American Journal of Remote Sensing
2026, Vol. 14, No. 2, pp. 25–33
https://doi.org/10.11648/j.ajrs.20261402.11

Research Article

Quantitative Analysis of Urban Expansion and Spatial Entropy in Lamka Town, India

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Abstract

Urban growth and spatial dispersion are important indications of changing land use dynamics, especially in fast growing municipalities. Rapid population growth and unplanned expansion in developing towns have significantly altered land use patterns, necessitating systematic assessment for sustainable planning. This study aims to evaluate the pattern, intensity and spatial characteristics of urban expansion in Lamka town. It employs geospatial techniques and quantitative analysis to provide a reliable understanding of urban transformation and its implications for future development. This study examines the spatio-temporal dynamics of urban growth and spatial dispersion in Lamka town, Manipur, over a 30-year period (1995-2025) using remote sensing and Shannon entropy analysis. Multi-temporal Landsat datasets were classified into built-up and non-built-up categories using the supervised Maximum Likelihood method. The study found that the built-up area increased from 8.5 km^2 in 1995 to 58.5 km^2 by 2025, whereas non-built-up land decreased. Accuracy assessment demonstrates strong dependability, with overall accuracy above 88% and Kappa values greater than 0.85. Shannon entropy values increased from 0.10 to 0.44, indicating a shift from compact to dispersed urban growth. The entropy graph shows a constant rising trend, with the most rapid growth occurring between 2015 and 2025. This reflects intensified peri-urban expansion and spatial fragmentation. The study exposes the expanding urban sprawl and highlights the urgent need for effective planning strategies and policy interventions to ensure sustainable urban development.

Keywords

Urban Growth, Spatial Dispersion, Land Use Land Cover, Entropy Analysis, Geospatial Techniques

1. Study Area

Lamka town, which is also referred to as Churachandpur, is situated in the south-western region of Manipur, India and acts as the administrative center of Churachandpur district. In terms of geography, the area under study falls within the Universal Transverse Mercator (UTM) Zone 46N, offering an accurate spatial reference framework for mapping and geospatial studies. The town is set within a hilly landscape marked by rolling terrain, along with narrow valleys and seasonal streams. Its typical elevation ranges from 900 to 1100 meters above mean sea level. Lamka has a subtropical monsoon cli-

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Received: 4 June 2026; **Accepted:** 13 June 2026; **Published:** 3 July 2026

mate characterized by moderate to heavy rainfall, which affects land usage and settlement trends. Recently, the region has experienced significant urban growth, fuelled by population increase, infrastructure development and migration from rural to urban areas. The surrounding areas are predominantly inhabited by tribal communities and the economy is largely based on agriculture, small-scale trade and services. This makes Lamka a significant center for studying urban growth and regional development dynamics.

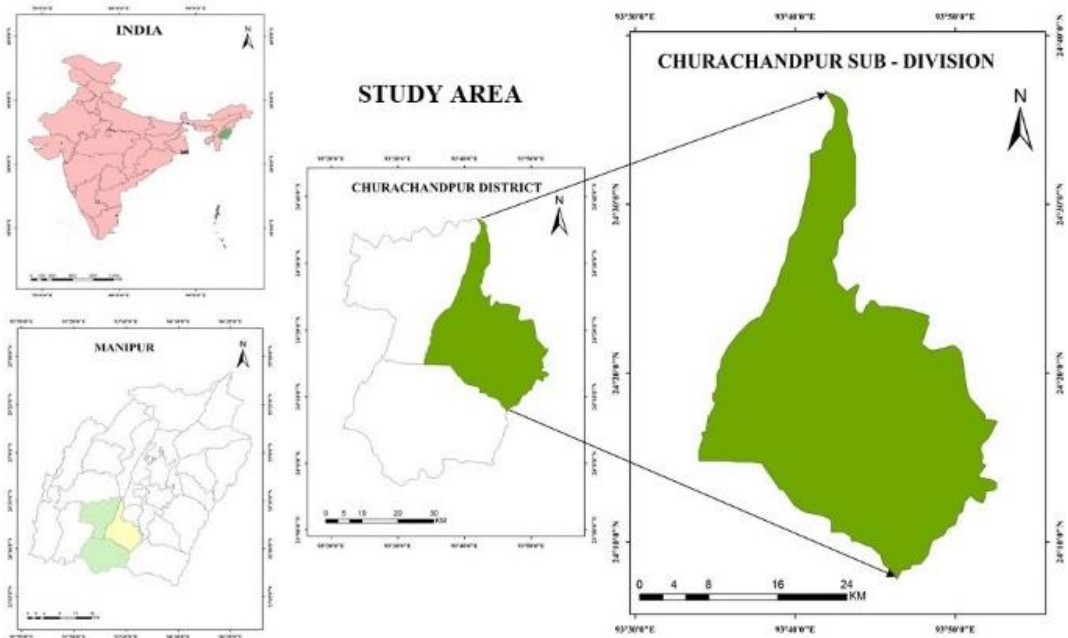

Figure 1. Locational map of the study area.

2. Introduction

Urbanization is one of the most influential forces shaping land use transformation across the globe, particularly in developing regions where rapid population growth, infrastructural expansion and economic activities accelerate the conversion of land [4]. This process often leads to the transformation of agricultural fields, forests and other natural landscapes into built-up areas, bringing both opportunities and challenges [5]. While urbanization can stimulate economic development and improve access to services, unplanned and uncontrolled growth frequently results in spatial dispersion, inefficient land utilization, environmental degradation, and increasing pressure on infrastructure and natural resources [7]. Therefore, understanding the pattern and nature of urban expansion is essential for sustainable planning and management.

In the context of India as a whole, urbanization has been progressing at an unprecedented pace over the past few decades [2]. The country has witnessed a steady rise in urban population due to rural-urban migration, industrialization, and economic liberalization [3]. Major metropolitan regions have expanded outward, often engulfing peri-urban and rural areas. However, this growth is not always systematic, leading to issues such as urban sprawl, traffic congestion, inadequate housing and environmental stress. The diversity in regional development across India further highlights the need for spatially informed planning strategies that can balance growth with sustainability.

The North Eastern region of India presents a unique scenario of urbanization characterized by geographical constraints, ethnic diversity and limited infrastructural development [6]. Urban growth in this region is relatively recent but rapidly increasing, especially in district headquarters and emerging towns [8]. The expansion is often unregulated due to hilly terrain, fragile ecosystems and weak planning frameworks, resulting in scattered and uneven urban forms. Understanding the dynamics of urban growth in this region is crucial for ensuring environmentally sensitive and culturally appropriate development [8].

Shifting cultivation has played a significant role in influencing urbanization in North East India [17]. Traditionally practiced as a subsistence livelihood, Jhum cultivation has become less sustainable due to increasing population pressure and the shortening of fallow cycles, leading to declining soil fertility and reduced agricultural productivity. As a result, many rural households are compelled to seek alternative sources of income and better living conditions. This transition often involves migration to nearby towns and urban centers, contributing to the growth of urban populations. Consequently, towns expand both spatially and demographically, accelerating urbanization. Thus, the gradual decline in the viability of shifting cultivation has indirectly driven rural-to-urban migration and urban growth in the region.

In recent years, the integration of geospatial techniques and remote sensing has emerged as a powerful approach for monitoring and analyzing urban dynamics. Multi-temporal satellite imagery enables consistent observation of land use/land cover (LULC) changes [15, 13], while spatial metrics such as Shannon entropy provide quantitative insights into urban form and dispersion. Entropy analysis is particularly useful in distinguishing between compact and sprawling urban growth, offering a deeper understanding of spatial organization [16].

Lamka town has experienced notable urban expansion over the past few decades due to population growth and changing land use practices. However, the spatial characteristics of this growth remain inadequately quantified [9, 10, 13]. Hence, this study employs remote sensing and Shannon entropy analysis to assess urban growth patterns and spatial dispersion in Lamka town from 1995 to 2025, providing valuable insights for sustainable urban planning and future development strategies [11, 12].

3. Materials and Methods

Using multi-temporal Landsat images, this study uses a geospatial technique to analyze urban expansion in Lamka town from 1995 to 2025. The 30 m spatial resolution data came from Landsat 5 TM (1995), Landsat 7 ETM+ (2005) and Landsat 8 OLI (2015 and 2025). To guarantee data consistency, pre-processing methods like radiometric correction, atmospheric adjustment, geometric correction and sub-setting were used. Supervised classification using the Maximum Likelihood algorithm was employed to categorize land use into built-up and non-built-up classes. Confusion matrices were used to test accuracy and the results showed high overall accuracy and Kappa coefficients for every year. Post-classification comparison was used to detect changes in land usage.

The percentage of built-up area to total area was used to calculate Shannon entropy (H) and normalized entropy (Hn) values between 0 and 1 were obtained to evaluate spatial dispersion. Compact growth is shown by lower values and diffused patterns are represented by larger values. Temporal changes in dispersion were visualized using the entropy graph, which demonstrated a consistent rise in Hn values over time. A thorough comprehension of both temporal growth and spatial organization was made possible by this integrated approach.

Table 1. *GIS data sources.*

Sl. No.	Date of Image	Sensor	Sensors	Resoln.	Band	Band Name	Bandwidth (µm)
1	06-04-1995	Landsat 5	Thematic Mapper	30	7	1-Blue	0.45 - 0.52
						2-Green	0.52 - 0.60
						3-Red	0.63 - 0.69
						4-Near Infrared	0.77 - 0.90
						5-SWIR-1	1.55 -1.75
						6-Thermal Infrared	10.40 - 12.50
						7-SWIR-2	2.09 - 2.35
2	22-04-2005	Landsat 7	ETM+	30	8	1-Blue	0.45 - 0.52
						2-Green	0.52 - 0.60
						3-Red	0.63 - 0.69
						4-NIR	0.77 - 0.90
						5-SWIR 1	1.55 - 1.75
						6-TIR	10.40 - 12.50
						7-SWIR 2	2.09 - 2.35
						8-Panchromatic	0.52 - 0.90
3	13-03-2015	Landsat 8	OLI	30	9	1-Costal/Aerosol	0.43 - 0.45
						2-Blue	0.45 - 0.51
						3-Green	0.53 - 0.59

Sl. No.	Date of Image	Sensor	Sensors	Resoln.	Band	Band Name	Bandwidth (µm)
						4-Red	0.64 - 0.67
						5-NIR	0.85 - 0.88
						6-SWIR 1	1.57 - 1.65
						7-SWIR 2	2.11 - 2.29
						8-Panchromatic	0.50 - 0.68
						9-Cirrus	1.36 - 1.38
4	05-03-2025	Landsat 8	OLI	30	9	1-Costal/Aerosol	0.43 - 0.45
						2-Blue	0.45 - 0.51
						3-Green	0.53 - 0.59
						4-Red	0.64 - 0.67
						5-NIR	0.85 - 0.88
						6-SWIR 1	1.57 - 1.65
						7-SWIR 2	2.11 - 2.29
						8-Panchromatic	0.50 - 0.68
						9-Cirrus	1.36 - 1.38

4. Results

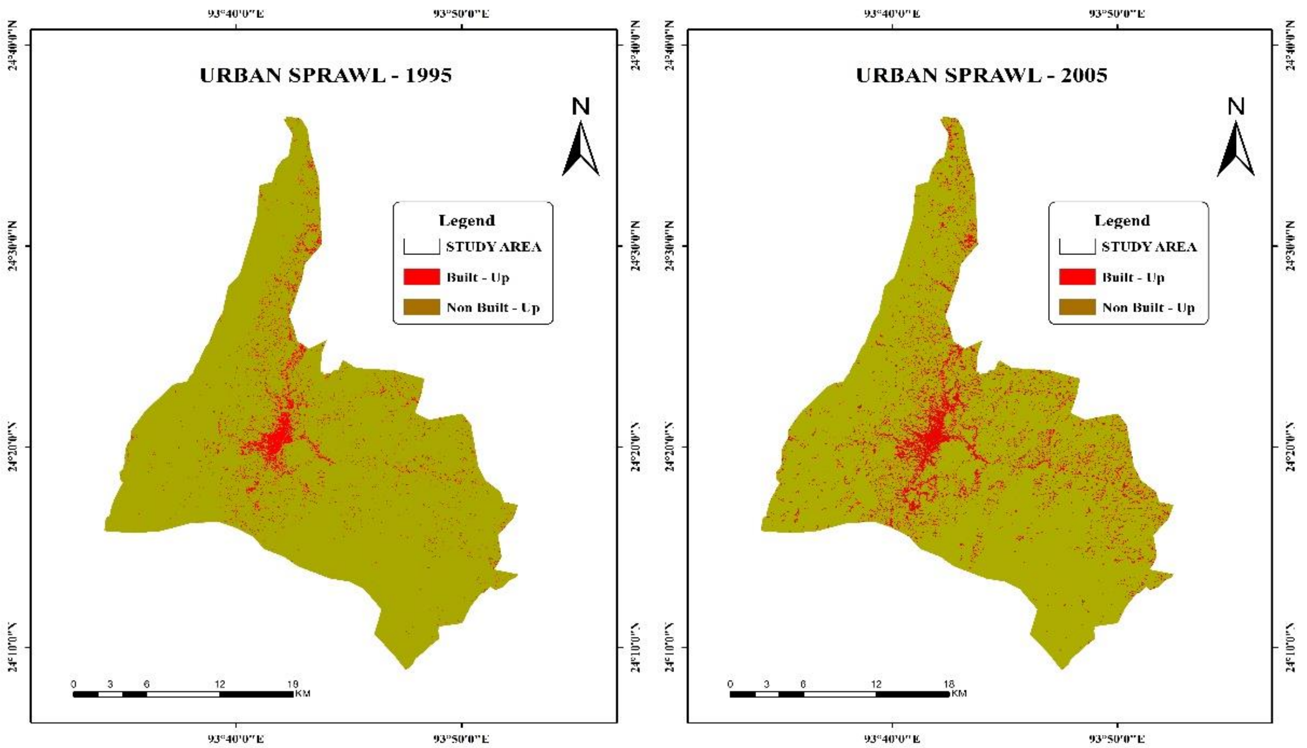

Figure 2. *Urban Sprawl, 1995 and 2005.*

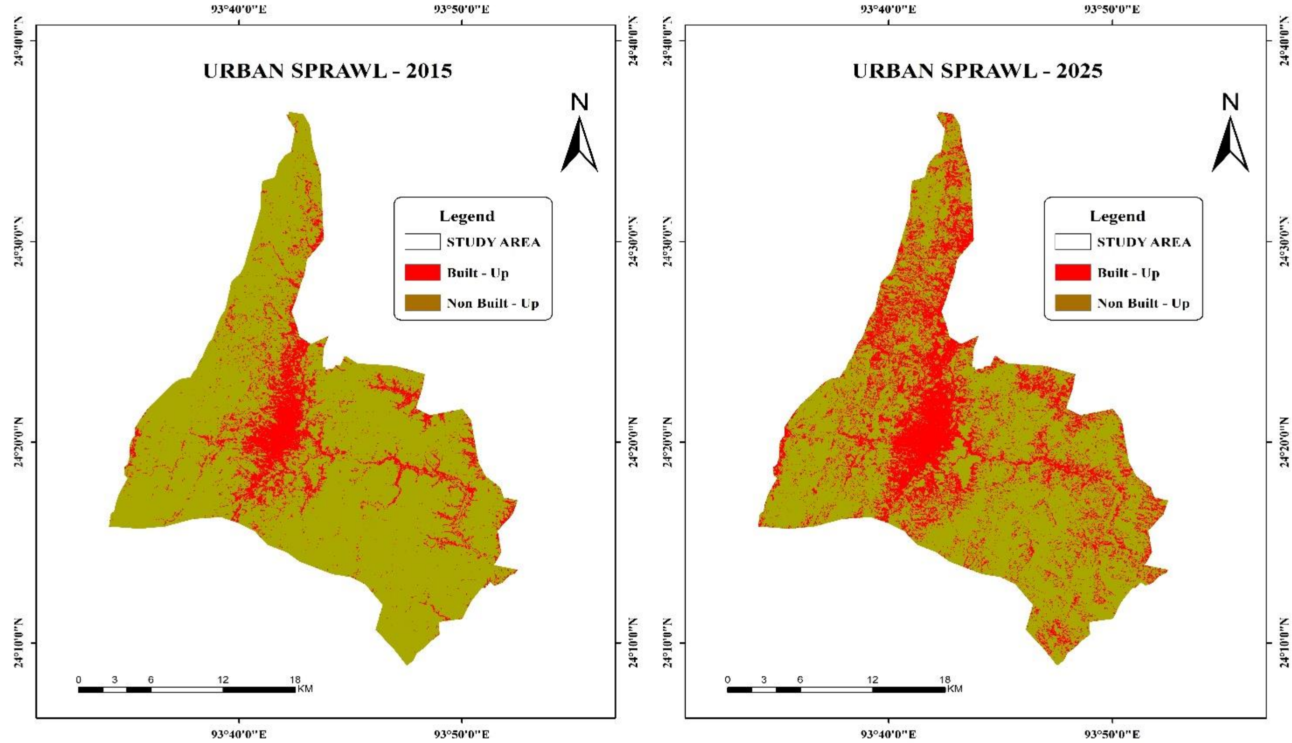

Figure 3. *Urban Sprawl, 2015 and 2025.*

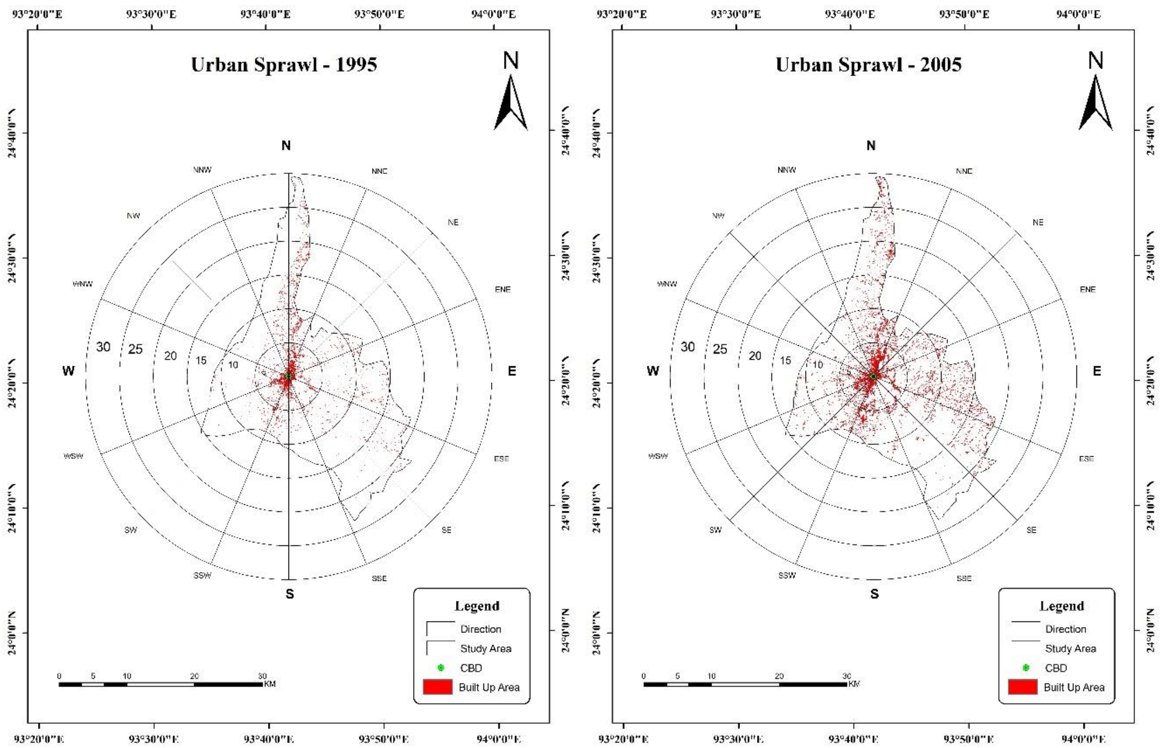

Figure 4. *Directional Analysis of Urban Sprawl from CBD.*

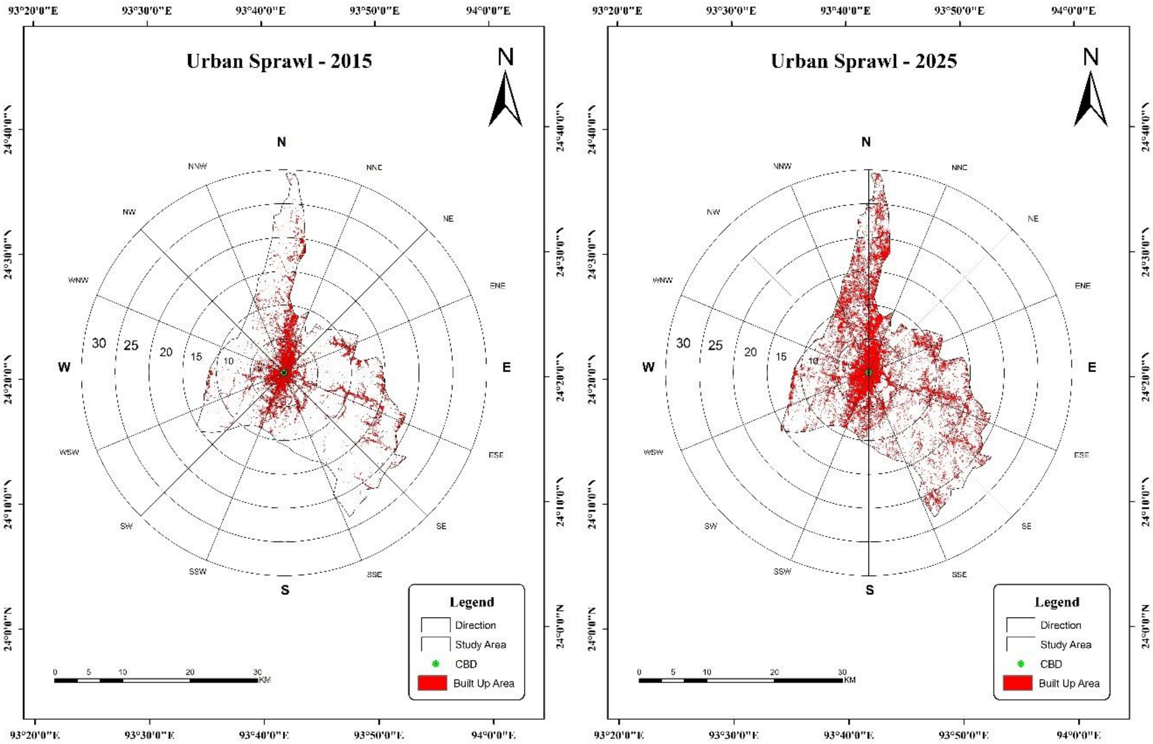

Figure 5. Directional Analysis of Urban Sprawl from CBD.

The results are derived from supervised land use/land cover classification and Shannon entropy analysis to assess urban growth patterns in Lamka town from 1995 to 2025 Figures 2-5. Built-up and non-built-up areas were quantified using post-classification comparison, revealing a significant increase in urban extent [12]. Spatial dispersion was evaluated using Shannon's entropy (H), calculated based on the proportion of built-up land relative to total area and normalized entropy The increasing entropy values indicate a transition from compact urban form to a more dispersed and fragmented spatial pattern over time.

Table 2. Accuracy Assessment.

Sl.No.	Accuracy Assessment	1995	2005	2015	2025	2035 projected
1	Overall Accuracy	88.5%	89.8%	91.2%	92.5%	93.5%
2	Kappa Coefficient	86.3%	87.9%	89.5%	91.1%	92.0%

Table 3. Land Use Land Cover for Built Up and Non-Built up areas, 1995-2025.

Sl.No.	Land Cover Classes	Land cover quantification from 1995 - 2025				% of Changes from 1995 - 2025
		1995	2005	2015	2025	
1	Built - Up (km^2)	8.5	16.5	33.0	58.5	+50
2	Non Built - Up (km^2)	641.5	633.5	617.0	591.5	-50

4.1. Shannon Entropy Analysis

4.1.1. Final Shannon Entropy

$$Pbuilt = \frac{Built}{Built + Non - Built}$$

pbuilt = 1 - pbuilt

4.1.2. Computed Entropy Values

***Table 4**. Entropy data.*

Year	Built-up (km²)	Non Built-up (km²)	p (built)	H	Hn (0-1)
1995	8.5	641.5	0.01308	0.0697	0.1006
2005	16.5	633.5	0.02538	0.1183	0.1707
2015	33.0	617.0	0.05077	0.2008	0.2897
2025	58.5	591.5	0.09000	0.3025	0.4365

***Table 5**. Shannon and Entropy data.*

Year	Built-up (km²)	Non Built-up (km²)	p (built)	p (non-built)	Shannon Entropy H	Normalized Entropy Hn
1995	8.5	641.5	0.01308	0.98692	0.0697	0.1006
2005	16.5	633.5	0.02538	0.97462	0.1183	0.1707
2015	33.0	617.0	0.05077	0.94923	0.2008	0.2897
2025	58.5	591.5	0.09000	0.91000	0.3025	0.4365

4.2. Normalized Shannon Entropy

$$H_n = \frac{H}{In}$$

Entropy Calculation

$$p_i = \frac{A_i}{A_T}$$

A_i = Area of Category
A_T = Area of Total area (Built + Non Built)

$$H = -\sum p_i \, In\,(p_i)$$

$$H_{max} = In\,(2)$$

$$H_n = \frac{H}{In(2)}\ (\leq H_n \leq 1)$$

Where,

1) Hn close to 0 → compact, concentrated development
2) Hn close to 1 → scattered, highly dispersed urban sprawl

It is evident from the Shannon entropy statistics that urban spatial dispersion in Lamka town increased steadily between 1995 and 2025. Between 1995 and 2025, the normalized entropy value rose from 0.10 to 0.44, signifying the expansion of built-up regions from a highly compact urban core to a more diffused and dispersed form [14].

The built-up area increased dramatically from 8.5 km² in 1995 to 58.5 km² in 2025 due to increased connectivity, population development, and horizontal settlement broadening. Each decade's increase in Hn indicates increasing land cover fragmentation, infilling of peripheral areas and advancing outward growth. The fastest phase of sprawl is revealed by the entropy leap from 0.29 (2015) to 0.44 (2025), which is consistent with the district's recent urban expansion pressures.

Overall, Lamka town has changed from a compact urban shape to a fairly scattered sprawl structure, with growing strain on the surrounding unbuilt landscapes, according to the entropy pattern. The spatial expanse of built-up regions has significantly changed, according to an examination of land use/land cover (LULC) changes in Lamka town from 1995 to 2025. According to the classified satellite photos, non-built-up regions decreased while built-up land rose dramatically from roughly 8.5 km² in 1995 to 58.5 km² in 2025 [1]. An accelerated period of urban growth is shown by the most noticeable expansion that took place between 2015 and 2025. The spatial distribution maps show that while later expansion spread to peripheral areas, creating a dispersed pattern, early development was concentrated around the urban core [18].

With total accuracy surpassing 88% and Kappa coefficients above 0.85 for every research year, accuracy testing validates the dependability of the categorization results. Shannon entropy values increased progressively from 0.10 in 1995 to 0.44 in 2025, reflecting a shift from a compact urban form to a more spatially dispersed structure. Urban growth has gotten more dispersed over time, according to the entropy tendency. These findings demonstrate the dynamic character of Lamka Town's urban growth and offer a quantitative foundation for comprehending the size and spatial distribution of growth during the study period.

5. Discussion

Lamka town's urban growth has shifted from a compact to a dispersed form, as evidenced by the observed increase in built-up area and matching rise in Shannon entropy values. Urban sprawl, in which growth spreads outward into neighbouring uninhabited areas rather than concentrating within the current urban core, is typified by this pattern of expansion [10, 11]. The quick expansion seen between 2015 and 2025 points to more intense Peri-urban development, most likely as a result of increased housing demand, population pressure and easier access to peripheral areas.

These distributed expansion patterns frequently result in inefficient land use, higher infrastructure expenditures, and environmental deterioration, such as the loss of agricultural land and vegetation. Difficulties in providing services and managing cities may also be caused by the fragmentation of land use. Recent patterns show a tendency toward less restricted expansion in contrast to previous decades, when development was comparatively concentrated.

The results highlight how crucial it is for urban studies to incorporate spatial analysis techniques like entropy measurements and remote sensing. Planners can recognize new trends and possible hazards thanks to these technologies, which offer insightful information about the scope and composition of urban growth. Proactive planning techniques that support compact development and sustainable land use practices are necessary to address these issues.

6. Conclusion

Using remote sensing and Shannon entropy analysis, this study offers a thorough evaluation of Lamka town's urban growth trends and spatial dispersion during a 30-year period. The findings unequivocally show that built-up area has significantly increased along with a shift from compact to dispersed urban growth. The increasing fragmentation of the urban landscape, especially in recent years, is confirmed by the rising entropy values. The report emphasizes the negative effects of unchecked urban growth, such as ineffective land use, stress on the environment and difficulties with infrastructure planning. These results highlight the necessity of efficient urban management techniques to direct future development in a sustainable way. The policies focusing on controlled expansion, land use zoning and the promotion of compact urban forms are essential to mitigate the adverse effects of urban sprawl.

Additionally, the combination of entropy analysis and geospatial approaches proven to be a successful method for tracking and assessing urban dynamics. This approach can be used for other quickly expanding municipalities dealing with comparable issues. Overall, the study advances knowledge of urbanization processes and offers a solid scientific foundation for sustainable urban planning and well-informed decision-making in Lamka town.

The Shannon entropy graph demonstrates a consistent rise in Hn from 0.10 (1995) to 0.44 (2025), signifying Lamka town's transition from compact to dispersed urban expansion. Up until 2005, the rise was modest, indicating minimal expansion; after 2015, it increased more sharply, indicating substantial peri-urban sprawl and fragmentation. This is in line with the findings, which show that development stretched outward and built-up area increased dramatically, indicating a shift toward dispersed and uncontrolled urban growth (Figure 5).

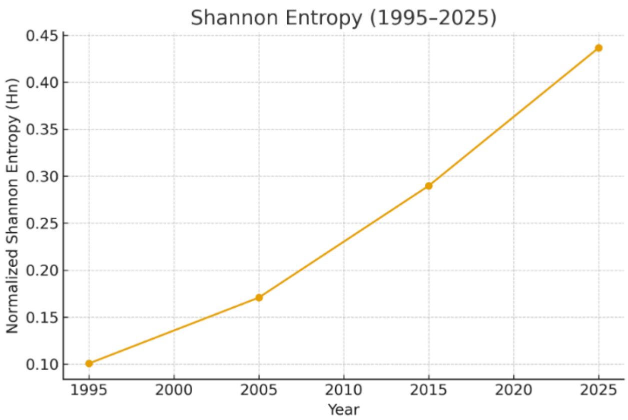

Figure 6. *Shannon Entropy for 1995-2025.*

Abbreviations

LULC	Land Use Land Cover Change
TM	Thematic Mapper
EMT+	Enhanced Thematic Mapper Plus
OLI	Operational Land Imager

GIS	Geographic Information System
CBD	Central Business District

Author Contributions

T. L. Haokip: Conceptualization, Methodology, Formal anaylsis, Software, Validation

T. K. Prasad: Data curation, Project administration, Supervision

Jayapal G.: Validation, Writing – original draft

P. Lienzapau Gangte: Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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