



# A Spatio-Temporal Analysis of Land Use/Land Cover Changes in Prayagraj City, India

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## Abstract

Urbanization is an important process of land-use change that influences the spatial structure and environmental conditions of cities. The present study is designed to study the temporal changes and decadal pattern of the Land Use/Land Cover (LULC) transformation in Prayagraj City, 1992 to 2023 through remote sensing and Geographic Information System (GIS) techniques. LULC maps for the selected years were prepared and change in five major classes namely waterbody, built up, vegetation, agriculture and barren land was identified. Net area change and percentage change over various periods were used to assess magnitude of change. The analysis results show that there is a significant change in the land use land cover pattern of Prayagraj City over the study period. The built-up area increased from 55.2087 km<sup>2</sup> in 1992 to 109.737 km<sup>2</sup> in 2023, representing an increase of 98.77 percent. On the other hand, the area of vegetation decreased from 103.975 km<sup>2</sup> to 25.8795 km<sup>2</sup>, this implies 75.11 percent decrease. The area of waterbody reduced from 2.9385 km<sup>2</sup> to 1.5786 km<sup>2</sup> which is 46.28 percent. Agricultural area showed a marginal decline of 0.19 per cent while barren area showed a positive increase of 64.39 per cent. The results show that the significant change in Prayagraj city was related to the increase in built-up areas and the decrease in vegetation and waterbody areas. The study offers valuable information on the evolution of the urban landscape and emphasizes the need for incorporating LULC monitoring in the sustainable urban planning and administration of Prayagraj City.

## Keywords

Land Use/Land Cover, Remote Sensing, GIS, Prayagraj City, Decadal Change.

## 1. Introduction

Urbanization is one of the major processes shaping the spatial structure of cities and surrounding regions. The physical environment is continually changed by the growth in the urban population, by expansion of infrastructure, economic activities, transport networks and by changes in land use. The transformation of built up, vegetated and open areas into agricultural areas is one of the most significant of these changes, given that it impacts ecological conditions, land resources and urban development sustainability. Land use/land cover (LULC) change is thus a valuable indicator of the typology and intensity of urban change. Lambin and Meyfroidt (2011) stated that the impact of land-use change is

not solely driven by population growth, but by a mixture of economic, social, institutional and environmental processes. Likewise, Seto et al. (2012) noted how urban expansion can have a direct impact on biodiversity, ecosystem productivity and carbon storage.

These methods have become useful tools for monitoring these changes, as they give a spatially continuous information for various time periods and are tools of remote sensing and Geographic Information System (GIS). Satellite observations can be used to detect changes in man-made areas, vegetation, agricultural land, water bodies and bare land, especially with Landsat data. The usefulness of multi-temporal Landsat data for the spatial expansion of the major cities of India and identify various patterns of urbanization was shown by Taubenböck et al., 2009. In rapidly developing cities, which have a challenge with traditional field-based monitoring, long-term satellite-based LULC analysis is especially useful. A similar approach has been used in India in recent years: image classification of Landsat data and GIS analysis have been used to quantify urban land cover and to explore the association between urban expansion and the decline of agricultural and vegetated cover.

The Indian context has seen rapid urbanisation, which has brought about significant alterations in the spatial distribution of land resources. Urban sprawl is not an even process, and can involve agricultural land and vegetation conversion, vacant land and other open areas. But in Delhi NCR, studies have found that built-up land and open/fallow land have been continuously increasing while the agricultural land and vegetation have been decreasing from 1990 till 2018. Studies conducted around the city of Delhi have also revealed that urban development can affect agricultural and vegetated landscape in various manners depending on the local development processes and land-use practices. Similar study in Lucknow has highlighted the need of temporal LULC analysis to address urban sprawl and to guide sustainable urban development. The studies have proved that the analysis of LULC change is valuable for measuring urban growth, but also for understanding the consequences of urban growth for land resources and environmental management.

Prayagraj city, situated at the confluence of Ganga and Yamuna river in Uttar Pradesh has undergone a significant amount of urban development in last few decades. The city has become an administrative, education, culture and religion and transportation centre which has led to changes in the city's urban landscape. The enrollment of Prayagraj in the Smart Cities Mission has added more relevance to the planning and monitoring of urban development through the application of technology. Since the city has been undergoing rapid transformation in its functions and expansion in its infrastructures, it is essential to monitor the changing land use pattern so as to understand the spatial effects of urbanization in Prayagraj.

In Prayagraj and its adjoining areas, several studies have already looked into the dynamics of the LULC. Sarif and Gupta (2022) analysed LULC changes with the help of Landsat imagery at Prayagraj City in 1988, 1997, 2008 and 2018. They applied supervised classification and estimated the changes in the city's LULC at the study periods, as a tool for monitoring the long-term transformation of the city's land use, which was proved to be useful by their study. CAS mentioned by Kumar and Agrawal (2019) has also analysed the agricultural land-use change in Allahabad region by using landsat data and GIS based change detection technique. More recently, Kumar and Agrawal conducted a study on the city of Prayagraj, focusing on its urbanisation trend over a long period of time, from 1988 to 2018, using the long time series of Landsat images, and found that built-up area had increased significantly, while the area of forest and agricultural land had decreased.

The latest studies also show that the LULC transformation of the Prayagraj area is related to the changes in the environmental conditions in the city. The correlation between land-use/land-cover changes and land surface temperature has been investigated, and it was found that alterations in built-up and vegetated cover affect LST over the cities. Other recent studies have also analysed LULC alterations in

Prayagraj for longer time horizons and reported that the growing built-up areas are the key parameter of spatial transformation of Prayagraj.

While there have been several studies that have provided valuable information related to the urban growth and change in LULC of Prayagraj, there is a need for an integrated assessment of the period 1992 to 2023, with comparable categories and time periods. The long-term assessment can give a clearer picture on the evolution of the land use structure in the city and of which categories have been the biggest winners or losers. This information can be helpful for understanding the direction of urban change and to inform the process of land-use planning.

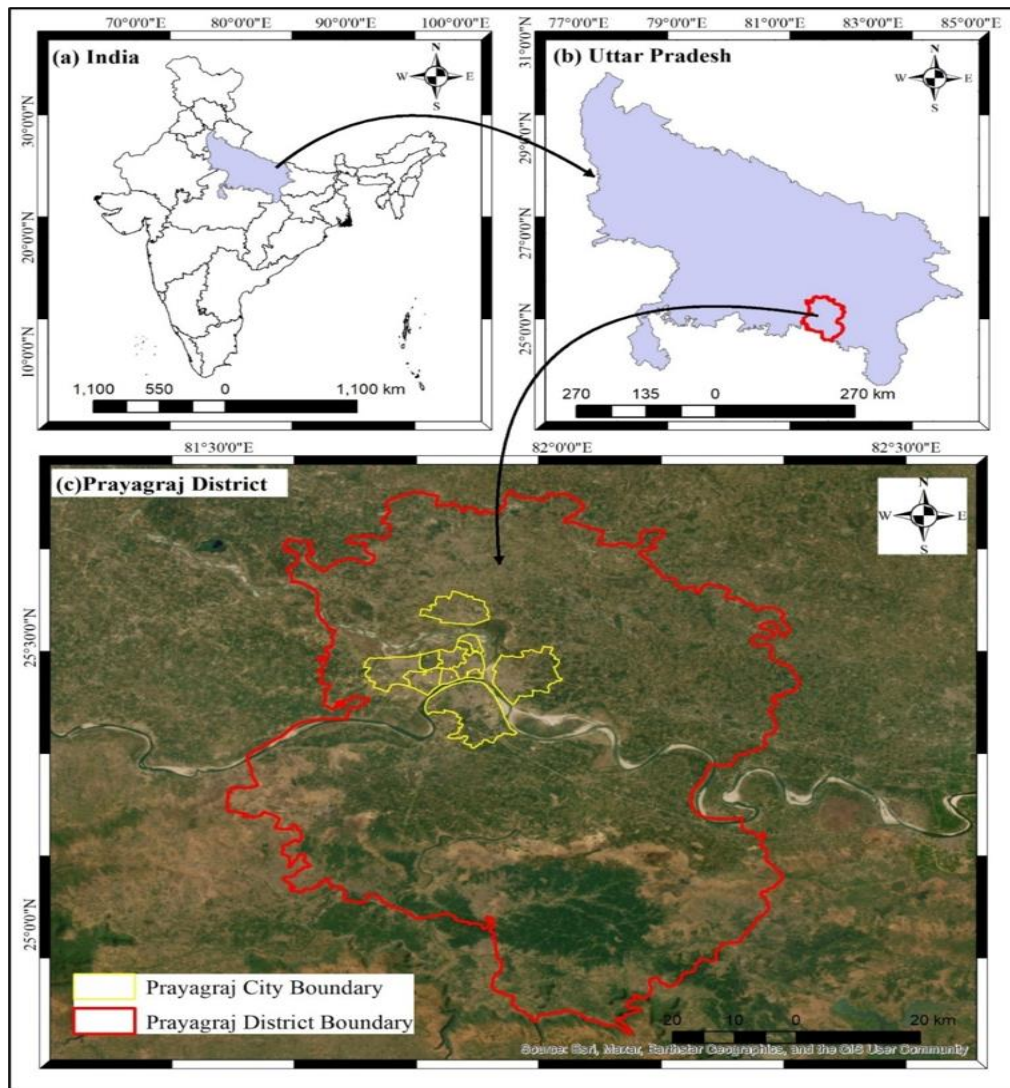
## **2. Research Objective**

1. To analyse the temporal changes in land use/land cover in Prayagraj City between 1992 and 2023.
2. To assess the decadal pattern of LULC Change between 1992 and 2023.

## **3. Data and Methodology**

### **3.1. Study Area**

Prayagraj City is a historically important urban centre in Uttar Pradesh. Its location at the confluence of the Ganga and Yamuna rivers has contributed to its religious, cultural and economic importance. The city has developed through several historical phases, including the growth of the traditional settlement, Mughal-period development, colonial planning, railway and road development, and recent peripheral expansion. Prayagraj is located approx. at 25.45° N latitude and 81.84° E longitude, with the principal urban area lying at an elevation of approximately 98 m above mean sea level (Government of Uttar Pradesh, 2026a; Ministry of Urban Development, 2015). Its relatively low elevation, gentle relief and proximity to major rivers have historically encouraged settlement, agriculture, transportation and urban development (Government of Uttar Pradesh, 2026a; CGWB, 2019). **(See Figure 1.)**



**Figure 1: (a) Geographical map of India (Survey of India), (b) Geographical map of Uttar Pradesh (Survey of India), (c) Geographical position of the Study Area (Landsat 9 imagery)**

Source: Created by Researchers, 2025

### 3.2. Data Sources

The Table 1 show that study uses multi-temporal Landsat satellite imagery for two years 1992 and 2023. The satellite datasets were obtained from the USGS Earth Explorer. Landsat TM, ETM+ and OLI/TIRS imagery were used for the long-term LULC analysis. GIS-based processing and area calculations were undertaken using ArcMap 10.8. The present study is limited to the administrative boundary of Prayagraj Municipal Corporation. Although Prayagraj is geographically associated with the confluence of the Ganga and Yamuna rivers. River stretches and areas located outside the municipal boundary have therefore not been included in the spatial analysis.

**Table 1. Satellite data specifications.**

| Date       | Satellite          | Path/Row | Spatial Resolution | Cloud cover          |
|------------|--------------------|----------|--------------------|----------------------|
| 17.02.1992 | Landsat 5 TM       | 142/043  | 30 x 30 m          | Less than 10 percent |
| 22.02.2023 | Landsat 8 OLI-TIRS |          |                    |                      |

Source: (Earth Resources Observation and Science (EROS) Center, 2013)

### 3.3. LULC Classification

The LULC maps were prepared using supervised classification of Landsat imagery. Five classes were considered such as waterbody, built-up land, vegetation, agricultural land and barren land. The classified maps were used to calculate the area and percentage share of each LULC class for each observation year.

### 3.4. LULC Change Analysis

Temporal change was calculated by comparing the area of each LULC class between two observation years.

The change in area was calculated using the formula:

$$\Delta A = A_{t2} - A_{t1} \dots \dots (1)$$

where  $A_{t1}$  and  $A_{t2}$  represent the area at the initial and final time points, respectively. The percentage change was calculated as:

$$\text{Percentage Change} = \left[ \frac{(A_{t2} - A_{t1})}{A_{t1}} \right] \times 100 \dots \dots (2)$$

This approach was applied to assess land-use/land-cover changes for the 1992-2023 periods.

### 3.5. Accuracy Assessment

Accuracy assessment was conducted to evaluate the reliability of the classified LULC maps. Overall accuracy and the Kappa coefficient were used. Producer's accuracy and user's accuracy were also considered for individual classes. Overall accuracy measures the proportion of correctly classified reference samples, while the Kappa coefficient measures agreement beyond chance (Congalton, 1991).

## 4. Results and Discussion

### 4.1. Temporal Pattern of LULC Change

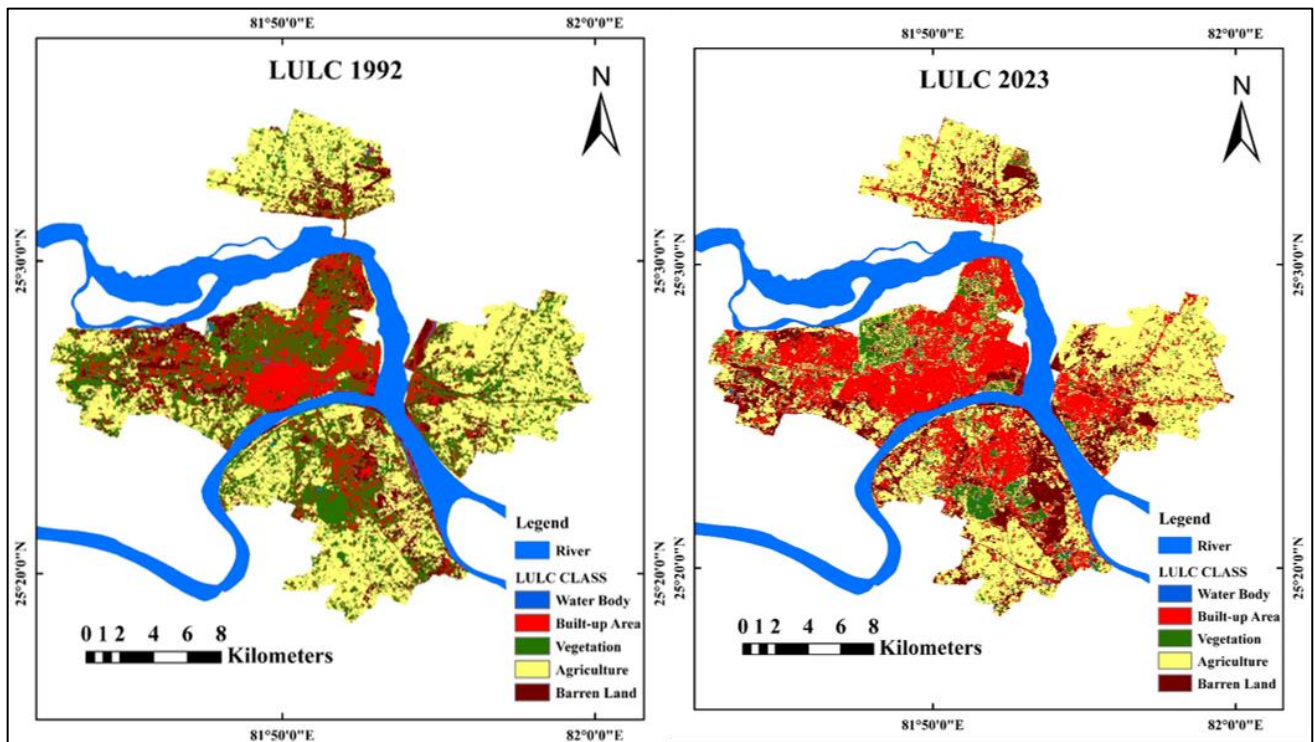
The results Table 2 shows the area of different LULC classes in Prayagraj City for 1992 and 2023. The results indicate clear changes in the land-use pattern during the study period. The built-up area

increased from 55.2087 km<sup>2</sup> in 1992 to 109.737 km<sup>2</sup> in 2023, showing a major expansion of urban areas. In contrast, vegetation decreased from 103.975 km<sup>2</sup> to 25.8795 km<sup>2</sup>. The area of waterbodies also decreased from 2.9385 km<sup>2</sup> to 1.5786 km<sup>2</sup>. Agricultural land remained almost stable, changing from 150.588 km<sup>2</sup> to 150.295 km<sup>2</sup>. However, barren land increased from 38.8917 km<sup>2</sup> to 63.9324 km<sup>2</sup>. Figure 2 show that major transformation in the land-use pattern of Prayagraj City, particularly due to the expansion of built-up areas and reduction in vegetation.

**Table 2. Temporal Changes in LULC Area of Prayagraj City during 1992-2023**

| LULC Class        | 1992 (km <sup>2</sup> ) | 2023 (km <sup>2</sup> ) |
|-------------------|-------------------------|-------------------------|
| Waterbody         | 2.9385                  | 1.5786                  |
| Built-up          | 55.2087                 | 109.737                 |
| Vegetation        | 103.975                 | 25.8795                 |
| Agricultural Land | 150.588                 | 150.295                 |
| Barren Land       | 38.8917                 | 63.9324                 |
| <b>Total Area</b> | <b>351.602</b>          | <b>351.423</b>          |

Source: Landsat satellite imagery (1992-2023), USGS Earth Explorer; calculated by the researcher using ArcMap 10.8.



**Figure 2. LULC map for Prayagraj City. (a) 1992 (b) 2023**

Sources: Landsat satellite imagery (1992-2023), USGS Earth Explorer; LULC classification and area calculation Created by author (s) on ArcMap, 2026.

## 4.2. Overall Net Change, 1992-2023

Table 3 presents the net change and percentage change in different LULC classes between 1992 and 2023. The built-up area recorded the highest positive change of 54.5283 km<sup>2</sup>, representing an increase of 98.77 percent. Barren land increased in 25.0407 km<sup>2</sup> (64.39 percent). On the other hand, vegetation recorded the largest decline of 78.0955 km<sup>2</sup> (75.11 percent), followed by waterbodies, which decreased by 1.3599 km<sup>2</sup> (46.28 percent). Agricultural land showed only a small decline of 0.2930 km<sup>2</sup> (0.19 percent). Overall, Table 3 shows that the major changes were the expansion of built-up and barren land and the reduction of vegetation and waterbody areas during 1992–2023.

**Table 3. Net and Percentage Change in LULC of Prayagraj City, 1992–2023**

| LULC Class        | 1992 (km <sup>2</sup> ) | 2023 (km <sup>2</sup> ) | Net Change (km <sup>2</sup> ) | Net Change (in percent) |
|-------------------|-------------------------|-------------------------|-------------------------------|-------------------------|
| Waterbody         | 2.9385                  | 1.5786                  | -1.3599                       | -46.28                  |
| Built-up          | 55.2087                 | 109.7370                | +54.5283                      | +98.77                  |
| Vegetation        | 103.9750                | 25.8795                 | -78.0955                      | -75.11                  |
| Agricultural Land | 150.5880                | 150.2950                | -0.2930                       | -0.19                   |
| Barren Land       | 38.8917                 | 63.9324                 | +25.0407                      | +64.39                  |

## 4.3. Accuracy Assessment

The Table 4 show that 1992 classification achieved 93.88 percent overall accuracy with a Kappa coefficient of 0.919. The classification achieved 97.60 percent overall accuracy and a Kappa coefficient of 0.969. The highest overall accuracy was recorded for, at 98.20 percent, with a Kappa coefficient of 0.9738. The 2023 classification recorded 97.40 percent overall accuracy and a Kappa coefficient of 0.9617.

The high accuracy values provide confidence in the broad spatial patterns identified in the study. However, classification uncertainty should still be considered when interpreting small changes between LULC classes. Large changes, such as the nearly 99 percent increase in built-up land and 75 percent decline in vegetation, are more meaningful than very small differences.

**Table 4. Accuracy assessment of LULC classification**

| Year | Overall Accuracy (%) | Kappa Coefficient |
|------|----------------------|-------------------|
| 1992 | 93.88                | 0.9190            |
| 2023 | 97.40                | 0.9617            |

Source: Landsat satellite imagery (1992-2023), USGS Earth Explorer; calculated by the researcher using ArcMap 10.8.

## 5. Discussion

The LULC analysis indicates that Prayagraj City experienced significant changes in its land-use pattern between 1992 and 2023. The major change was the rapid expansion of built-up land, while vegetation

and waterbody areas declined considerably. The built-up area increased from 55.2087 km<sup>2</sup> in 1992 to 109.737 km<sup>2</sup> in 2023, showing a net increase of 54.5283 km<sup>2</sup> or 98.77 percent. This indicates that the built-up area almost doubled during the study period. The increase may be associated with the expansion of residential areas, roads, commercial activities and other urban infrastructure. Earlier research also reported considerable urban growth in Prayagraj. Kumar and Agrawal (2023) found that the built-up area increased from 40.22 km<sup>2</sup> in 1990 to 85.89 km<sup>2</sup> in 2020, demonstrating a long-term trend of urban expansion in the city.

In contrast, vegetation showed a major decline, decreasing from 103.975 km<sup>2</sup> in 1992 to 25.8795 km<sup>2</sup> in 2023. This represents a net decrease of 78.0955 km<sup>2</sup> or 75.11 percent. The reduction in vegetation indicates the conversion of vegetated and open areas into other land-use categories during the process of urban development. Similar changes have been reported in Prayagraj City. Srivastava et al. (2023) observed a decline in tree cover between 2000 and 2020, while built-up areas increased during the same period. They also reported that changes in land use were related to changes in land surface temperature in the city.

The waterbody area also decreased, from 2.9385 km<sup>2</sup> in 1992 to 1.5786 km<sup>2</sup> in 2023, representing a reduction of 1.3599 km<sup>2</sup> or 46.28 percent. This decline indicates a considerable change in the surface-water component of Prayagraj City. Srivastava et al. (2023) also reported a reduction in waterbody area in Prayagraj between 2000 and 2020. Their study suggested that changes in water-related land cover were associated with changes in the urban environment and land surface temperature.

Agricultural land remained almost stable during the study period. Its area decreased slightly from 150.588 km<sup>2</sup> in 1992 to 150.295 km<sup>2</sup> in 2023, showing a net decrease of only 0.2930 km<sup>2</sup> or 0.19 percent. Although the overall change is small, some agricultural areas may have changed into built-up, barren or other land-cover classes, while changes in other locations may have compensated for these losses. A study of the wider Prayagraj district by Kumar and Agrawal (2023) found a gradual decline in agriculture land along with a strong increase in built-up land, showing the importance of land conversion in the region.

The study, barren land increased from 38.8917 km<sup>2</sup> to 63.9324 km<sup>2</sup>, showing a net increase of 25.0407 km<sup>2</sup> or 64.39 percent. This increase may include vacant land, exposed soil and areas undergoing construction or land-use conversion. Such areas can increase during periods of rapid urban development before being converted into permanent built-up land. The wider Prayagraj study also identified changes among barren, agricultural and built-up classes over time.

Overall, the findings show that Prayagraj City experienced considerable urban transformation between 1992 and 2023. The almost doubling of built-up land, together with the substantial reduction in vegetation and waterbody areas, reflects major changes in the city's spatial structure. These results are broadly consistent with earlier studies of Prayagraj that have documented increasing built-up areas and changes in natural land-cover classes. The findings highlight the importance of effective land-use planning, protection of vegetation and water resources, and appropriate management of urban expansion for the sustainable development of Prayagraj City.

## 6. Conclusion

The present study focuses on the land use and land cover (LULC) change analysis in Prayagraj City, from 1992 to 2023, using remote sensing and GIS techniques. These results indicate that the city had major alterations in land use over the study period. The most important change was the rapid expansion of built-up areas. The built-up area increased from 55.2087 km<sup>2</sup> in 1992 to 109.737 km<sup>2</sup> in 2023,

representing an increase of 98.77 percent. This significant expansion is indicative of the ongoing urbanization and development in Prayagraj City. There was also a significant reduction in the natural land-cover classes. The area of vegetation reduced from 103.975 km<sup>2</sup> to 25.8795 km<sup>2</sup>, a decrease of 75.11 per cent. Similarly, the area of waterbodies decreased by 46.28 percent, from 2.9385 km<sup>2</sup> to 1.5786 km<sup>2</sup>. Changes in these indicate increasing pressure on natural and environmentally important areas from urban development and land-use transformation. In contrast, agricultural land remained almost stable, with only a 0.19 percent decrease during the study period. The barren land category grew by 64.39 percent and could be related to vacant land, exposed surfaces and development areas. The overall findings indicate that the city of Prayagraj has undergone significant urban changes over the past 30 years, primarily in the form of an increase in built-up land while vegetation and waterbody cover have decreased. The results indicate the importance of adequate land use planning and proper management of urban development. In future urban development the protection of existing vegetation, waterbodies and open spaces should be given more attention. The study can help planners and decision-makers in Prayagraj to create more balanced and sustainable urban development strategies by offering them spatial information about the urban landscape.

## References

1. CGWB. (2019). [Groundwater report]. Department of Water Resources, River Development and Ganga Rejuvenation, Government of India.
2. Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37(1), 35–46.
3. Kumar, V., & Agrawal, S. (2019). Agricultural land use change analysis using remote sensing and GIS: A case study of Allahabad, India. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-3/W6, 397–402. <https://doi.org/10.5194/isprs-archives-XLII-3-W6-397-2019>
4. Kumar, V., & Agrawal, S. (2023). A multi-layer perceptron-Markov chain based LULC change analysis and prediction using remote sensing data in Prayagraj district, India. *Environmental Monitoring and Assessment*, 195, 619. <https://doi.org/10.1007/s10661-023-11205-w>
5. Kumar, V., & Agrawal, S. (2024). Predicting Prayagraj's urbanization trajectory using CA-ANN modelling: Population pressures and land use dynamics. *Journal of Environmental Management*, 370, 122469. <https://doi.org/10.1016/j.jenvman.2024.122469>
6. Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, 108(9), 3465–3472. <https://doi.org/10.1073/pnas.1100480108>
7. Ministry of Housing and Urban Affairs. (2016). *India Habitat III National Report* [National Report]. Government of India. <https://smartnet.niua.org/sites/default/files/resources/1560.pdf>
8. Sarif, M. O., & Gupta, R. D. (2022). Spatiotemporal mapping of land use/land cover dynamics using remote sensing and GIS approach: A case study of Prayagraj City, India (1988–2018).
9. Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, 109(40), 16083–16088. <https://doi.org/10.1073/pnas.1211658109>



10. Srivastava, A., Shukla, S., Singh, P., & Jha, P. K. (2023). Spatio-temporal dynamics of land use/cover and land surface temperature in Prayagraj city, India. *Indoor and Built Environment*, 32(6), 1250–1268. <https://doi.org/10.1177/1420326X231159633>
11. Taubenböck, H., Wegmann, M., Roth, A., Mehl, H., & Dech, S. (2009). Urbanization in India—Spatiotemporal analysis using remote sensing data. *Computers, Environment and Urban Systems*, 33(3), 179–188. <https://doi.org/10.1016/j.compenvurbsys.2008.09.003>
12. United Nations. (2019). *World Urbanization Prospects: The 2018 Revision* [ST/ESA/SER.A/420]. United Nations. <https://population.un.org/wup/>