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Green to Grey: Spatial Transformation and Urban expansion of Panjim City -India (2003-2023)

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Abstract

Urban expansion in cities poses critical challenges to sustainability and environmental resilience. The study evaluates the spatial pattern of urban expansion and transformation of Panjim, the capital of Goa, India, from 2003 to 2023. The core focus is to analyze the transformation of green landscapes into built-up areas. Using a combined approach of geospatial techniques, demographic indicators, and the Shannon entropy index, it quantifies patterns of urban expansion and change. The research analyses changes in land use and land cover (LULC), demographic trends, and real estate values. For LULC change, Satellite imagery from IRS LISS III and LISS IV was used to map built-up areas and vegetation loss, while Shannon's Entropy Index was used to measure urban sprawl and spatial dispersion. Results reveal that as the population increases and land values rise, built-up areas increase significantly from 29.37% in 2003 to 34.10% in 2023, accompanied by a sharp decline in agricultural land and vegetation. The core areas of Panjim exhibited optimal land utilization, while peripheral areas such as Bambolim and Chimbel witnessed rapid real estate growth, indicating decentralization. Demographic estimates show a 43% rise in population from 2011 to 2025, with proportionate land value escalation, particularly in outgrowths due to rising demand. The study reveals interconnections among urban expansion, demographic change, and rising land values, highlighting the reshaping of the city and underscoring the urgent need for integrated urban policies that balance infrastructural growth with ecological sustainability.

1. Introduction

Urbanization, as a global phenomenon, is intricate and multi-dimensional across diverse disciplinary frameworks (Guevara-Rosero et al., 2019). Urbanization as a process undergoes dynamics in population, infrastructure and land use/land cover (LULC). Therefore, each discipline frames urbanization through its own analytical lens. The geographers emphasize spatial concentration and expansion, and their implications (Knox & Marston, 2007). Sociologists highlight transformations in social structures and societal dynamics (Wirth, 1938) while economists interpret urbanization as an engine of economic growth, catalyzing productivity, innovation, and agglomeration economies (World Bank, 2009). In recent years, the environmental dimension of urbanization has been critically debated by natural scientists, emphasizing the ecological costs of rapid urban expansion and its implications for resilience and sustainability (Grimm et al., 2008). Considering the above discussion, the disciplinary orientation thus shapes the conceptualization and measurement of urbanization, but there is a need to integrate socio-ecological development to achieve sustainable urban development (Shawly, 2022).

Accordingly, the core essence of the present research is to understand the dynamics of urban sprawl, which serves as a diagnostic and analytical tool for examining the spatial pattern of urban growth, where both urban sprawl and peri-urbanization are critical aspects of modern urban expansion (Getu & Bhat, 2021), driven primarily by population growth and the overspill of population into surrounding regions (Bruegmann, 2005; Ewing, 1997). Therefore, in this context, in the 21st century, urban sprawl has arisen due to a new approach of people's desire to live in spacious large houses and open areas, a tendency towards comfort (Brueckner, 2000) while this would be much attributed to developed nations.

On the contrary, in less developed countries like India, urban sprawl is characterized by the unplanned and uncontrolled expansion of cities, leading to the encroachment of agricultural land, the depletion of natural resources, and the haphazard development of urban infrastructure (Sharma et al., 2024). It is driven by multitude factors, including population growth, rural-to-urban migration, ineffective urban planning, and inadequate land-use regulations (Chhangani, 2023). Alshammari et al. (2022) and Bhagat (2014) argue that inadequate urban planning, coupled with population pressure, intensifies urban sprawl, thereby reinforcing unsustainable development.

The transformation of Indian metropolises signifies this trend; for instance, Bangalore, the "Garden City", has become a sprawling metropolis with worsening traffic congestion and pollution (Kaushik & Kakoty, 2025). This impact has now trickled down to smaller cities too. Margao and Panjim, Goa, are experiencing accelerated sprawl, in which anthropogenic pressures increasingly threaten fragile coastal ecosystems (Ferro & Sawant, 2020; Vaz et al., 2017). Across urban landscapes, convergent patterns of environmental degradation highlight the urgency of adopting sustainable planning frameworks. Addressing the challenges of sprawl requires a multidisciplinary approach that integrates efficient land-use regulation, enhanced public transportation systems, and eco-sensitive infrastructure to mitigate adverse socio-ecological impacts. Therefore, this study investigates the implications of urban expansion on land use and land cover dynamics, population redistribution, and land value increases, thus situating urban expansion within the context of sustainability and resilience.

In the contemporary research scenario, especially in the post-globalization era, the connections between the core and the periphery have emerged at the forefront of urbanization. Urban cores have become more interconnected through interlinkages that have transformed core-periphery relations, thereby driving the socio-dynamics within the urban framework (Chakravorty, 2003) However, Hernández-Moreno & Reyes-Paecke, (2018) argue that the core has significant resources concentrated in the core region, while the periphery tends to be overcome by underdevelopment. Moreover, this calls for better urban planning and sustainable core-periphery (Suburban) development. Although extensive research on urban sprawl has been carried out globally, with core-periphery dynamics in focus. Here, it needs to be reemphasized that there is an unseen gap, contextualized in the studies that explore the process of manifesting referencing in medium-sized cities.

The present study evaluates the spatial pattern of urban expansion and transformation of Panjim, the capital of Goa, India, from 2003 to 2023. With a core focus on Land use change, population overspill and changing land values. Therefore, the essence of the study lies in its integrated assessment of urban expansion from two broad perspectives. The first employs geospatial techniques and Shannon entropy-based urban sprawl analysis, while the second focuses on demographic dynamics and land value trends. Therefore, the study contributes to the urban planning literature by linking land-use change, population dynamics, and real estate pressures within a unified analytical framework.

This study aims to examine the spatial dynamics of urban expansion in Panjim, the capital city of Goa, India, with a particular focus on its impacts on land-use patterns, population distribution, and land-value trends over the past two decades. The core focus is the assessment of the spatial urban expansion from 2003 to 2023. Therefore, the objectives are (1) Assessing the spatial expansion of Panjim and the changing landscape of land use & land cover and (2) Evaluate Growth Patterns in Relation to Population Density & Land Value of Panjim (core) and Outgrowths (Periphery).

2. Data and Methods

2.1. Study Area

Goa, the second smallest State of India, is the most urbanized State in India, and its urban landscape is dominated by three major urban agglomerations (UAs), i.e., Panjim, Margao, and Mormugao (Sawant, 2022a). Panjim, the capital city, is situated on the banks of the River Mandovi and has evolved into a modern capital while retaining its colonial heritage (Ahmed & Shankar, 2012). Moreover, under the governance of the Corporation of the City of Panjim (CCP), it serves as an administrative and cultural hub for Goa. Presently, it covers an area of 56 sq kms encompassing Panjim Municipal Corporation and Outgrowth (Figure 1).

Historically, during the Portuguese colonial era (1510-1961), Panjim (then called Nova Goa) was designated as the capital of Portuguese India in 1843, replacing Old Goa (Velha Goa), which had declined due to repeated epidemics and unsanitary conditions. The Portuguese provided the impetus for it to become the most urbanized center (Sawant, 2022b). In the post-liberation era (1961 onwards), Panjim recorded significant infrastructural advancements, enabling it to emerge as the growth center in the State (Rath, 1998). The development of the city has been accelerated and enhanced through the AMRUT (Atal Mission for Rejuvenation and Urban Transformation) scheme and under the SMART city program. Presently, the city features a diverse urban landscape that includes colonial heritage areas such as Fontainhas, planned residential colonies, government buildings, and reclaimed-land developments (Ahmed & Shankar, 2012) along with a venue for an international film festival, tourism related activities and a commercial hub. Its unique mix of colonial architecture, tourism-driven economy, and recent infrastructural developments and smart city initiatives make it a significant urban center for examining the processes and impacts of urbanization. The expansion of built-up areas into surrounding zones has not only altered land use patterns but also threatened the integrity of cultural landscapes and traditional urban morphology.

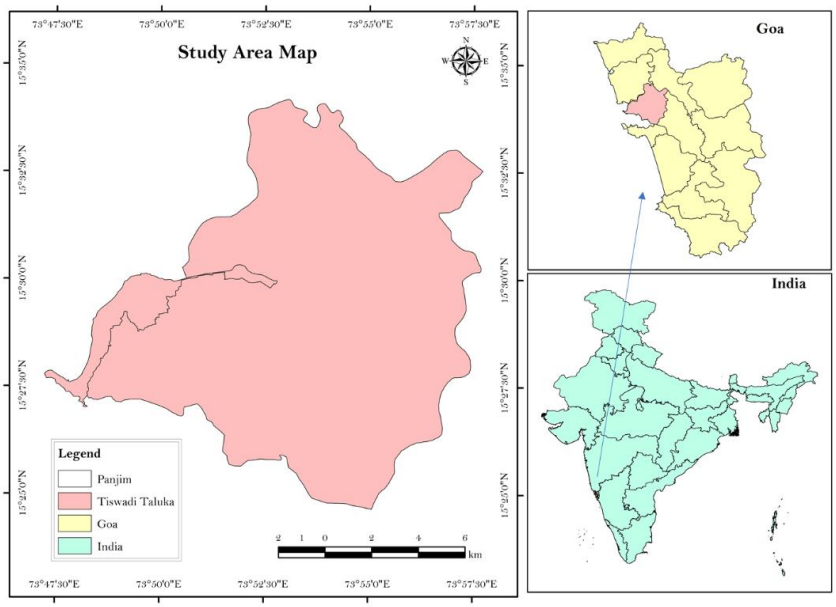


Figure 1. Area of Study

2.2. Data

This Detecting and measuring urban sprawl involve an array of approaches, including scale analysis, remote sensing (RS) and GIS techniques, landscape metrics, entropy indexes, and typological classifications. However, in developing nations, limited access to reliable data poses a major challenge to effective assessment

methods tailored to such constraints (Chettry, 2023; Kumar et al., 2025). Considering the limitations, the present research adopts a mixed-method approach by integrating geospatial analysis with demographic and economic data to evaluate the impact of urban sprawl over two decades (2003- 2023). The research employs secondary data sources, such as satellite imagery from the IRS LISS III and LISS IV, to assess temporal changes in land use and land cover (LULC) for 2003, 2013, and 2023 (Table 1).

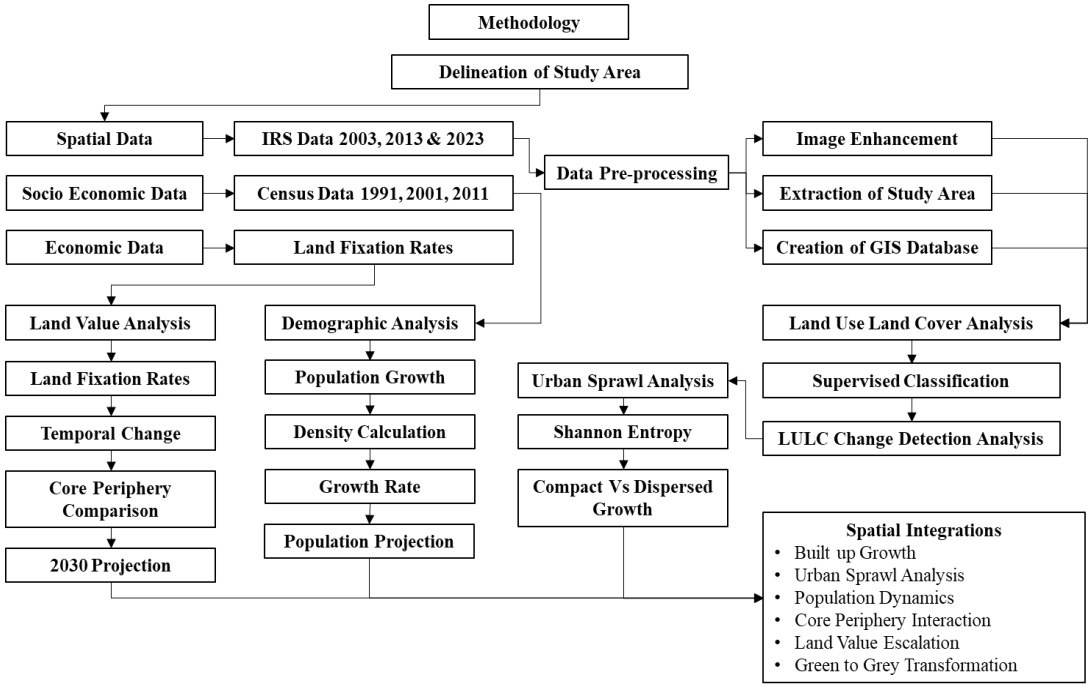
Table 1. Satellite Details

Sr. No	Satellite	Month	Sensor	Spatial Resolution
1	Resourcesat1	December 2003	LISS III	23.5
2	Resourcesat2	November 2013	LISS IV	5.8
3	Resourcesat2	November 2023	LISS IV	5.8

Source: Analysis, 2025

For spatial data analysis, QGIS 3.34.12 and ArcGIS 10.8 were used to perform the analysis and extract the necessary outputs. A supervised classification method was employed to delineate urban, vegetation, water, and other land use categories. A change detection analysis was performed to identify the spatial and temporal dynamics of urban sprawl. For validation, a confusion matrix and kappa statistics were performed (Table 4).

To measure the degree and dispersion of sprawl, the Shannon Entropy Index was derived. It measures the degree of spatial disorder in urban growth, helping to determine the compactness and dispersion. Urban sprawl can also be measured using single and multi-index methods. The single-indicator approach tracks population, land, or both, using density and growth-rate metrics (Shi et al., 2023). Sultana & Weber (2014) suggest key indicators, including population density, residential density, employment density, urban land growth rate, and urban population growth rate. Accordingly, to validate urban sprawl in the present research, a multi-index method has been applied. Demographic changes were analysed through population size and density trends from census and district handbooks (1991, 2001, and 2011). Additionally, land fixation pricing was extracted from the Goa Gazetteer (2009, 2013, 2020) for regional assessment (Figure 2).



Source: Analysis, 2025

Figure 2. Methodology Flow Chart

3. Results and Discussion

Panjim is the cynosure due to its status as the capital city and the only first-order settlement in the State (Morkar & Mulimani, 2014). The city being multifunctional, its interlinkages with the surrounding areas are quite significant. Therefore, the dynamics of centripetal and centrifugal forces are evident in land transformation and socio-economic variables. Accordingly, the following research investigates variation in land use and land cover change, core and periphery densities, and land values over time.

Population numbers and densities are critical for assessing city growth and expansion, which can lead to urban sprawl. Therefore, demographically in 1960, just prior to the liberation of Goa from the yoke of the Portuguese, the population of Panjim was 21,894, concentrated in an area of 4.2 sq kms (Estado da Índia, 1961) As developments were initiated, the town also experienced population growth. It was designated as a city in 2016, from a Class III town (GOI, 2005). Presently, the Municipal Corporation and Outgrowths (M.CI+ OG) of Panjim is composed of Panjim City, Taleigao, and Merces, whereas UA comprises Chimbel, Calapur, and Bambolim Murda (Table 2).

Table 2. Demographic Attributes of Panjim

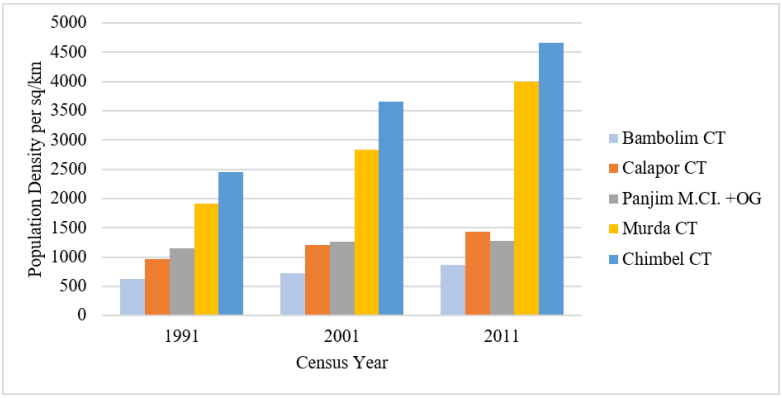
		Population			Population growth (%)	Population density (km²)			Population density Rate of Change (%)
	Area in km²	1991	2001	2011	(1991-2011)	1991	2001	2011	1991-2011
Panjim M.CI. +OG	55.55	64,069	70,078	70,991	9.75	1,153	1,262	1,278	110
Chimbel CT	3.28	8,024	11,984	15,289	47.52	2,446	3,654	4,661	190
Calapor CT	9.82	9,519	11,830	14,077	32.38	969	1,205	1,434	147
Bambolim CT	7.94	4,952	5,785	6,885	28.08	624	729	867	138
Murda CT	1.88	3,587	5,314	7,517	52.28	1,908	2,827	3,998	209
Total	78.47	90,151	99,677	114,759	21.54	1,149	1,270	1,462	127

Source: Census of India (1991, 2006, 2014)
*Note: *2021 census not available*

Overall, the population of Panjim UA increased from 90,151 to 114,759 over two decades, corresponding to a growth rate of 21.54 percent. The increase in population density was markedly greater in peripheral areas than in the urban core. Notably, the census towns of Chimbel and Murda recorded population growth rates of 47.52% and 52.28%, (see Table 2), highlighting the outward expansion of urban development and the redistribution of population from the city center to surrounding peripheral settlements.

A rising density level suggests a consistent increase in both absolute population and land-use intensity, revealing urban sprawl and infrastructural stress. The estimated population of Panjim in 2025 is around 165,000, based on official government projections, marking a sharp increase of more than 43% compared to 2011.The corresponding population density is expected to increase to 2,163 persons/km² which indicates accelerated urban compaction and reduced availability of space. This trend signifies urban sprawl, in which peripheral areas accommodate residential and commercial growth, likely driven by affordability and infrastructure expansion.

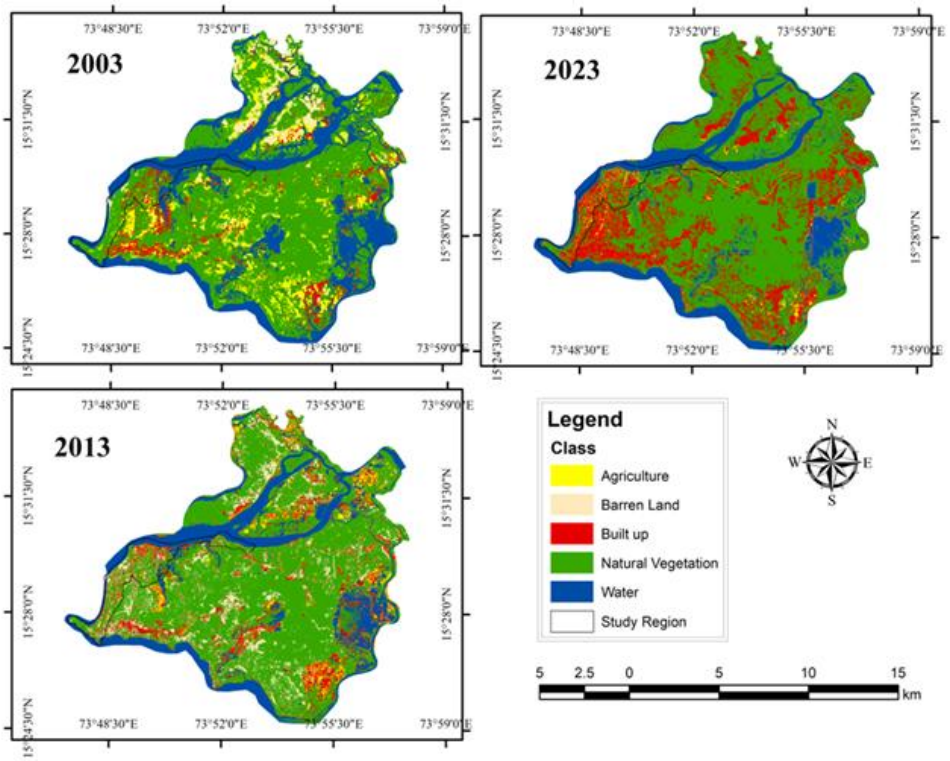
An exponential population growth, coupled with the demand for space, has resulted in urban sprawl. The direct implication was the manifestation of the change in land use and land cover. Therefore, to gauge LULC changes on a broader scale over a two-decade period (2003 to 2023) in Tiswadi taluka to assess the impact of sprawl, an assessment has been undertaken. Broadly, LULC has been categorized into five Major Classes that delineate natural and human interference, including agriculture, barren land, built-up areas, vegetation, and water bodies (Figure 3).



Source: (Census of India, 1991 - 2011)

Figure 3. Population Density of Panjim Urban Agglomeration

The demographic expansion in Panjim and its surroundings increases housing demand and places additional pressure on infrastructure, public services, and environmental resources. Therefore, population growth acts both as a driver and a consequence of urban expansion, reinforcing the cycle of land conversion and urban sprawl. The ever-expanding Panjim and its peripheries call for an investigation into the changing trends in land use and land cover. Universally, it has been observed that as cities expand, they usually encroach on agricultural peripheries for infrastructural development (Azadi et al., 2011). In this case the focus does not restrict only to land use land cover change (Figure 4) but also to its implications on land values, for this purpose along with the Panjim Corporation whole of Tiswadi Taluka has been considered. Panjim, being the State capital, has a shadow effect not only on the city and its periphery but beyond.



Source: Analysis, 2025

Figure 4. Land Use Land Cover Map Panjim +UA+ OG 2003, 2013, 2023

For the purpose of analyzing the dynamics of land use land cover two decades (2003-2023) have been considered. Standard NRSC level 1 classification (Pandi et al., 2022) has been applied. As the built-up area has increased, other sectors have declined over the last two decades. Agricultural land represents a drastic decline from 1/10th to 2.31% in 2023.

Table 3. Land Use Land Cover Classification of Tiswadi Taluka

Class	Years			Decadal Change		
	Area (%)			Change (%)		
	2003	2013	2023	2003 - 2013	2013 - 2023	2003 - 2023
Agriculture	9.48	4.99	2.31	-4.48	-2.68	-7.17
Barren Land	3.50	8.64	9.24	5.14	0.60	5.74
Built up	5.57	9.47	20.06	3.90	10.59	14.49
Natural Vegetation	56.97	58.97	50.30	2.00	-8.67	-6.67
Water	24.48	17.92	18.09	-6.56	0.17	-6.40

Source: Analysis, 2025

This reflects urban encroachment, or shift to other land uses, possibly linked to peri-urban farming or reclamation. Simultaneously, the share of Barren land has increased from 3.50% to 9.24% in 2023. Indicating changing landscapes, deforestation, or unplanned development, with minimal recovery efforts (see Table 3).

A cursory glance at the LULC change over the two decades shows an increase in built-up and barren land. In contrast, there is a subsequent decline in agricultural land, waterbodies and natural vegetation. Built-up shows an increasing trend between the two decades. The rate of land transformation to built-up is higher in the last decade (2013-2023) than in the previous decade. The issue is, where is the transformation occurring? The outskirts of Panjim, as a continuum, are witnessing the land-use change. This reflects urban sprawl, infrastructure development, and population pressure, particularly over the last decade, as well as a preference for living in peri-urban areas. Barren land also shows an upward trend as demand for infrastructure development escalates; therefore, agriculture has been discontinued to accommodate prospective real estate development.

In the context of vegetation, Panjim and the surrounding areas are still remarkably "Green carpeted", though there is a decline from 56.97% in 2003 to 50.30% in 2023; the "green lungs" still mark the urban landscape. The proportion of land under water bodies declined overall (Table 3). In Panjim, land reclamation is occurring at the expense of wetlands, reducing the number of water bodies in the study region. The vast Khazan, comprising agricultural and wetland areas in Panjim, Chimbel, Taleigao and Ribandar, was a contiguous ecosystem before it was severely bisected by landfilling for a network of roads, highways and other infrastructure (Fernandes, 2021).

To sum up, the data indicate an overall increase in built-up, with a corresponding decline in agriculture and natural vegetation, especially after 2013. This pattern is consistent with trends observed in rapidly urbanizing regions, where ecological resources are under pressure from infrastructure expansion. This temporal analysis of LULC reveals trends of urbanization, ecological stress, and land transformation over two decades. The most striking change observed in the built-up area was a geometric increase from 5.57% in 2003 to 20.06% in 2023, a rise of over 260%. The increase clearly illustrates intensive development in urban areas, including residential, commercial, and institutional growth. It highlights Panjim Urban Agglomerations and Outgrowths transforming into a dense urban cluster, mainly influenced by its administrative importance, population influx and tourism development.

Land use and land cover (LULC) classification for the years 2003, 2013, and 2023 reveals consistent overall reliability with Kappa statistics above 0.85 in all three-time scales. Indicating a strong period, relationship between classified and reference data. All the classes, maintain a higher user's accuracy and showing improvement in producer's accuracy reflecting reliable classifications. Natural vegetation also showed

progressive improvement, with user's accuracy rising from 81.5% in 2003 to 92.7% in 2023, although producer's accuracy slightly declined in 2023, suggesting occasional Overall, the results reveals that classification accuracy has generally been stable and reliable, challenges remain in accurately distinguishing agriculture from natural vegetation and built-up areas.

Table 4. Confusion Matrix Accuracy Assessment for 2003, 2013, 2023

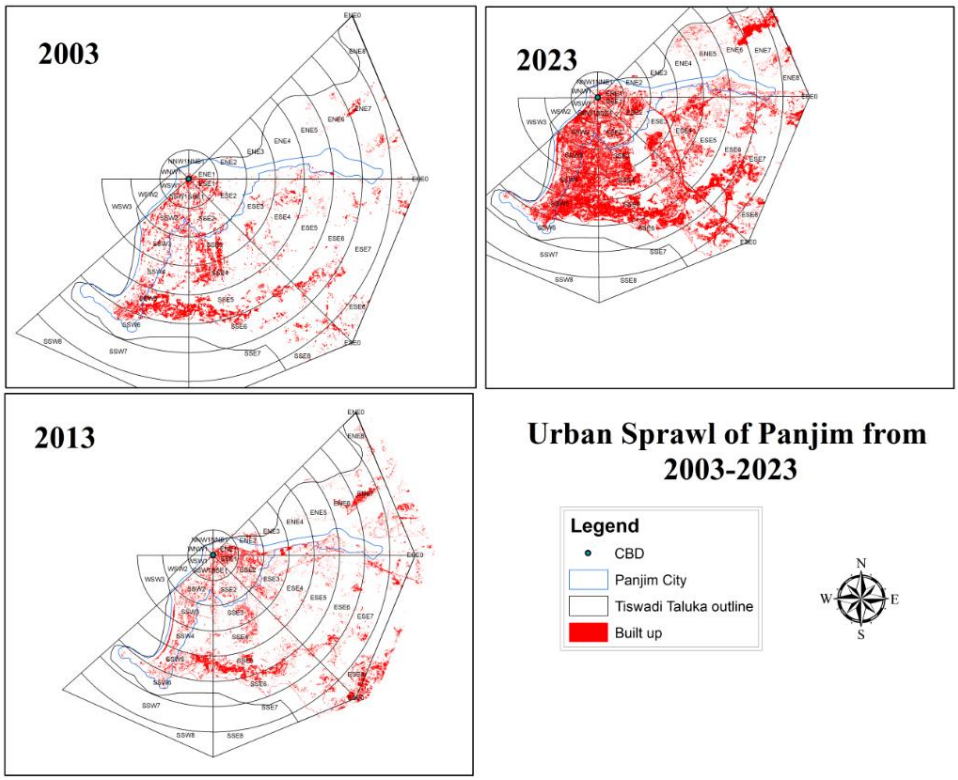
	Class Value	Water	Natural Vegetation	Built up	Agriculture	Barren Land	Total	U_Accuracy	Kappa
2003	Water	**22**	0	0	0	0	22	1	
	Natural Vegetation	5	**22**	0	0	0	27	0.815	
	Built up	0	3	**23**	0	0	26	0.885	
	Agriculture	0	0	1	**14**	0	15	0.933	
	Barren Land	0	0	1	0	**9**	10	0.9	
	Total	27	25	25	14	9	**100**	0	
	P_Accuracy	0.814	0.88	0.92	1	1	0	**0.9**	
	Kappa								**0.871**
2013	**Class Value**	**Water**	**Natural Vegetation**	**Built up**	**Agriculture**	**Barren Land**	**Total**	**U_Accuracy**	**Kappa**
	Water	**35**	0	0	0	0	35	1	
	Natural Vegetation	1	**40**	0	2	1	44	0.909	
	Built up	0	1	**5**	0	0	6	0.833	
	Agriculture	0	0	0	**8**	2	10	0.8	
	Barren Land	0	0	0	0	**5**	5	1	
	Total	36	41	5	10	8	**100**	0	
	P_Accuracy	0.972	0.975	1	0.8	0.625	0	**0.93**	
	Kappa								**0.897**
2023	**Class Value**	**Water**	**Natural Vegetation**	**Built up**	**Agriculture**	**Barren Land**	**Total**	**U_Accuracy**	**Kappa**
	Water	**29**	0	0	0	0	29	1	
	Natural Vegetation	1	**38**	0	2	0	41	0.927	
	Built up	0	2	**18**	1	0	21	0.857	
	Agriculture	0	1	1	**8**	0	10	0.8	
	Barren Land	0	1	0	0	**9**	10	0.9	
	Total	30	42	19	11	9	**111**	0	
	P_Accuracy	0.967	0.905	0.947	0.727	1	0	**0.919**	
	Kappa								**0.891**

Source: Analysis, 2025

The land-use and land-cover analysis reveals a noticeable transformation of Panjim's landscape, predominantly from green spaces toward increasingly built-up surfaces, over the last two decades. The built-up area increased from 5.57% in 2003 to 20.06% in 2023, reflecting a more than threefold increase in urbanised land. Simultaneously, agricultural land declined from 9.48% to 2.31%, while natural vegetation decreased by 6.67%.

These changes indicate a typical pattern of urban expansion in which productive and ecological landscapes are progressively converted into residential, commercial, and institutional uses. Similar trends have been reported in rapidly urbanising Indian cities such as Bengaluru and Pune, where urban growth has resulted in significant reductions in agricultural and vegetated land cover (Bharath et al., 2018; Butsch et al., 2017; Sheladiya & Patel, 2023). The findings further support observations by Vaz et al. (2017), urban growth in Goa increasingly extends beyond traditional city limits into surrounding peri-urban areas.

The transformation from green to grey landscapes is particularly significant in a coastal heritage city such as Panjim, where environmental resources are limited and ecosystem services are essential for climate resilience. The reduction of vegetation cover and wetland-associated landscapes may increase vulnerability to urban heat island effects, flooding, and biodiversity loss. Therefore, the observed land transformation raises concerns regarding the long-term sustainability of urban growth within ecologically sensitive coastal regions (Prabhu Gaonkar et al., 2022).



Source: Analysis, 2025

Figure 5. Urban Sprawl of Panjim (2003 - 2023)

Urban expansion of Panjim city has geographical limitations. Being flanked by the River Mandovi and the Arabian Sea on the northern and western frontiers, the sprawl is directed towards the south and partially East. This is mainly along the transport arteries towards two important cities, Margao and Ponda. The emergence of educational institutions in Cujira, the development of healthcare infrastructure in Bambolim, and improved transportation connectivity have transferred the pressure from the core towards the periphery. These developments have reduced dependence on the traditional city centre and encouraged outward expansion. Similar patterns have been observed in medium-sized cities across Asia, where infrastructure investments stimulate peri-urban growth and alter traditional core-periphery relationships (Tayi et al., 2025).The area to the South of the city has undergone massive transformation over the decades due to demand and investment in infrastructure, coupled with improved connectivity. To validate the rate of urban sprawl, the degree has been measured using Shannon Entropy (see Figure 5).

According to Yeh & Li (2001) entropy values approaching one indicate highly dispersed urban development, whereas lower values suggest compact urban growth. The values observed for Panjim are considerably high in both years, suggesting that urban sprawl has been a characteristic of the city. However, the increase during the study period indicates that urban development has progressively expanded into peripheral areas rather than remaining concentrated within the city core.

Entropy increased over decades from 4.353 in 2003 to 4.556 in 2023. Indicative that urban built-up areas have witnessed spatial dispersion in 2023. A higher normalized entropy value indicates that the built-up has spread more evenly across zones, reducing concentration in the core areas. In 2003, lower entropy depicts a more compact or clustered urban built-up, emphasizing the core zones. Urban sprawl likely increased over the past 20 years due to population growth, infrastructure expansion, and planning policies.

Table 5. Degree of Level of Urbanisation Using Shannon Entropy

Year	Shannon Entropy (H)	Normalized Entropy (H_norm)	Number of Zones (n)
2003	4.353	0.856	34
2023	4.556	0.888	34

The Shannon Entropy analysis reveals a transition from a relatively compact urban form concentrated at the core of the city limits in 2003 (H_norm = 0.856) to a more dispersed, sprawled pattern by 2023, driven by policy planning and the upgradation of urban infrastructure and public utility services (H_norm = 0.888) (see Table 5). The Shannon Entropy demonstrates a gradual shift from compact urban development toward a more dispersed urban structure. The normalized entropy value increased from 0.856 in 2003 to 0.888 in 2023, indicating greater spatial dispersion of built-up areas across the study region. The findings align with contemporary urban sprawl that emphasizes infrastructure-driven decentralization rather than purely population-driven expansion. Consequently, the urban structure of Panjim appears to be evolving from a compact administrative city into a functionally integrated urban region.

Urban sprawl inflates peri-urban land prices, reinforcing expansion (Mukherjee & Panda, 2024). Therefore, the third section of the present research attempts to analyze land value pricing from 2009 to 2020. The focus is on correlating and evaluating the dynamics of land pricing with the increasing demand for infrastructure development, largely driven by urban sprawl. The land rate of the study region, Panjim and its surroundings, from 2009 to 2020 reveals significant trends in urban development and real estate dynamics. The core of Panjim City, i.e., Wards 1–16, constantly had the highest land rates, which increased from ₹2,500 in 2009 to ₹6,000 by 2020, representing a 240% rise and reaffirming its role as the urban core. Likewise, Panjim City-II Wards 17 & 18 and Taleigao showed the same growth rate of 140%, though at slightly lower values, highlighting their steady but secondary role in the real estate landscape. Though the core city of Panjim has the highest land value, the rate of change is insignificant as compared to the outgrowths and the census towns within the city corporation. Applying the Bid Rent Theory Chidi (2019) it is indicative that land prices are highest in the core and gradually decline towards the periphery.

Table 6. Land Fixation Rates of Panjim and Surroundings

Land Rates in Panjim and Surroundings (₹/m²)					
Location	**2009**	**2013**	**2020**	**% Rate of Change from 2009-2020**	**Projected Land Rate for 2030**
Panjim City - (Ward Nos. 1,2,7,8,9,10,11,12, 13,14,15 & 16)	2,500	5,000	6,000	240	7,200 – 8,500
Panjim City-II (Ward No. 17 & 18)	1,500	3,000	3,600	240	4,300 – 5,000
Taleigao	2,000	4,000	4,800	240	6,500-7,500
Bambolim	500	3,000	3,600	720	22,000 – 24,500
Chimbel	500	3,000	3,600	720	22,000 -24,500
Cujira	500	3,000	3,600	720	22,000 -24,500

Source:(Dept of Goa Gazetter, 2009, 2013, 2020)

The most noticeable changes occurred in Bambolim, Chimbel, and Cujira, where land rates surged from ₹500 to ₹3,600, a massive 720%. This steep growth suggests that these peripheral areas, once undervalued, have rapidly urbanized, likely due to increased demand for land for infrastructure development and housing, as well as spillover from Panjim (Table 6). The uniform growth of villages towards the periphery indicates a broader pattern of urban sprawl and spillover development. Shifts underline the urgent need for sustainable urban planning and infrastructure support to ensure balanced growth, particularly in newly developing zones. Overall, Panjim land rate trends between 2009 and 2020 reflect a transformation from a concentrated urban centre to a more dispersed and integrated metropolitan region. Though Panjim remains the most populous, the rate of change indicates that the outskirts (outgrowth) are growing faster than Panjim. Multiple factors have contributed to urban sprawl over the last decade.

In 2014, the Government of Goa allotted land at Cujira, Bambolim, on a long-term lease to decongest Panjim city and to provide modern infrastructure for schools. Subsequently, development occurred, thereby increasing demand, and the implications were an increase in land value and a change in land use (Verma, 2015). Land rates in Bambolim, Chimbel, and Cujira are projected to rise sharply in 2030 (₹22,000+), reinforcing their transformation into high-value urban zones. Panjim's core will see steady appreciation (₹7,500) but will remain less volatile. Panjim remains the premium location but shows stable appreciation trends rather than drastic spikes. Bambolim, Chimbel, and Cujira have evolved into rapidly growing real estate hotspots, demanding better infrastructure planning. Urban expansion pressure is evident in peripheral locations, signaling a need for balanced growth strategies.

The economic dimension of Panjim's core continues to maintain the highest absolute land values, and the peripheral settlements of Bambolim, Chimbel, and Cujira recorded the highest rates of increase between 2009 and 2020. These areas experienced an increase of approximately 720%, significantly exceeding the growth observed within the city centre. The rate of rapid appreciation of land values in peripheral areas reflects changing patterns of urban investment and residential preferences. Improved infrastructure, educational institutions, healthcare facilities, and transportation connectivity have transformed these localities into attractive development corridors. This process is consistent with core-periphery theory, which suggests that growth pressures originating in urban cores eventually diffuse into surrounding areas. Panjim is experiencing a transition from a monocentric urban structure toward a more polycentric form of development.

4. Conclusion

This study reveals a strong interrelationship between demographic growth, land-use transformation, and urban expansion in Panjim. Population growth has increased the demand for residential, commercial, and institutional land, thereby intensifying pressure on available urban space. As demand for land increased, land values in the city core rose substantially, making central locations less affordable and encouraging development in peripheral areas such as Bambolim, Chimbel, and Cujira. The expansion of infrastructure and services in these outgrowths further accelerated their attractiveness as investment and settlement destinations. Consequently, large patches of agricultural land and natural vegetation were transformed into built-up areas, resulting in a progressive transformation from green landscapes to grey urban surfaces. This process is reflected in the increasing Shannon Entropy values, which indicate a shift from relatively compact development towards a more dispersed pattern of urban growth. The study therefore demonstrates that urban sprawl in Panjim is not merely a spatial phenomenon but the outcome of interconnected demographic, economic, and land-use dynamics that are reshaping the structure and sustainability of the urban region. The study contributes to the understanding of urban expansion in medium-sized heritage cities by demonstrating how demographic growth, land-market dynamics, and spatial transformation interact to shape contemporary urban development. Unlike many studies focused on metropolitan regions, the findings highlight the unique challenges faced by coastal heritage cities where development pressures must be balanced with environmental conservation and cultural preservation.

5. Suggestion

The findings of this study underscore the urgent need for integrated urban planning and rational land-use policies to address the challenges associated with urban sprawl and to promote balanced and sustainable development. Policy interventions should emphasize the implementation of GIS-based monitoring systems to track land-use change, ecological degradation, traffic congestion, and housing shortages, thereby supporting evidence-based decision-making and timely interventions. More broadly, the study provides valuable insights into urbanization processes in emerging Indian cities, offering a useful framework for understanding and mitigating the adverse impacts of rapid and uncontrolled urban growth. Proactive governance, resilience-oriented policies, and sustainability-focused planning strategies, including the preservation of green spaces, the development of planned satellite townships, and improved urban connectivity, are essential to ensuring balanced regional development. Future research should incorporate high-resolution satellite imagery, predictive urban growth modeling, and climate-resilience indicators to better understand the long-term implications of urban expansion and to strengthen evidence-based planning for sustainable urban futures.

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