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# RESEARCH ARTICLE

## ASSESSMENT OF LAND USE LAND COVER CHANGES IN PRAYAGRAJ CITY AND ITS IMPACT: A SPATIO-TEMPORAL ANALYSIS

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## ABSTRACT

Urbanization has significantly altered the landscape of Indian cities, and Prayagraj is no exception. This study examines Land Use- Land Cover (LULC) changes in Prayagraj city over a 32-year period between 1991 to 2023 using geospatial techniques. By comparing satellite-derived maps and classified LULC categories using GIS, the study quantifies the extent and pattern of urban expansion while identifying the sectors most affected by this transformation. The findings reveal a sharp increase in built-up areas—from 52.5% in 1991 to 77.5% in 2023—accompanied by a corresponding decline in vegetation, open land, and agricultural zones. These shifts are closely linked to population growth, infrastructure development, and socio-economic changes.The study further interprets the key drivers behind these transformations and discusses the spatial patterns of land conversion. Based on these insights, the paper provides targeted recommendations for sustainable urban land management, emphasizing compact city planning, green infrastructure, strict land-use regulation, and the integration of geospatial monitoring in urban policy frameworks. The research highlights the urgent need for proactive planning to ensure that urban growth in Prayagraj remains ecologically and socially balanced.



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# INTRODUCTION

Land Use Land Cover changes have emerged as one very critical area in contemporary urban and environmental research studies. These transformations, driven by both anthropogenic and natural factors, significantly influence ecological sustainability, urban growth dynamics, resource availability, and land degradation (Lambin *et al*., 2001). In rapidly urbanizing countries like India, the transition from agrarian land uses to built-up areas has intensified over the past few decades, reshaping the spatial and functional organization of cities. Tracking LULC changes is essential for understanding urban sprawl, monitoring environmental degradation, and guiding sustainable urban planning practices. From providing habitats for diverse flora and fauna to supporting agriculture, infrastructure, and urban settlements, land resources play a pivotal role in sustaining life and facilitating human well-being (Vlek *et al*., 2017).LULC changes has come up as a critical area of geographical and environmental research due to its far-reaching implications on urban development, agricultural productivity, hydrology, and climate systems. While "land cover" refers to the physical and biological surface of the land (such as vegetation, water, or built-up surfaces), "land use" denotes the human purpose or intent applied to these surfaces (such as residential, commercial, or agricultural use) (Meyer & Turner, 1994).Numerous scholars have emphasized that understanding LULC dynamics is essential for sustainable spatial planning and resource management. Lambin *et al*. (2003) argue that land use changes are driven by complex interactions between biophysical conditions and socio-economic forces, including population growth, urbanization, and technological advancement. This aligns with Turner *et al*.'s (2007) notion of LULC as both a cause and consequence of environmental change, where urban sprawl and land conversion serve as indicators of anthropogenic pressure. Geographic Information System (GIS) and remote sensing technology have transformed the research of LULC changesby enabling consistent, large-scale, and long-term observations. Jensen (2005) notes that satellite data from platforms like Landsat provide cost-effective and reliable means to classify land cover types, monitor transitions, and detect change patterns. These tools allow for continuous monitoring of land surfaces and the development of thematic maps that support planning, policy-making, and academic research (Rawat & Kumar, 2015). By integrating satellite imagery and geospatial analysis, researchers can delineate how landscapes transform due to demographic pressures, infrastructural developments, and administrative decisions. Urban centers in India have undergone unprecedented growth over the last few decades,

and Prayagraj is no exception. The time frame from 1991 to 2023 encapsulates three key decades of India's post-liberalization era, marked by increased economic activities, infrastructure development, and urban expansion.

**Study Area:** The historic city of Prayagraj, formerly known as Allahabad, is one of India's holiest cities. The city occupies an area of 75 square kilometres. The research area is located in the southern region of Uttar Pradesh, India, and is bounded by latitudes 25° 27′ to 25° 45′ and longitudes 81° 24′ to 81° 50′. The average elevation is 98.0 m MSL.

**Objectives of the Study**

- To identify the changes in land use categories and the resultant spatial patterns, and extent of urban expansion between 1991-2023.
- To interpret the driving factors responsible for observed LULC changes, including population growth, infrastructure development, and socio-economic shifts.
- To suggest recommendations for sustainable urban development and land management based on the findings.

# METHODOLOGY

This study examines the changes in Prayagraj city's land use and land cover (LULC) between 1991 and 2023 using satellite imagery and GIS techniques. The official USGS (United States Geological Survey) website provided the satellite pictures for the concerned years.The satellite images utilized in the present work are from Landsat 5 and Landsat 8, for the month of March, the resolution is 30 metres. These images were carefully selected to ensure they were clear and covered the entire study area. After basic corrections to improve image quality, the landuse was categorized into five main types (based on NRSA, Hyderabad classification): built-up areas, vegetation, agricultural land, water bodies, and open land was done using a supervised classification method. To ensure accuracy, the results were checked using field visits and Google Earth. Finally, maps and tables were created to show how much each land type changed over the study period and to identify the areas where the most change occurred.

# RESULTS AND DISCUSSION

The study of Prayagraj city's land use and land cover (LULC) variations from 1991 to 2023 shows significant changes in regards to how land resources are utilised and organised spatially. The classified satellite imagery and area calculations for six major land cover categories—built-up areas, vegetation, open land, agricultural land, sand, and water bodies—highlight the patterns and extent of urban expansion and environmental modification over the 32-year period. The results have been summarised in the table below and discussed further category-wise:

**Increase in Built-up Area:** The most prominent change observed over the time period under study is the substantial expansion in built-up land. In 1991, built-up areas covered approximately 48.81 sq. km, accounting for 52.5% of the total area under study. In 2023, this had expanded to 72.12 sq. km, making up 77.5% of the total. This represents a sanguine rise of 23.31 sq. km, or a 47.7% rise in spatial terms. The sharp growth in builtup area reflects rapid urbanization- mailny driven by population growth, infrastructural development, and the conversion of agricultural and open lands into residential, commercial, and institutional uses.

**Decline in Vegetation Cover:** Vegetation has seen a marked decrease over the study period. In 1991, vegetation covered 18.97 sq. km (20.4%), but by 2023, it had shrunk to 10.1 sq. km (10.86%). This decline of nearly 8.87 sq. km, or 46.7%, can be attributed to the clearing of green spaces and tree cover for construction, infrastructure expansion, and the widening of transport corridors. Such a reduction in vegetation is of concern due to its implications for local microclimates, air quality, and urban biodiversity.. For urban ecosystem functions such as mitigating heat islands, allowing water to penetrate, lowering $NO_x$ and $PM_{10}$ levels, etc., vegetation cover is particularly crucial. (Tyrväinen *et al*., 2005)

**Reduction in Open Land:** Open land—comprising barren plots, fallow grounds, and undeveloped spaces—also experienced a significant decrease. In 1991, this category occupied 11.62 sq. km (12.5%), which reduced to 4.67 sq. km (5.02%) in 2023. This suggests a loss of nearly 6.95 sq. km, or around 59.8%, over three decades. Much of this transformation is likely the result of land consolidation and construction activities, as vacant lands are increasingly brought under urban use.

**Shrinking Agricultural Land:** Agricultural land within the study area saw a steady decline from 10.42 sq. km (11.2%) in 1991, came down to 4.52 sq. km (4.86%) in 2023, a reduction of 5.9 km sq. or about 56.6%. The encroachment of agriculture by urban settlements and the decline in peri-urban farming practices—driven by land value appreciation and lack of institutional support—are likely reasons behind this trend. The loss of cultivable land within city boundaries is an indicator of shifting livelihoods and urban sprawl.

**Decrease in Sand and Water Bodies:** Smaller categories such as sand (likely riverine or exposed sandy patches along water bodies) and other water bodies (excluding major rivers) also show a downward trend. Sand areas decreased from 2.14 sq. km (2.3%) in 1991 to 1.01 sq. km (1.08%) in 2023, while water bodies declined from 1.02 sq. km (1.1%) to 0.56 sq. km (0.6%). These changes might result from increased sediment deposition, channel modification, or encroachment on wetlands and small lakes due to urban construction.

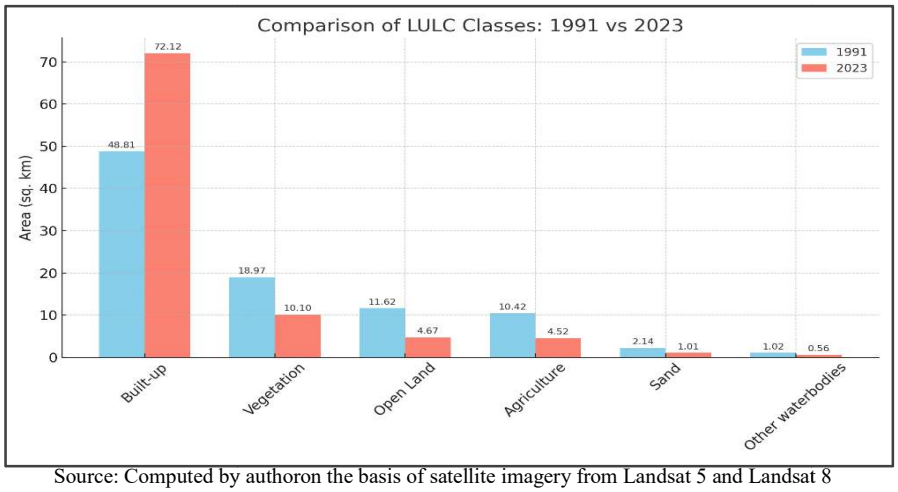
**Overall Land Transformation Trends:** The overall spatial analysis shows a clear trend of urban land expansion at the cost of ecological and rural land uses. In 1991, non-built-up categories (vegetation, agriculture, open land, sand, and water bodies) together constituted 44.17 sq. km or 47.5% of the area. By 2023, their combined share declined to 20.86 sq. km, or just 22.5%. This means that nearly 23.31 sq. km of non-built-up land has been converted to urban infrastructure over 32 years. Such a transformation underlines the urgent need for sustainable urban planning and the preservation of green and open spaces.

**Reduced percolation surfaces:** The increasing trend of concretization in Prayagraj between 1991 and 2023 has led to a significant reduction in open soil surfaces. As built-up areas expanded—rising from 52.5% to 77.5% of the total land cover—natural, permeable land surfaces such as green fields and open vegetation steadily diminished. This transformation

**Table 1. Changes of LULC in Prayagraj city**

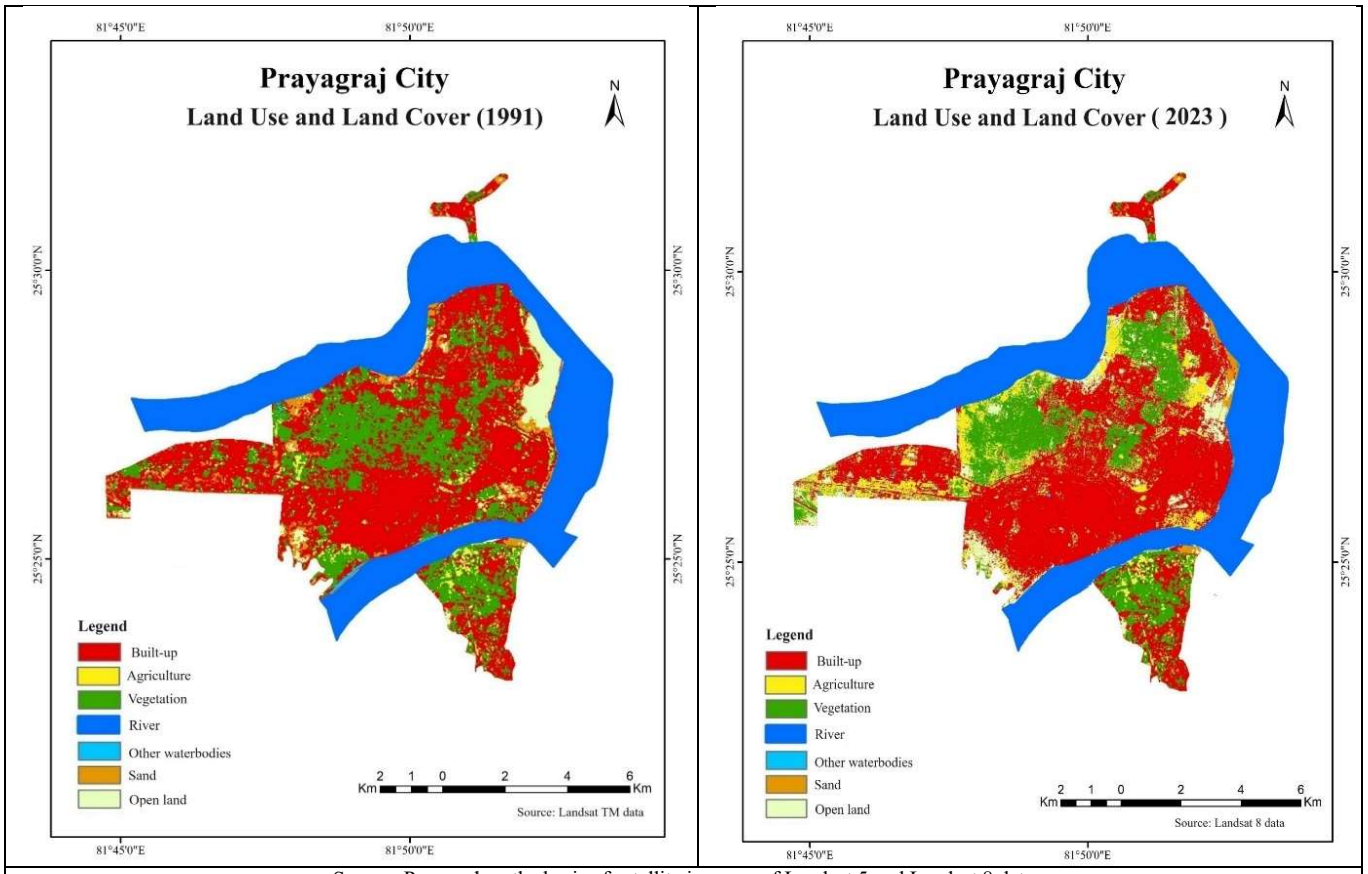
| S No. | Land Use lasses | 1991 | | 2023 | |
|---|---|---|---|---|---|
| | | Area (in km sq) | Area (in percentage) | Area (in km sq.) | Area (in percentage) |
| 1 | Built-up | 48.81 | 52.5 | 72.12 | 77.5 |
| 2 | Vegetation | 18.97 | 20.4 | 10.1 | 10.86 |
| 3 | Open Land | 11.62 | 12.5 | 4.67 | 5.02 |
| 4 | Agriculture | 10.42 | 11.2 | 4.52 | 4.86 |
| 5 | Sand | 2.14 | 2.3 | 1.01 | 1.08 |
| 6 | Other waterbodies | 1.02 | 1.1 | 0.56 | 0.6 |
| | Total | 92.98 | | 92.98 | |

Source: Prepared by author on the basis of satellite imagery from Landsat- 5 and Landsat- 8




Source: Computed by authoron the basis of satellite imagery from Landsat 5 and Landsat 8

**The Fig. 1 and Fig. 2 depict comparison of land use - land cover classification and changes: between 1991- 2023**




Source: Prepared on the basis of satellite imagery of Landsat 5 and Landsat 8 data

**Fig. 2. LULC changesin Prayagraj city between 1991 and 2023**

has disrupted the ecological balance of the city by replacing porous soil, which naturally absorbs rainwater, with impervious concrete structures that accelerate surface runoff. This shift has had a direct impact on the process of groundwater recharge. With the decline of natural percolation zones, the infiltration of rainwater into the subsurface aquifers has significantly reduced. Consequently, the overall recharge potential of groundwater reserves in the region has diminished over time. This situation poses long-term concerns for urban water security, particularly in a growing city like Prayagraj.

**Changes in agricultural landscape:** Another significant shift observed during the study period is the transformation in agricultural land use patterns, driven largely by commercialization and changing economic priorities. Between 1991 and 2023, there has been a marked decline in traditional food crops such as wheat and rice, which once dominated the rural fringes of Prayagraj. In their place, farmers are increasingly turning to high-value cash crops, horticulture, and floriculture, which offer better returns in a shorter time frame. This change reflects a broader shift in land use from subsistence farming toward market-oriented agriculture. The above data is illustrated in the form of a bar graph for better comparison and also represented in forms of maps of Prayagraj city depicting land use and land classification maps of the concerned years: The findings from the LULC analysis of Prayagraj city between 1991 and 2023 clearly indicate rapid urban expansion and associated environmental transformations. The most striking trend is the significant growth in built-up areas, which expanded by over 47%, largely at the cost of vegetation, open spaces, and agricultural areas. This trend reflects the increasing pressure of urbanization driven by: growth in population, migration, and infrastructural development, particularly after the city's integration into national urban development missions and transport corridor projects.The sharp decline in vegetation and agricultural land raises concerns about ecological sustainability. These changes not only reduce biodiversity and green cover but also impact the microclimate, water retention capacity, and food security within the urban periphery. Open lands, which often serve as transitional zones or buffer areas, have also shrunk drastically—suggesting intensified land utilization and minimal space left for future planning flexibility. The loss of sand deposits and small water bodies points toward unchecked construction activities near rivers, encroachments on floodplains, and poor water resource management. Such patterns, if continued, could increase the city's vulnerability to environmental hazards such as flash floods and groundwater depletion. Overall, the spatial transformation observed over the three decades underscores a clear shift from an ecologically balanced landscape to a more concretized urban setting. While development is essential, the rate of land conversion and its trends underscore the pressing necessity of integrated land use planning, green infrastructure policies, and environmental safeguards to ensure sustainable urban growth

# CONCLUSION

This study has successfully quantified and analysed the Land Use - Land Cover changes that have occurred in Prayagraj city between 1991 and 2023, revealing widespread urban changes over the past three decades. The results clearly indicate a significantrise in built-up areas—from 52.5% reaching 77.5%—primarily at the expense of vegetation, agricultural land, and open spaces. These spatial shifts reflect the intensifying pressure of urban expansion, particularly along major transportation routes and peripheral zones. The driving forces behind the changes described above are connected torapid increase in population, expanding infrastructure, and socio-economic transitions such as increased demand for housing, commercial space, and public utilities. These dynamics have reshaped the urban landscape, often without adequate environmental consideration, leading to reduced green cover, declining water bodies, and shrinking agricultural zones. In light of these findings, a set of practical recommendations becomes essential. First, there is an urgent need to adopt compact and integrated urban development models that reduce horizontal sprawl and preserve non-urban land. Secondly, green infrastructure including urban tree cover, community open spaces, vegetated buffers etc.—should be incorporated into city plans to improve ecological balance and urban liveability. Additionally, zoning regulations must be strictly enforced to prevent unauthorized construction and encroachment on environmentally sensitive areas like riverbanks and agricultural zones.Further, periodic geospatial monitoring using satellite data and GIS tools should be institutionalized to track land use dynamics and guide timely interventions. Public awareness and community engagement are equally important in ensuring land use decisions are inclusive and sustainable. Lastly, policymakers should align urban expansion with climate resilience and sustainability goals, ensuring that future growth does not compromise environmental quality. Overall, this study underscores the critical need for a balanced and informed approach to land management that harmonizes urban growth with environmental sustainability—securing a liveable future for Prayagraj city and its residents

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