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Peri-Urban Growth and Agricultural Land Fragmentation in Hisar District, Haryana: A Geospatial Assessment

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ABSTRACT

Peri-urban growth is transforming agricultural landscapes around many medium-sized Indian cities, yet the effect is often measured only as a decline in cultivated area. This paper examines a related but less visible process: the fragmentation of the agricultural landscape around Hisar City in Haryana. The study uses a secondary geospatial re-analysis of published Landsat-based land-use classifications and landscape metrics for 1991, 2001, 2011, 2021 and 2023. Built-up growth, agriculture-to-built-up conversion and changes in number of patches, patch density, edge density, mean patch size and largest patch index are interpreted together to assess fragmentation pressure on the agricultural matrix. Built-up land in peri-urban Hisar increased from 2,179.71 ha in 1991 to 6,993.09 ha in 2023, a rise of about 220.83 per cent. Across the study period, at least 1,752.57 ha of agricultural land was converted directly to built-up uses, representing 36.41 per cent of the total built-up gain. The most intense conversion occurred during 2011-2021, when 1,303.38 ha of agricultural land was absorbed by urban development. At the same time, the number of built-up patches increased from 165 to 346, patch density from 0.21 to 0.45, and edge density from 9.33 to 13.69 m/ha. These trends indicate a shift from relatively compact urban development towards a mixed process of leapfrog expansion, corridor growth, edge extension and later coalescence. The findings show that peri-urban agriculture in Hisar is affected not only by land loss but also by increasing spatial discontinuity, with implications for farm accessibility, irrigation continuity, mechanisation and long-term agricultural viability. The paper argues for agricultural continuity zones, development control along major corridors and routine use of landscape metrics in peri-urban land-use planning.

Keywords: Peri-urban growth; agricultural land fragmentation; landscape metrics; remote sensing; GIS; Hisar; Haryana

1. INTRODUCTION

Urban expansion in India is no longer confined to the legal boundary of large metropolitan areas. Medium-sized cities are also spreading into their surrounding rural landscapes, creating transitional spaces in which agricultural fields, village settlements, highways, institutions, industries, housing colonies and vacant plots occur side by side. These transitional spaces are commonly described as peri-urban areas. Their boundaries are often difficult to fix because they are defined less by a single administrative line than by changing flows of people, land, services and capital. Recent reviews of peri-urbanisation emphasise this hybrid character and show that physical land transformation is one of the most consistent indicators of peri-urban change (Ahani & Dadashpoor, 2021; Chettry, 2023).

Agriculture is usually the most extensive land use at the urban edge and therefore becomes the main land reserve for outward growth. The immediate effect is visible when cultivated land is converted to housing, industry, roads or institutional uses. A second effect, however, may occur before complete conversion. New development can divide a large and continuous agricultural block into smaller pieces, lengthen its edges, isolate fields and interrupt access between plots. In such cases the total agricultural area may still appear substantial, yet the landscape becomes progressively more difficult to manage as a coherent farming space. This distinction between land loss and spatial fragmentation is important because agricultural performance depends not only on the quantity of land but also on the size, continuity, shape and accessibility of fields.

Landscape fragmentation has therefore become an important part of geospatial research on urban growth. Patch-based metrics are useful because they measure the configuration of land-cover classes rather than area alone. The number of patches and patch density indicate the degree to which a class is divided into separate units; edge density measures the amount of boundary relative to area; mean patch size provides information about the average size of individual patches; and the largest patch index indicates the dominance of the largest contiguous patch (McGarigal et al., 2012; Zhang et al., 2013). When these measures are read together with land-conversion statistics, they help distinguish compact expansion from scattered, corridor-based or leapfrog development.

Indian studies have repeatedly shown that peri-urban agriculture is exposed to this kind of spatial restructuring. In Jalandhar, the development of urban corridors, commercial facilities and institutions converted prime cropland and increased rural land fragmentation (Ratnam & Kaur, 2023). Long-term work in the Kolkata Metropolitan Area found persistent conversion and fragmentation of cropland as built-up land advanced into the urban fringe (Mazumder et al., 2021). Research in English Bazar similarly demonstrated that expansion of built-up patches was accompanied by growing landscape fragmentation (Bindajam et al., 2023). These findings suggest that urbanisation should be understood as a process that changes both land-cover proportions and the spatial arrangement of the remaining land.

Hisar provides a particularly relevant setting for such an assessment. The city is a major administrative, educational, industrial and commercial centre in western Haryana and is surrounded by a strongly agricultural landscape. It is linked to Delhi and other regional centres by major highways and has experienced sustained expansion along transport corridors and around census towns, institutions, industries and residential developments. Published geospatial work shows that Hisar's built-up area has increased rapidly and that a large share of this expansion has occurred outside the municipal core (Kirdolia & Kaur, 2024a; Sharma & Kumar, 2023). A later landscape-metric analysis of peri-urban Hisar further documented the increasing number, density and edge complexity of built-up patches over time (Kirdolia & Kaur, 2024b).

Existing work on Hisar, however, has largely focused on urban sprawl, built-up expansion, land-use/land-cover change and peri-urban delineation. These studies are valuable for establishing how much land has changed and where the urban footprint has grown, but they leave scope for a more agriculture-centred interpretation. The same urban patch dynamics that signify sprawl also represent intrusions into a predominantly rural matrix. When built-up patches multiply, extend along roads and merge at the edges of existing settlements, the spaces between them are increasingly occupied by remnant agricultural parcels. The agricultural consequence is therefore not exhausted by the reported decline in farmland.

The present paper addresses this gap through a geospatial re-assessment of published data for peri-urban Hisar. Rather than claiming a new satellite classification, it combines verified land-conversion statistics with landscape metrics already derived from multi-temporal Landsat images and reinterprets them from the perspective of agricultural fragmentation. This approach makes it possible to identify the periods in which agricultural conversion accelerated, to examine the changing spatial structure of urban intrusion, and to consider the implications for continuity of farming land. The analysis is especially useful for planning because fragmentation can become difficult to reverse once roads, plotted colonies and dispersed construction have divided the agricultural landscape into small and disconnected units.

2. REVIEW OF LITERATURE AND RESEARCH GAP

Peri-urban research has developed from a simple rural-urban contrast towards a more relational understanding of city regions. Ahani and Dadashpoor (2021) show that peri-urban studies now combine physical, demographic, economic and governance indicators, although land-use change remains a central component in most quantitative approaches. Chettry (2022), while delineating the peri-urban zone of Thiruvananthapuram, demonstrated the value of combining demographic indicators with geospatial measures of land-cover change and urban sprawl. Such work is relevant to Hisar because the peri-urban interface cannot be represented satisfactorily by municipal boundaries alone.

A second strand of literature examines the relationship between urban expansion and agricultural transformation. Patel et al. (2019) found that peri-urban land-use change around Varanasi involved a complex reorganisation of cultivated, vegetated and built-up land. Mazumder et al. (2021) showed that cropland in Kolkata's metropolitan fringe was repeatedly absorbed by expanding urban uses and fragmented by new development. In Jalandhar, Ratnam and Kaur (2023) documented extensive rural land transformation along corridors and around institutional and commercial nodes, linking these processes directly with cropland loss and fragmentation. Taken together, these studies underline that peri-urban agriculture can be altered even where cultivation persists, because roads and new built-up patches change the geometry and connectivity of farmland.

A third body of work uses landscape metrics to quantify such structural change. Zhang et al. (2013) emphasised that fragmentation should be analysed through spatial configuration rather than through area alone. FRAGSTATS and related approaches have subsequently been used to measure patch number, density, edge, size, shape and dominance across a variety of urban and ecological landscapes (McGarigal et al., 2012). Bindajam et al. (2023) applied landscape metrics to urban growth in English Bazar and found that increasing built-up development was accompanied by higher fragmentation of the surrounding landscape. The usefulness of these metrics lies in their ability to distinguish multiple small patches from a single contiguous block, even when both occupy a similar total area.

For Hisar, Sharma and Kumar (2023) analysed LULC change over 1991-2021 and reported a large increase in built-up area together with substantial agricultural land loss. Kirdolia and Kaur (2024a) delineated the peri-urban area through a multi-indicator approach and found that built-up area in the combined city and peri-urban zone almost doubled between 2001 and 2021. Their analysis also showed that major urban gains came from open and

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agricultural land and that expansion was pronounced along National Highways 9 and 52. In a separate landscape-metric analysis focused on peri-urban Hisar, Kirdolia and Kaur (2024b) documented strong growth in the built-up class between 1991 and 2023, with rising patch number, patch density and edge density.

The research gap lies in the way these findings are interpreted. In most Hisar studies, patch metrics are used primarily to describe the morphology of urban growth. Yet in a predominantly agricultural peri-urban matrix, dispersed built-up patches also indicate the spatial subdivision of the land through which they expand. A rise in edge density means more contact between built-up and non-built-up land; an increase in patch number creates more potential interruptions within the agricultural matrix; and corridor expansion can split large farming tracts into smaller operational units. The present paper therefore uses existing geospatial evidence to shift the analytical emphasis from urban morphology to agricultural continuity.

3. OBJECTIVES OF THE STUDY

- To examine the long-term pattern of built-up expansion in the peri-urban area of Hisar.
- To quantify the direct conversion of agricultural land to built-up uses during successive periods.
- To interpret changes in selected landscape metrics as indicators of fragmentation pressure on the agricultural landscape.
- To identify the principal temporal and spatial tendencies of fragmentation and draw planning implications for peri-urban agriculture.

4. STUDY AREA

Hisar District lies in western Haryana and covers about 3,983 km2. According to the District Administration, the district had a population of 1,743,931 in the 2011 Census and contains 276 villages, nine development blocks and one municipal corporation (District Administration Hisar, 2026). The district is part of the semi-arid plains of north-western India, where agriculture remains an important land use and economic activity. Wheat, mustard, cotton, bajra and paddy are among the major crops, while irrigation is supported by canals and groundwater.

Hisar City functions as the main administrative, educational, industrial and commercial centre of the district. Its location on important regional transport routes has encouraged outward development. The National Highway 9 corridor links Hisar with Delhi, while National Highway 52 provides another major axis of regional movement. The city's periphery contains census towns, rural settlements, institutional campuses, industrial establishments, residential colonies and extensive agricultural land. This combination creates a wide transitional belt rather than a sharply defined urban edge.

A published multi-indicator delineation identified a peri-urban zone extending roughly 13 to 23 km from the city centre, with a greater reach towards the west and south. Five census towns - Gangwa, Satrod Khurd, Satrod Khas, Satrod Kalan and Mayyer - form important urbanising nodes around the city, while adjoining villages remain closely linked to Hisar through transport, markets, employment and service flows (Kirdolia & Kaur, 2024a, 2024b). The same studies indicate that urban expansion is especially prominent along the ESE, WSW and WNW directions, reflecting the influence of census towns, highways, institutions and other development corridors.

This spatial setting is well suited to an assessment of agricultural fragmentation. Agriculture continues to form the background matrix of much of the peri-urban area, yet new built-up patches appear within and along its edges. As these patches enlarge or multiply, the continuity of agricultural land is progressively altered. The present analysis therefore treats the peri-urban zone surrounding Hisar City as the principal study area rather than the entire administrative district.

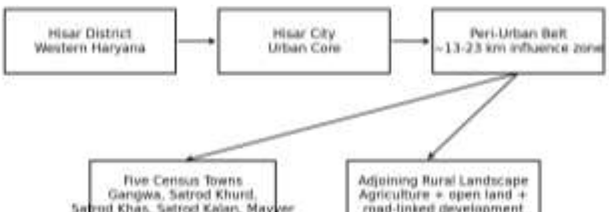

Figure 1. Analytical framework of the peri-urban study area.

5. DATABASE AND METHODOLOGY

Table 1. Satellite imagery underlying the published peri-urban Hisar dataset.

Year	Satellite/Sensor	Acquisition Date	Path/Row	Resolution/Source
1991	Landsat 5 TM	05 March 1991	147/40	30 m; USGS
2001	Landsat 5 TM	16 March 2001	147/40	30 m; USGS
2011	Landsat 5 TM	12 March 2011	147/40	30 m; USGS
2021	Landsat 8 OLI/TIRS	07 March 2021	147/40	30 m; USGS
2023	Landsat 8 OLI/TIRS	05 March 2023	147/40	30 m; USGS

The paper follows a secondary geospatial re-analysis design. No new land-use classification or field survey is claimed. Instead, the analysis draws on published multi-temporal Landsat classifications, class-transition statistics and landscape metrics for peri-urban Hisar, and then derives additional comparative measures from those data. This design is appropriate because the underlying satellite datasets, image dates, spatial resolution, classification procedure and landscape metrics have already been documented in peer-reviewed or scholarly sources, allowing the present paper to focus on an agriculture-centred interpretation.

The principal time series covers 1991, 2001, 2011, 2021 and 2023. Kirdolia and Kaur (2024b) used Landsat 5 TM images for 1991, 2001 and 2011 and Landsat 8 OLI/TIRS images for 2021 and 2023. All scenes correspond to path/row 147/40 and have a 30 m spatial resolution. Images were selected from the same season, reducing the influence of seasonal differences on classification. The original study processed the imagery through band stacking, subsetting, image enhancement and supervised maximum-likelihood classification. Six land-cover classes were mapped: water bodies, built-up land, agriculture, vegetation, open land and mining. Ancillary boundaries were obtained from the Survey of India and Town and Country Planning, Haryana. A separate Hisar study for 2001 and 2021 reported classification accuracies of 91.20 and 94.00 per cent and kappa coefficients of 0.8911 and 0.9269, respectively, supporting the general reliability of the Landsat-based interpretation for the area (Kirdolia & Kaur, 2024a).

Three groups of variables are used in the present re-analysis. The first group represents the magnitude of urban growth: built-up area, absolute built-up gain and percentage change. The second group records direct agricultural conversion to built-up use. For each period, the annualised agricultural conversion rate was calculated by dividing agricultural land converted to built-up by the number of years in the interval. The agricultural contribution to built-up gain was calculated as: Agricultural Conversion Share = (Agricultural Land Converted to Built-up / Total Built-up Gain) x 100. These derived values allow the intensity of agricultural pressure to be compared across unequal periods.

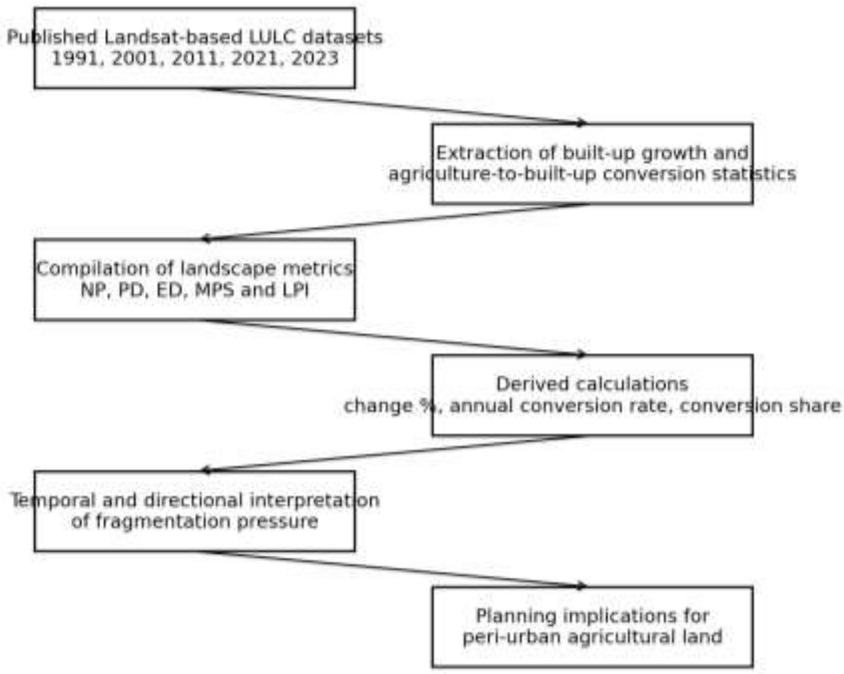

Figure 2. Methodological workflow adopted for the geospatial re-assessment.

The third group consists of five class-level landscape metrics originally calculated for the built-up class using FRAGSTATS-type measures: Number of Patches (NP), Patch Density (PD), Edge Density (ED), Mean Patch Size (MPS) and Largest Patch Index (LPI). NP counts discrete built-up patches. PD expresses patch number relative to landscape area. ED measures total edge length per unit area and therefore reflects the degree of boundary complexity. MPS gives the average size of patches. LPI expresses the percentage of the landscape occupied by the single largest patch. Interpretation does not rely on any one metric in isolation. Rising NP, PD and ED generally indicate stronger dispersion and subdivision; increases in MPS and LPI can indicate patch growth, infilling or coalescence. When high edge density persists while larger patches also emerge, the pattern can represent simultaneous consolidation of some urban areas and continued fragmentation at the urban-rural interface (McGarigal et al., 2012; Zhang et al., 2013).

The agricultural interpretation is based on a matrix-intrusion logic. In peri-urban Hisar, agriculture and open land occupy most of the non-built-up landscape. New built-up patches inserted into this matrix can divide continuous agricultural land even before all intervening farmland is converted. Therefore, the combination of agricultural conversion statistics with changes in built-up patch structure provides an indirect but spatially meaningful measure of fragmentation pressure. The method does not equate built-up fragmentation with agricultural fragmentation in a one-to-one manner; rather, it interprets the urban pattern as the spatial mechanism through which agricultural continuity is disrupted.

The analysis proceeds in five steps. First, published built-up-area values are compared across the five dates. Second, agriculture-to-built-up transitions are summarised for four intervals. Third, conversion rates and shares are derived. Fourth, the trajectories of NP, PD, ED, MPS and LPI are interpreted jointly. Finally, temporal results are read alongside published directional evidence to identify where fragmentation pressure is likely to be most pronounced. Descriptive statistics and graphs were prepared from the published numerical data. Because the purpose is a transparent re-assessment, no synthetic satellite values or fabricated field observations are introduced.

6. RESULTS AND ANALYSIS

6.1 Spatio-Temporal Growth of Built-up Land

Table 2. Built-up expansion in peri-urban Hisar.

Year	Built-up Area (ha)	Change (ha)	Change from Previous Date (%)
1991	2,179.71	-	-
2001	2,850.30	670.59	30.77
2011	3,695.94	845.64	29.67
2021	6,893.01	3,197.07	86.50
2023	6,993.09	100.08	1.45

Built-up land in peri-urban Hisar expanded continuously over the study period. It occupied 2,179.71 ha in 1991, 2,850.30 ha in 2001, 3,695.94 ha in 2011, 6,893.01 ha in 2021 and 6,993.09 ha in 2023. The net increase between 1991 and 2023 was 4,813.38 ha, equivalent to about 220.83 per cent of the 1991 built-up area. The pattern, however, was not uniform. Growth was moderate during the first two decades and accelerated sharply after 2011. Between 1991 and 2001, built-up land increased by 670.59 ha. A further 845.64 ha was added between 2001 and 2011. The 2011-2021 interval alone added 3,197.07 ha, nearly two-thirds of the total increase recorded across the entire 32-year period. Growth slowed markedly in the short 2021-2023 interval, when the net increase was 100.08 ha.

This temporal break is important for interpreting fragmentation. The early phase represents a period in which urban development was spreading outward through new patches and extensions around existing settlements. The 2011-2021 surge indicates a major transformation of the peri-urban landscape, with many earlier patches expanding and new development occupying previously non-built-up land. By 2023, the total built-up share had reached about 9 per cent of the delineated peri-urban area. Although that proportion still appears modest, its spatial effect is much larger than the percentage suggests because development is distributed along roads, census towns and scattered nodes rather than contained in a single compact block.

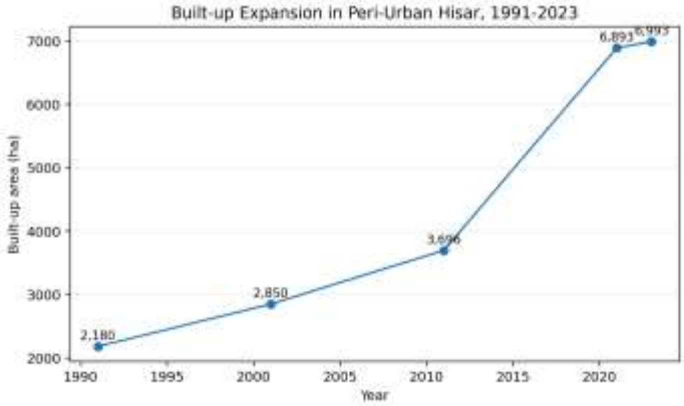

Figure 3. Built-up expansion in peri-urban Hisar, 1991-2023.

6.2 Agricultural Land Conversion

Table 3. Agricultural land converted to built-up uses.

Period	Agriculture Converted (ha)	Annual Rate (ha/year)	Share of Built-up Gain (%)
1991-2001	190.89	19.09	28.47
2001-2011	178.56	17.86	21.12
2011-2021	1,303.38	130.34	40.77
2021-2023	79.74	39.87	79.68

The direct conversion of agricultural land to built-up uses provides the clearest quantitative evidence of pressure on farming space. Agricultural land contributed 190.89 ha to built-up growth during 1991-2001 and 178.56 ha during 2001-2011. The amount increased dramatically to 1,303.38 ha during 2011-2021. A further 79.74 ha was converted between 2021 and 2023. Cumulatively, 1,752.57 ha of agricultural land was converted directly to built-up uses during the periods for which transition data are available.

Agricultural land accounted for 28.47 per cent of total built-up gain in 1991-2001 and 21.12 per cent in 2001-2011. Its share rose to 40.77 per cent in 2011-2021. In the short 2021-2023 interval, agriculture supplied 79.68 per cent of the net built-up gain, indicating that the limited additional development during these two years was concentrated heavily on agricultural parcels. Over the full 1991-2023 period, the recorded agricultural conversion represents approximately 36.41 per cent of total built-up gain.

The annualised conversion rate further clarifies the intensity of change. Agricultural conversion averaged about 19.09 ha per year in 1991-2001 and 17.86 ha per year in 2001-2011. It then rose to about 130.34 ha per year during 2011-2021. The short 2021-2023 interval averaged 39.87 ha per year. Thus, the decade from 2011 to 2021 stands out as the principal phase in which peri-urban growth directly consumed agricultural land. This phase also coincides with a large increase in total built-up area, suggesting that agricultural fragmentation was not an isolated local event but part of a broader restructuring of the peri-urban landscape.

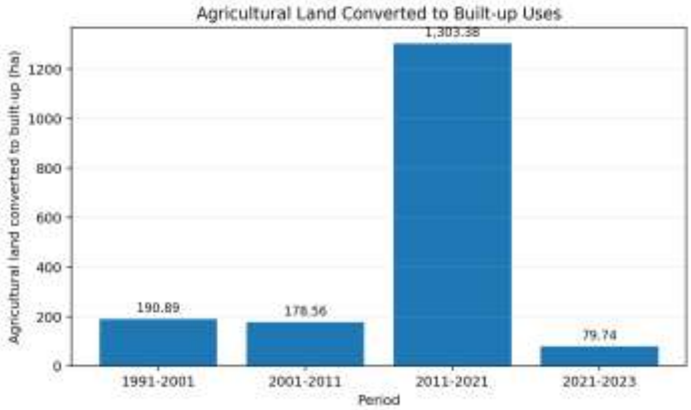

Figure 4. Agricultural land converted to built-up uses by period.

6.3 Landscape Metrics and Fragmentation Pressure

Table 4. Landscape metrics of the built-up class in peri-urban Hisar.

Year	NP	PD	ED (m/ha)	MPS (ha)	LPI (%)
1991	165	0.21	9.33	13.21	0.44
2001	243	0.31	10.14	11.73	0.51
2011	291	0.37	11.10	12.70	1.12
2021	300	0.39	13.26	22.98	4.34
2023	346	0.45	13.69	20.21	4.36

Changes in the landscape metrics reveal how the spatial form of built-up development evolved. The number of built-up patches increased from 165 in 1991 to 243 in 2001 and 291 in 2011. It reached 300 in 2021 and then 346 in 2023. The long-term increase of 181 patches indicates that new urban fragments continued to appear in the peri-urban landscape even as some older patches enlarged and merged. Patch density followed a similar trend, rising from 0.21 to 0.45 over the study period. This confirms that the multiplication of patches was not simply a function of an expanding analytical area; it represented a higher density of built-up fragments within the same peri-urban landscape.

Edge density rose from 9.33 m/ha in 1991 to 10.14 in 2001, 11.10 in 2011, 13.26 in 2021 and 13.69 in 2023. The increase is especially significant from an agricultural perspective because edges are the contact zones between built-up and surrounding non-built-up land. More edge per unit area means that a larger proportion of agricultural and open land lies next to construction, roads, plots or settlement boundaries. Such a configuration is consistent with increased subdivision of the agricultural matrix and greater exposure of remaining fields to conversion pressure.

Mean patch size did not change monotonically. It declined from 13.21 ha in 1991 to 11.73 ha in 2001, then rose slightly to 12.70 ha in 2011. A sharp increase to 22.98 ha occurred by 2021, followed by a decline to 20.21 ha in 2023. This pattern suggests a sequence rather than a single type of sprawl. The initial fall in mean patch size is consistent with the creation of numerous small built-up patches. The strong rise between 2011 and 2021 indicates enlargement and partial coalescence of earlier urban fragments during the phase of most rapid growth. The slight decline after 2021, together with the increase in patch number and patch density, points to renewed formation of smaller patches at the expanding edge.

The largest patch index provides complementary evidence. LPI increased from only 0.44 per cent in 1991 to 0.51 in 2001, 1.12 in 2011 and 4.34 in 2021, reaching 4.36 in 2023. The rapid increase after 2011 indicates the emergence of a much larger dominant built-up patch, most likely through expansion and joining of previously separate urban areas. Importantly, this consolidation did not eliminate fragmentation. Edge density remained high and patch number continued to rise. Peri-urban Hisar therefore displays a dual morphology: consolidation of some major built-up clusters alongside continued creation of new fragments at the urban fringe.

For agriculture, this dual morphology is particularly disruptive. Leapfrog patches can isolate fields and break large farming blocks; later edge expansion may absorb the land between those patches; and corridor development can create narrow, elongated divisions that complicate movement of machinery and irrigation continuity. The observed metrics thus indicate a progression from scattered intrusion to partial coalescence rather than a transition to purely compact growth.

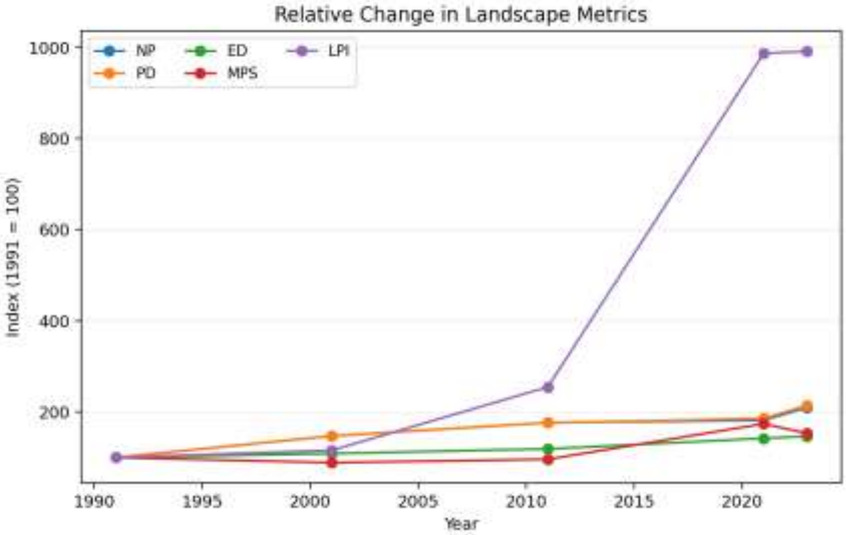

Figure 5. Relative change in selected landscape metrics (1991 = 100).

6.4 Directional Pattern and Stages of Fragmentation

Directional evidence adds a spatial dimension to the temporal pattern. Published data show that the ESE direction consistently contained the largest concentration of built-up land, increasing from 538.56 ha in 1991 to 1,640.34 ha in 2023. The WSW direction rose from 397.35 to 1,353.42 ha, while WNW increased from 357.30 to 1,048.86 ha. These three directions remained major axes of expansion throughout the period. The pattern reflects the location of census towns and the influence of regional transport corridors, including National Highways 9 and 52 (Kirdolia & Kaur, 2024b).

From the standpoint of agricultural fragmentation, corridor-led growth is important because it does not consume land in a simple inward-to-outward sequence. Development along highways and around separate settlements produces ribbons, nodes and gaps. Agricultural parcels may remain between them for years, but their spatial context changes. A field that was once part of a large continuous block may become bounded by a road on one side, plotted residential land on another and an expanding settlement on a third. Such land can remain classified as agriculture in a satellite image while becoming increasingly fragmented in operational terms.

The results therefore point to three stages of fragmentation pressure in Hisar. The first, from 1991 to 2011, was characterised by steady patch multiplication and relatively modest agricultural conversion. The second, from 2011 to 2021, was a phase of rapid expansion, high agricultural conversion and strong edge growth, during which many existing built-up patches enlarged and merged. The third, after 2021, shows slower net area growth but renewed patch proliferation and a high share of new built-up land coming from agriculture. This sequence suggests that the spatial risk to agricultural continuity can remain high even when the rate of total built-up growth begins to slow.

7. DISCUSSION

The Hisar evidence confirms a broader finding in peri-urban research: the agricultural impact of urban expansion cannot be reduced to a simple hectare-for-hectare loss calculation. Land conversion is only one part of the process. The spatial arrangement of development determines whether the remaining agricultural land continues to function as a large, connected production landscape or becomes a mosaic of smaller parcels surrounded by roads and construction.

The combination of rising patch number, patch density and edge density is especially important. Similar patterns have been reported in other Indian cities where dispersed development created a fragmented urban-rural interface (Bindajam et al., 2023; Ratnam & Kaur, 2023). In Hisar, the increase in NP from 165 to 346 and the more than doubling of PD indicate that urban development did not simply extend as a uniform front. Instead, new patches continued to appear across the peri-urban belt. From the perspective of agriculture, each additional patch has the potential to divide or constrain surrounding fields.

The 2011-2021 period represents the most decisive transformation. More than 1,300 ha of agricultural land was converted directly to built-up uses in this decade, while built-up area increased by over 3,197 ha. At the same time, edge density rose sharply and the largest patch index expanded from 1.12 to 4.34. This combination suggests that some earlier fragments were being incorporated into larger urban clusters while the outer fringe remained structurally complex. The process resembles the transition described in peri-urban studies elsewhere: initial leapfrog growth creates scattered development, followed by infilling and edge expansion that gradually converts the intervening rural land (Mazumder et al., 2021; Chettry, 2022).

Fragmentation has practical consequences for farming. Smaller and irregular parcels may increase turning time for machinery, complicate access, raise the relative length of field boundaries and make irrigation channels more difficult to maintain. Urban roads can improve market access but can also divide holdings or increase pressure for non-agricultural conversion. Proximity to construction may create drainage problems, waste disposal, traffic conflicts and speculative landholding. These effects are not captured adequately by aggregate LULC statistics.

The findings also show why landscape metrics should be interpreted jointly. The sharp increase in mean patch size and LPI after 2011 might appear to indicate less fragmentation if considered alone. Yet NP, PD and ED remained high or continued to increase. The more plausible interpretation is simultaneous coalescence in established growth corridors and continuing fragmentation at newer edges. This mixed pattern is typical of rapidly changing peri-urban areas and is precisely why a single indicator can be misleading (Zhang et al., 2013).

For planning, the key issue is not to stop all urban growth but to influence its spatial form. Compact or contiguous development generally creates fewer new interfaces with farmland than scattered ribbon or leapfrog construction. Hisar's strong growth along the ESE, WSW and WNW directions therefore deserves particular attention. Development-control policies that protect continuous agricultural blocks, limit unserviced ribbon development and coordinate road expansion with land-use zoning could reduce further fragmentation. Agricultural land should be evaluated not only by soil quality or total area but also by continuity, accessibility and its role in maintaining viable farming units.

8. MAJOR FINDINGS

- Built-up land in peri-urban Hisar increased from 2,179.71 ha in 1991 to 6,993.09 ha in 2023, an overall rise of approximately 220.83 per cent.
- At least 1,752.57 ha of agricultural land was directly converted to built-up uses across the reported transition periods, equal to about 36.41 per cent of total built-up gain.
- The decade 2011-2021 was the most intense phase of agricultural conversion, with 1,303.38 ha converted at an average rate of about 130.34 ha per year.
- Built-up patch number increased from 165 to 346 and patch density from 0.21 to 0.45, showing persistent multiplication of urban fragments within the peri-urban landscape.
- Edge density increased from 9.33 to 13.69 m/ha, indicating a growing interface between built-up and surrounding non-built-up land and therefore stronger fragmentation pressure on agriculture.
- The simultaneous rise in LPI and continued growth of NP, PD and ED indicates a dual process of urban coalescence in established corridors and continuing fragmentation at the outer edge.
- The ESE, WSW and WNW directions remained major axes of urban expansion, linking fragmentation pressure to census towns and transport corridors.

9. CONCLUSION AND PLANNING IMPLICATIONS

Peri-urban growth around Hisar has produced a substantial and spatially complex transformation of the agricultural landscape. The most visible change is the expansion of built-up land, which more than tripled between 1991 and 2023. The agricultural consequence, however, is broader than the 1,752.57 ha of farmland recorded as direct conversion to built-up use. The changing geometry of urban development - more patches, greater patch density, longer edges and the simultaneous growth of large urban clusters - shows that remaining agricultural land has increasingly been surrounded, divided and exposed to further conversion.

The strongest transformation occurred during 2011-2021, when built-up growth and agricultural conversion accelerated sharply. The subsequent period shows that fragmentation pressure can persist even when net built-up growth slows: a larger share of the limited new development after 2021 came from agricultural land, while patch number and density continued to rise. This is a reminder that the spatial pattern of new construction matters as much as its total area.

For Hisar, peri-urban land-use policy should therefore move beyond a simple distinction between urban and agricultural land. Continuous agricultural blocks should be identified as planning units, particularly in areas where farming remains viable and irrigation networks are intact. Ribbon development along major highways should be controlled through serviced growth nodes and access management. New residential or institutional projects should be encouraged to adjoin existing built-up areas rather than create isolated enclaves within farmland. Where infrastructure corridors are unavoidable, planning should seek to maintain farm access and minimise the creation of small residual parcels.

Landscape metrics can support this process because they provide early warning of structural change before all agricultural land is converted. Periodic monitoring of agricultural patch size, edge density and connectivity should therefore be incorporated into peri-urban planning and development-plan revisions. Such monitoring would help identify not only how much agricultural land remains, but whether it still forms a coherent landscape capable of supporting efficient farming. In this sense, safeguarding peri-urban agriculture in Hisar requires attention to spatial continuity as well as area conservation.

The study is limited by its reliance on published geospatial datasets rather than a new independent classification of agricultural patches. Its contribution is therefore interpretive and comparative: it demonstrates how established urban-growth and landscape-metric evidence can be re-read to reveal fragmentation pressure on agriculture. Future work can strengthen this assessment through field-level cadastral data, high-resolution imagery and village-wise measurement of agricultural patch connectivity.

REFERENCES

[1] Ahani, S., & Dadashpoor, H. (2021). A review of domains, approaches, methods and indicators in peri-urbanization literature. Habitat International, 114, 102387. https://doi.org/10.1016/j.habitatint.2021.102387

[2] Bindajam, A. A., Mallick, J., & Hang, H. T. (2023). Assessing landscape fragmentation due to urbanization in English Bazar Municipality, Malda, India, using landscape metrics. Environmental Science and Pollution Research, 30(26), 68716-68731. https://doi.org/10.1007/s11356-023-27252-2

[3] Chettry, V. (2022). Peri-urban area delineation and urban sprawl quantification in Thiruvananthapuram Urban Agglomeration, India, from 2001 to 2021 using geoinformatics. Applied Geomatics, 14, 639-652. https://doi.org/10.1007/s12518-022-00460-0

[4] Chettry, V. (2023). A critical review of urban sprawl studies. Journal of Geovisualization and Spatial Analysis, 7, 28. https://doi.org/10.1007/s41651-023-00158-w

[5] District Administration Hisar. (2026). Demography. Government of Haryana. https://hisar.gov.in/demography/

[6] Mazumder, S., Saha, J., Nandi, G., Naskar, M., Gayen, J., & Datta, D. (2021). Long-term monitoring of cropland transformation in Kolkata Metropolitan Area, India using open-source geospatial technologies. SN Applied Sciences, 3, 98. https://doi.org/10.1007/s42452-020-04064-4

[7] McGarigal, K., Cushman, S. A., & Ene, E. (2012). FRAGSTATS v4: Spatial pattern analysis program for categorical and continuous maps. University of Massachusetts, Amherst.

[8] Patel, S. K., Verma, P., & Singh, G. S. (2019). Agricultural growth and land use land cover change in peri-urban India. Environmental Monitoring and Assessment, 191(9), 600. https://doi.org/10.1007/s10661-019-7736-1

[9] Ratnam, R., & Kaur, R. (2023). Spatially contextualizing rural land transformation in peri-urban area: A case of Jalandhar City, Punjab (India). International Journal of Geoinformatics, 19(2), 11-24. https://doi.org/10.52939/ijg.v19i2.2561

[10] Sharma, M., & Kumar, V. (2023). Assessment of urban sprawl, land use/land cover changes and land consumption rate in Hisar City, Haryana, India. Human Geographies - Journal of Studies and Research in Human Geography, 17(1). https://doi.org/10.5719/hgeo.2023.171.3

[11] U.S. Geological Survey. (2026). Landsat 8-9 Operational Land Imager and Thermal Infrared Sensor Collection 2 Level-1 data. https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archives-landsat-8-9-operational-land-imager-and

[12] Yeh, A. G. O., & Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. Photogrammetric Engineering & Remote Sensing, 67(1), 83-90.

[13] Zhang, S., York, A. M., Boone, C. G., & Shrestha, M. (2013). Methodological advances in the spatial analysis of land fragmentation. The Professional Geographer, 65(3), 512-526. https://doi.org/10.1080/00330124.2012.700501