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Urban growth and land use dynamics: A case study of Jhajjar district using GIS and remote sensing

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Abstract

The rapid expansion of urban areas necessitates precise monitoring and assessment to understand their impact on land use and land cover (LULC). This study employs Geographic Information Systems (GIS) and remote sensing techniques to analyze urbanization trends in Jhajjar district over two decades (2004-2024). Utilizing multi-temporal LANDSAT and Sentinel-2 satellite imagery, along with Survey of India (SOI) topographical maps and Google Earth Pro data, this study conducts supervised classification and vector extraction to assess urban sprawl. Various GIS tools, including ArcGIS, ERDAS Imagine, and QGIS, are used to delineate LULC patterns and urban expansion. Findings reveal that non-agricultural land accounts for 18.85% of the total geographical area, with built-up areas comprising 10.2%, indicating moderate urbanization. Additionally, wasteland (2.5%) and fallow land (2.2%) highlight potential areas for sustainable land management. The study emphasizes the necessity of integrating satellite-based analysis with ground surveys for an accurate environmental impact assessment. The results offer critical insights for urban planners and policymakers to formulate sustainable land use strategies and manage urban growth effectively.

Keywords: Urbanization, GIS, remote sensing, Land Use and Land Cover (LULC), urban sprawl

Introduction

Urbanization is a dynamic process that significantly influences land use and land cover (LULC) patterns, often leading to extensive socio-economic and environmental transformations (Seto *et al.*, 2011) ^[9]. The rapid growth of urban areas has necessitated advanced monitoring techniques to assess changes in land utilization and ensure sustainable urban development. Geographic Information Systems (GIS) and remote sensing have emerged as essential tools in analyzing urban expansion by providing spatially and temporally explicit data (Bhatta, 2010) ^[11].

Jhajjar district, located in Haryana, India, has witnessed considerable urban growth over the past two decades due to its proximity to Delhi and inclusion in the National Capital Region (NCR). The expansion of built-up areas has led to a shift in LULC, impacting agricultural land, open spaces, and natural ecosystems (Kumar *et al.*, 2020) ^[5]. Understanding these changes through GIS and remote sensing is critical for sustainable urban planning and environmental management.

This study employs multi-temporal LANDSAT and Sentinel-2 satellite imagery, in conjunction with Survey of India (SOI) topographical maps and Google Earth Pro data, to analyze urbanization trends in Jhajjar district from 2004 to 2024. Supervised classification and vector extraction techniques are used to delineate LULC patterns and assess urban sprawl. GIS-based tools, including ArcGIS, ERDAS Imagine, and QGIS, facilitate spatial analysis and visualization of urban growth trends.

The findings indicate that non-agricultural land accounts for 18.85% of the district's total geographical area, with built-up regions constituting 10.2%. The presence of wasteland (2.5%) and fallow land (2.2%) underscores potential areas for sustainable land management and development. By integrating satellite-based observations with field surveys, this study provides a comprehensive approach to understanding urban expansion and its environmental implications. The results serve as a valuable resource for policymakers and urban planners in devising sustainable land use strategies to manage future growth effectively (Ramachandra & Kumar, 2012) ^[8].

Study area

Jhajjar, a town with a rich historical heritage, is the headquarters of Jhajjar district, one of Haryana's 22 districts. Jhajjar district lies between $28^{\circ} 21' 31''$ N and $28^{\circ} 50' 19''$ N latitude and between $76^{\circ} 17' 06''$ E and $76^{\circ} 58' 15''$ E longitude. It has a geographical area of 1834.00 sq. kms. Carved out of Rohtak district on July 15, 1997, it is located about 65 km from Delhi. Founded by Chhaju, the town derives its name from him. The district spans 1834 sq. km and comprises six blocks with 264 villages. It experiences hot summers, cold winters, and scanty rainfall. Encircled by a flood protection bundh, its expansion is limited. The population stands at 9.58 lakh (2011 census) with a low sex ratio of 862 females per 1000 males.

Jhajjar has good road connectivity and basic infrastructure but lags in irrigation and marketing facilities. It is well connected via NH-352, NH-334B, and other major roads. As part of the NCR, it holds development potential. The district hosts two industrial areas with 2408 plots, featuring major industries like ceramics, glass, chemicals, and engineering.

Bahadurgarh, in the eastern part of the district, is an industrial hub on the Delhi border. It has major industries including Hindustan National Glass, Relaxo, Parle Biscuits, and a dedicated footwear park. The town is well-connected via the Delhi Metro Green Line and Delhi Western Peripheral Expressway, making it a key industrial center in Haryana NCR.

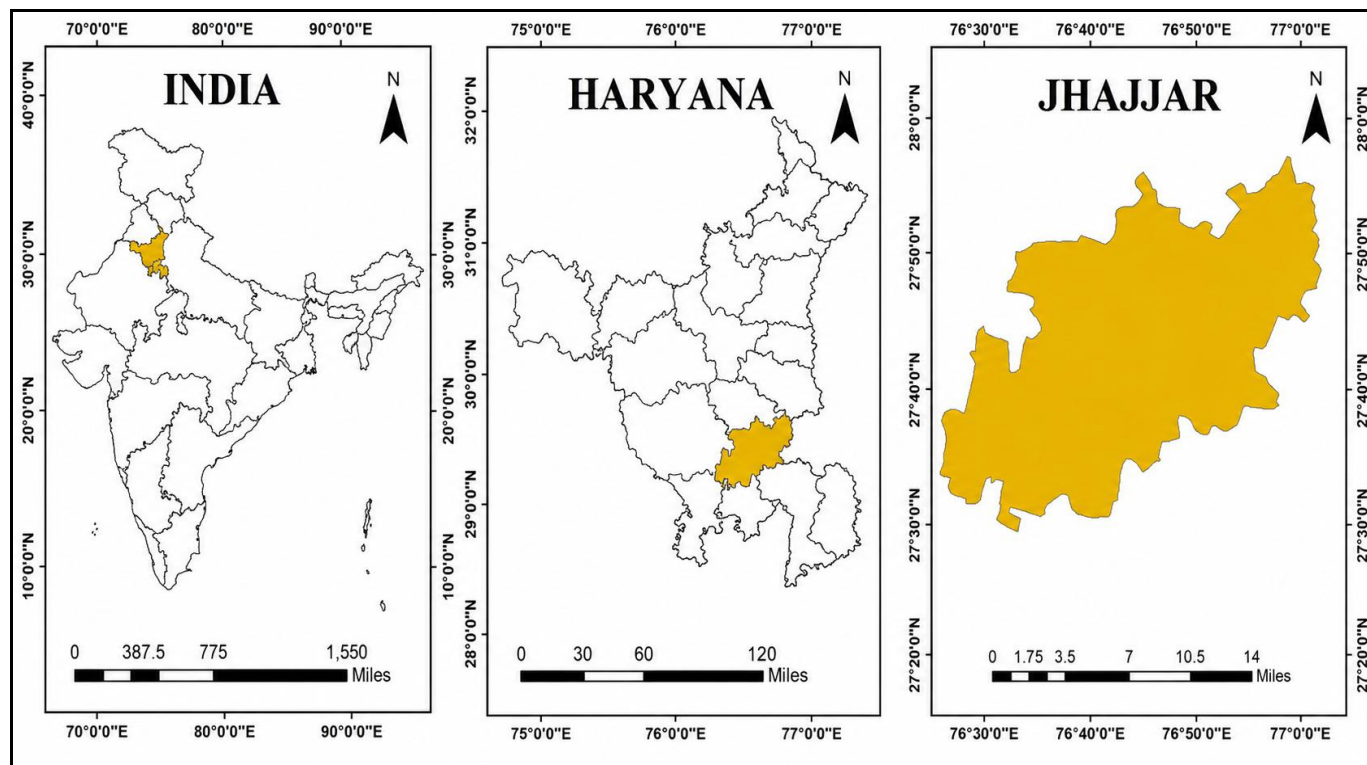


Fig 1: Location map of study area

Methodology

Geographical Information Systems (GIS) together with remote sensing data are used for scrutinizing the emerging urbanization of the cities using digital satellite images. Basic satellite image processing procedures like layer stacking, image enhancement and improvement process are done for the raw satellite images to obtain clear pixels for performing classification analysis. Land use and land cover classifications are done by a supervised classification algorithm for the satellite images. From the classified images, the urban land features are extracted from raster to vector format. Survey of India (SOI) topographical maps are considered for abstracting urban sprawl impacts on the environment. LULC analysis and urban sprawl assessment are the main intentions of data analysis. The detailed analysis of them is provided below under different subtitles. Ground survey is also used to assess the environmental impact. The data for the present study were taken from both primary and secondary sources. The main data of this study are the municipal committee boundary map of Jhajjar district, LANDSAT Images (2004 & 2024, resolution 30 m),

Sentinel-2 Images (2024), Google Earth Pro (2011, resolution less than 1 m) and GPS survey. ArcGIS, ERDAS Imagine, QGIS and MS Office software are used for demarcation of land use and land cover for different years and for preparation of maps.

Results and Discussion

The analysis of LULC changes in Jhajjar district over two decades (2004-2024) reveals significant transformations driven by urban expansion, agricultural shifts, and environmental factors.

Land Use and Land Cover (LULC)

The Land Use and Land Cover (LULC) classification for Jhajjar district reflects the distribution and usage of land resources in the region. This classification helps understand how land is utilized for agriculture, settlements, industrial purposes, natural landscapes, and other activities. Below is an overview of the typical LULC classification for Jhajjar district.

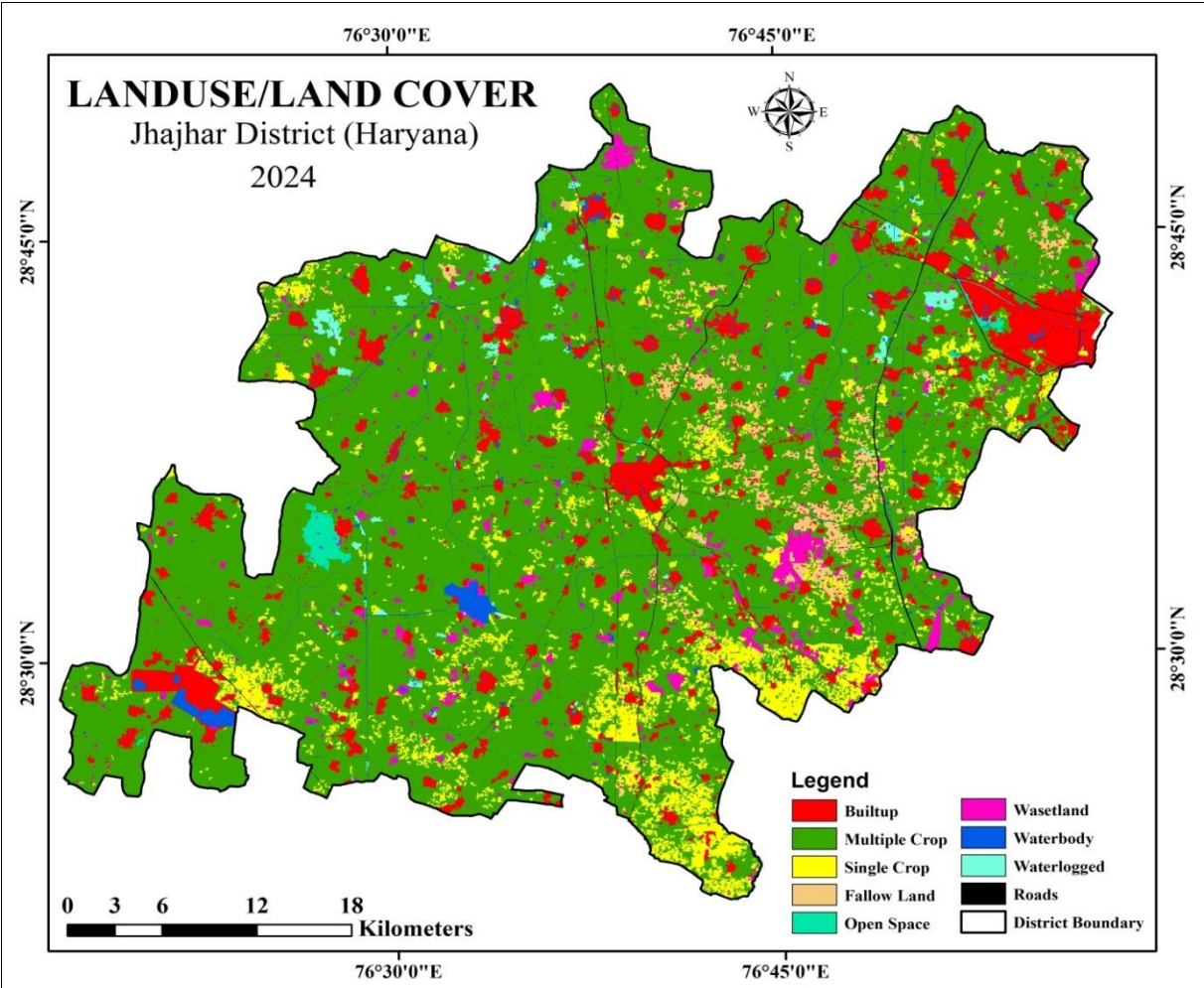


Fig 2: Landuse/Land Cover map of Jhajhar District (2024)

The Land Use and Land Cover (LULC) classification for Jhajhar District provides a comprehensive breakdown of how land is utilized across various categories (Show in table-1). Agriculture dominates the district's land use, with 73.1% (138,907.51 hectares) dedicated to multiple cropping,

indicating extensive reliance on agricultural activities that allow for the cultivation of more than one crop annually. Additionally, 8.1% (15,351.93 hectares) of the area is under single-crop cultivation, reflecting a smaller but significant portion of land devoted to single-season farming.

Table 1: Area of Landuse Land cover of Jhajhar District (2024)

Sr. No.	LULC Class (2024)	Area in Hectare	Area in%
1	Multiple Crop	138907.51	73.1
2	Single Crop	15351.93	8.1
3	Builtup	19336.44	10.2
4	Wasetland	4830.24	2.5
5	Fallow Land	4098.03	2.2
6	Waterbody	3786.98	2.0
7	Waterlogged	1608.75	0.8
8	Roads	1077.27	0.6
9	Open Space / Layout	959.77	0.5
Total		189956.93	100

Built-up areas, including urban centers, industrial zones, and villages, account for 10.2% (19,336.44 hectares) of the district, signifying moderate urbanization and development. Wasteland, which constitutes 2.5% (4,830.24 hectares) of the district, includes degraded or barren land, highlighting potential areas for reclamation or other productive uses. Similarly, 2.2% (4,098.03 hectares) is classified as fallow land, representing temporarily uncultivated agricultural areas that might be brought back into use.

Water bodies such as rivers, lakes, and ponds cover 2.0% (3,786.98 hectares) of the total area, while 0.8% (1,608.75 hectares) is waterlogged land, which may pose challenges for land use but also presents opportunities for wetland management or reclamation. Roads occupy 0.6% (1,077.27 hectares) of the district's area, reflecting a modest transportation infrastructure footprint. Open spaces or layouts, often vacant or reserved for future planning, cover 0.5% (959.77 hectares).

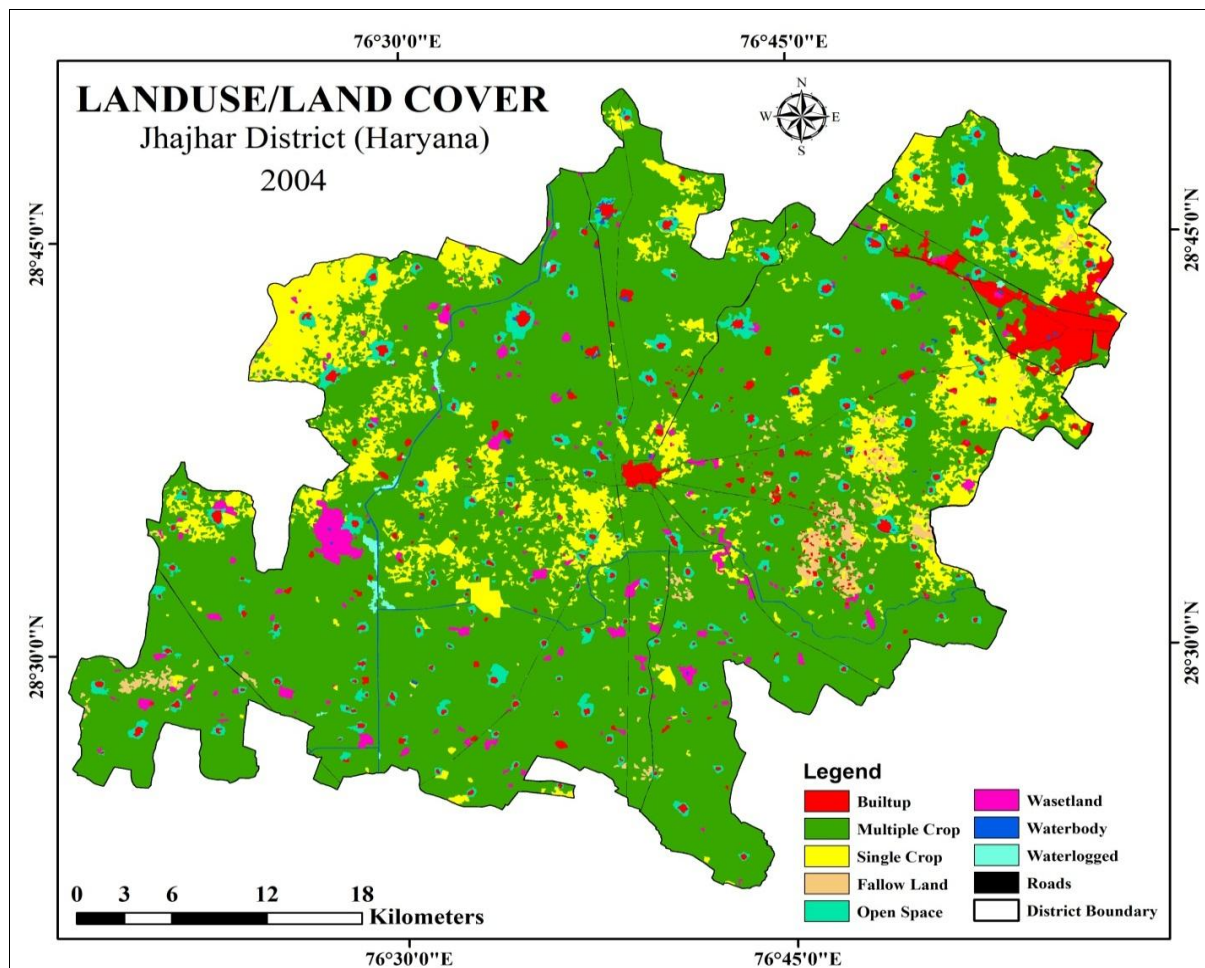


Fig 3: Landuse/Land Cover map of Jhajhar District (2004)

According to table-2, Jhajjar district in 2004 reveals a predominantly agricultural landscape, with multiple crop land covering 77.1% (146,400.21 ha) and single crop land at 12.3% (23,413.84 ha), indicating extensive farming activities. Built-up areas account for 3.5% (6,670.06 ha), reflecting limited urbanization, while wasteland (1.7% - 3,188.54 ha) and fallow land (1.2% - 2,239.38 ha) highlight

underutilized regions. Water bodies (0.4% - 838.37 ha) and waterlogged areas (0.2% - 474.74 ha) signify minimal surface water presence. Roads occupy 0.4% (747.95 ha), and open space/layouts cover 3.2% (5,983.82 ha). The total mapped area is 189,956.93 ha (100%), illustrating the dominance of agriculture with limited built-up expansion and infrastructure development.

Table 2: Area of Landuse Land cover of Jhajhar District (2004)

Sr. No.	LULC Class (2004)	Area in Hectare	Area in%
1	Multiple Crop	146400.21	77.1
2	Single Crop	23413.84	12.3
3	Builtup	6670.06	3.5
4	Wasteland	3188.54	1.7
5	Fallow Land	2239.38	1.2
6	Waterbody	838.37	0.4
7	Waterlogged	474.74	0.2
8	Roads	747.95	0.4
9	Open Space / Layout	5983.82	3.2
Total		189956.93	100

Change Analysis of Land Use and Land Cover (2004-2024): The Change Analysis of Land Use and Land Cover (2004-2024) in Jhajjar District Using Remote Sensing and

GIS investigates the spatial and temporal changes in LULC patterns during the Kharif seasons of 2004 and 2024, shown in map-4.

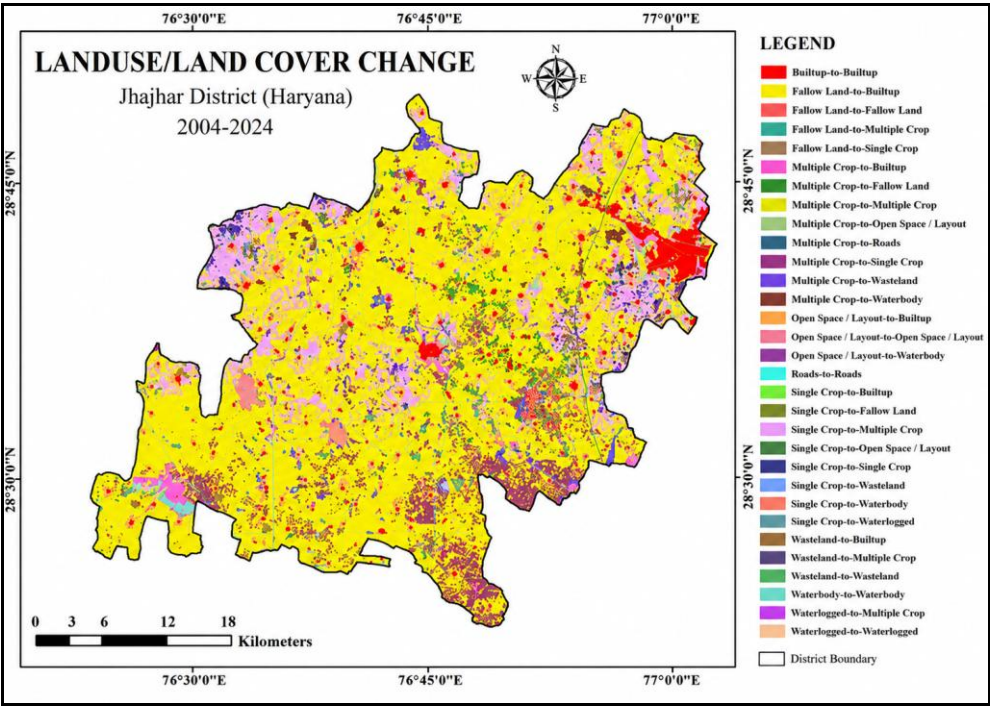


Fig 4: Landuse/Land Cover Change map of Jhajhar District (2004-2024)

The LULC change analysis (Table-3) in Jhajjar district highlights significant transformations between 2004 and 2024, with built-up expansion primarily from multiple crop land (3.4% - 6,424 ha), open space/layout (2.5% - 4,657.6 ha), single crop (0.7% - 1,313.2 ha), fallow land (0.1% - 234.9 ha), and wasteland (0.5% - 1,006.2 ha), contributing to urban growth. Agricultural shifts are evident, with

multiple crop land retaining 62.6% (118,826.1 ha) of its area but also converting into single crop land (6.8% - 12,903.1 ha), fallow land (1.3% - 2,393.4 ha), and wasteland (1.6% - 3,035.3 ha). Single crop areas expanded into multiple crop land (9.5% - 18,026.2 ha), while minor transitions occurred from single crop to wasteland (0.3% - 497.1 ha) and waterbody (0.3% - 523.3 ha).

Table 3: Area of Landuse Land cover Change of Jhajhar District (2004-2024)

Sr. No.	LULC Change Class	Area in Hectare	Area in%
1	Builtup-to-Builtup	6672.3	3.5
2	Fallow Land-to-Builtup	234.9	0.1
3	Fallow Land-to-Fallow Land	1035.7	0.5
4	Fallow Land-to-Multiple Crop	676.8	0.4
5	Fallow Land-to-Single Crop	232.4	0.1
6	Multiple Crop-to-Builtup	6424.0	3.4
7	Multiple Crop-to-Fallow Land	2393.4	1.3
8	Multiple Crop-to-Multiple Crop	118826.1	62.6
9	Multiple Crop-to-Open Space / Layout	196.9	0.1
10	Multiple Crop-to-Roads	248.7	0.1
11	Multiple Crop-to-Single Crop	12903.1	6.8
12	Multiple Crop-to-Wasteland	3035.3	1.6
13	Multiple Crop-to-Waterlogged	1206.7	0.6
14	Open Space / Layout-to-Builtup	4657.6	2.5
15	Open Space / Layout-to-Open Space / Layout	771.4	0.4
16	Open Space / Layout-to-Waterbody	424.0	0.2
17	Roads-to-Roads	748.0	0.4
18	Single Crop-to-Builtup	1313.2	0.7
19	Single Crop-to-Fallow Land	793.4	0.4
20	Single Crop-to-Multiple Crop	18026.2	9.5
21	Single Crop-to-Open Space / Layout	43.5	0.0
22	Single Crop-to-Single Crop	1962.6	1.0
23	Single Crop-to-Wasteland	497.1	0.3
24	Single Crop-to-Waterbody	523.3	0.3
25	Single Crop-to-Waterlogged	216.8	0.1
26	Wasteland-to-Builtup	1006.2	0.5
27	Wasteland-to-Multiple Crop	548.2	0.3
28	Wasteland-to-Wasteland	971.0	0.5
29	Waterbody-to-Waterbody	2884.5	1.5
30	Waterlogged-to-Multiple Crop	213.6	0.1
31	Waterlogged-to-Waterlogged	269.9	0.1
Total		189956.9	100

Water dynamics remained stable, with waterbodies persisting at 1.5% (2,884.5 ha), while waterlogged areas shifted into multiple crop land (0.1% - 213.6 ha). Road infrastructure showed minimal expansion (0.1% - 248.7 ha from multiple crop), while open space/layout changes included minor conversions to waterbodies (0.2% - 424 ha). The findings underscore the urban encroachment on agricultural land, emphasizing the need for sustainable planning in Jhajjar.

Conclusions

The study's findings underscore significant land use and land cover changes in Jhajjar district over the past two decades, driven largely by urban expansion. The increase in built-up areas, primarily at the expense of multiple crop land, open spaces, and fallow land, reflects ongoing urbanization pressures. While multiple crop land retains a substantial portion of its area, notable conversions to single crop land, wasteland, and fallow land indicate agricultural fragmentation. The stability of water bodies and minimal road expansion further highlight the dominance of urban growth as a key transformation factor. These changes emphasize the urgent need for sustainable urban planning strategies to balance development with environmental conservation. Integrating remote sensing with ground-based surveys proved crucial in accurately assessing these trends, offering valuable insights for policymakers to implement informed land management practices. Moving forward, proactive strategies that prioritize agricultural preservation, efficient land use, and ecological balance will be essential to ensuring sustainable development in Jhajjar district.

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