

Spatial Urban Growth Dynamics of Tier-2 Urban Centre in India: A Case of Bareilly, India

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Abstract: Rapid urbanization in India has increasingly shifted focus from saturated metropolitan hubs to tier-2 cities, which are experiencing accelerated spatial expansion often characterized by unplanned sprawl and fragmented morphologies. This study investigates the spatial urban growth dynamics of Bareilly, a prominent tier-2 urban centre in Uttar Pradesh, to elucidate the patterns, intensity, and driving forces of its expansion over recent decades. Leveraging multi-temporal remote sensing data and Geographic Information Systems (GIS), the research employs advanced classification techniques, such as Maximum Likelihood Classification, to map Land Use/Land Cover (LULC) transitions with high accuracy. Spatial metrics, including the Urban Expansion Intensity Index (UEII) and Landscape Expansion Index (LEI), are utilized to quantify the spatiotemporal dynamics of built-up areas, distinguishing between infill, edge, and spontaneous growth types. The analysis reveals a significant conversion of agricultural and vegetative lands into impervious surfaces, driven primarily by population pressure, industrial decentralization, and infrastructure development along major transportation corridors. Results indicate a trend towards dispersed and fragmented urban patches, particularly in peri-urban zones, which complicates service delivery and exacerbates environmental degradation. Furthermore, spatial entropy models highlight increasing dispersion in urban growth, suggesting a departure from compact, sustainable development trajectories. The findings underscore the critical need for integrating predictive modelling, such as Cellular Automata and Markov Chain simulations, into urban planning frameworks to manage future expansion scenarios effectively. By providing a comprehensive assessment of Bareilly's urban trajectory, this study contributes to the broader understanding of tier-2 city dynamics in developing nations and offers evidence-based recommendations for sustainable urban governance and infrastructure planning.

Keywords: Urban Sprawl; Tier-2 Cities; Bareilly; Spatial Metrics; Land Use/Land Cover Change; Remote Sensing; GIS; Urban Expansion Intensity Index; Peri-urban Dynamics; Sustainable Urban Planning

1. Introduction

The rapid urbanization of India is increasingly characterized by the accelerated expansion of tier-2 cities, which are absorbing population and economic activity from saturated metropolitan regions. While extensive literature exists on the spatial dynamics of megacities like Delhi and Mumbai, tier-2 urban centres such as Bareilly in Uttar Pradesh represent a critical yet under-researched frontier in urban geography. These cities exhibit unique growth trajectories driven by localized industrial drivers, peri-urban transformation, and infrastructural decentralization. Understanding the spatial urban growth dynamics of Bareilly requires a synthesis of remote sensing data, geographic information systems (GIS), and spatial metrics to quantify land use/land cover (LULC) changes, fragmentation patterns, and the intensity of urban sprawl. This analysis integrates findings from diverse Indian urban contexts to construct a robust framework for evaluating Bareilly's urban evolution, highlighting the mechanisms of unplanned expansion and the consequent environmental and socio-economic implications.

1.1. Mechanisms of Urban Expansion in Tier-2 Cities

Urban growth in developing nations is fundamentally driven by industrialization, economic shifts, and rural-to-urban migration, creating complex spatiotemporal patterns that challenge traditional planning frameworks. In India, tier-2 cities are expanding at a significantly faster pace than their tier-1 counterparts in the 21st century, often outstripping statutory administrative boundaries. This expansion is frequently unplanned, resulting in dispersed and fragmented urban

patches that hinder sustainability. The dynamics of this growth are not merely linear but involve bidirectional urbanization, where peri-urban areas undergo profound transformations that blur the lines between rural and urban landscapes.

For a city like Bareilly, located in the Indo-Gangetic plains, these dynamics are influenced by its role as a regional commercial and educational hub. Studies on similar medium-sized cities in the Indo-Gangetic region, such as Lucknow and Patna, reveal that urban sprawl is often triggered by the saturation of larger metropolitan areas and the subsequent decentralization of growth drivers. The lack of comprehensive databases on urban transformation in these tier-2 centres exacerbates the challenge for policymakers, who struggle to control the swift expansion of impervious surfaces. Consequently, the urban footprint of Bareilly is likely characterized by a mix of infill development and edge-expansion, leading to a heterogeneous urban morphology that requires detailed spatial metric analysis to decipher.

1.2. Spatial Development of the Bareilly town

Urban development Patterns may be divided into five periods. The periods are ancient, classic, medieval, colonial, and modern. There are overlaps or transition years between these periods. The origin of Bareilly urban centres came into being as early as 6000-5000 B.C. When it was Panchal Pradesh mention in the Epic Mahabharata that pours an essential importance and growth of the town. As many early urban civilizations developed in the river valleys like the Indus, this was developed on the banks of Rāmgangā river though it was Linier in the pattern. The Classic and medieval period's earlier beginning and was the crossroad of ancient world civilization before. In the colonial rule, the city got developed in terms of infrastructure and administration, though settlement pattern changed towards the transportation linkages, and after independence till the date the city focused on the Import export and regional linkages with religious tourism though the settlement got developed on the stream line of the Regional and transportation linkages. Bareilly development/planning area recognized on 1st November, 1971 under the Uttar Pradesh Nirman act, 1958. The development area includes the Bareilly Nagar Nigam and the surrounding 198 revenue villages. Later the Bareilly Development Authority (BDA) formulated on 19th April, 1977 to regulate and develop the planning area. The first Master plan of Bareilly (1971 – 1996) was prepared and approved on 29th August 1978. BDA extended its area by inculcating the surrounding 66 revenue villages in May 2008. The city of Bareilly, with in a jurisdiction of 10605 Ha (106.05 sq. km) of area, housing a population of 8,98,167 (as per 2011 census) is a Municipal Corporation administered by Bareilly Nagar Nigam.

2. Materials and Methods

2.1. Methodological Framework for Spatial Analysis

To accurately assess the spatial urban growth dynamics of Bareilly, a rigorous geospatial methodology is essential. This involves the utilization of multi-temporal satellite imagery, such as Landsat datasets, to classify LULC changes over distinct temporal intervals. The integration of remote sensing with GIS allows for the precise mapping of built-up areas, vegetation, water bodies, and agricultural lands, providing a baseline for quantifying urban expansion. Advanced classification techniques, including Maximum Likelihood Classification (MLC) and machine learning algorithms like Support Vector Machines (SVM), have proven effective in achieving high accuracy in LULC mapping, often exceeding 85% reliability.

Furthermore, the application of spatial metrics and indices is crucial for moving beyond simple area calculations to understand the pattern of growth. Metrics such as the Urban Expansion Intensity Index (UEII) and the Landscape Expansion Index (LEI) enable researchers to differentiate between spontaneous, edge, and infill growth types. The UEII, for instance, normalizes the rate of urban expansion against the total urban area, allowing for comparative analysis across different time periods. Similarly, spatial entropy models can assess the degree of dispersion and diversity in urban growth, providing insights into whether the expansion is compact or sprawling. For Bareilly, employing these metrics would reveal the specific trajectory of its urban sprawl, identifying whether growth is concentrated around existing cores or dispersing into peripheral agricultural zones.

GROWTH DIRECTION OF THE TOWN

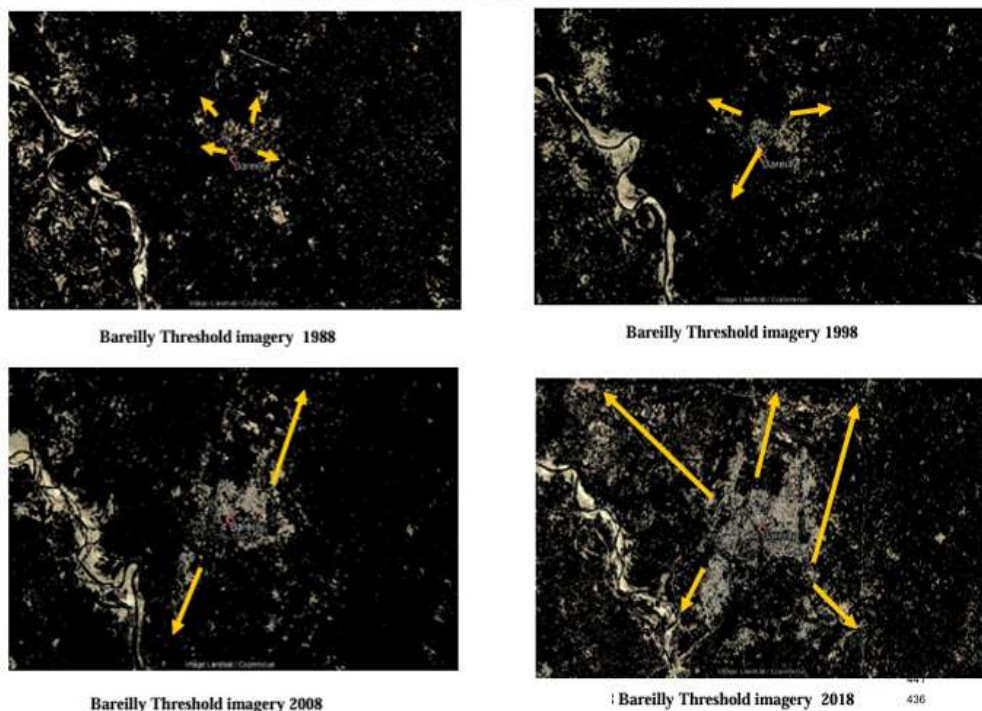
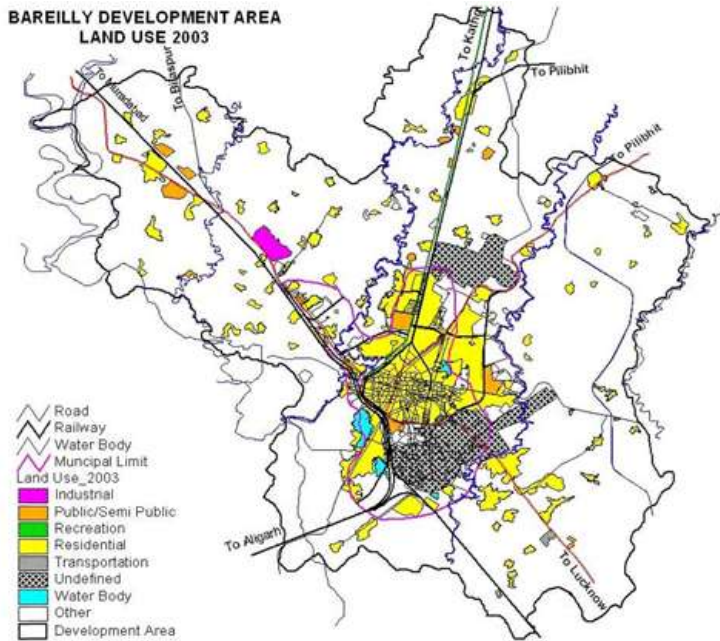


Figure 1 Growth Direction of the Bareilly town

2.2. Patterns of Sprawl and Land Use Transformation

The spatial pattern of urban sprawl in Indian tier-2 cities is often marked by fragmentation and the formation of secondary cores or satellite towns in the peri-urban space. In the context of Bareilly, this likely manifests as the conversion of agricultural land into residential and commercial plots along major transportation corridors. Studies on similar cities, such as Varanasi and Siliguri, indicate that urban sprawl is heavily influenced by transportation networks, which act as primary drivers of linear expansion. The interaction between urban growth and transportation infrastructure creates a viscous loop, where new roads stimulate further development, which in necessitates additional infrastructure, leading to continuous sprawl.

Land use transformation in these regions is predominantly characterized by the loss of green cover and agricultural fields to built-up areas. Research on mid-sized Indian cities shows that this transition is often haphazard, lacking the structured zoning seen in planned urban developments. The resulting urban landscape exhibits high lacunarity, indicating a gappy or heterogeneous texture of development interspersed with vacant or agricultural plots. This fragmented morphology not only complicates service delivery but also increases the ecological footprint of the city. In Bareilly, the directionality of growth is likely influenced by local topographical constraints and existing industrial clusters, leading to anisotropic expansion patterns that can be detected through directional spatial metrics.



Development change in the Bareilly city morphology

Figure 2 Bareilly Development area Landuse 2003

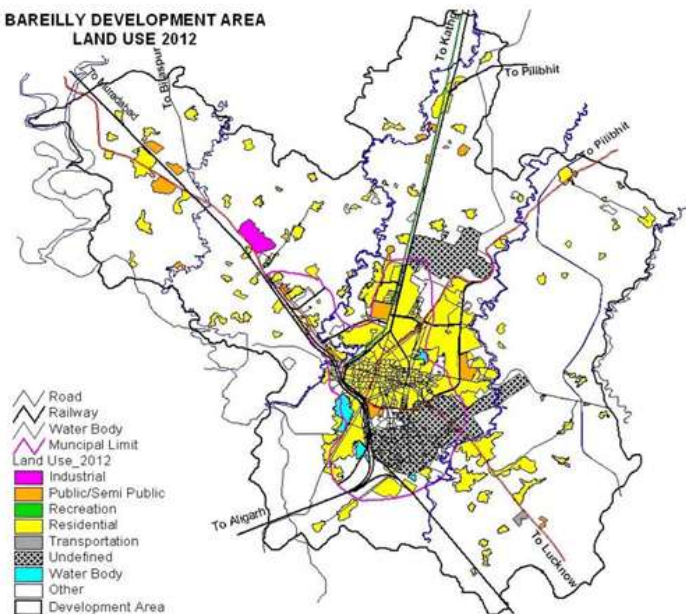


Figure 3 Bareilly Development area Landuse 2012

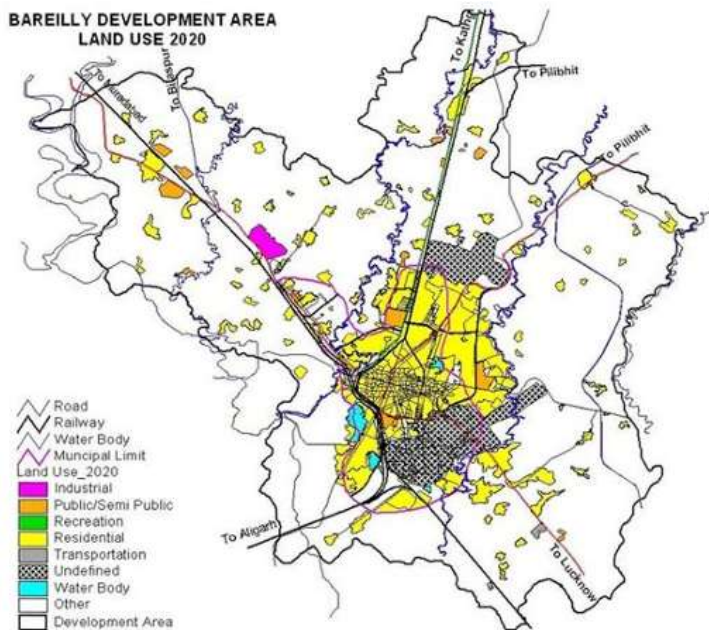


Figure 4 Bareilly Development area Landuse 2020

2.3. Driving Forces and Socio-Economic Implications

The drivers of urban growth in Bareilly are multifaceted, encompassing demographic pressures, economic opportunities, and policy interventions. Population growth and economic development are primary influencers, creating a demand for housing and infrastructure that often outpaces supply. In many tier-2 cities, industrial growth serves as a significant catalyst for urban expansion, altering the morphological structure of the city. For Bareilly, its historical significance as a trade centre and its emerging role in education and healthcare likely attract migrants from surrounding rural areas, intensifying the pressure on urban land resources.

The socio-economic implications of this unplanned growth are profound. Rapid urbanization without adequate planning leads to increased congestion, strain on public utilities, and environmental degradation. The proliferation of informal settlements and the fragmentation of urban footprints hinder the efficiency of public transport and waste management systems. Moreover, the loss of agricultural land threatens local food security and livelihoods, creating social tensions in peri-urban zones. The urban heat island effect, exacerbated by the replacement of vegetative cover with impermeable surfaces, further impacts the quality of life and public health in these expanding urban centres.

3. Results

3.1. Spatial Development and Housing

- **Unplanned Growth:** Analysis of satellite imagery (2003–2020) indicates that unplanned residential areas account for 74.3% of new developments, primarily on fertile agricultural land.
- **Agricultural Loss:** The city is losing agricultural land at a mean rate of 12.5% per year in the 2012–2020 period.
- **Housing Shortage:** By 2031, the total additional housing units required is estimated at 97,513 to accommodate the projected population of 1.25 million.
- **Slum Dynamics:** 24% of the city population resides in 47 identified slums, most of which have existed for 20–30 years.

Table 1 Land Use Change in Bareilly (2003-2012) Areas in hectors

Landuse	2003	In %	2012	In %	Areas change	% change 2003-11
Residential	5688.499	52.10	6217.51	6217.51	6217.51	9.30
Industrial	153.827	1.41	153.827	1.41	0	0.00
Public/Semi Public	571.128	5.23	593.128	5.43	22	3.70

Commercial	27.221	0.25	27.221	0.25	0	0.00
Recreation	0.546	0.01	0.546	0.01	0	0.00
Recreation	2111.449	19.34	2111.449	19.34	0	0.00
Water Body	201.681	1.85	201.681	1.85	0	0.00
Others	2163.198	19.81	1612.187	14.77	(-)551.011	-24.46
Total	10917.55	100.00	10917.55	100.00		

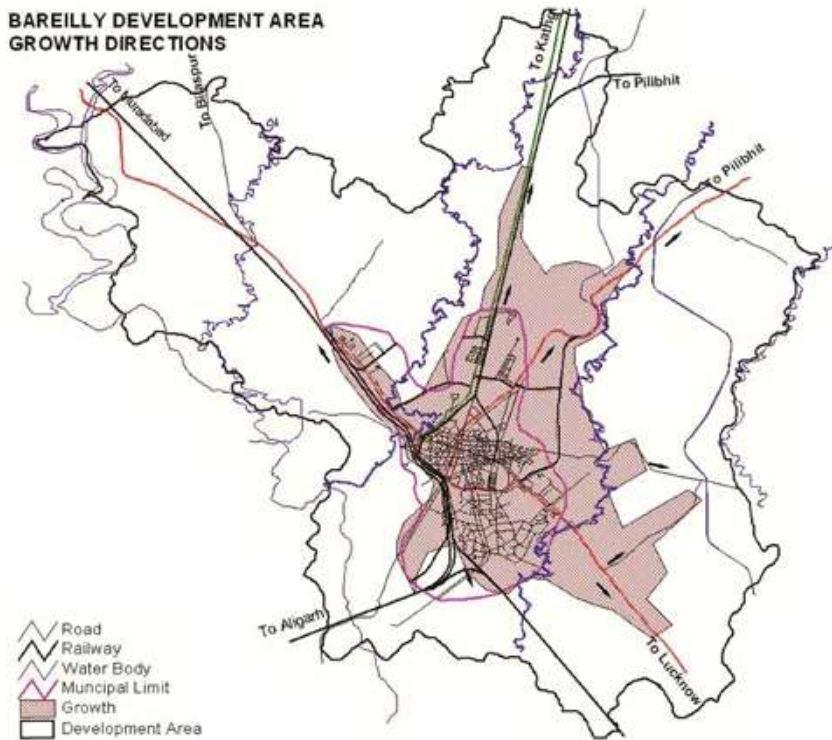


Figure 5 Bareilly Development Area Growth Directions

3.2. Future Trajectories and Planning Strategies

Addressing the challenges of urban growth in Bareilly requires a shift towards sustainable and resilient planning strategies. The integration of disaster resilience into urban planning is critical, particularly for cities facing rapid and unplanned expansion. Utilizing predictive modelling techniques, such as Cellular Automata (CA) and Markov Chain models, can help simulate future urban growth scenarios under different policy interventions. These models allow planners to visualize the potential impacts of infrastructure projects and zoning regulations, facilitating evidence-based decision-making.

Furthermore, the adoption of smart city initiatives offers opportunities to manage urban growth more effectively. However, these initiatives must be tailored to the specific context of tier-2 cities, focusing on improving infrastructure efficiency, enhancing green spaces, and promoting mixed-use development. Decentralizing growth by strengthening sub-tier urban centres can also alleviate pressure on the main city, promoting a more balanced regional development. For Bareilly, this might involve developing satellite towns with adequate connectivity and amenities to absorb future growth in a controlled manner. Ultimately, a holistic approach that combines geospatial monitoring, participatory planning, and sustainable policy frameworks is essential to guide the spatial urban growth dynamics of Bareilly towards a more equitable and environmentally sound future.

4. Discussion

The spatial urban growth dynamics of Bareilly, as a representative tier-2 urban centre in India, reflect broader trends of rapid, often unplanned urbanization characteristic of developing economies. By leveraging remote sensing, GIS, and spatial metrics, it is possible to quantify and analyze the patterns, drivers, and implications of this growth. The evidence suggests that Bareilly's expansion is marked by fragmentation, peri-urban transformation, and a heavy reliance on transportation corridors, leading to significant environmental and socio-economic challenges. Addressing these issues

requires a proactive planning approach that integrates predictive modelling, sustainable infrastructure development, and regional decentralization strategies. Future research should focus on longitudinal studies to track the long-term impacts of these growth dynamics and evaluate the effectiveness of emerging planning interventions in tier-2 cities.

To enforce and achieve smart and vibrant Bareilly, there must be 1. Spatial Regulation: Implement strict zoning to protect fertile agricultural land from further unplanned residential encroachment. 2. Economic Diversification: Leverage the city's status as an educational and medical hub to attract service-sector MSMEs and invest in solar energy for government buildings.

Bareilly stands at a crossroads. While its demographic and regional position offers immense potential, the prevalence of unplanned growth and infrastructure deficits poses a risk to its long-term sustainability. The GIS-based Master Plan would definitely provide the necessary technical framework to transition Bareilly into a "Smart" and "Vibrant" economic centre.

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