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Assessment of urban sprawl, land use/land cover changes and land consumption rate in Hisar City, Haryana, India

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Keeping in mind the detrimental effects of sprawl on the urban landscape, an accurate and thorough analysis of the spatiotemporal growth pattern is necessary for well-organized and sustainable urban progression. This study mainly focuses on urban sprawl and land use/land cover changes (LULCC) in Hisar City of Haryana, India. The extent of urban sprawl and changes in different land utilization over 30 years have been assessed using Shannon's entropy technique. Additionally, the land consumption rate and land absorption coefficient are introduced to support the quantitative evaluation of changes. Finally, the accuracy assessment (producer's, user's, and overall) with the Kappa coefficient was applied for spatial accuracy valuation to confirm the land use/land cover (LULC) reliability based on Landsat multi-temporal satellite data from 1991 to 2021. The study deals with water bodies, open/bare land, vegetation, agricultural lands and built-up area as LULC categories for changes evaluations. As per findings, the built-up area has increased more than twice (2,826.72 hectares) by the total area throughout the studied period, whereas farming land has lost almost half part (3,497.94 hectares). The urban sprawl and LULC change mechanisms have directly influenced other natural resources, including farming land. The increasing entropy values also confirm the sprawl or fragmented development in the city, mainly from the centre to the periphery. This unrestricted expansion has changed the geography of the concerned region and surpassed the land use

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plans. The suggested policy options may assist decision-makers in resolving the urban impediments, minimizing the additional loss of peripheral landscape, and achieving long-term urban growth planning in the study area.

Key Words: ***land consumption rate, satellite data, Shannon's entropy, urban sprawl.***

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Introduction

Since ancient times, the earth's surface has witnessed various degrees of spatial and temporal modifications gradually or rapidly. All these changes are the shared outcomes of natural and anthropogenic actions (Zhou & Chen, 2018). Among natural occurrences, inundations, hot-tempered outbursts, famines, earth tremors, and other kinds of hazards and disasters are responsible for changing the terrain, whereas setting fire to forested areas for animal hunting, clearance of woodlands for agriculture, housing and extra constructions, shrinkage of water resources to get more lands, are some human-induced doings that bring changes for the prevailing terrestrial systems (Garg et al., 2019). Here, the nature-stimulated moderations are not a matter of great concern, as these events take place in a particular relief type and affect the same space. Opposite to this, man-intended amendments belonging to everlasting desires disturb the entire arrangement of the earth's surface. Urbanisation - turning natural spaces into developed areas for different human purposes, like residential, business, and manufacturing - is an example of such modifications (Xie et al., 2005; Pal & Ziaul, 2017). The urbanisation process is nourished by the general nature of humans that demands more superiority in living standards and economic and social security after fulfilling the fundamental requests. These factors' complexity, extent, and magnitude determine urbanization in an urban environment (Mubareka et al., 2011).

It acts like an engine of development; when it is appropriately managed; otherwise, it threats a city's sustainability (Sharma & Kumar, 2022). Presently, the speedy growth in the number of urban residents has played a direct and significant role in making sprawl more intricate worldwide. The UN estimations state that the urban population level was 54% in 2015 when Agenda 2030 was adopted for sustainable development. This share is projected to be 62% by 2036 and 68% by 2050. The report also highlights less developed regions of south and east Asia and Africa as hotspots of urbanisation, accounting for 96% of urban growth. Moreover, 35% of total growth has been expected only in trio nations, namely, China, India and Nigeria, between 2018-2050 (UN-HABITAT, 2020). The growing number of people in cities demands basic facilities like accommodations, conveyances, sewage and water, commercial, educational, recreational sites, medical centres, etc.

These demands require extra land to be fulfilled, further forcing urban areas to expand their existing confines or sprawl. In growing cities, the consequences become more serious, which can be seen in the loss of fertile land, decline in vegetation cover and water area, high land values, deterioration of resources, a decline in living standards through the appearance of slums or illegal occupancies and delay in providing qualitative essential urban services. For example, the addition of 45 million persons per year to the urban population of Asian countries results in the alteration of more than 10 km^2 of productive cultivable land into different urban practices. India is also marked as a fast-urbanizing nation where 600 billion people have been predicted as urbanites by 2030 (Hoelscher & Aijaz, 2016; Ahluwalia et al., 2014).

Urban sprawl is one of the expected consequences of urbanisation that may be defined as the unrestricted and unplanned expansion of accommodations, business centres, and infrastructure in urban areas. It is a customary after-effect of converting an agrarian society to an industrial one fueled by the accumulation of people in cities or towns (Cobbinah & Darkwah, 2016; Xu et al., 2019; Sharma & Kumar, 2022). As sprawl is not monitored and taken into consideration in its initial stages, it soon speeds up due to the growth in population and becomes uncontrolled, causing several social and environmental snags. The associated environment always remains a silent cost-payer for unplanned urbanisation. Mainly, agriculture and forests become the prime and soft targets to fulfill the land demands for other urban uses. The vegetation, aquatic and arable lands that significantly contribute to the city's ecosystem by supplying fresh air, water and sustenance are continuously reducing over the landscape.

Moreover, such grounds act like a sponge that engrosses the negative urban impacts on the environment. These are the transitional regions between the urban sites and natural countryside locales that manage and restore the associated metrological phenomena that get disturbed by increasing urban settlements (Doygun, 2009; Sati & Mohan, 2018). Encroaching over these areas makes sprawl (having both urban and rural characteristics) a standard feature on the outskirt of large cities. Today, various parts of the world witness alterations in land use/land cover with varying extent and intensity determined by social, economic, physical and biological features. These enticing factors are directly associated with micro and macro commercial activities, interior and exterior policies, ecological aspects, and vital events in the demography of the related one (Turner et al., 1993; Feranec et al., 2017).

Alternatively, sprawl can be stated as a specific form of urban advancement characterised by inadvertent, scattered, self-supporting and socio-environmental affecting attributes (Hasse & Lathrop, 2003; Sridhar et al., 2020). The spatial and sequential operations on land or its consumption by humans determine the land use pattern in any area. Detecting change in different land utilisation helps local administrations and urban planners recognise the causes and consequences of this transformation and formulate an effective strategy to solve the uninvited problems. The adverse impacts force administrations to find an alternative for the expansion other than moving the centre to the periphery.

In this context, authorities usually apply the zonal segregation approach for ongoing land operations and activities. On the priority bases, the residential and commercial land utilisation (mainly heavy manufacturing units with high pollution) are detached to ensure the urban's better health, hygiene, and security (Gillham, 2002). The integrated geo-informatics technology has made evaluating, monitoring, managing, and predicting urban phenomena like sprawl easier and more accurate. In urban cases, the geographical information system (GIS), in particular, assists in calculating the growing fragmentation, absorbency, diversity, unevenness, area density, dispersion and linkages, and dominance for the description of urban landscape regarding its structure, functioning and conversion (Civco et al., 2002; Sharma et al., 2012; Sharma & Kumar, 2019; Löw et al., 2022). It offers a profound vision for sustainably managing the sprawl.

Generally, the developed or imperious structure within an urban area is considered the parameter to measure the intensity of sprawl (Epstein et al., 2002). Topographical sheets or satellite images demarcate this built-up area. The making of cities, along with human habitats, more shielded, resistant, all-inclusive and sustainable is one of the main goals set by the United Nations for completion by 2030 (United Nations, 2015).

Under the expert's evaluation, the accurate, precise, and regular monitoring of urban growth is a prime requirement for designing the strategies and their implementation justifiably. The study uses open-source satellite data to analyse the direction, trends, and pattern of sprawl in Hisar City from 1991 to 2021. As a consequence of sprawl, the next aim is to evaluate the space and time-based changes in LULC in the study area for the same period.

Study Area

Hisar, known as 'Steel City', is situated west of Haryana state in the North Indian great plain. Geographically, it is characterised by semi-arid and arid climatic conditions. It is placed in the west of New Delhi, at a distance of around 160 kilometres (Figure 1). Because of its proximity to the national capital city, it has been declared a counter-magnet city (alternative growth centre of the main city) in the National Capital Region's Development Plan 2001. The earlier literature correlates the foundation of Hisar city (1354-1356 AD) with *Firoze Sah Tughlak*, a Muslim ruler of the Tughlaq dynasty. At that time, the city was protected by four gates (*Delhi* in the north, *Nagori* in the south, *Mori* in the east and *Talaqi* in the west) in four main directions.

Due to this construction speciality, the city was initially called 'Hisar a Firoza', which means the fort. The city has tremendous historical relevance and is also recognised for many sites from the medieval period.

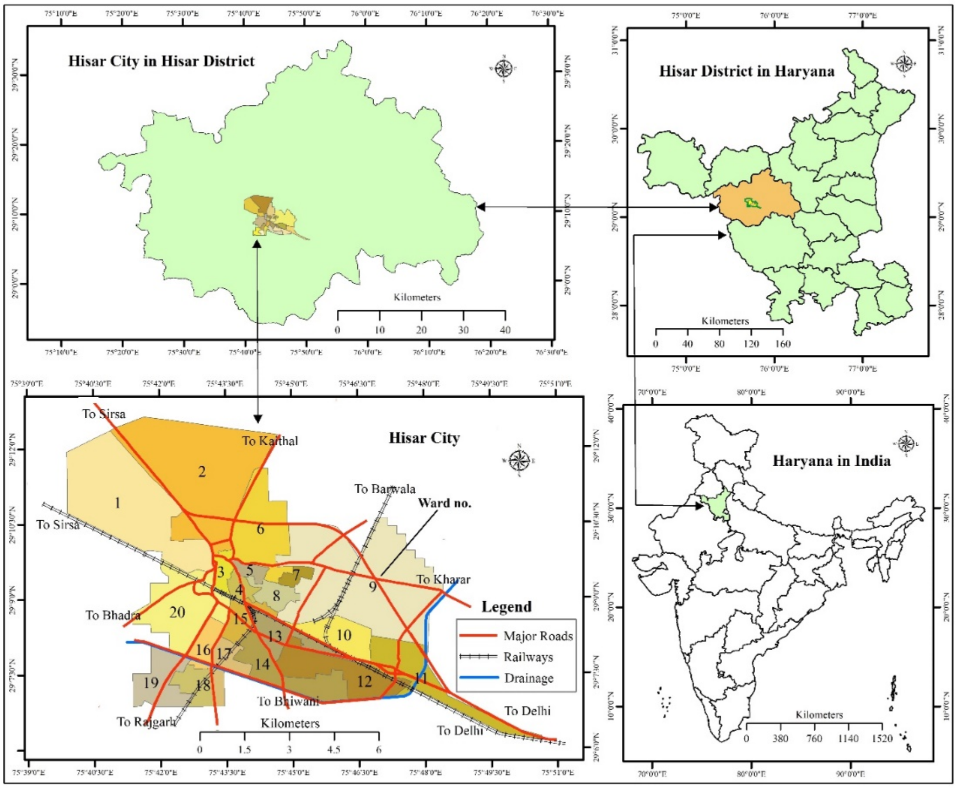

Figure 1. Study Area's Location

Presently, Hisar City is an administrative headquarter of the district with the same caption. It has good connectivity with its surrounding districts. The presence of various state and national levels educational, commercial, industrial and research institutes is enough to signify and glorify the city's existence.

Methodology

The research has used mainly two, satellite and population, data types obtained from secondary sources. The satellite data of different periods like Landsat TM dated 05 March 1991, Landsat 7 ETM+ on 08 March 2001, 21 April 2011 and Landsat 8 OLI/TIRS on 24 April 2021, is derived from the U.S. Geological Survey for measuring the spatial growth of the city, the direction of expansion and alterations in different land operations (Table 1). The data relating to population has been compiled from the various census enumerations in 1991, 2001 and 2011.

The municipal office of Hisar City has also been approached for information regarding administrative confines. The whole adopted procedure for methodology has been depicted in Figure 2.

Figure 2. Methodological Flowchart

Supervised Classification

The supervised classification with a maximum likelihood algorithm was applied to develop LULC maps for the research times 1991, 2001, 2011, and 2021 by using the classification tool of ERDAS Imagine 2014. ArcGIS software was used to prepare the layouts of the maps.

Table 1. Used Satellite Statistics Details

No.	Satellite's type	Scene ID	Acquisition date/year	Path/Row	Resolution
1	(Landsat 4-5 TM)	LT514704019910305064ISP00	)5-March-1991	(147/040)	30
2	(Landsat 7 ETM+)	LE71470402001067SGS00	)8-March-2001	(147/040)	30
3	(Landsat 7 ETM+)	LE71470402011111ASN00	21-April-2011	(147/040)	30
4	(Landsat 8 OLI/TIRS	LC81470402021114LGN00	24-April-2021	(147/040)	30

Source: https://www.usgs.gov/

Accuracy Assessment and Kappa statistics

The following methods were applied to assess accuracy (Canada Centre for Remote Sensing, 2010) and the Kappa coefficient.

$$\textbf{Users Accuracy} = \frac{\text{Number of Correctly Classified Pixels in each category}}{\text{total Number of Classified Pixels in that category (The Row Total)}} \times 100$$

$$\textbf{Producer Accuracy} = \frac{\text{Number of Correctly Classified Pixels in each category}}{\text{Total Number of Classified Pixels in that category (The Column Total)}} \times 100$$

$$\textbf{Overall Accuracy} = \frac{\text{Total Number of Correctly Classified Pixels (Diagonal)}}{\text{Total Number of Reference Pixels}} \times 100$$

Kappa statistics are more capable than the overall accuracy assessment of the satellite images (Lillesand et al., 2015). It is calculated as:

$$\hat{K} = \frac{n\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_i + x_{+i})}{n^2 - \sum_{i=1}^{r}(x_{i+}x_{+i})}$$

where, r = rows numbers in the matrix, x_{ii}= observations numbers in row I and column I, x_{i+} and x_{+i} = marginal totals of row I and column I, correspondingly, and n = total observations (samples/pixels).

The following statistical methods and models were applied to assess sprawl better. The following formula (Swanson & Siegel, 2004) was applied for the calculation of the predicted population number:

$$P = P_b\left(1 + \frac{R}{100}\right)^n$$

where; P = desired period's population; Pb= base year's population; R = growth rate of population and n = numbers of years (e.g., 1, 2, 3, . . ., n).

Shannon's Entropy Index

The detection of arrangement and urban growth type is done using the entropy index. This index determines the spatial clustering and diffusion of geographical variables (x_i) in n wards or zones (Theil, 1967; Thomas, 1981). The formula is as follows:

$$H_n = \sum_{i=1}^{n} P_i \log\left(\frac{1}{P_i}\right)$$

where, Pi, refers to the proportion of a variable occurring in the i^{th} zone $\left(P_i = \frac{x_i}{\sum_{i=1}^{n} x_i}\right)$

where, x_i means the phenomenon's value in the ith zone, and n denotes the zones/wards numbers in the study area. The value in the entropy model ranges from zero to log n. A value that is closer to zero suggests that the urban area is growing in a compact form. The sprawl dispersion, which denotes mixt land utilisation (developed area, agricultural, and other services) of a specific physical portion, is represented by a value far from zero or close to log n. The relative entropy (*H'n*) that reorders the entropy values from 0 to 1 (Yeh & Li, 2001) is calculated as:

$$H'_n = \sum_{i=1}^{n} P_i \log\left(\frac{1}{P_i}\right) / \log(n)$$

The relative entropy (*H'n*) threshold worth is 0.651, the equidistant mark for the all-out value of log (n). The low or close (0) relative entropy value of a built-up area specifies zero-degree sprawl or its concentration in a particular zone, whereas high values up to 1 refer to higher sprawl. Since entropy measures the distribution of a geographical phenomenon, the difference of entropy values from time $t1$ to $t2$ can be applied to determining the grades of difference in urban sprawl:

$$\Delta H_n = H_n[t_2] - H_n(t_1)$$

Built-up density

An essential metric for determining the relationship between the total built-up area and the total area of the spatial unit is built-up density (Aljoufie, 2012). It is a helpful method for assessing a region's urbanisation level.

$$\text{Builtup density (\%)} = \frac{\text{Built up area of ward}}{\text{Total area of ward}} \times 100$$

Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC)

The LCR is also calculated for the urban area's compactness and progressive spatial expansion. The high LCR value refers to compactness and vice-versa. The estimated LAC shows the variations in the utilization of new urban lands for built-up purposes with each unit increase in population. The formulas are, in that order:

$$\text{LCR} = \frac{\text{A}}{\text{P}}$$

where, A and P denote the city's built-up area (in hectares), and total population, respectively.

$$\text{LAC} = \frac{\text{A2} - \text{A1}}{\text{P2} - \text{P1}}$$

A1 and A2 mean early and later years areal extents in hectares, and P1 and P2 refer to the initial and last year population, in that order (Yeates & Garner, 1976).

Results

Population and Area Growth in Hisar City (1901-2021)

In recent decades, Hisar City has experienced immense growth in urbanisation within the centre and the adjacent suburbs. Table 2 shows the population and area growth patterns in from 1901 to 2021. It reveals that in the city (municipality and civil lines), the population size was 17,647 people in 1901, which decreased by 485 persons in 1911. After this, the city experienced a continuous increase in its population as well as its designation. There was an increase of 4,253, 3,764 and 3,439 persons in 1921, 1931 and 1941, with a decadal growth rate of 24.78%, 17.58% and 13.66%, respectively. From a municipality in 1951, the city's urban status was replaced by a municipality committee, and the population was observed at 35,297 persons, which increased to 60,222 in 1961, with an addition of 24,925 persons in the following census. The growth rate has also jumped more than three times prior and is documented as 70.62%. From 1971 to 2011, the succeeding decades confirm the absolute increase of 29,215, 41,872, 4,1368, 84,012 and 44,694 persons in the particular enumeration period.

The second aspect of representation (space) indicates that the municipality's area was just 1,753 hectares in 1961, with a population of 60,222 that grew to 3,134 and 3,738 hectares in 1971 and 1981, with a population of 89,437 and 1,31,309 people.

Table 2. Population and Area Growth in Hisar City (1901-2021)

Census Year	Urban Status	Population	Variations since the preceding Census		MC Area in Hectares
			Absolute	Percentage	
1901	Municipality and Civil Lines	17,647	-		NA
1911	Municipality	17,162	-485	-2.75	NA
1921	Municipality	21,415	4,253	24.78	NA
1931	Municipality	25,179	3,764	17.58	NA
1941	Municipality	28,618	3,439	13.66	NA
1951	Municipal Committee	35,297	6,679	23.34	NA
1961	Municipal Committee	60,222	24,925	70.62	1,753
1971	Municipal Committee	89,437	29,215	48.51	3,134
1981	Municipal Committee	131,309	41,872	46.82	3,738
1991	Municipal Committee	172,677	41,368	31.50	4,543
2001	Municipal Committee	256,689	84,012	48.65	4,543
2011	Municipal Corporation	301,383	44,694	17.41	9,278.37
2021	Municipal Corporation	358,161*	56,778	17.41	9,278.37

Source: Census of India, 2001 and 2011 and MC Office, Hisar.
Note: * refers to estimated population; NA= Data not available

The area was augmented by two and a half in forty years (1961-2001) and documented as 4,543 hectares in the following censuses of 1991 and 2001, (same in both) having a population of 172,677 and 256,689 respectively. The city saw a considerable increase in area in 2011 and 2021 (equal area in both), and the administration has confirmed the municipal area as 9,278.37 hectares.
In contrast, the census reported an upsurge of 56,778 persons in the total population between these same enumerations (Table 2). Presently, the city is enjoying the title of municipal cooperation, granted in 2011 by the Haryana Government's Urban Local Bodies Department. However, there has been no change in municipal (MC) area in 2021 from 2011, yet, the nature and speed of projected population growth demonstrate that the city has more probability of physical and demographical expansion in future for the completion of its residents' demands.

An Appraisal of Artificial and Natural Arrangement of Land

The section refers to land uses by humans (land use) and area coverage by natural aspects (land cover). Table 3 informs the alterations in LULC in Hisar City over a period of time. The statistics reveal that in 1991, more than a third-fourth (77.70%) of the city's area was under agricultural practices, and this class ranked first with a total area of 7,209.36 hectares. This sequence was followed by the second leading land-use type of built-up area (14.41%), vegetation (4.14%), bare/open land (2.90%) and water bodies (0.84%). In 2001, agricultural land again occupied the top position with an area coverage of 67.25%; however, it got a reduction of 970.11 hectares in absolute and 10.45 in percentage to the previous record. The area under built-up, vegetation, bare or open land and water bodies categories increased by 7.89%, 1.04%, 1.05% and 0.48%, respectively and were observed as 22.30%, 5.18%, 3.95% and 1.32% one-to-one.

In 2011, as the city received a more than a doubled-fold increase (4,735.57 hectares) in its MC area, all categories witnessed an increase in their total area and proportion except the decline of 7.29% in farming land. The agricultural land was listed as 59.96%, followed by 27.79% of built-up area, 5.83% of vegetation, 4.91% of bare/open land and 1.52% of water bodies. In 2021, significant interchanges happened in areas of different land operations due to rapid urban growth. The built-up area replaced arable land in position and emerged as dominating category first time, with a proportion of 44.48% and an absolute area of 4,164.12 hectares. This expansion has occurred on agricultural land as it received a significant loss of 19.95% only in a decade from 2011 to 2021. The increase of 0.29%, 2.29% and 0.28% in vegetative land, open/bare land and water bodies to the previous decade's statistics have offered is a good sign for the city's environment (Table 3).

The spatial and temporal presentation in Figure 3 reveals that the city's rapid urbanisation has brought momentous changes in nature and the extent of existing land operations. In 1991, the developed area was mainly concise in the city's centre, surrounded by arable land.

Table 3. Land use/land Cover (LU/LC) in Hisar City (1991-2021)

Sr. No.	LU/LC Classes	1991 Area (hectare)	1991 Area (%)	2001 Area (hectare)	2001 Area (%)	2011 Area (hectare)	2011 Area (%)	2021 Area (hectare)	2021 Area (%)
1	Built-up Area	1,337.40	14.41	2,069.46	22.30	2,578.59	27.79	4,164.12	44.88
2	Agriculture Land	7,209.36	77.70	6,239.25	67.25	5,562.9	59.96	3,711.42	40.00
3	Vegetation	384.48	4.14	480.60	5.18	540.81	5.83	568.17	6.12
4	Bare/open land	269.19	2.90	366.66	3.95	455.4	4.91	667.98	7.20
5	Water bodies	77.94	0.84	122.40	1.32	140.67	1.52	166.68	1.80
	Total	9,278.37	100	9,278.37	100	9,278.37	100	9,278.37	100

Source: Compiled by authors

Some constructions in elongated strips and patches were also present in the south-east and southwest parts. In 2001, the city started to grow on surrounding agricultural land at a sluggish speed. The re-demarcation of the city's administrative boundary in 2011 offered more space for expansion without worry. It resulted in intensive growth in the centre and fragmented evolution of other classes, mainly vegetative and agricultural lands in the southern area.

In 2021, great ups and downs appeared in the city's ongoing artificial land practices and natural coverage. Due to encroachment on other categories, the impervious structure has become more condensed in the town and along the margins due to new constructions. A significant loss was reported from arable land from areas in the west, southwest and south-east. Vegetation or greenery has also been reduced, and some new waterbodies spots have been observed around the edges (Figure 3).

Figure 4 shows that farming land and built-up area classes have encountered maximum changes in their areas and decline in first, augmented to second. Where agricultural land has lost a significant area of 3,497.94 hectares (37.70%) from the beginning to end years of study, the built-up class has gained an area of 2,826.72 hectares (30.47%) in the same period.

The rest of the three categories have recorded a slight but significant increase in their actual and proportional area. The land transformation from one to another also justifies the city's sprawling nature. It has been noticed that during the entire studied period, the built-up area category has gained the maximum addition by invading other types, mainly agricultural land. The farming land has the highest overall loss, whereas the built-up area has received the highest benefit throughout the period (Table 4).

In the general glimpse of the pictographic depiction, it appears that agricultural land is directly and continuously losing land to the built-up class as their bars are moving on opposite sides, almost in the same proportion. However, green cover, water resource areas, and open/bare land have also experienced growth. Nevertheless, it is favourable for urban and urbanites yet, which is not a significant increase (Figure 5).

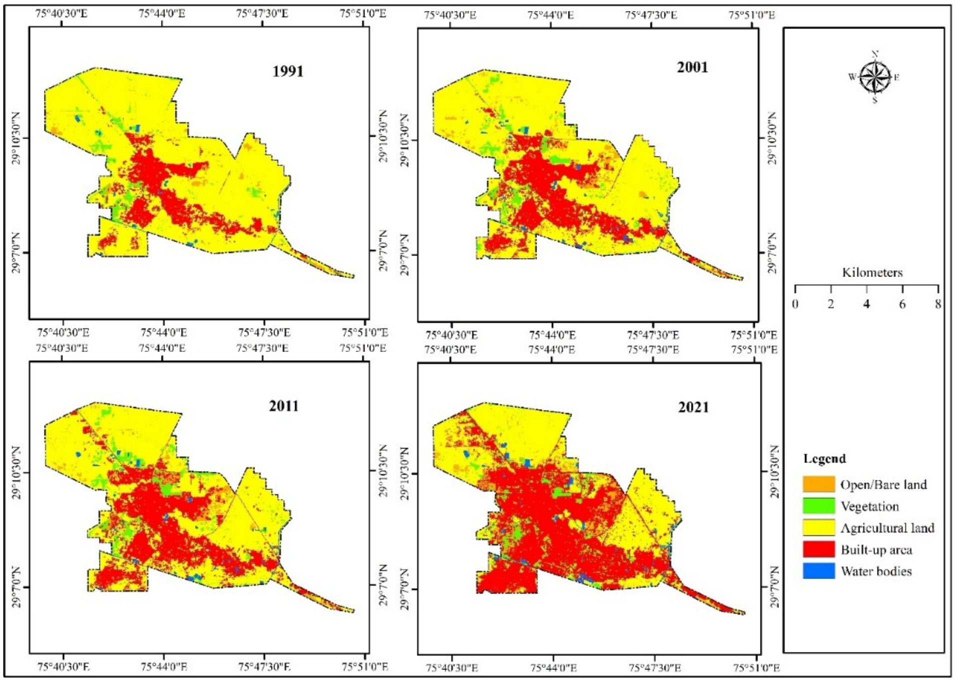

Figure 3. Land use/land Cover in Hisar City (1991-2021)
Source: Satellite Data Based

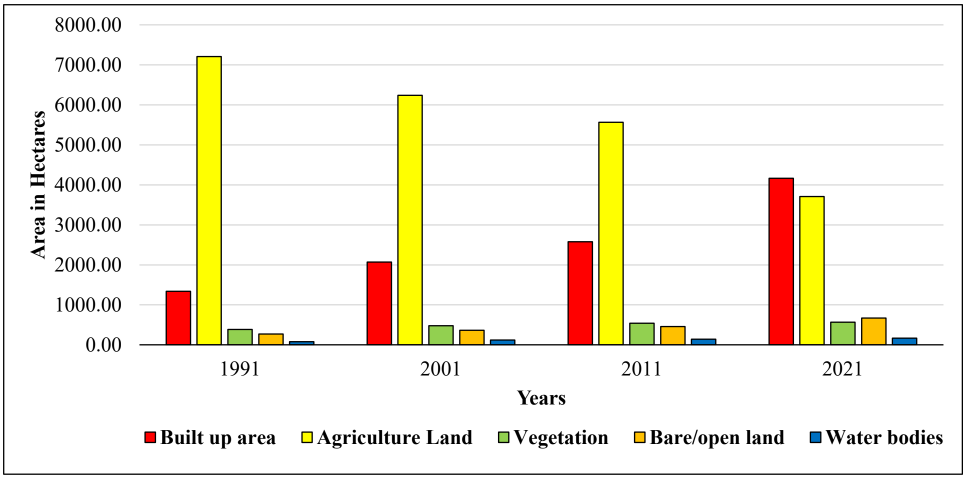

Figure 4. Change Detection in LU/LC in Hisar City (1991-2021)
Source: Compiled by authors

Spatial Expansion and Built-up Density

The physical or spatial expansion refers to the growth in geographical perimeters of a city that turns into sprawl after joining the persistent occurrence. It is a multifactor supported process in which urban centres and surrounding countryside work as pull and push factors. First, natural growth takes place in own's population of a city, and second, the presence of various urban facilities fascinates the people for migration, and both generate the demands for more space which force the administration to expand the existing boundaries. The spatial expansion refers to the fact that in the initial study period, the built-up area was compact in the city's centre and started to expand along the transport routes in all directions in the subsequent phases (Figure 6).

Table 4. Land Use/Land Cover Change (LULCC) Information in Hisar City (1991 - 2021)

Sr. No.	LU/LC Classes	Area Change (in hectares)			Area Change (in Percent)		
		1991-2001	2001-2011	2011-2021	1991-2001	2001-2011	2011-2021
1	Built-up Area	732.06	509.13	1,585.53	7.89	5.49	17.09
2	Agriculture Land	-970.11	-676.35	-1,851.48	-10.46	-7.29	-19.95
3	Vegetation	96.12	60.21	27.36	1.04	0.65	0.29
4	Bare/open land	97.47	88.74	212.58	1.05	0.96	2.29
5	Water bodies	44.46	18.27	26.01	0.48	0.20	0.28

Source: Compiled by authors

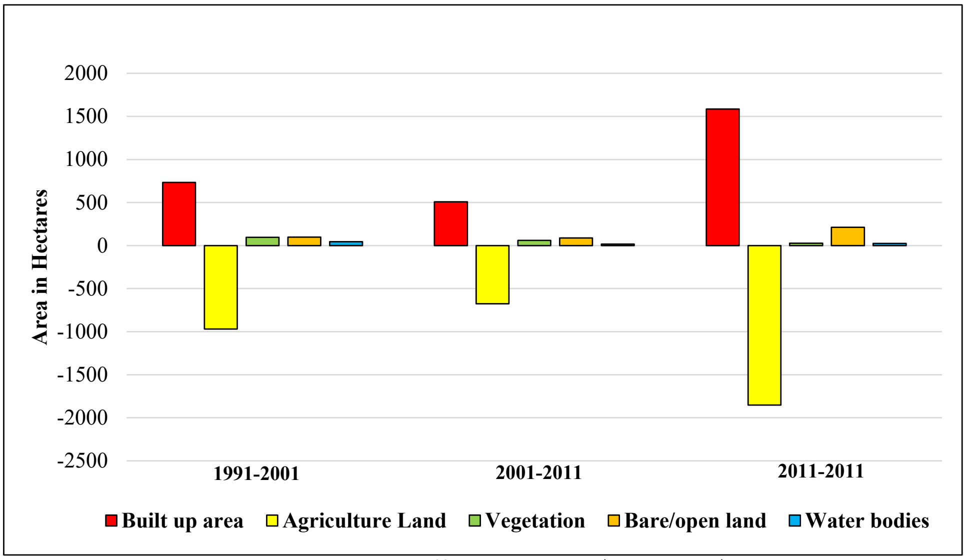

Figure 5. Gain and Loss in Area under Different Classes (1991-2021)
Source: Compiled by authors

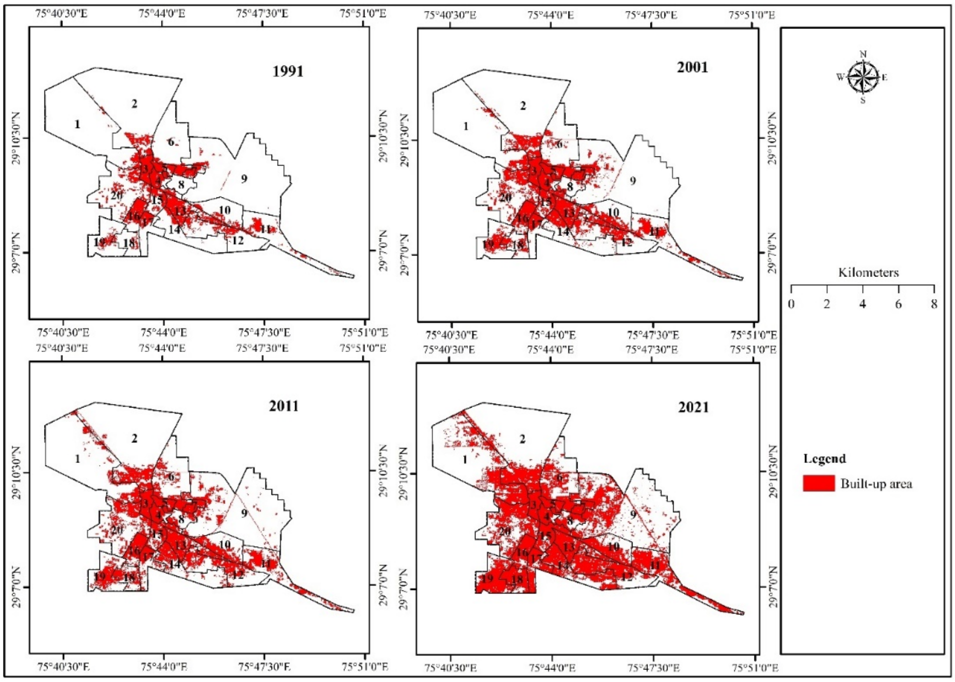

Figure 6. Spatial Expansion of Built-up Area, 1991-2021
Source: Satellite Data Based

The built-up density for different times was also calculated as the percentage of a specific unit's built-up area to the overall unit area, and it has been represented in Table 5. In 1991, the highest built-up density (more than 80%) was identified in the city's central part, i.e., ward no. 3 and 5, whereas very low values (below 20%) were observed in 10 wards, namely 1, 2, 6, 8, 9, 10, 11, 14, 18 and 19. In the second and third studied phases (2001 and 2011), the city got additional built-up areas.

The number of wards with the lowest density was 4 in 2001 and 3 in 2011, significantly declining. More than 80% density was calculated in five wards (no. 3, 4, 5, 7 and 13) in the city's core area for both years. The adjacent area of the centre also registered moderate to high built-up density. The year 2021 has been marked by substantial changes in built-up density overall. The least density (less than 20%) was registered only in the ward no. 2, followed by low (20-40%) in wards 1 and 9, medium (40-60%) in 6, 10 and 20, high (60-80%) in 8, 11, 12, 14 and 19. The number of wards with very high built-up density increased four and half times (from 2 in 1991 to 9 in 2021) in the recent period (Tables 5 and 7).

The graphical representation of built-up density reveals that in 2001 and 2011, the newly developed area appeared in Haryana Agricultural University on the west side along Sirsa road in the north-west. Owing to more opportunities, the dense growth in buildings has been seen along with the Delhi Road network in the south-east and Rajgarh Road in the south. In contrast, scattered development and the city's local road structure have arisen. Next, in 2021, the fast urban growth made a more byzantine visual appearance of Hisar City.

Table 5. Built-up Density of Hisar City

Ward No.	1991	2001	2011	2021
		Built-up Density (%)		
1	2.96	6.27	9.70	27.53
2	5.40	9.41	12.28	18.11
3	97.81	98.47	98.47	99.24
4	76.12	82.44	82.66	85.71
5	85.43	95.00	95.00	97.57
6	10.28	18.39	28.15	43.68
7	69.93	92.26	95.62	97.52
8	10.74	26.61	45.60	63.20
9	1.59	5.60	9.91	26.63
10	16.10	32.03	39.71	54.97
11	16.73	29.28	37.54	64.10
12	21.19	32.30	42.68	66.41
13	77.52	84.05	84.94	87.43
14	7.58	22.99	32.69	69.62
15	49.05	69.52	71.48	86.77
16	66.18	78.48	78.91	88.18
17	26.88	32.09	48.63	84.50
18	13.81	37.20	51.00	86.63
19	11.79	28.10	38.29	72.49
20	21.52	32.47	35.00	54.12

Source: Compiled by authors

During this time, the physical confines of the city have not been extended; still, massive constructions appeared on the available open space within it that made the previous structure more condensed. The airport's operational domestic aviation augmented the contemporary emergence of built-up areas in the south-eastern direction.

The ribbon-shaped structure in the south-east became denser with new creations in 2021, and the city has mingled with a cantonment town situated a distance of 10 km from the main city in the beginning. The previously scattered constructions in other directions became congested using the conjunction of regional conveyance routes. The maximum growth happened as intensive infill formed, and afterwards, the expansion started to move towards the margin and periphery for edge and outgrowths correspondingly (Figure 7).

Overall, the built-up area will become dense with the passage of time and regional and national transport routes, mainly towards the south-east and south, have assisted to the city's sprawl.

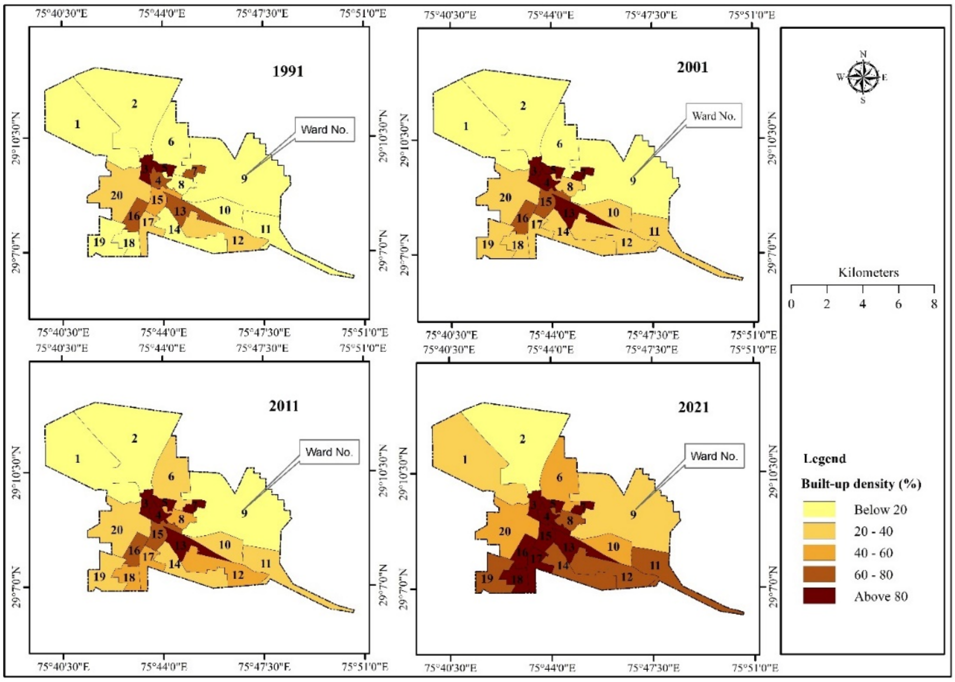

Figure 7. Ward-wise Built-up Density in Hisar City (1991-2021)
Source: Compiled by authors

Sprawl Measurement by Shannon Entropy

Table 6 represents the varying entropy values for Hisar City for the entire studied period. The lowest entropy value of 1.231 in 1991 points to the compact growth of the city, whereas the highest value of 1.266 in 2011 refers to dispersal. In the preliminary periods of 1991, 2001 and 2011, the H'_n values 0.946, 0.970 and 0.973, respectively, are continuously approaching 1, which means sprawl is occurring mainly outskirt the city on the extended municipal area (Table 6).

Contrary to supposition, the H_n value for 2021 declined and was calculated as 1.233, which is 0.033 less than the previous year's figure. However, as the value is close to 1, namely 0.948, which points to the sprawling nature of the city, during this time, the dispersion is taking place inside the municipal boundaries, and it is making the city dense due to the utilisation of open space for new constructions.

Table 6. Shannon's Entropy Values

Years	H_n	ΔH_n	H'_n
1991	1.231	-	0.946
2011	1.262	0.031	0.970
2011	1.266	0.004	0.973
2021	1.233	-0.0.32	0.948

Source: Compiled by authors

Accuracy Assessment and Kappa Statistics

The accuracy assessment is a method of determining the accuracy between the actual scenario and the classed visuals of the images. An accuracy evaluation is performed across a categorised map to measure the precision of classification. Because of the nature of LULC, which varies depending on geographical conditions, and the lack of ground values, there are no formal standards for checking the correctness of classified maps (Congalton, 1991; Campbell & Wynne, 2011). Kappa statistics are another popular way of determining the accuracy of categorisation. It outperforms the overall accuracy of satellite images (Lillesand et al., 2015). The evaluation of the classified images advocates that the all-land use/land cover use accuracy is considered satisfactory and reliable. It is a metric for comparing the categorisation results to values generated by chance. It can have a range of values from 0 to 1. There is no conformity between the categorized image and the reference image if the kappa coefficient is equivalent to 0. If the kappa coefficient is 1, the categorised and ground truth images are similar. As a result, the higher the kappa coefficient, the better the classification. The Kappa values such as 0.86 (i.e., 86%) represent a strong agreement between 0.40 and 0.80 (i.e., 40–80%) represent moderate agreement; and a value below 0.40 (i.e., less than 40%) represent the poor agreement (Monserud & Leemans, 1992; Dutta & Das, 2019).

The conditional Kappa values in Table 7 show that built-up area, agricultural land, vegetation, bare/open land, and water bodies strongly agree with the LULC classification throughout the study period. In 1991, the classified LULC map had an overall accuracy of 89.17%, and the overall Kappa statistics was 0.86. While analysing the class-wise classification accuracy, it was seen that water bodies have 95% user and producer accuracy. Regarding producer's and user accuracies, all classes (except bare/open area only for producer accuracy) have more than 80%. In 2001, the overall accuracy was 86%, and the Kappa coefficient was 0.82.

Table 7. Accuracy assessment and Kappa coefficient

Accuracies and Kappa Coefficient	LU/LC Classes	Years			
		1991	2001	2011	2021
User's Accuracy (%)	Built-up Area	82.35	81.81	84.61	85.71
	Agriculture Land	90.91	90.90	88.88	89.47
	Vegetation	85.71	85.00	85.71	86.36
	Bare/open land	84.61	83.33	87.09	84.61
	Water bodies	95.00	88.88	94.44	85.71
Producer's Accuracy (%)	Built-up Area	87.50	85.71	88.00	85.71
	Agriculture Land	86.95	86.95	80.00	80.95
	Vegetation	90.00	80.95	90.00	82.60
	Bare/open land	78.57	83.33	87.09	88.00
	Water bodies	95.00	94.11	94.44	94.73
Overall Accuracy (%)		89.17	86.00	87.71	86.20
Kappa coefficient		0.86	0.82	0.84	0.82

Source: Compiled by authors

On investigating the user's accuracy, the accuracies for the built-up area, agricultural land and vegetation were found to be 81.81%, 90.9% and 85%, respectively. In the case of bare/open land and water bodies, the values were 83.33% and 88.88% in that order. At the same time, the producer's accuracies for the built-up area, agricultural land, vegetation, bare/open land and water bodies were 85.71%, 86.85%, 80.95%, 83.33% and 94.11%, respectively.

In 2011, the overall accuracy assessment was 87.71%, with a Kappa coefficient of 0.84. On examining the user and producer's accuracy, each LULC class revealed over 80%. In 2021, the overall accuracy assessment was 86.20%, with a Kappa coefficient of 0.82, i.e., 82%. The user accuracies statistics were 85.71%, 89.47%, 86.36%, 84.61% and 85.71%, whereas the producer's accuracies were 85.71%, 80.95%, 82.6%, 88% and 94.73% for different LULC classes in the same order mentioned in the concerned table. On examining the user and producer's accuracy, each LULC class also exhibited more than 80%. In individual classes, the highest user accuracy was found for agriculture and water bodies, whereas the highest producer accuracy was registered for vegetation and water bodies.

Temporal and Projected Statistics of Population, Built-up Area, LCR and LAC

Increasing population and developmental events are the primary drivers of land usage and built-up land expansion within the city and suburbs. These two aspects' association further determines the region's land consumption rate. LCR is a gauge of compactness that shows how an area expands over time. Regarding Hisar City, the LCR values for the years 1991, 2001, 2011 and 2021 were found to be 0.008, 0.008, 0.009 and 0.012, respectively, which shows the tendency of increasing compactness (Table 8).

The projections based on previous and contemporary data report values of 0.018 and 0.027 LCR by 2031 and 2041, which means that the city will continue to be congested as a measure of compactness and spatial growth in future. Generally, the growing population is devouring the land to meet its demands. Land resources are being exploited for development reasons such as the construction of factories, educational, health, medical, residential and commercial buildings, transport and other infrastructure.

Table 8. Temporal and Projected Statistics of Population, Built-up Area, LCR and LAC

Years	Built-up Area (hectares)	Built-up Area Growth Rate (%)	Population (absolute)	Population Growth Rate (%)	LCR (hectares/ person)	LAC (hectares/ person)
1991	1337.40	-	172677	-	0.008	-
2011	2069.46	57.74	256689	48.65	0.008	0.009
2011	2578.59	24.60	301383	17.41	0.009	0.011
2021	4146.12	61.49	358161	17.41	0.012	0.028
2031*	7562.67	61.49	425643	17.41	0.018	0.050
2041*	13734.95	61.49	505840	17.41	0.027	0.077

Source: Census of India, 2001 and 2011. Satellite data
*Projected Population, built-up area, LCR and LAC

As the city's growth is constrained in the west due to CCS Haryana Agricultural University, more land use in different directions results in high LCR. The study highlighted a forecasted increase in city and maximum urbanized area in these parts. Land absorption coefficient (LAC) is another measure that tells how additional or new land is being exploited for every unit growth in population and how the population is growing to the outskirts or sprawling.

The calculated LAC values for Hisar City stand as 0.009 for 1991-2001, 0.011 for 2001-2011, and 0.028 for 2011-2021 periods and are expected to be 0.050 and 0.077 by the years 2031 and 2041 (Table 8). The lowest LAC value (1991-2001) refers that the maximum built-up area was concentrated in the central parts in the beginning, whereas the high values (for 2011-2021 and predicted years of 2031 and 2041) stated that the expansion towards the outskirts as planned and unplanned residential and commercial constructions. In current conditions, the low land prices and better living conditions offered in planned construction by Haryana Shahari Vikas Pradhikaran and other private builders have accelerated the growth. The high absorption value also clears that the rate at which additional lands have been acquired for built-up development in Hisar is too fast. This predicament will have significant consequences for the city's long-term viability.

Discussions

Urban sprawl and unrestrained urban growth have become a matter of great apprehension in today's world. Several studies conducted in different regions have confirmed that sprawl is mainly induced by the natural growth of population and other push factors of surrounding that accelerate the migration to nearby cities. Sprawl takes place first on agricultural, vegetation and bare/open lands in a city, then proceeds to the periphery to furnish the never-ending desire for land. Such expansion and infringement bring substantial changes in LU/LC. Moreover, it further compromises the environment and impedes the region's sustainability by declining the production of crops and other forest products.

The investigation of other studies with similar issues conducted in different urban areas also strengthens the present study's findings. For example, a study conducted in Addis Ababa, Ethiopia, exhibits significant transformation in LULC with considerable evidence of environmental degradation in the city area and surroundings due to the horizontal expansion of urban boundaries (Mohamed and Worku, 2019). Another study related to Zagazig City, a part of the Nile Delta in Egypt, also drags attention towards the alarming dropping of original farming land due to sprawl and the emergence of new structures in peri-urban areas (Taiema & Ramadan, 2021). While conducting the same caption study for Rohtak City of Haryana state, the authors have encountered a four-fold growth in built-up areas in the past three decades. This vast development has appeared in both ways, intentional and accidental, in all directions in the city, with significant modifications in its peripheral landscape (Sharma & Kumar, 2022). While presenting the literature regarding sprawl, especially in the context of Iran and

Egypt, it has been found that wholesale selling of land, rapid population growth, inefficient planning and migration are the main drivers of sprawl that bring a threat to the sustainability of the concerned urban areas (Masoumi et al., 2018). A study related to Romania's sprawl characteristics has found that the adjacent rural areas have experienced the highest intensity of sprawl and maximum changes in land operations. So, the administration needs to revise the accommodation and infrastructural plans and policies to mitigate the changes in urban terrain and surroundings caused by the expansion of developed areas (Suditu et al., 2010). The author further explained that legal tools and effective and factual cooperation between different order urban local bodies are more helpful in handling the sprawl-induced impediments in cities (Suditu, 2012). The selected metropolitan cities of Romania have also witnessed drastic changes in their terrestrial arrangements after the 1990s. The unplanned appearance of urban structures not only grabbed the lands from agriculture and forests but also augmented the exploitation of such resources (Grigorescu et al., 2012).

In the case of the present study, the city has witnessed similar spatial changes over the urban ground as any town or city experiences. The growth between the period 1991-2001 was mainly supported by the new establishment like the government polytechnic (1992), Guru Jambheshwar University of Science and Technology (1995) and the new police line area, PLA (1998) in the north-east, the emergence of manufacturing units along with Delhi -road in south-east and legalization of illegal occupancies in the south-west and south along with Rajgargh and Kaimri roads respectively. The expansion was confined to the western side due to Chaudhary Charan Singh Haryana Agricultural University (CCS HAU). In the next decade (2001-2011), the attraction of armoured divisions or cantonment towns augmented the ribbon-shaped progression along with the road network in the south-eastern part. In contrast, the intensification of built-up area was observed within HAU in the western region. The availability of open land along with Kaithal and Sirsa roads (in the north-east and north-west correspondingly) accelerated the intentional and accidental development of the built-up area for residential and commercial resolutions. From 2011 to 2021, growth occurred within the city in available open space, and several medical centres, educational institutions and shopping complexes appeared. The advantage of the existing military station and the recently activated facility of Hisar Airport have also amplified the forest of buildings in the south-eastern direction. This growth has diversified the city's spatial functioning and modified the ongoing land arrangement with substantial loss of agricultural land and decaying of the natural environment.

The assessment of entropy values (for comprehending the spatial arrangement of built-up area distribution in terms of the degree of scattering or compactness by time dimensions) also expresses the sprawling nature of the city as the values for each year from 1991 to 2011 recorded higher than the threshold value of 0.650. Similarly, the relative entropy figures have registered consistently higher figures, close to 1.00. The advancing change in entropy between time $t1$ and $t2$, explains that the city has followed a progressively sprawling pattern except for the decade between 2011 to 2021. But it does not mean that sprawl has been reduced in that phase. On the contrary, it informs that built-up density has increased more in core parts (Figure 7) as the urban authorities have not extended the municipal area in this period. Hence, the fragmented growth occurred beyond the city limits as well. The results obtained from built-up density and land consumption indices have also confirmed the swelling urbanization in the city's all directions. Yet, it has been found intensive in the south, south-west, south-east and north-west in a linear form along the conveyance routes and compact form around the city service points.

Conclusion

The expansion of urban boundaries and its intrusion into peripheral areas are the expected outcomes of urban growth, and every city or town has to face this. Though it is not possible to avoid the sprawl-like consequences of growing urbanization yet, it can be managed through proper monitoring and evaluation. The geospatial techniques and other statistical methods are very effective for quantitatively measuring various aspects of the urban land arrangement. Overall, the city has undergone considerable sprawl in the past thirty years mentioned in the study, which has further resulted in significant modifications in contemporary land practices. However, assorted infrastructural development, industrial and commercial operations, real estate, construction of amusement or entertainment spaces and residential erections all have played their role in this expansion and interchange of land from one to another category. Yet, the fast-growing population and proportional increase in the built-up area have contributed more to this subject. As the proximity of the city to the semi-arid and arid region has already set its limitations in terms of the availability of fertile arable land. Hence, the reducing agrarian ground owing to rapid urban growth has become a significant concern in present situations.

The built-up area has increased more than twice (2,826.72 hectares) by the total area throughout the period, whereas the farming land has lost almost half part (3,497.94 hectares) substantially for the same. The increasing entropy values also approve of the sprawl or fragmented development in the city. The outcomes of all other indices used for the study strongly confirm that urban claws have grabbed the peripheral parts by vitiating the natural richness and gulping the open spaces and purity of the green environment within the city. As urbanization is a process of growth that comes at the expense of the surroundings, many hectares of fertile agricultural and forest land are hidden beneath the urban sprawl. So, it is a need of the hour for the city's long-term development that urban government and management should be attentive to real-time growth monitoring and implementation of well-organized urban plans and improve the agricultural or agroforestry outputs inside and outside the city.

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