabling more precise detection of small-scale landscape changes and seasonal variations (Drusch et al., 2012).

The substantial increases in built-up areas and corresponding reductions in vegetation cover due to rapid development pressures (Kumar et al., 2020; Malik & Singh, 2021). These findings highlighted the growing need for high-resolution monitoring at local and block levels. Vegetation indices had also been widely used to assess vegetation health and ecological conditions. Among these, the Normalized Difference Vegetation Index (NDVI) had been recognized as one of the most effective indicators for measuring vegetation, biomass, and land degradation. NDVI utilized spectral reflectance properties of red and near-infrared wavelengths to distinguish healthy vegetation from stressed or barren land (Tucker, 1979). Earlier studies had successfully applied NDVI to monitor crop health, drought stress, and land degradation trends in agricultural regions (Pettorelli et al., 2005; Wang et al., 2010). Land use & Land cover analysis with satellite-based land cover mapping improved the interpretation of change and environmental stress (Xie et al.,

2008). Advancements in classification techniques had further enhanced LULC change detection. Traditional classification methods such as Maximum Likelihood Classification had been widely used; however, machine learning algorithms such as Random Forest and Support Vector Machines had demonstrated superior accuracy and robustness in recent studies (Belgiu & Drăguț, 2016; Maxwell et al., 2018). Regional studies conducted in Haryana and the Indo-Gangetic plains had documented significant land transformation driven by urban expansion, agricultural intensification, and infrastructure growth (Singh et al., 2018). Madlauda Block, located in Panipat District within the fertile Indo-Gangetic plains, had experienced increasing agricultural intensification, settlement expansion, and pressure on natural resources. Understanding LULC dynamics become essential for sustainable land management and environmental planning.

## STUDY AREA

Madlauda Block is an administrative and rural development block located in Panipat District of the state of Haryana, India. It lies in the fertile plains of the Indo-Gangetic region, which is known for its highly productive agricultural land. The block is situated to the south of Panipat city and is well connected by rural road networks linking nearby towns and markets. Its location within one of Haryana's agriculturally advanced districts has shaped its economy, settlement pattern, and land use structure. Geographically, the block forms part of the alluvial plains formed by the depositional processes of the Yamuna river system. The terrain is almost flat with a gentle slope, which supports irrigation and intensive cultivation. The soils are predominantly loamy and alluvial in nature, making them suitable for crops such as wheat, rice, sugarcane, mustard, and vegetables. The climate of the block is characterized by hot summers, cold winters, and a monsoon season from July to September. Rainfall is moderate and highly seasonal, so agriculture relies heavily on canal irrigation and groundwater extraction. Madlauda Block has a predominantly rural settlement pattern consisting of numerous villages and small habitations. The population is mainly engaged in agriculture and allied activities such as dairy farming, livestock rearing, and small-scale agro-based occupations. Traditional village settlements are surrounded by cultivated fields, while recent years have witnessed gradual expansion of residential areas along roads and near market centers. Social infrastructure such as schools, health centers, and local markets supports rural livelihoods and community life. Agriculture forms the backbone of the local economy. The region practices intensive farming supported by irrigation canals, tube wells, and modern agricultural inputs. Double cropping is common, and mechanization has increased productivity.

### Objectives

- To analysed the changing dynamics of LULC in Madlauda Block using multi-temporal Sentinel-2 satellite imagery.
- To understand how agricultural dominance has evolved under increasing human pressure.

### Data collection & Processing

The researcher used satellite imaging data to evaluate spatiotemporal LULC and carry out change detection analysis for Madlauda Block. The researcher has collected the Sentinel-2 satellite data from the USGS website, <https://ers.cr.usgs.gov/>, from 1994, 2009 to 2025 (accessed on 3 June 2025). In this study, Sentinel-2 pictures from 1994, 2009, and 2025 were used, respectively.

In order to reduce cloud interference, the satellite photos were chosen with a cloud coverage range of 0–5%, with a focus on the drier months. The Sentinel-2 offers 13 spectral bands, including three red-edge bands that capture the intense reflectance of vegetation in the near-infrared portion of the electromagnetic spectrum, as well as 10 m, 20 m, and 60 m spatial resolution outputs. Since the B8 near-infrared band and the 10 m RGB band sets offer significantly higher spatial resolution than other satellite products, the Sentinel-2 multispectral imagery is utilized for LULC. photographs from Sentinel-2A are categorized as multispectral photographs with medium resolution. The satellite products Landsat and Sentinel-2 are the most widely used open-access remote sensing data for picture classification. Sentinel-2 imagery has a reasonably high spatial resolution of 10 to 20 m. In order to accurately classify images in the research area's heterogeneous state, a high spatial resolution was necessary. The near-infrared (NIR) and red bands, namely Band 8 (NIR) and Band 4 (red), are used to compute the NDVI (Normalized Difference Vegetation Index) for Sentinel-2 data.  $NDVI = (NIR - RED) / (NIR + RED)$  is the formula. By utilizing the high NIR reflectance and low red band reflectance of healthy vegetation, this index efficiently assesses the density and health of vegetation. Sentinel-2's frequent revisit time and 10-meter spatial resolution improve NDVI accuracy for environmental monitoring and land use/land cover (LULC) mapping.

## RESULT & ANALYSIS

### Land Use/Land Cover in Madlauda Block

Table 1 showed the land use and land cover pattern of Madlauda Block from 1994 to 2025. The total geographical area remained same, 349.91 km<sup>2</sup>. Agriculture dominated the landscape in all years. It covered about 63.69% area in 1994 and increased to 68.13% in 2009. Later it slightly decreased to 66.56% in 2025. This suggested farming remained the

main activity. Vegetation area reduced sharply from 18.54% in 1994 to only 5.88% in 2009 and further down to 5.00% in 2025. This decline looked serious. It indicated pressure on green cover and maybe expansion of cultivation and settlements.

Built-up land increased continuously during the study period. It was 14.86% in 1994, rose to 21.34% in 2009, and reached 26.14% in 2025. This showed growing population and infrastructure. Sand area showed fluctuation. It increased in 2009 but dropped again in 2025. Water bodies also expanded from 2.41% to 3.83% in 2009 but later reduced to 2.09%. These changes suggested seasonal variation and human use of water resources. Overall, Table 1 indicated agricultural dominance but also clear growth of built-up area and decline of vegetation. The landscape had changed slowly. But the change was visible.

**Table 1: Land Use/Land Cover in Madlauda Block, 1994 to 2025**

LULC Classes	1994		2009		2025	
	Area (In Km <sup>2</sup> )	%	Area (In Km <sup>2</sup> )	%	Area (In Km <sup>2</sup> )	%
Sand	1.73	0.49	2.89	0.82	0.72	0.21
Vegetation	64.89	18.54	20.58	5.88	17.50	5.00
Agriculture	222.87	63.69	238.38	68.13	232.91	66.56
Built-Up	51.99	14.86	74.68	21.34	91.45	26.14
Water bodies	8.43	2.41	13.39	3.83	7.32	2.09
<b>Total</b>	<b>349.91</b>	<b>100</b>	<b>349.91</b>	<b>100</b>	<b>349.91</b>	<b>100</b>

Source: calculated by Researchers based on Sentinel-2 data, 1994, 2009, & 2025

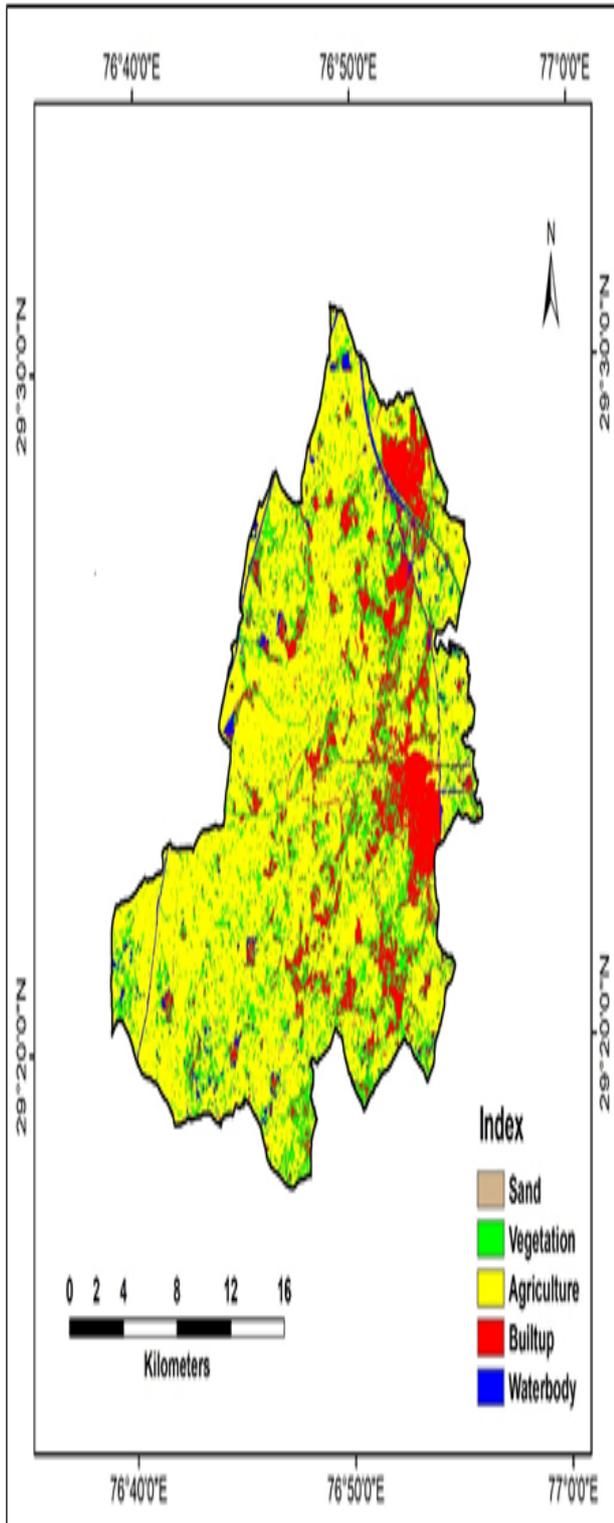
Map 1 presented the land use/land cover pattern of Madlauda Block for February 2009. Agriculture dominated almost the entire block and appeared as the most widespread category. Large continuous patches of agricultural land were visible across the central and western parts. Vegetation was limited and scattered, mostly found along field boundaries and small pockets.

Built-up areas appeared in clusters, mainly in the north-eastern and central parts, indicating settlement concentration. Water bodies were few and appeared as small blue patches, suggesting limited surface water presence. Sand patches were sparse and scattered. Overall, the map showed a rural agricultural landscape with localized settlement growth (Map 1a). Map 1b showed the land use/land cover distribution in February 2025 and revealed noticeable changes. Agriculture still covered most of the block, but built-up areas had expanded and appeared more dense and widespread compared to 2009.

Settlement growth was clearly visible in the north-eastern zone and along transport routes. Vegetation patches looked reduced and fragmented. Water bodies appeared fewer and smaller, suggesting pressure on surface water resources. Sand patches remained scattered with minor variation. The comparison of Map 1a and Map 1b indicated gradual urban expansion and declining vegetation cover while agriculture remained dominant. The landscape had changed slowly, but the growth of built-up land was clearly visible (Map 1b).

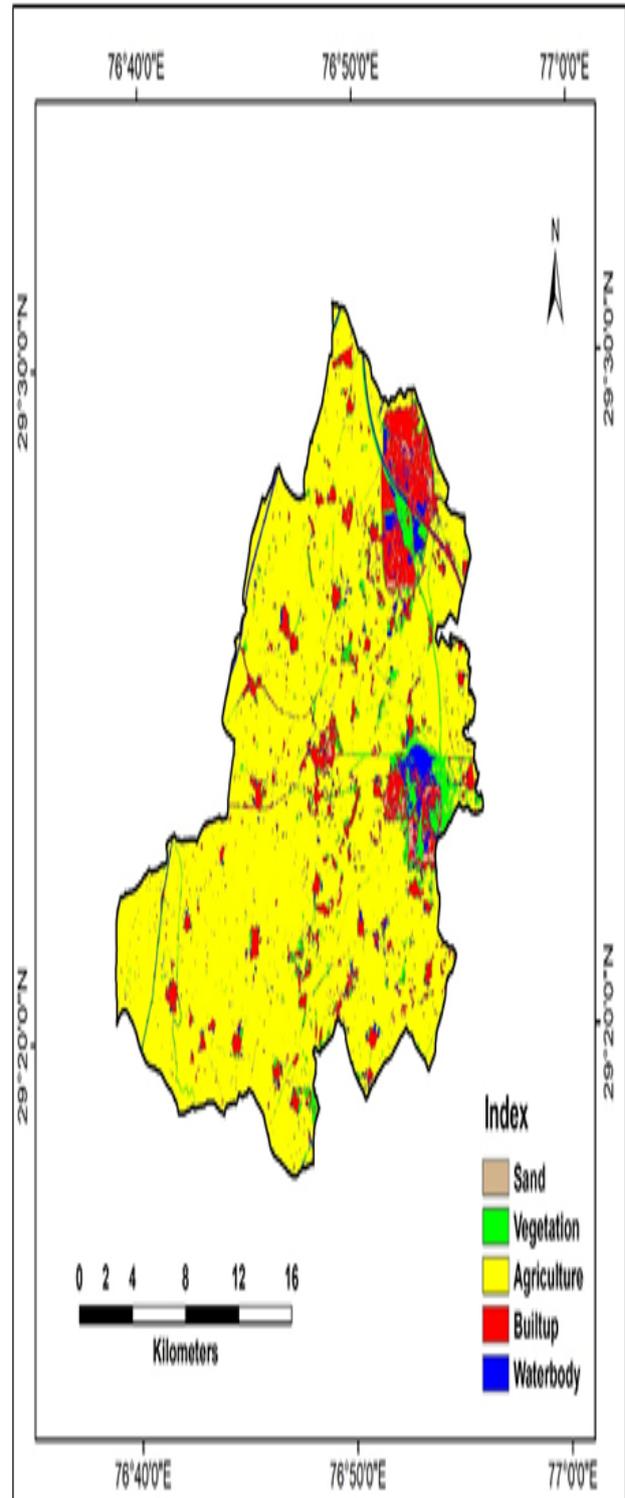
Map 3 showed the land use/land cover pattern of Madlauda Block for 2025. Agriculture dominated the entire region and appeared as large continuous yellow patches across the central, western and southern parts. It clearly remained the primary land use. Built-up areas were marked in red and appeared dense in the north-eastern part of the block. Smaller clusters were also scattered along roads and village settlements.

**Map 1: Land Use/Land Cover in Madlauda Block, 1994 & 2009**



Source: Prepared by Researchers based on sentinel-2 Images

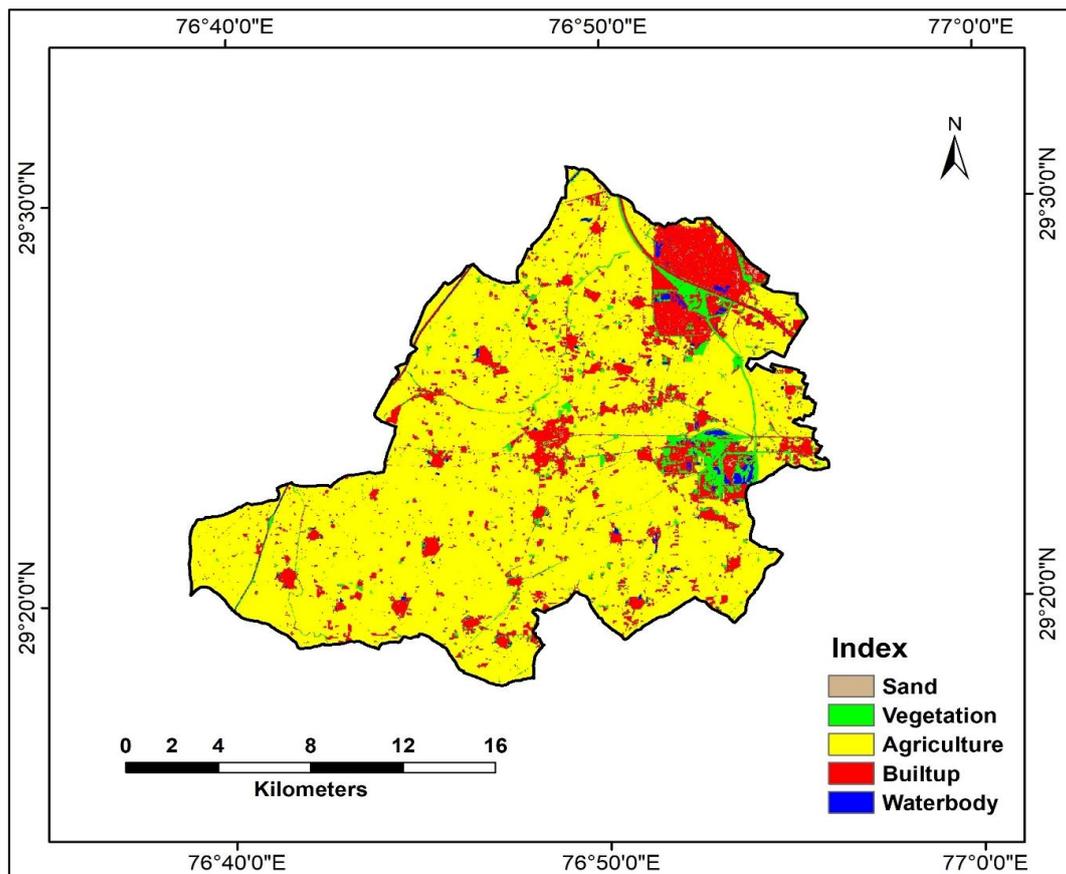
Map 1a



Source: Prepared by Researchers based on sentinel-2 Images

Map 1b

Map 2: Land Use/Land Cover in Madlauda Block, 2025



Source: Prepared by Researchers based on sentinel-2 Images

This indicated expansion of residential areas and infrastructure growth. Vegetation patches were shown in green but remained small and fragmented. They were mostly confined to field edges and scattered pockets. Water bodies appeared in blue and were limited in number. They were mainly concentrated near settlement clusters and low-lying zones. Sand patches were very few and appeared in isolated pockets (Map 2).

#### Changing Land Use/Land Cover: 1994-2025

Table 2 presented the changing pattern of land use/land cover in Madlauda Block between 1994 and 2025. During 1994–2009, sand area increased by 1.16 km<sup>2</sup> (66.83%), while water bodies also showed a rise of 4.96 km<sup>2</sup> (58.85%). Agriculture expanded slightly by 15.51 km<sup>2</sup> (6.96%), indicating improvement in cultivated land. Built-up area increased significantly by 22.69 km<sup>2</sup> (43.63%), showing growing settlements and infrastructure. In contrast, vegetation declined sharply by 44.31 km<sup>2</sup> (–68.29%).

Table 2: Changing Land Use/Land Cover in Madlauda Block, 1994 to 2025

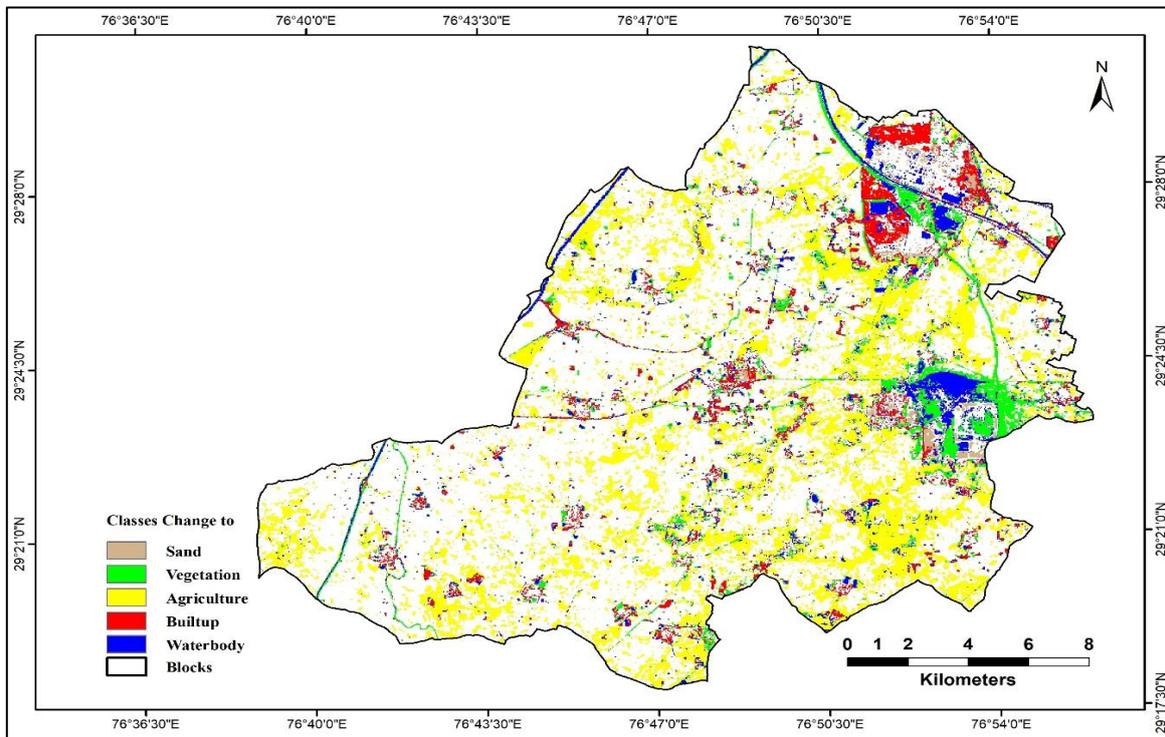
LULC Classes	Change: 1994-2009		Change: 2009-2025		Change: 2009-2025	
	Area (In Km <sup>2</sup> )	%	Area (In Km <sup>2</sup> )	%	Area (In Km <sup>2</sup> )	%
Sand	1.16	66.83	-2.17	-75.04	-1.01	-58.36
Vegetation	-44.31	-68.29	-3.07	-14.93	-47.39	-73.02
Agriculture	15.51	6.96	-5.47	-2.29	10.04	4.50
Built-Up	22.69	43.63	16.77	22.46	39.46	75.90
Water bodies	4.96	58.85	-6.07	-45.35	-1.11	-13.19

Source: Calculated by Researchers based on Sentinel-2 data 1994, 2009, & 2025

This was a big drop. It suggested clearing of green cover for farming and construction activities. Between 2009 and 2025, the trend changed in several categories. Sand area declined by 2.17 km<sup>2</sup> (–75.04%), while water bodies also decreased by 6.07 km<sup>2</sup> (–45.35%), possibly due to land conversion and water stress. Vegetation continued to decline,

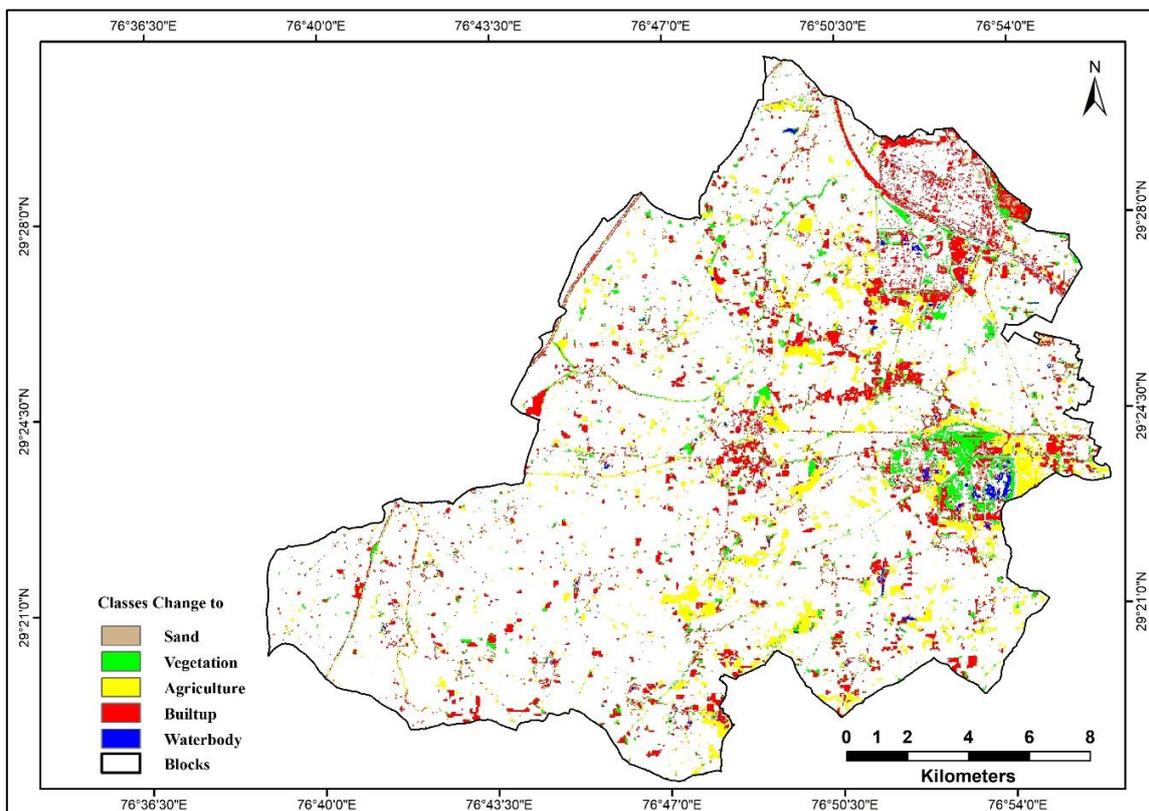
though at a slower rate ( $-3.07 \text{ km}^2$ ;  $-14.93\%$ ). Agriculture slightly reduced by  $5.47 \text{ km}^2$  ( $-2.29\%$ ), showing adjustment in land use. Built-up land kept increasing and expanded by  $16.77 \text{ km}^2$  ( $22.46\%$ ) (Table 2).

**Map 3: Changing Land Use/Land Cover in Madlauda Block, 1994 to 2009**



Source: Prepared by Researchers based on sentinel-2 Images

**Map 4: Changing Land Use/Land Cover in Madlauda Block, 2009 to 2025**



Source: Prepared by Researchers based on sentinel-2 Images

Overall change from 1994 to 2025 showed major growth in built-up area (39.46 km<sup>2</sup>; 75.90%) and noticeable decline in vegetation (-47.39 km<sup>2</sup>; -73.02%). Agriculture showed a moderate net increase (10.04 km<sup>2</sup>; 4.50%). Table 2 clearly indicated expanding settlements and shrinking vegetation cover. Map 4 shown the spatial pattern of land use/land cover change in Madlauda Block. The map showed that agricultural land remained dominant across most parts of the block, but several localized transformations were visible. Built-up expansion appeared in red patches and was mainly concentrated in the north-eastern zone and along major road networks. These clusters indicated settlement growth and increasing infrastructure development. Vegetation change appeared scattered and fragmented, mostly around field margins and village surroundings. Waterbody changes were visible in limited pockets, especially in low-lying areas. Sand patches were sparse and occurred in isolated locations (Map 3). Map 4 presented the areas that experienced conversion to different land use classes. Built-up expansion appeared more widespread compared to other changes and was scattered throughout the central and north-eastern parts. This indicated increasing human pressure on land resources. Some areas showed conversion towards vegetation, visible in green patches, mainly near water sources and irrigated zones. Waterbody changes were limited but noticeable in localized depressions. Agricultural land conversion appeared scattered, suggesting shifting cultivation patterns and land adjustments. The maps together indicated that while agriculture still dominated, settlement expansion and fragmentation of vegetation were clearly visible (Map 4).

### CONCLUSION

The analysis revealed clear changes in the land use/land cover pattern of Madlauda Block between 1994 and 2025. Agriculture remained the dominant land use throughout the period, showing only minor fluctuations and a modest overall increase. This indicated that farming continued to be the primary economic activity of the block. However, the most noticeable change was the continuous expansion of built-up land, which increased significantly over the three decades. This growth reflected rising population, settlement expansion, and infrastructure development. In contrast, vegetation cover declined sharply, indicating pressure on natural green cover due to agricultural expansion and construction activities. The fluctuations in sand areas and water bodies. Sand area increased during the earlier period but later declined, while water bodies expanded between 1994 and 2009 and then decreased by 2025, suggesting changing hydrological conditions and human interference. Overall, the findings suggested that the landscape remained predominantly agricultural but was gradually transforming under increasing human pressure.

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