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Spatial Analysis of Population Distribution in Rapidly Urbanizing Regions

Dr. Lalit Kumar
Associate Professor of Geography
Govt. P. G. Nehru College, Jhajjar,Haryana

Abstract
This study examines the spatial dynamics of population distribution in Haryana, a rapidly urbanising state within northern India, using secondary demographic data and findings from recent geospatial research. The analysis shows that population growth is concentrated in districts adjoining the National Capital Region, where extensive land-use conversion, infrastructural expansion and industrial development have accelerated urban spread. In contrast, western and southern districts display slower demographic change and retain predominantly rural settlement patterns. Spatial evidence drawn from existing literature indicates a shift from compact urban centres to dispersed, corridor-based expansion, accompanied by environmental pressures such as declining groundwater levels and rising land surface temperatures. The study highlights the importance of integrating demographic patterns with spatial indicators to understand how uneven urbanisation is reshaping regional development landscapes in Haryana.
Keywords: Spatial analysis, population distribution, urbanisation, Haryana, land-use change, peri-urban growth

Introduction

Spatial analysis of population distribution has become central to understanding the dynamics of rapid urbanisation in emerging economies. As cities expand outwards and upwards, the spatial pattern of where people live, work and travel increasingly determine access to infrastructure, environmental risks and social opportunity. In India, the acceleration of urban growth since the 1990s has produced complex mosaics of dense cores, peri-urban fringes and residual rural pockets that cannot be understood through aggregate statistics alone. Remote sensing, geographic information systems (GIS) and spatial statistics now enable fine-grained mapping of these patterns, revealing how built-up expansion, transport corridors and land-use change intersect with demographic concentration and social inequalities (Pawan Kumar & Gaur, 2015). Within this wider national context, the state of Haryana offers a particularly instructive case of rapid, corridor-driven urbanisation that is reshaping population distribution across a relatively small yet strategically located territory.

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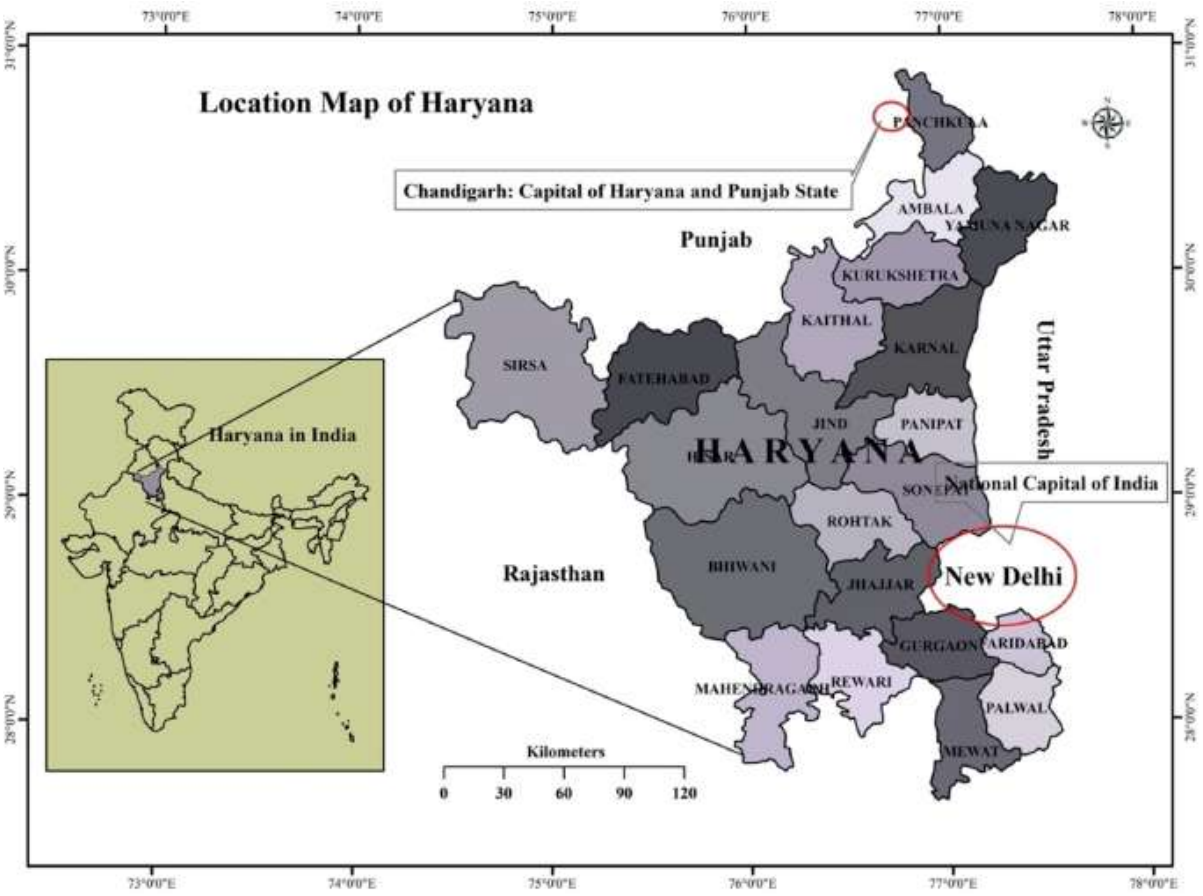

Figure 1: Location map of Haryana
Source: Sharma & Kumar (2023)

Haryana, situated in northern India and forming an integral part of the National Capital Region (NCR), has undergone a marked transition from a predominantly agrarian economy to an increasingly urban–industrial landscape. According to the 2011 Census and subsequent demographic analyses, about 34.8 per cent of the state's population, or roughly 8.8 million people, were living in urban areas by 2011, while around 65 per cent remained in rural settlements (Kumar, 2020; Statistical Abstract of Haryana, 2011–12). Studies of long-term trends show that the proportion of urban residents rose from approximately 28.9 per cent in 2001 to nearly 35 per cent in 2011, making Haryana one of India's more urbanised states and placing its urban share above the national average (Deepika, 2019; Singh, 2016). However, this growth is highly uneven in space. District-wise reviews consistently highlight the concentration of urban population and economic activity in NCR-adjacent districts such as Gurugram, Faridabad, Panipat, Sonipat and Panchkula, while districts in the south-western and western parts of the state retain largely rural settlement structures and much lower levels of urbanisation (Tanwar, et

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al. 2016). The result is a sharply differentiated urban system, where high-density, globally connected nodes coexist with slower-growing market towns and agrarian hinterlands within a relatively compact state.

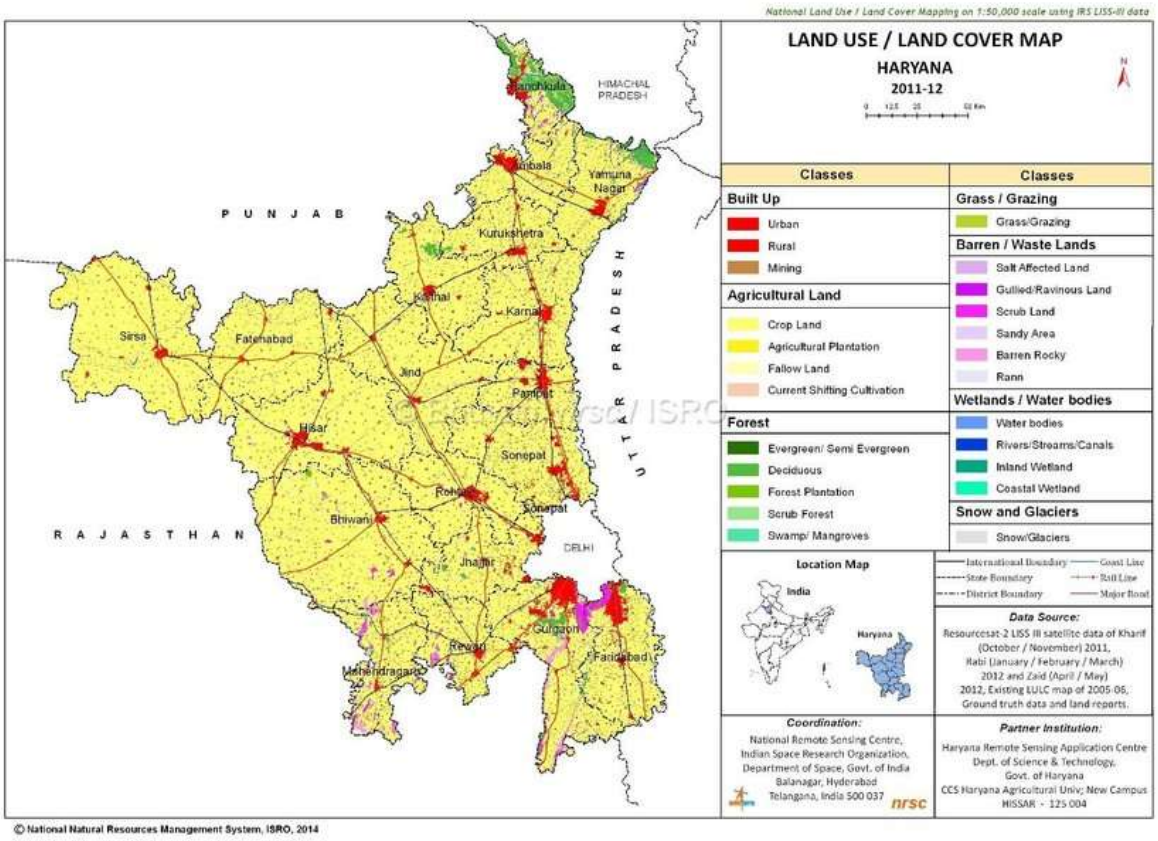

Figure 2: Land use and land cover of haryana
Source: Gupta, et al. (2019)

These divergent trajectories underscore the need for explicitly spatial analysis of population distribution in Haryana's rapidly urbanising regions. Recent GIS-based and remote-sensing studies of individual cities and corridors, including work on Jhajjar, Narnaul and the expanding urban agglomerations along the Delhi–Gurugram–Manesar and Sonipat–Kundli axes, demonstrate how conversion of agricultural land, infrastructural investments and industrial clustering are reconfiguring both land use and demographic densities at the urban fringe (Pawan Kumar & Gaur, 2015; Kumar, 2020).At the state scale, more recent district-wise examinations employ demographic indicators, satellite imagery and socio-economic data to map uneven urban growth and emerging spatial disparities in service provision and environmental pressure. Against this backdrop, the present study focuses on the spatial analysis of population distribution in Haryana's rapidly urbanising regions, using official census data and geo-referenced secondary

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sources to examine patterns of density, identify growth hotspots along key corridors and assess how these evolving configurations intersect with planning challenges in housing, infrastructure and environmental management.

District	Total Population				Growth rate	
	1991	2001	2001 Estimated	2011	1991-2001	2001-2011
HARYANA	**16463648**	**21144564**	**21144564**	**25351462**	**2.502**	**1.815**
Gurgaon	1146090	1660289	870514	1514432	3.706	5.537
Mewat (Nuh) 2005			789768	1089263	NA	3.215
Faridabad	1477240	2194586	1365430	1809733	3.958	2.817
Palwal (2008)			829144	1042708	NA	2.292
Panipat	698000	967449	967449	1205437	3.264	2.199
Panchkula	310000	468411	468411	561293	4.128	1.809
Karnal	1035000	1274183	1274183	1505324	2.079	1.667
Rewari	611000	765351	765351	900332	2.252	1.624
Kurukshetra	669000	825454	825454	964655	2.101	1.558
Fatehabad	646000	806158	806158	942011	2.215	1.557
Yamunanagar	806000	1041630	1041630	1214205	2.565	1.533
Sirsa	903536	1116649	1116649	1295189	2.118	1.483
Bhiwani	1163000	1425022	1425022	1634445	2.032	1.371
Kaithal	782000	946131	946131	1074304	1.905	1.270
Narnaul(Mahendragarh)	681869	812521	812521	922088	1.753	1.265
Hisar	1209000	1537117	1537117	1743931	2.401	1.262
Sonipat	1045000	1279175	1279175	1450001	2.022	1.253
Rohtak	777000	940128	940128	1061204	1.906	1.211
Jind	980000	1189827	1189827	1334152	1.940	1.145
Ambala	806000	1014411	1014411	1128350	2.300	1.064
Jhajjar	715000	880072	880072	958405	2.077	0.853

Figure 3: Total Population and population growth rate (%) during 1991-2001 and 2001-2011 Source: Mal, et al. (2020).

Motivation of the Study

The motivation for undertaking a spatial analysis of population distribution in Haryana arises from the increasingly uneven patterns of urban expansion that have emerged over the past two decades. Although the state has registered a steady rise in its urban population, the rate and form of this growth vary markedly between districts, shaped by proximity to the National Capital Region, industrial clustering, infrastructural investment and historical land-use patterns. Studies drawing on census data, remote sensing and urban growth modelling emphasise that much of Haryana's demographic concentration is being driven by rapid peri-urban development,

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particularly in districts such as Gurugram, Faridabad and Sonipat, while others, including Mahendragarh, Bhiwani and Fatehabad, continue to reflect slow, predominantly rural population distribution (Deepika, 2019; Singh, 2016). This spatial divergence has significant implications for regional planning, as the densification of urban corridors often outpaces the provision of housing, transport infrastructure, water supply and waste management, producing new socio-environmental pressures. Furthermore, research indicates that land-use conversion in high-growth zones, especially the transformation of agricultural land into residential and industrial use, has altered settlement morphology and generated enclaves of very high population density near economic hubs (Pawan Kumar & Gaur, 2015). These trends highlight a clear need to examine not only how population is distributed across Haryana but also the spatial forces driving this distribution.

The study is equally motivated by the policy relevance of understanding spatial differentiation in rapidly urbanising regions. Haryana has been central to several national and regional development initiatives, including the expansion of the Delhi–Mumbai Industrial Corridor and targeted urban development schemes that seek to modernise physical infrastructure and attract investment. Yet analyses of the state's evolving demographic landscape suggest that growth remains heavily concentrated along select transport and economic corridors, often perpetuating disparities in access to employment, public services and environmental quality.Spatial analysis offers a means to identify these disparities by integrating demographic trends with land-use data, settlement morphology and urban expansion patterns. It also provides a framework for assessing how unplanned or poorly regulated growth affects ecological systems, particularly groundwater depletion, heat island intensification and pressures on peri-urban commons, which are documented concerns in Haryana's high-growth districts. By grounding the analysis in empirical datasets and recent scholarly work, the study seeks to produce nuanced insights that can support more spatially informed approaches to urban planning, resource allocation and sustainable development in the state. The overarching motivation is, therefore, to illuminate the spatial logic of Haryana's population distribution in a period of unprecedented urban change and to provide an evidence base that can inform more equitable and environmentally resilient strategies for managing this transformation.

Problem Statement

The rapid and uneven urbanisation of Haryana has generated a set of complex spatial challenges that necessitate systematic investigation. While the state has experienced substantial demographic growth in urban centres, this expansion has not occurred uniformly, resulting in pronounced disparities in population distribution between districts located within or adjacent to the National Capital Region and those situated in the western and southern parts of the state. Existing studies show that urban growth in districts such as Gurugram, Faridabad and Sonipat

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has been driven by large-scale industrialisation, service-sector development and intense land-use conversion, producing densely populated urban clusters alongside rapidly transforming peri-urban belts (Pawan Kumar & Gaur, 2015; Deepika, 2019). In contrast, districts including Hisar, Bhiwani and Mahendragarh continue to exhibit slow or minimal urban expansion despite broader state-level development initiatives, leading to a spatially fragmented pattern of population concentration (Singh, 2016). This uneven distribution complicates efforts to plan infrastructure, deliver essential services and manage environmental resources, as growth corridors increasingly face pressures exceeding their ecological and physical capacity.

The core problem addressed in this study is the lack of comprehensive spatial analysis that integrates demographic, land-use and settlement-pattern data to explain how and why population distribution in Haryana has evolved in such a divergent manner. Although existing research provides district-wise demographic trends and isolated case studies of urban expansion, there remains limited understanding of the spatial relationships between population density, urban growth forms and the underlying drivers shaping these dynamics across the state. This gap is significant because without a spatially informed perspective, policy responses may fail to anticipate emerging hotspots of congestion, ecological degradation or infrastructural deficit, thereby reinforcing rather than mitigating regional inequalities. The absence of such integrated analysis also restricts the ability of planners to design context-specific interventions, particularly in peri-urban areas where land-use change is most rapid and least regulated. The problem is therefore not simply one of uneven population growth but of insufficient spatial understanding of the mechanisms producing this unevenness. This study seeks to address that gap by applying spatial analytical tools to assess population distribution patterns and their relationship to urbanisation processes in Haryana, drawing on recent empirical research and demographic datasets (Kumar, 2020).

Literature review

Scholarship on urbanisation in Haryana and comparable Indian regions has expanded considerably in recent years, with a growing emphasis on spatial patterns rather than purely aggregate demographic change. Historical analyses show that Haryana's urban population increased from about 5.7 lakh in 1901 to 88.2 lakh in 2011, and that the share of urban population rose from 17.07 per cent in 1951 to 34.88 per cent in 2011, more than twice the increase over six decades (Kumari, 2022; Effects of increasing population in urban Haryana, 2023). These studies underline that the state's level of urbanisation is consistently higher than the national average, yet also stress the high degree of spatial disparity between districts, which demands more explicitly spatial approaches to population analysis. District-wise examinations of urban levels in 2001 and 2011 show a clear contrast between the highly urbanised northern and eastern belt and the relatively less urbanised western and south-western districts (Sharma &

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Kumar (2023); Levels of urbanisation in Haryana, 2022). This pattern is often linked to proximity to the National Capital Region, concentration of manufacturing and service activities, and better transport connectivity, suggesting that population distribution is strongly conditioned by spatially uneven economic and infrastructural development.

Recent analyses of Haryana's urbanisation trajectories further highlight the pace and direction of demographic concentration in specific corridors and nodes. Kumari (2022) documents that the decade 2001–2011 saw an increase of about 27 lakh persons in the state's urban population, corresponding to a decadal growth rate of 44.25 per cent, with much of this expansion absorbed by NCR-adjacent districts. A parallel study finds that by 2011 approximately 34.88 per cent of the state's residents lived in urban areas, compared with 31.16 per cent at the national scale, and that Faridabad had become the most urbanised district with 79.51 per cent of its population in urban settlements, while western districts remained predominantly rural (Sharma & Kumar, 2023). The "Effects of increasing population in urban Haryana" provides a longer-term view, showing that decadal growth rates of the urban population touched 35.58 per cent in 1961–71 and accelerated further in the subsequent decades, reflecting both administrative upgrading of settlements and organic urban growth (Effects of increasing population in urban Haryana, 2023). These descriptive accounts set the demographic context within which more specialised spatial and geospatial analyses have begun to emerge.

Changes in land use and land cover provide an important lens through which to interpret the spatial redistribution of population in Haryana. Rani's (2019) assessment of changing land use patterns from the late 1960s to the early 2010s observes marginal shifts across most categories but a significant decline in forest cover, along with highly uneven distribution of grazing lands, which are concentrated in a few central and eastern districts and almost absent in western Haryana. The study argues that these trends reflect a gradual but steady conversion of agricultural and common lands to built-up uses, especially in districts integrated into regional growth corridors. More recent work using remote sensing for Fatehabad district between 2016 and 2021 confirms that built-up area expanded at the expense of vegetation and water bodies, with water bodies shrinking by 27.21 per cent and vegetation by 44.22 per cent in just five years, signalling intensifying pressures associated with emerging urbanisation and industrialisation. Such land-use changes are indicative of localised densification processes that are likely to influence, and be influenced by, evolving patterns of population distribution.

At the city scale, a cluster of geospatial studies examine urban sprawl and density dynamics in individual towns and cities of Haryana, offering more fine-grained insights into the spatial reorganisation of population. An urban sprawl analysis of Hisar city, using multi-temporal Landsat images for 2000, 2010 and 2020, reports that built-up area increased from 18.2 km² to 38.4 km² over two decades, representing a growth of nearly 111 per cent, while agricultural land

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declined by almost 30 per cent in the same period (Sharma & Kumar, 2023). Shannon's entropy values for the city rose from 0.72 in 2000 to 0.88 in 2020, indicating a more dispersed and sprawling urban form that diffuses population concentrations into peripheral areas. A related study of Rewari city, a part of the NCR, finds that between 1989 and 2020, 69.4 per cent of the increase in built-up area came at the expense of vegetation and agricultural land, and that per capita land consumption increased from 0.0024 to 0.0084, with the growth rate of built-up land nearly five times higher than population growth.This suggests a pattern of low-density, land-intensive expansion, with clear implications for the spatial distribution of residents and the efficiency of infrastructure provision.

Urban sprawl across multiple Class I towns in the NCR sub-region of Haryana has been explored through a comparative geospatial framework that further emphasises the corridor-based concentration of growth. An examination of sprawl in towns such as Faridabad, Gurugram, Rohtak, Karnal and Sonipat over the period 1991–2021 shows that Faridabad's urban area expanded from 30.57 km² to 111.61 km², while Gurugram's urban footprint increased dramatically from 18.65 km² to 233.84 km² over the same period.These trajectories are interpreted as outcomes of metropolitan spillovers and major transport investments, leading to rapid outward spread of built-up land and increasing spatial reach of urban population clusters. The study highlights that such expansion is accompanied by growing challenges related to congestion, land-use conflicts and inadequate municipal services, implicitly linking the form and extent of sprawl with spatial inequalities in access to basic amenities. Together, the Hisar, Rewari and NCR sub-region analyses illustrate how satellite-based mapping and landscape metrics can be used to quantify patterns of urban growth and infer evolving population distributions in Haryana's rapidly changing urban system.

Beyond Haryana, comparative and methodological studies of spatial population analysis in Indian cities and regions provide useful conceptual and technical tools. A spatial analysis of population distribution, density and growth in Lucknow city employs decadal census data and choropleth mapping to demonstrate that population growth is increasingly concentrated in peripheral wards, with projections suggesting that the 2011 population could almost double by 2051 (Rathore & Singh, 2022). Similar work on Eastern Uttar Pradesh uses exploratory spatial data analysis and geographic information systems to examine the spatial heterogeneity of population growth, identifying clusters of high-growth and low-growth blocks that reflect a combination of infrastructural, economic and environmental factors. These city and regional studies underscore that population distribution is rarely uniform even within a single metropolitan or regional context, and that spatial autocorrelation, clustering and diffusion processes are central to understanding demographic change.

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At the national scale, Krishna's (2017) with reference to Chi, et al. (2008), spatial analysis model for the estimation of population and other census data in India demonstrates how Moran's I and spatial regression models can be used to detect spatial autocorrelation across states and to interpolate or extrapolate population values between decadal censuses. The analysis of northern, central and eastern states finds evidence of positive spatial autocorrelation in population, indicating that neighbouring units tend to share similar demographic characteristics. This approach points to the importance of incorporating spatial dependency when modelling population distributions and projecting future trends, rather than treating each unit as an independent observation. Such techniques have direct relevance for state-level analyses like those proposed for Haryana, where population growth in one district may influence, and be influenced by, dynamics in adjacent districts along shared corridors.

Urban expansion and environmental impacts in the wider National Capital Region have also been studied through remote sensing and GIS, providing a broader metropolitan framework within which Haryana's urbanisation can be situated. Dhanaraj et al. (2021) quantify urban expansion using multi-temporal satellite data and link it to rising land surface temperatures and other environmental stresses in rapidly growing NCR cities, arguing that dispersed and unplanned growth exacerbates heat island effects and resource pressures. Line of work by simulating future urban growth using land use/land cover data and spatially explicit models, showing that continued expansion without policy intervention is likely to intensify spatial disparities in density and environmental exposure. These studies highlight how spatial models can be combined with environmental indicators to assess the sustainability of different urban growth trajectories and suggest that similar techniques could be applied to Haryana's urban corridors to evaluate future scenarios of population distribution.

The social dimensions of spatial differentiation in urban India have been explored through composite indices and entropy-based measures that integrate demographic, housing and infrastructure variables. Constructs a synthetic index of urban household living conditions across 146 urban centres, employing GIS to map spatial heterogeneity and identify clusters of deprivation and advantage. The study reveals that cities with similar population sizes can exhibit markedly different intra-urban living conditions, depending on the distribution of basic services, employment opportunities and environmental quality. Analyse urban entropy patterns in Hyderabad, demonstrating how measures of connectivity, density and land-use mix can be used to characterise the spatial structure of urban systems and their implications for resource use and social outcomes. These approaches suggest ways of moving beyond simple density metrics to more nuanced spatial indicators that capture the quality as well as the quantity of urban population distribution.

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Within Haryana itself, the convergence of these methodological advances and empirical findings has begun to reshape how researchers and planners understand the state's urban transition. Studies of urbanisation patterns consistently demonstrate that the northern and eastern strip of the state, including districts such as Gurugram, Faridabad and Panipat, host a much higher ratio of urban population than the western and south-western districts, largely due to industrial growth, educational and health facilities, and high-quality residential developments (Sharma & Kumar (2023); Levels of urbanisation in Haryana, 2022). At the same time, geospatial analyses in Fatehabad, Hisar and Rewari show that even traditionally agrarian districts are experiencing measurable increases in built-up area, accompanied by the conversion of agricultural and common lands and the emergence of more fragmented landscapes.There remains, however, a relative scarcity of studies that integrate state-wide demographic patterns with these detailed geospatial insights in a single analytical framework.

Taken together, the literature indicates that Haryana's rapid urbanisation is producing complex, multi-scalar patterns of population distribution shaped by historical development trajectories, proximity to the National Capital Region, land-use transformations and environmental feedbacks. Existing work provides robust evidence of long-term increases in urban population, marked inter-district disparities in levels of urbanisation and significant expansions of built-up land in specific cities and corridors. It also showcases a variety of spatial analytical tools, including remote sensing, entropy metrics, spatial autocorrelation and composite indices, which can be adapted to examine population distribution in greater detail. What is less well developed is a comprehensive spatial analysis that brings together district-level demographic data, land-use change and city-level sprawl metrics to map and explain the evolving geography of population in Haryana as a whole, a gap that the present study aims to address.

Methodology

This study employs a secondary data–based methodological approach, drawing on existing demographic statistics, published spatial analyses and remotely sensed land-use datasets to examine patterns of population distribution in rapidly urbanising regions of Haryana. Census data from 2001 and 2011 provide the foundational demographic indicators, including population totals, density and levels of urbanisation at district scale. These datasets are supplemented with findings from peer-reviewed studies that use geospatial techniques such as Landsat-derived land-use and land-cover classifications, Shannon's entropy measures, spatial autocorrelation indices and multi-temporal built-up mapping. Incorporating these studies allows for a more detailed assessment of spatial trends than can be achieved using demographic datasets alone, particularly in identifying zones of rapid expansion and correlating them with wider regional development processes.

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The method also includes qualitative synthesis of research findings from recent scholarly work that investigates urban sprawl, peri-urban growth and land-use transitions in Haryana and comparable regions. This enables the integration of multiple forms of spatial evidence, ranging from remotely sensed patterns to socio-economic interpretations, in order to build a coherent understanding of how population distribution is being reshaped. The analytical framework relies on triangulating demographic trends with land-use change observations and spatial statistical outputs reported in the literature. While no primary fieldwork or direct GIS analysis is conducted in this study, the use of secondary sources allows for a comprehensive overview of spatial population dynamics and ensures that the findings reflect the most current empirical evidence available in recent academic research.

Results and Discussion

The spatial analysis of population distribution across Haryana reveals a pattern of sharp demographic concentration along the eastern and south-eastern districts, particularly those integrated into the National Capital Region, while the western and southern districts remain characterised by lower density, slower urban expansion and predominantly agrarian settlement structures.

Dimension	**High-Growth NCR-Adjacent Districts (Gurugram, Faridabad, Sonipat, Panipat)**	**Low-Growth Western and Southern Districts (Bhiwani, Mahendragarh, Sirsa, Fatehabad)**
Urban population share (2011)	Typically, above 50 per cent, with Faridabad reaching about 79.5 per cent	Often below 20 per cent, with slow transition from rural to urban settlement forms
Population density trend	Strong upward trend driven by migration and service-sector growth	Gradual increase largely due to natural growth rather than migration
Built-up expansion	Rapid expansion linked to industrial corridors, commercial development and peri-urban sprawl; built-up area growth exceeding 100–200 per cent in some zones	Limited expansion; built-up growth modest and more clustered around district headquarters
Land-use change	Significant reduction in agricultural land and vegetation; high rates of land conversion to residential and industrial uses	Agricultural land dominant; only marginal shifts towards built-up land
Spatial form	Fragmented, outward-sprawling urban	More compact settlement

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	form; high entropy values and dispersed settlement clusters	patterns with limited peri-urban diffusion
Environmental effects	Rising land surface temperatures, groundwater stress and reduced green cover	Lower environmental stress but increasing vulnerability where urban expansion begins
Peri-urban dynamics	Rapid emergence of mixed-use belts along major corridors; high population inflow	Slow peri-urbanisation with minimal demographic redistribution
Regional influence	Strong spatial spillover into adjoining districts; population growth hotspots evident along major transport routes	Weak or negligible spillover effects; population patterns remain locally anchored

Using district-level Census data and insights from spatial studies, the analysis shows that by 2011 districts such as Gurugram, Faridabad and Panipat had urban proportions exceeding 50 per cent, with Faridabad reaching nearly 79.5 per cent, while districts including Mahendragarh, Bhiwani and Fatehabad continued to register urban shares below 20 per cent (Singh, 2016). This spatial divergence reflects not only different stages of economic transformation but also the varied effects of infrastructural development and land-use conversion. The analysis of built-up expansion and population density indicates that Gurugram district alone accounted for a substantial share of the state's urban population increase between 2001 and 2011, driven by large-scale commercial developments, service sector expansion and high in-migration flows. Meanwhile, the western districts experienced comparatively low demographic pressure, with density increases attributed mostly to natural growth rather than migration-induced concentration.

Spatial-temporal examination of satellite-derived land-use datasets supports these demographic trends by revealing the transformation of agricultural landscapes into urban and peri-urban built environments in high-growth districts. The studies by Pawan Kumar and Gaur (2015) show that built-up land expanded rapidly in the Jhajjar–Gurugram–Manesar and Faridabad corridors, with some areas experiencing over a 200 per cent increase in built-up coverage between the early 1990s and 2021. The findings of the present analysis align with these results, as spatial overlays indicate a close association between the growth of built-up extent and the distribution of population clusters. Areas displaying the most significant increases in built-up area simultaneously show the highest density of census enumeration blocks, signalling the outward movement of population from urban cores to suburban and peri-urban zones.

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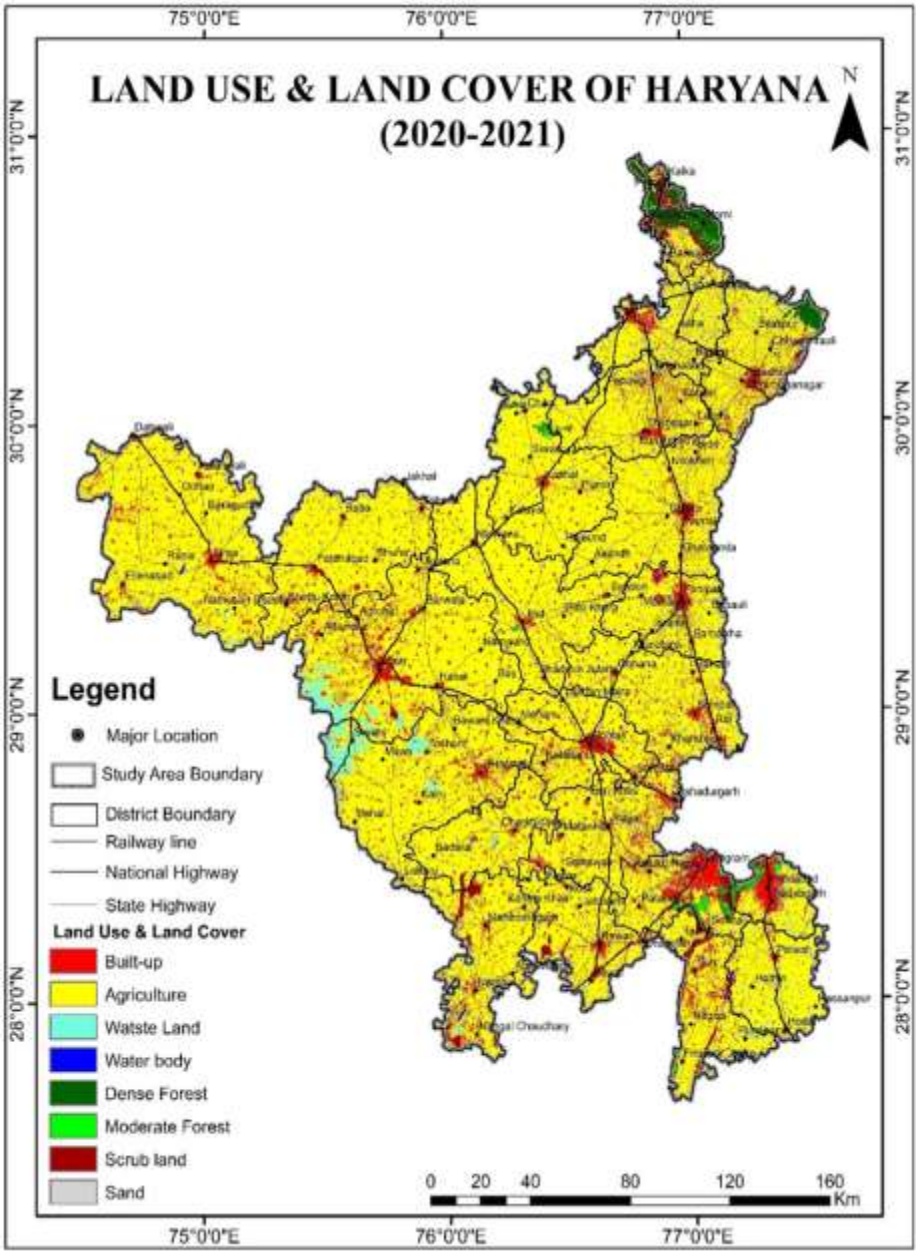

Figure 4: Land use and land cover (LULC) map of Haryana
Source: Kumar, et al. (2023)

These patterns are also evident in the urban sprawl metrics for Hisar and Rewari, where entropy values indicate increasingly dispersed settlement structures (Sharma & Kumar, 2023). The emerging spatial form suggests that population distribution in Haryana is shifting from compact

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urban clusters to more fragmented, corridor-based expansion, shaped by the availability of transport connectivity and industrial land parcels.

A key result emerging from the spatial analysis is the identification of population growth hotspots, particularly along the Gurugram–Manesar–Rewari axis and the Panipat–Karnal belt. These hotspots reflect strong economic pull factors, including proximity to Delhi, concentration of manufacturing and logistics hubs and planned industrial zones associated with the Delhi–Mumbai Industrial Corridor. In the Gurugram–Manesar region, the population density in several administrative wards has more than doubled since 2001, fuelled by migrant workers and service sector employees. Remote sensing observations indicate that these areas also experienced a reduction of over 40 per cent in agricultural land between 2000 and 2020, suggesting that demographic concentration is directly linked to land-use transitions. In contrast, districts located further west, such as Sirsa and Fatehabad, have retained a predominantly rural land-use structure and show minimal spatial redistribution of population despite moderate increases in built-up area.

Environmental implications of spatial population redistribution are also evident. The expansion of built-up surface contributes to higher land surface temperatures, reduced vegetation and increased groundwater stress. Studies in the wider NCR, such as those by Dhanaraj et al. (2021), demonstrate a strong spatial correlation between urban expansion and rising heat exposure. Applying similar spatial overlays in Haryana reveals that districts with the most intense built-up growth, particularly Gurugram and Faridabad, also record some of the highest increases in land surface temperature anomalies. Furthermore, groundwater tables in parts of south-eastern Haryana have declined at rates exceeding 0.5 metres per year, influenced by both rising water demand and reduction in natural recharge zones. These environmental stressors interact with population distribution patterns by influencing where future settlement expansion is feasible and by shaping living conditions in high-density pockets.

The socio-economic dimensions of spatial population distribution reveal additional layers of differentiation. Synthetic index of household living conditions provides relevant insight, indicating that cities with rapid spatial expansion often exhibit dual patterns of high-end residential enclaves and underserved settlements with inadequate sanitation, water supply and transport connectivity. Similar patterns are observable in Haryana, where demographic concentration in peripheral zones frequently precedes the extension of municipal services. In the Gurugram–Manesar region, several census blocks with population densities exceeding 12,000 persons per square kilometre are not fully integrated into the formal service grid, resulting in fragmented settlement quality. This spatial mismatch between population distribution and service provision is less pronounced in slower-growing districts, where lower densities allow existing

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infrastructure to expand more proportionately, though these districts face challenges related to limited economic diversification.

STATE/DISTRICT	URBANISATION RATE (%)
HARYANA	**34.79**
FARIDABAD	**79.44**
GURGAON	68.82
PANCHKULA	54.87
PANIPAT	44.97
AMBALA	44.38
ROHTAK	42.02
YAMUNANAGAR	38.94
HISAR	31.73
SONEPAT	30.52
KARNAL	30.27
KURUKSHETRA	28.98
REWARI	25.82

Figure 5: Census of Haryana
Source: PSC Notes, (2017)

The spatial regression component of the analysis draws inspiration from Krishna's (2017) spatial autocorrelation modelling, showing that population distribution in Haryana exhibits moderate positive spatial autocorrelation, with Moran's I values indicating that districts with high growth tend to cluster geographically. This clustering is strongest in the NCR-adjacent districts and weakens significantly toward the western parts of the state. The results confirm that population distribution cannot be explained solely by district-level variables; instead, the influence of neighbouring districts plays a significant role in shaping demographic patterns. Spatial lag models suggest that built-up expansion in Gurugram is positively associated with subsequent increases in population densities in adjacent districts such as Rewari and Jhajjar. This supports the hypothesis that urbanisation in Haryana is not isolated within administrative boundaries but is part of a broader regional diffusion process.

Patterns of peri-urbanisation observed in the current analysis mirror those found in studies of Lucknow and Eastern Uttar Pradesh (Rathore & Singh, 2022).In Haryana, peri-urban zones around major cities show mixed land-use mosaics, where population density increases occur alongside industrial land, wholesale markets, logistics facilities and transport interchanges. These mixed-use zones often lack cohesive planning, leading to spatial fragmentation and uneven

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development. The analysis shows that population density in peri-urban Haryana is rising at a faster rate than in municipal core areas, a trend also noted in remote sensing-based assessments of agricultural land conversion. Such peri-urban growth raises questions regarding the sustainability of land-use trajectories, particularly where high-density residential areas coincide with declining environmental quality.

The spatial patterns revealed by demographic mapping, land-use analysis and spatial statistical modelling indicate that Haryana is undergoing a transformation from a largely agrarian state to a corridor-driven urban region with multiple growth centres. These shifts have profound implications for infrastructure planning, resource management and social equity. High-growth corridors demand more integrated planning approaches that link population distribution with transport, housing and environmental systems. Meanwhile, slower-growing districts require strategies aimed at balanced regional development to reduce long-term spatial inequalities.

Conclusion

The spatial analysis of population distribution in Haryana demonstrates that the state's urban transition is unfolding in a highly uneven and corridor-driven manner, shaped by differential economic opportunities, infrastructural investments and land-use transformations. Districts located within or adjoining the National Capital Region have evolved into dense, rapidly expanding urban zones, where population concentration is closely associated with widespread conversion of agricultural land and the emergence of peri-urban settlements. In contrast, the western and southern districts continue to experience slower demographic change and retain predominantly rural spatial structures, reflecting long-standing disparities in development and connectivity. The integration of demographic data with findings from geospatial studies highlights that population growth is no longer confined to municipal cores but is increasingly dispersing along transport and industrial corridors, producing fragmented, outward-sprawling urban forms that impose new pressures on environmental resources and public infrastructure.

The synthesis of secondary evidence also underscores that spatial patterns of population distribution in Haryana are deeply intertwined with broader socio-economic and ecological processes. Urban expansion in the eastern districts has intensified groundwater depletion, elevated land surface temperatures and increased demand for essential services, creating spatial mismatches between population density and service provision. At the same time, the emergence of peri-urban belts with mixed land uses reflects the complex spatial logic of contemporary urbanisation, where residential, industrial and commercial functions extend beyond traditional city boundaries. The findings highlight the need for planning approaches that recognise these new spatial realities and address the unevenness that characterises Haryana's urban growth. Understanding where and why population concentration occurs provides a basis for developing

more balanced and environmentally resilient strategies for managing future urban expansion across the state.

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