Trans. Inst. Indian Geographers
ISSN 0970-9851
Indexed in Scopus

Characterising the urban growth and quantification of built-up density consequent to urban expansion in Hisar city, Haryana, India and its peri-urban area

Rahul* and Ravinder Kaur, Chandigarh

Abstract

Developing nations frequently experience unplanned and haphazard urban growth. The peri-urban areas are current sites for active urban growth. In order to characterise the growth pattern based on the Urban Expansion Index (UEI), three types of growth patterns have been identified, namely infilling, edge expansion and outlying, along with their distance and directional analysis over the period of three decades from 1991 to 2021. In addition, pixel-based built-up density was also calculated. The result indicated that the edge expansion type of growth was prominent in the study area, but its share in the total growth decreased continuously from 1991 to 2021. On the other hand, the share of outlying growth to total growth increased regularly during the same period. The directional analysis indicated that the infilling, edge expansion and outlying mainly prevailed in the west, east and north directions, respectively. The evaluation of built-up density revealed that the area under the category of medium density was maximum and its proportion decreased over time. The proportion under the category of high density continuously increased. This study provides a detailed analysis of types of growth and built-up density with their spatial pattern and distribution. This understanding is significant for the planning body to promote effective and sustainable planning.

Keywords: *Urbanisation, urban growth types, urban expansion index, built-up density, peri-urban area.*

Introduction

Swift expansion of a city irreversibly impacts the natural setup and environment in and around a city due to inevitable loss of agricultural land, natural vegetation and waterbodies. This growth in the peri-urban landscape occurs in a haphazard manner, resulting in lateral expansion and creating a major challenge in developing nations like India. In India, the small and intermediate towns are growing faster both in terms of demography and spatial expansion as compared to the large towns. Consequently, the peri-urban area around these towns is witnessing accelerated land-use change, increased population mobility and a blending of rural and urban livelihoods. The peri-urban growth of the urban population in small and medium towns raises the demand for more and more resources over time, including space for urban housing, industries, commerce and

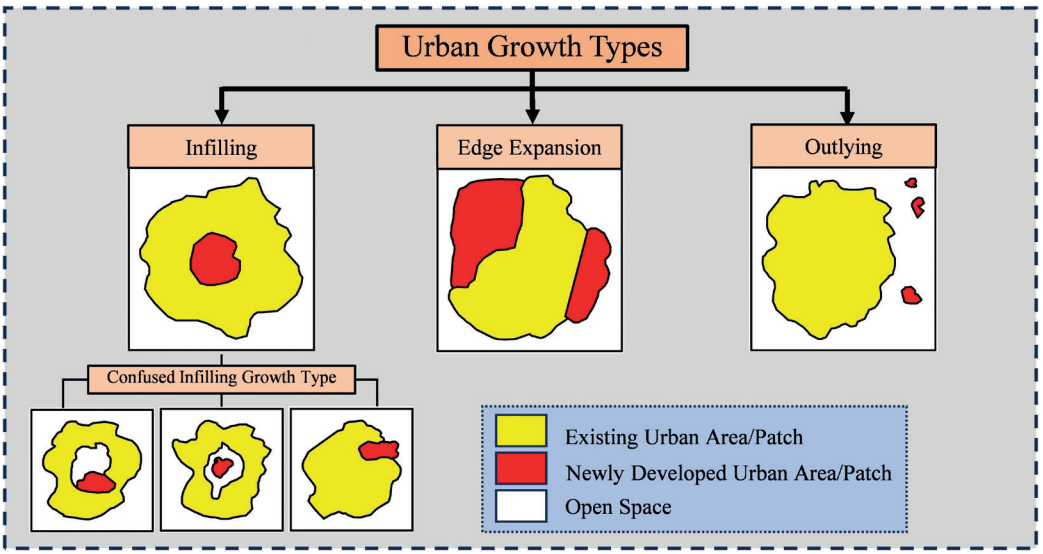

Fig. 1: Types of urban growth

Source: Forman (1995)

transport infrastructure. This results in the concentration of the city population on the city outskirts to meet their needs.

The pattern of urban growth varies throughout the periphery, depending upon where and how the built-up area has grown. It could be classified as infilling, edge expansion and outlying (after Forman,1995) as shown in figure 1. The first is 'infilling'- representing the emergence of a built-up area on a non-built-up area that is surrounded by existing built-up areas. The second type is called 'edge expansion' in which the new development spreads out from the adjoining pre-existing built-up or developed area. The third type of growth is 'outlying', which represents the development of the built-up area apart from the existing built-up patch of the urban area. It is an isolated type of urban growth. The growth of the urban area is actually positively related to the growth of the built-up patches. All types of urban growth lead to a change in built-up density in and around a city. The built-up density depends on urban growth which changes due to the redevelopment of prior built-up areas or with the infilling of new developments in non-built-up patches. In this paper, an effort has been made to empirically assess the pattern of urban growth around Hisar city- an emerging urban centre which is currently experiencing accelerated urban sprawl, manifested in low-density, dispersed and mixed land use patterns in the peri-urban area. The urban built-up density and its spatial distribution have been used to analyse and demarcate the urban spatial geometry and change in the urban form.

Statement of the problem

Hisar urban agglomeration is the second largest city in Haryana and has been subject to continuous growth of its population and in its spatial extent. The proximity of Hisar to the national capital, New Delhi, plays a significant role in the urban demographic and spatial dynamics. By virtue of its location,

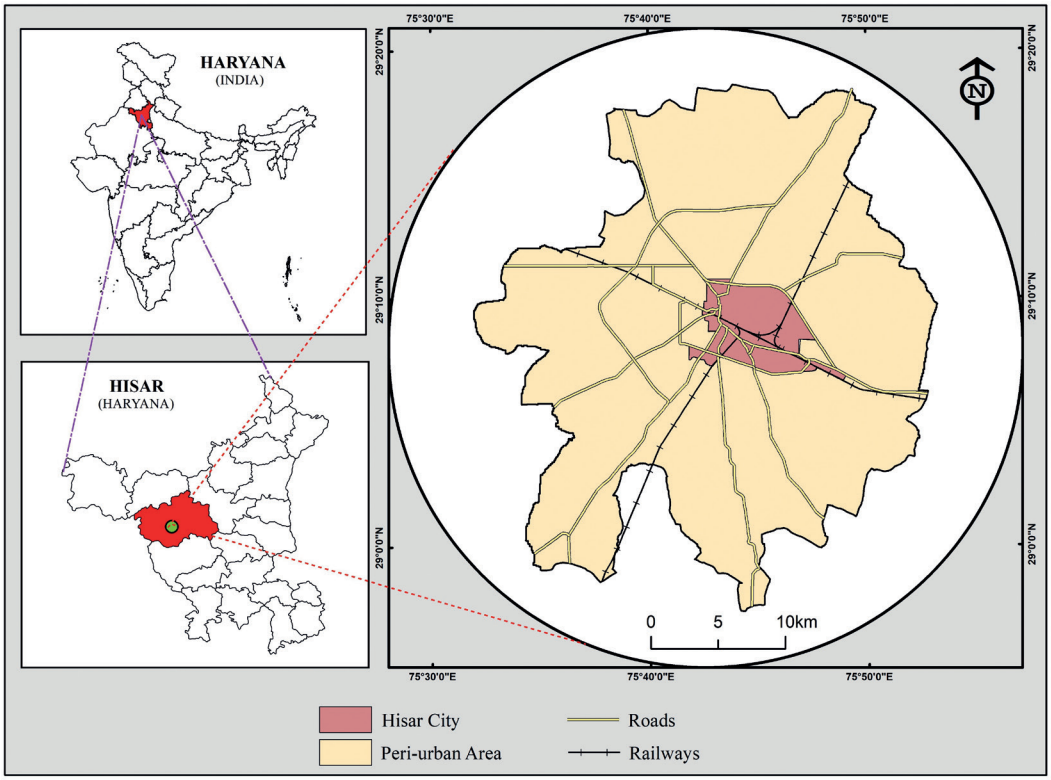

Fig. 2: Location of study area: Hisar and its peri-urban area

Hisar city was declared a counter-magnet city of the national capital region which served as alternative centre of economic and population growth, encouraging decentralised development and balanced regional expansion. After becoming a counter-magnet city, the government policies in Hisar primarily aimed at developing its peripheral area to restrain out-migration. With the passage of time, the city grew out of its municipal limits and the periphery of the city was influenced and integrated with the city functions. The sprawling nature of the city led to city growth outside of the administrative boundary. However, the pattern of the urban growth is not uniform. It varies with distance and exhibits all the three processes of infilling, outlying and edge expansion. The paper examines the characteristics of the various patterns and how they are influenced by distance. Further, an attempt has also been made to explore the change in built-up density consequent to urban expansion in the city periphery.

Review of literature

In the Indian context, studies on small and medium towns and cities were carried out by a large number of scholars (Denis *et al.*, 2012; Samanta, 2017; Dutta & Das, 2019; Chakraborty *et al.*, 2021; Chettry, 2022; Kumar & Emayavaramban, 2023; Singh & Nathawat, 2023; Barman *et al.*, 2024; Dutta & Banerjee, 2024; Kumar *et al.*, 2025;

Sharma *et al.*, 2025). Most of these studies were related to the spatio-temporal urban growth dynamics, urban growth detection, assessment of urban sprawl, pattern of urban landscape, driving forces of urban growth, characteristics of sprawl, measurement of urban sprawl and analysis of peri-urban developments by applying various geospatial techniques and metrics. However, the studies which determine the typology of urban growth and quantification of built-up density consequent to urban expansion are few and far between. The small and medium towns of India, in particular, have received scant attention with respect to urban growth typology and built-up density quantification. This study is an attempt to contribute in this direction.

Thus, the objective of this paper is to determine the typology of urban growth and quantify the built-up density consequent to urban expansion in Hisar City.

Study area

The city of Hisar gets its name as an abbreviation of Hisar-e-Firoza, the name acquired by the original town of Warais, as a result of the construction of a fort (Hisar) by Feroz Shah Tughlaq about A.D. 1354 (Census, 2011). Hisar is a major city of Haryana state in India. The city is located in western Haryana. The geographical location of the city is 29.09 N and 75.43 E. The city covers an area of 45 km^2 as per the census of India, 2011, which was only 17.53 km^2 in 1971. In 1971, the population of the city was only 60222 reaching 172677 in 1991. The city's population increased to 301383 in 2011. This marks a population increase of approximately 75 percent between 1991 and 2011.

For the present study, Hisar city with its peri-urban area, as shown in Figure 2, is selected to analyse the type of growth and built-up density. The peri-urban area of Hisar was delineated with the administrative, demographic and economic variables (see Rahul & Kaur, 2024). The total area of the peri-urban region is 776 km^2 in 2023. The total area of the city and its peri-urban region which is included in the study area is 821 km^2 (82100 ha).

Data

This study employed an integrated Geoinformatics Information System with a remote sensing-based approach to acquire essential data and statistics. Landsat imagery served as the primary data source, providing structured and reliable inputs to achieve the objectives of the study. The data is accessed from https://earthexplorer.usgs.gov. This study analysed data from four temporal intervals over three decades (1991–2021), as detailed in Table 1. The boundary of city was delineated using the official master plan, obtained from the Town and Country Planning Department, Haryana website.

Methodology

The main focus of the study is the analysis of urban growth types and the quantification of built-up density in Hisar city and its peri-urban region. In order to make the study more precise and accurate, the following methodology is adopted, as shown in figure 3.

Landsat image: pre-processing and classification

The acquired satellite images have been analysed with the help of ERDAS Imagine and ArcGIS Map software. The image was

Table 1: Details of multi-temporal satellite imageries.

Satellite	Sensor	Path/Row	Spatial Resolution	Year
Landsat 5	TM	147/40	30	1991
Landsat 5	TM	147/40	30	2001
Landsat 5	TM	147/40	30	2011
Landsat 8	OLI	147/40	30	2021

Table 2: Value of urban expansion index and type of urban growth

Value of UEI	Type of Urban Growth
$50 < UEI \leq 100$	Infilling
$0 < UEI \leq 50$	Edge expansion
0	Outlying

Table 3: Types of urban growth

Growth Type	1991-2001		2001-2011		2011-2021	
	Area (Ha)	Percent	Area (Ha)	Percent	Area (Ha)	Percent
Infilling	154.08	9.86	298.53	20.85	953.55	27.83
Edge Expansion	1180.08	75.49	977.22	68.25	1777.05	51.87
Outlying	229.05	14.65	155.97	10.89	695.16	20.29
Total	1563.21	100	1431.72	100	3425.76	100

classified by employing a supervised image classification method with a maximum likelihood classifier. The image was categorised into the built-up and non-built-up categories as per the requirement to fulfil the objectives. An assessment was carried out post-classification to check the accuracy and reliability of classified images. The overall accuracy is 89.2 percent, 91.20 percent, 92.40 percent and 94 percent for the images of 1991, 2001, 2011 and 2021, respectively. The kappa statistics for the classified images were 0.86 (1991), 0.89 (2001), 0.90 (2011) and 0.92 (2021).

Characterising the types of urban growth

As explained previously, urban growth is mainly of three basic types: infilling, edge expansion and outlying. There are however subtypes or variants to these three. In identifying urban growth type, Liu *et al.* (2010) developed an index based on remote sensing and geospatial technology. This index works on the relationship between the existing and new development. It used buffer-based analysis to distinguish the type of growth. This index is the base for the Urban Expansion Index (UEI). The types of growth have been determined by applying the UEI- an index mainly used to characterise the type of growth. The formula for the UEI is:

$$UEI = \frac{A_0}{A_0 + A_X}(100)$$

Where UEI = Urban Expansion Index of newly developed patch/area; A0= intersection between existing category and

buffer zone; Ax= intersection between open space and buffer zone. The value of the index lies between 0 and 100. Types of growth is determined by the index value obtained as shown in Table 2. The working of the Urban Expansion Index is shown in figure 4 for better understanding.

Quantification of built-up density

The built-up density reveals the spatial pattern of urban built-up as well as its distribution. In general, the built-up density of a city decreases from the city centre to its outskirts. In developing countries, small and medium-sized cities are not so much developed to have multiple centres. So, the built-up density decreases with the distance from the city centre. In the present study, density was calculated with the help of a kernel density tool, after converting the pixels of built-up into point data. The values of kernel density were converted into the range of 0 to 1 by applying the fuzzy membership. The last step for the quantification of built density was to divide the range into three categories: i) high density, ii) medium density and iii) low density. The high density of built-up refers to the compact and clustered nature of the spatial distribution of built-up, while medium built-up density denotes semi-compact and the low built-up density specifies the sparsely distributed built-up area.

Results

Characterisation of urban growth pattern

The UEI characterised the types of urban growth over the period of three decades from 1991 to 2021. From 1991 to 2021, there was a rising trend in the built-up area of Hisar city and its peri-urban area. The built-up area increased by more than 200 percent, from 2950.9 ha in 1991 to 9371.61 ha in 2021. It was noted that the built-up area was increased by 1563.23 ha during the period of 1991-2001. During the 2001–2011 period, the built-up area increased by 1,431.72 ha, which was the lowest increment in the three decades. The highest rise was noted during 2011-2021 with an increase of 3425.76 ha in built-up area.

Throughout the period of 30 years, the edge expansion was the dominant type of built-up growth. During 1991-2001, the infilling type was less significant, with only 154.08 ha of land under it and its share was only 9.86 percent in built-up growth. On the other hand, the edge expansion was the highest at 1180.08 ha, accounting for 75.79 percent of all types of growth. Subsequently, during 2001 to 2011, the outlying growth had the lowest area under it with 155.97 ha accounting for only 10.89 percent. With 977.22 ha, edge expansion continued to be dominant claiming 68.25 percent of the growth in this decade. In more recent decade i.e. 2011-2021, the edge expansion had a share of 51.87 percent. The least occurring type of growth was outlying, with an area of 695.16 ha and a share of only 20.29 percent (see table 3).

As shown in the figure 6(a), the edge expansion was the major type of urban growth in terms of absolute area, despite a slight decline in its area in 2001-2011 but increasing significantly during 2011-2021. The same pattern was noted with the outlying type of growth. Conversely, the area under the Infilling type of growth has been continuously rising.

In the study area, the significant growth type in the three decades was the edge

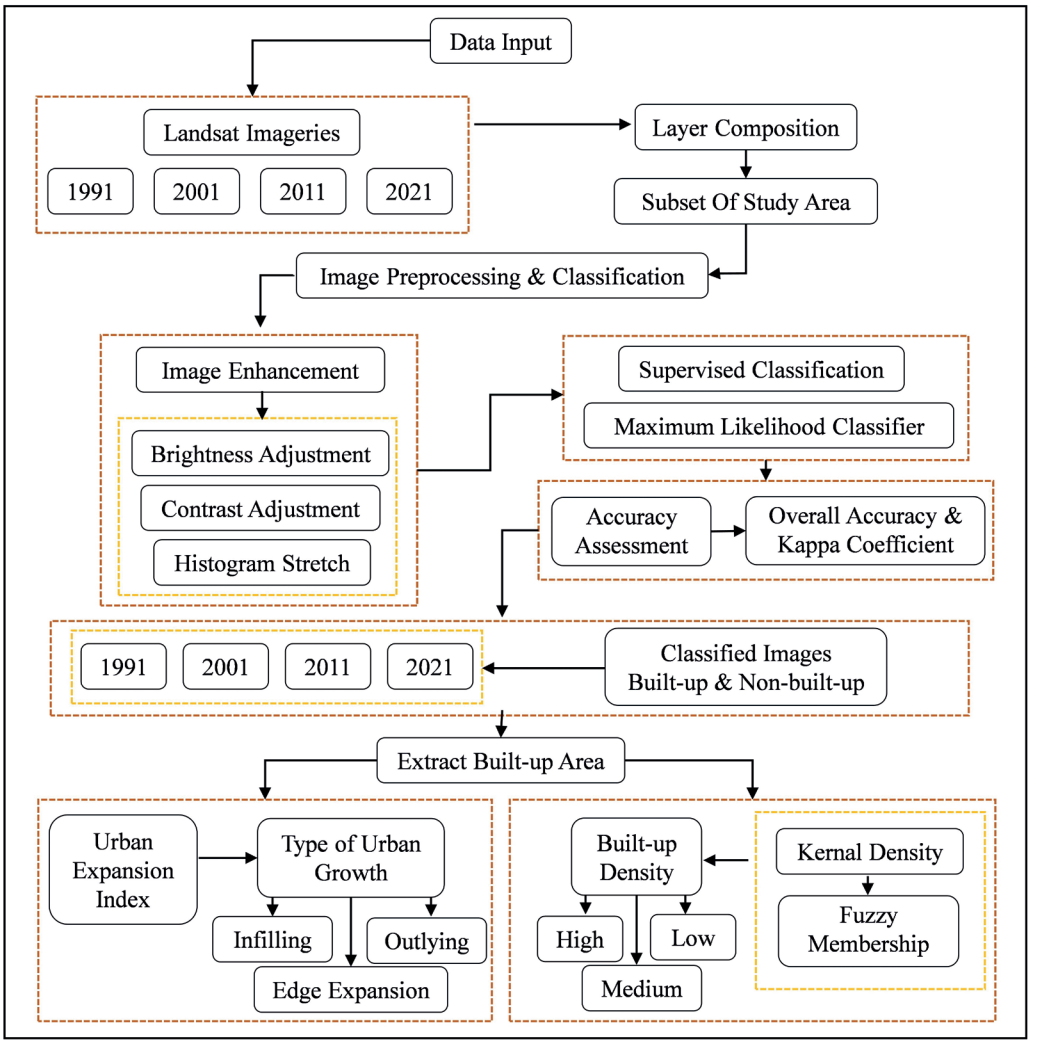

Fig. 3: Methodology flow chart

expansion though its share continuously declined. Its share in the growth remained nearly 52 percent during the 2011-2021 period. The percentage share of infilling type in total growth increased throughout the entire study period, from 9.86 percent in 1991-2001 to 27.83 percent in 2011-2021. Although the share of outlying types of growth decreased initially in 2001-2011 as compared to the previous decade of 1991-2001, it increased more recently in the 2011-2021 period accounting for a little over one fifth (20.29%) as shown in figure 6(b).

Urban growth type and distance

The built-up growth in the different distance zones was calculated by creating multiple-buffer of 2 km each from the city centre. A total of 12 zones were created, as shown in figure 5. Firstly, overall growth according to

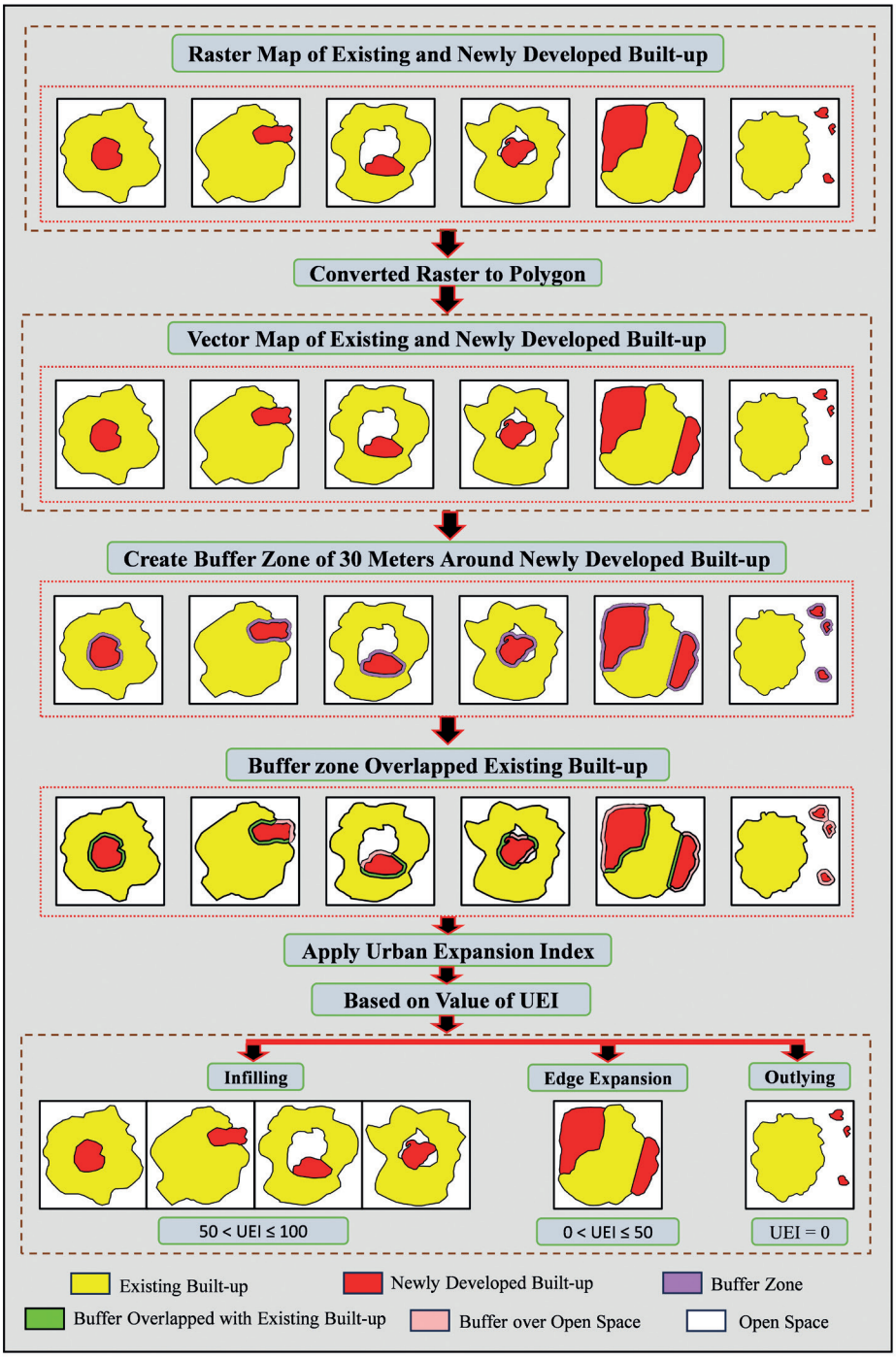

Fig. 4: Process for identifying the types of urban growth

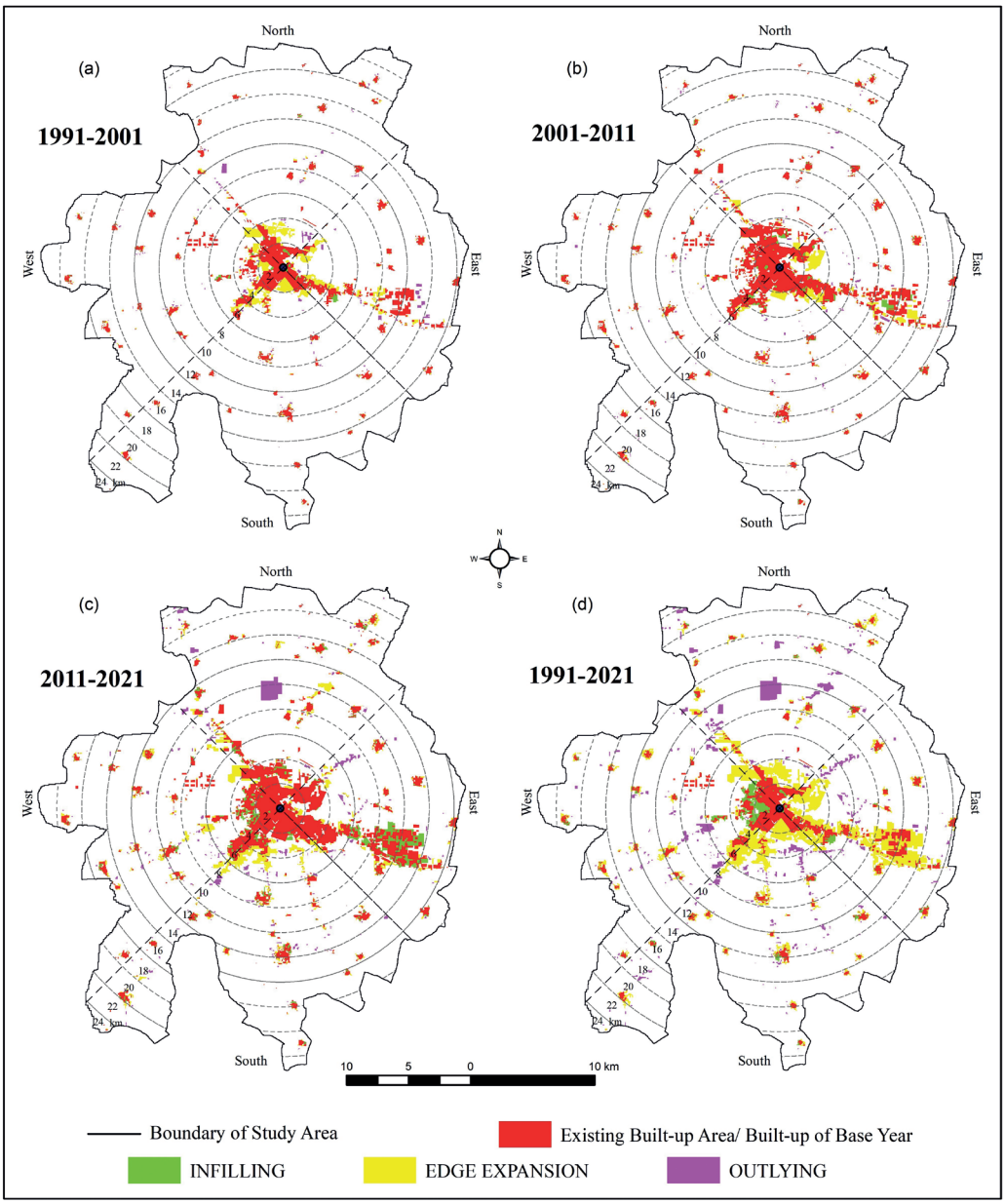

Fig. 5: Spatial pattern and distribution of types of growth

its type in different distance zones from 1991 to 2021 was calculated and analysed (Figure 7). The infilling type of growth for the period of study was highest in the zone of 2-4 km, followed by the zone of 0-2 and 4-6 km. It is clearly observed that the infilling type of growth was more prominent near the city centre. The edge expansion mainly occurred between 2-4 and 4-6 km zones. Both the infilling and edge expansion types of growth showed a sudden rise in the zone of 2-4 km, decreasing subsequently. they made a small bump in the 10-12 km zone and after which they continuously decreased. The outlying type of growth increased as it moved away from the city centre and attained its maximum strength in the zone of 8-10 km, declining thereafter.

The decadal analysis of patterns of growth in relation to distance from the city centre is shown in figure 8. The growth of infilling during 1991-2001 was highest in the zone of 4-6 km which was approximately 44 ha and it is negligible after 18 km. For the period of 2001-2011, it made two peaks, one in the zone of 2-4 km and the other in 8-10 km followed by a decrease. The infilling type of growth between 2011 and 2021 was highest in the zone of 10-12 km followed by 2-4 km zone. The infilling growth showed a dip in the zone of 4-6 km and an increase in the 10-12 km zone, beyond 12 km this decreased continuously.

Edge expansion was more significant close to the city centre, 2-4 km away in both the dacades. A sudden fall however was noticed 4 km away from the city centre. The exception was that it showed a small rise in 10-12 km distance zone during 2001-2011. The edge expansion rose from the city centre to 4-6 km zone in 2011-2021 and made a step like shape after the 4-6 km zone. As the outlying growth occurred away from the city, the major outlying growth occurring during 1991-2001 in the 8-12 km zone. During the next decade from 2001-2011, the outlying growth accelerated with an increase in distance away from the city centre. Again, the maximum outlying growth was recorded in the zone of 8-10 km after which there was a decrease. The same pattern was noted during the period of 2011-2021.

Urban growth type and direction

The city grows and expands continuously, but not with the same intensity in all directions. This expansion crosses the limits of the administrative boundaries of the city and spreads in some specific direction due to various physical and anthropogenic reasons. The overall directional analysis (figure 9) for the period of three decades from 1991 to 2021 shows that the infilling mostly occurred in westerly direction (355 ha), and some in the eastern direction. The edge expansion mainly took place in the east and the south (1814 and 1175 ha respectively). The outlying growth primarily appeared in the north direction in 570 ha of area.

Figure 10 makes it clear that the infill type of growth during 1991-2001 occurred mainly in east and west directions with the same intensity in an area of approx 50 ha. But during the period of 2001-2011, primarily in the east (154 ha) followed by the south. During 2011-2021, again, the easterly direction led with 450 ha area, but the south direction was replaced by the west direction.

The edge expansion in 1991-2001 mainly occurred in the east and north directions. In the next decade, the edge expansion mainly took place in the east direction, followed by the south direction. The scenario was

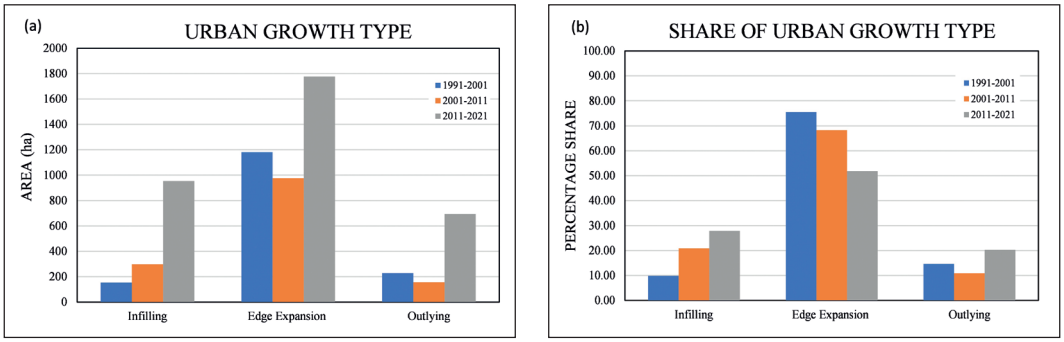

Fig. 6: (a) Urban growth types and area coverage; (b) Share of urban growth types

completely changed during 2011-2021 and major directions of edge expansion were south and west. The outlying type of growth in all three decades occurred in the north direction.

Built-up density

In order to quantify, the built-up density is divided into 3 types, namely: low, medium and high. The spatio-temporal distribution of built-up density is shown in figure 11.

It is clear from Figure 11 that the patch of high built-up density was the central patch of the city, surrounded by the medium and low built-up density patches. Major proportion of the area is of medium built-up density. In the year 1991, the major proportion of the area was under the category of medium density, followed by low density and the area under the high density was very low. This situation changed in 2001, when medium density was followed by high built-up density. During this period, the area under the low built-up density was the lowest among the three categories. A similar pattern was observed in 2011 and 2021, as shown in table 4 and figure 12 (a).

It is obvious that the share of low and medium built-up density has been decreasing over time, as high density area has increased in the period 1991-2021 [Figure 12(b)]. The share of low built-up density did decrease during the same period, but increased slightly in 2021. The share of medium density decreased throughout the study period decreasing from 57 percent in 1991 to 49 percent in 2021. Conversely, the share of high built-up density was approximately 19 percent in 1991 which increased to 42 percent in 2021. The changes in density pattern clearly depicts substantial increase in the high built-up density areas in Hisar and its periphery.

Discussion

The analysis reveals that all major types of growth—infilling, edge expansion and outlying—in Hisar city were evident during the study period. Infilling was particularly pronounced in the western part of the city between 1991 and 2021, primarily due to the establishment of new residential sectors. Edge expansion was most prominent along the city boundaries, especially towards the east, where the emergence of census towns, residential colonies, factories and commercial establishments contributed significantly to this type of growth. The presence of the army cantonment and the Jindal Steel industry further accelerated this process. Outlying growth was mainly concentrated in the northern direction, within a distance of 6–12 km from the city centre. This type of growth

Table 4: Built-up density and its share to total built-up area

Built-up Density	1991		2001		2011		2021	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Low	666.27	22.58	401.13	8.89	461.16	7.76	817.56	8.72
Medium	1700.55	57.63	2557.8	56.66	3152.52	53.02	4606.83	49.16
High	584.1	19.79	1555.2	34.45	2332.17	39.22	3947.22	42.12

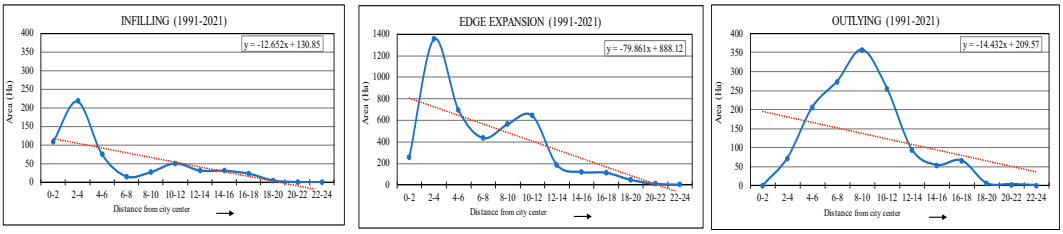

Fig. 7: Built-up growth type in different distance zones from 1991-2021

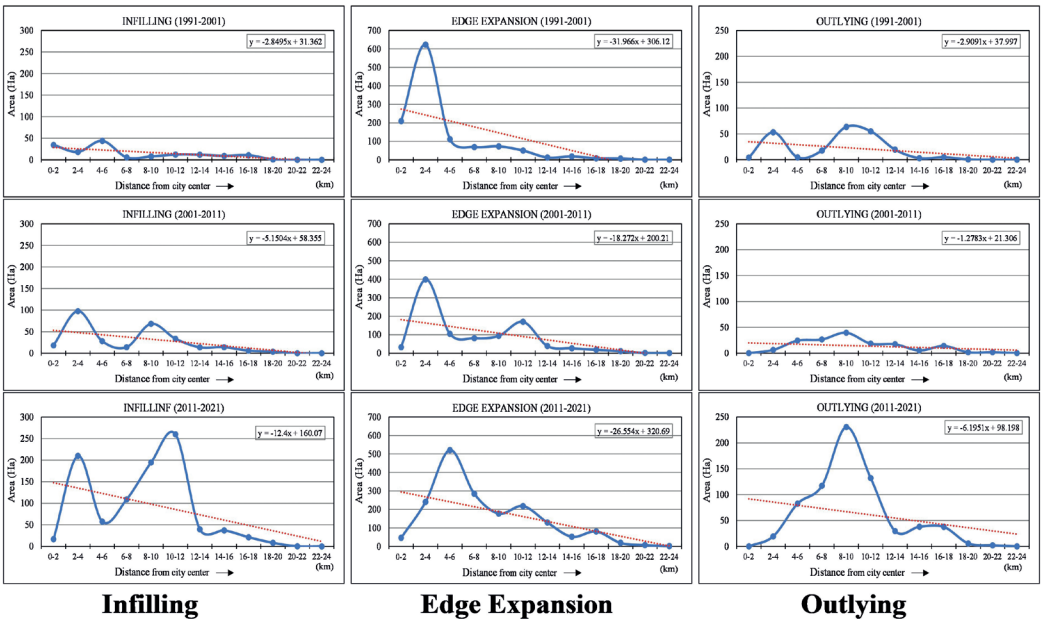

Fig. 8: Patterns of growth type based on distance on a decadal basis from 1991-2021

included the establishment of industries, warehouses, government institutions, research and educational facilities, recreational centres and residential clusters. The transportation network played a crucial role in shaping these developments. During 1991–2011, growth was concentrated along the national highways, while in later years, it extended along all major roads radiating from the city. A well-connected transport system, therefore, acted as a major catalyst for both edge expansion and outlying growth. Medium-density areas continue to dominate the city's landscape, though the share of

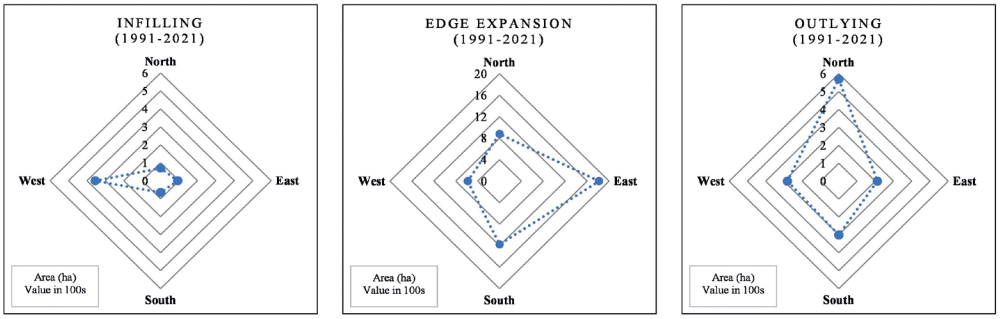

Fig. 9: Direction of built-up growth type from 1991 to 2021

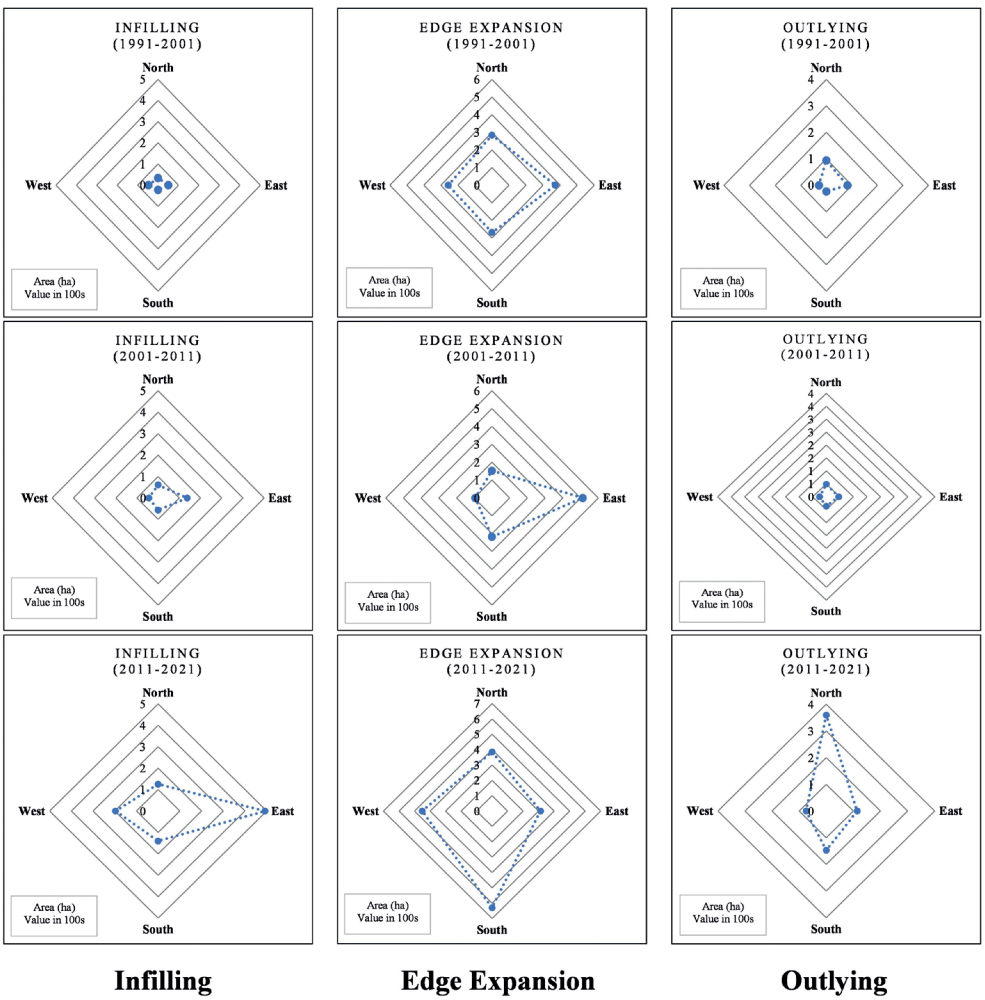

Fig.10: Decadal directional analysis of growth type

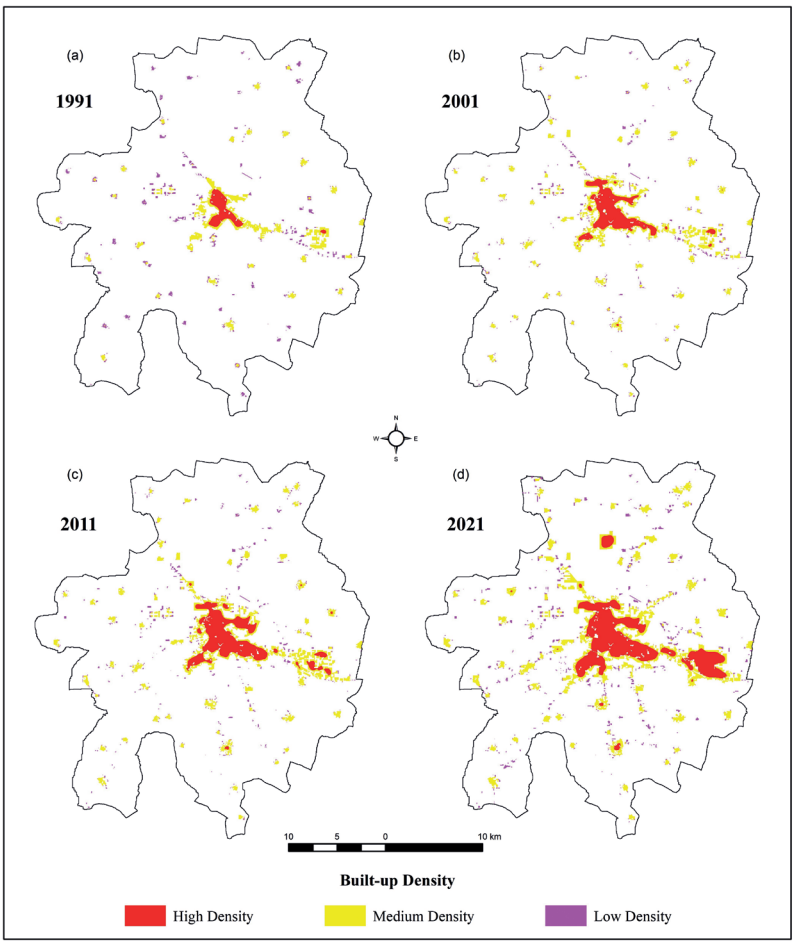

Fig. 11: Spatio-temporal distribution of built-up density

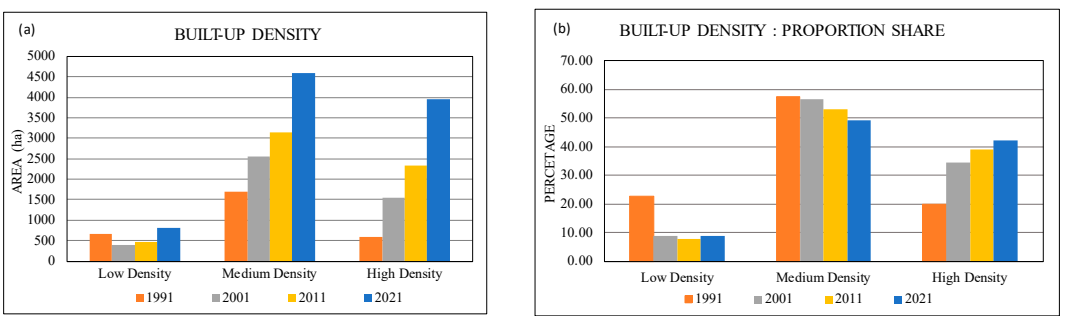

Fig. 12: (a) Category-wise distribution of built-up density;
(b) Category-wise share of built-up density among total built-up.

high-density zones is experiencing significant and consistent increase over time. This trend was largely the outcome of infilling and the development of built-up areas at the urban fringe. Rising population, high land prices and limited space within the city encouraged peri-urban expansion, resulting in continuous land conversion and outward urban growth.

Conclusion

Urban growth is one of the most defining features of the 21st century, with its most significant expression occurring in developing countries like India. Rapid urbanisation in such regions is largely driven by population growth, rural-to-urban migration and the expansion of modern transport networks. These factors collectively accelerate growth in city peripheries, resulting in significant land use and land cover changes. However, in the absence of strong policy frameworks and effective governance, this growth often takes place in an unplanned and haphazard manner. Against this backdrop, the present study characterised urban growth and quantified built-up density in Hisar city and its surrounding peri-urban areas. The loss of over 1097 hectares of prime agricultural land, primarily due to edge expansion raises concern about the sustainability of urban growth. Further emergence of peripheral settlements like four census towns around Hisar are characterised by poor provision of amenities and facilities, weak infrastructure leads to poor quality of life in the city periphery.

This calls for sustainable urban planning through integrated measures to manage edge expansion and peripheral growth. Key strategies include enforcing urban growth boundaries, promoting mixed-use development and incentivising the use of vacant or underutilised land to improve land use efficiency. Active community engagement and adaptive reuse of existing structures further support cultural preservation and resource optimisation. Together, these approaches encourage compact, inclusive and environmentally sustainable urban development. The study acknowledges certain limitations, including reliance on medium-resolution Landsat data and the exclusion of socio-economic variables. Future research should incorporate high-resolution imagery and demographic insights to provide a more comprehensive understanding of urban growth dynamics and their implications for sustainable city planning.

Competing interest

The corresponding author declares that they have no conflict of interest.

References

Barman, S., Roy, D., Chandra Sarkar, B., Almohamad, H., & Abdo, H. G. (2024). Assessment of urban growth in relation to urban sprawl using landscape metrics and Shannon's entropy model in Jalpaiguri urban agglomeration, West Bengal, India. *Geocarto International, 39*(1), 2306258.

Chakraborty, S., Maity, I., Patel, P. P., Dadashpoor, H., Pramanik, S., Follmann, A., Novotny, J., & Roy, U. (2021). Spatio-temporal patterns of urbanization in the Kolkata Urban Agglomeration: A dynamic spatial territory-based approach. *Sustainable Cities and Society, 67*, 102715.

Chettry, V. (2022). Geospatial measurement of urban sprawl using multi-temporal datasets from 1991 to 2021: Case studies of four Indian medium-sized cities. *Environmental Monitoring and Assessment, 194*(12), 860.

Denis, E., Mukhopadhyay, P., & Zerah, M. H. (2012). Subaltern urbanisation in India.

Economic and Political Weekly, 47(30), 52–62.

Dutta, I., & Das, A. (2019). Application of geo-spatial indices for detection of growth dynamics and forms of expansion in English Bazar Urban Agglomeration, West Bengal. *Journal of urban management, 8*(2), 288-302.

Dutta, R., & Banerjee, I. (2024). Analysing Spatio-temporal Dynamics of Urban Sprawl, Evolving Pattern of Urban Landscape and Driving Forces of Urban Growth: A Case of Varanasi Planning Region, India. *Journal of Asian and African Studies*, 1-25.

Forman, R. T. T. (1995). *Land mosaics: The ecology of landscapes and regions. Cambridge*. Cambridge University Press.

Kumar, A. K., Rakesh, C. J., & Lokanath, S. (2025). Appraising the Degrees of Sprawl, Freedom and Goodness of Urban Growth Detection Using Geoinformatics Approach-A Study of Tumkur City in Karnataka State, India. *Nature Environment & Pollution Technology, 24*, 77-96.

Kumar, B. P., & Emayavaramban, V. (2023). Analyzing the urban sprawl-form and characteristics: a case study of Thiruvananthapuram, Kerala, India. *Journal of the Indian Society of Remote Sensing, 51*(12), 2521-2535.

Liu, X., Li, X., Chen, Y., Tan, Z., Li, S., & Ai, B. (2010). A new landscape index for quantifying urban expansion using multi-temporal remotely sensed data. *Landscape ecology, 25*, 671-682.

Rahul & Kaur, R. (2024). Peri-urban Delineation and Urban Expansion Quantification from 2001 to 2021 of Hisar City, India, using Geospatial Techniques. *International Journal of Geoinformatics, 20*(4), 86-99.

Samanta, G. (2017). New urban territories in West Bengal: Transition, transformation and governance. In Denis, E., Zerah, MH. (Eds.), *Subaltern urbanisation in India: An introduction to the dynamics of ordinary towns* (pp 421-441). Springer, New Delhi.

Sharma, K., Tiwari, R., Wadhwani, A. K., & Chaturvedi, S. (2025). Analyzing the Spatiotemporal Urban Growth Dynamics in Nashik, India from 1992 to 2042 Using MLC and MLP-MCA Algorithms. *Journal of the Indian Society of Remote Sensing*, 1-19.

Singh, N. K., & Nathawat, M. S. (2023). Quantifying the characteristics and types of urban growth of Varanasi city using multi-temporal remotely sensed data and geospatial techniques. *Transactions, 45*(1), 27.

Rahul*
Assistant Professor,
Department of Geography
M. N. S. Government College,
Bhiwani, Haryana,
India - 127021

Ravinder Kaur
Professor,
Department of Geography,
Panjab University, Chandigarh,
India - 160014

*Author for correspondence
E-mail: rahulkirdolia1996@gmail.com