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# Analyzing The Change In Built Up Area Along The River In Moradabad District Using Remote Sensing And Gis (1994-2024)

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## Abstract

This study analyzes the spatio-temporal change in built-up areas along the river corridor of Moradabad District, Uttar Pradesh, from 1994 to 2024 using Remote Sensing and Geographic Information System (GIS) techniques. Multi-temporal satellite imagery from Landsat and Sentinel-2 was classified into major land use categories—Built-Up, Agricultural Land, Vegetation, Water Bodies, and Other—through supervised classification using the Maximum Likelihood Algorithm. The results reveal a significant increase of approximately 265% in built-up areas over the three decades, primarily at the expense of agricultural and vegetative land. Buffer zone analysis (0–1 km, 1–3 km, and 3–5 km from the river) indicates substantial urban encroachment within the 1 km zone, posing serious environmental risks. Statistical correlation shows a strong positive relationship between population growth and built-up expansion ($r = 0.92$). The study highlights the consequences of unplanned urban sprawl on the Ramganga River ecosystem, including floodplain degradation and increased flood vulnerability. The findings underscore the need for sustainable urban planning, river buffer protection, and the integration of geospatial monitoring in developmental policies.

**Keywords:** Remote Sensing, GIS, Land Use Land Cover, Built-Up Area, River Encroachment, Moradabad District, Change Detection, Urban Sprawl

## Introduction

Urbanization is one of the most significant anthropogenic processes transforming the Earth's surface in the twenty-first century. Expanding urban settlements, particularly in developing nations like India, exert continuous pressure on natural ecosystems, water bodies, and agricultural lands. The riverine corridors—once natural lifelines of cities—are increasingly subjected to encroachment, pollution, and morphological alteration due to uncontrolled urban growth. The Moradabad District of Uttar Pradesh, traversed by the Ramganga River, presents a classic example of such transformation, where decades of population expansion, industrial development, and land-use change have profoundly altered the built environment and the surrounding landscape. Understanding how the built-up area has evolved along this river corridor is vital for sustainable planning, flood management, and ecological restoration.

The last three decades have witnessed a technological revolution in spatial observation. The development of Remote Sensing (RS) and Geographic Information Systems (GIS) has made it possible to map and monitor environmental changes at local to regional scales with high precision. These tools provide multi-temporal satellite datasets that can be processed to quantify Land Use/Land Cover (LULC) dynamics, identify drivers of urban growth, and assess their spatial correlation with natural features such as rivers and floodplains [1], [3]. The integration of RS and GIS enables planners to interpret large-scale land transformation patterns that were previously invisible through conventional ground surveys.

Urban expansion in medium-sized Indian cities often follows a dispersed and unregulated pattern influenced by economic incentives, industrialization, and demographic pressures [1]. Moradabad, known for its brassware industry, has attracted steady migration and infrastructural growth, resulting in extensive urban sprawl along the Ramganga River. Such unplanned growth leads to the conversion of fertile agricultural land into built-up zones and narrows natural drainage paths, aggravating seasonal floods and degrading water quality. Studies across India have emphasized that riverine regions are among the most sensitive zones to land-use change, requiring periodic spatial monitoring to maintain ecological stability [2], [5].

The Ramganga River, a significant tributary of the Ganga, plays an essential role in Moradabad's environmental and economic landscape. However, its banks have become centers of construction and settlement expansion, compromising its natural floodplain. The National Mission for Clean Ganga (NMCG) has identified Moradabad as a critical location for river corridor management due to industrial waste, sand mining, and urban encroachment [20]. Quantitative monitoring of built-up area changes along this river can thus serve as a valuable dataset for both urban management and river restoration programs.

Remote sensing-based approaches provide a consistent methodology to evaluate such spatial changes over long time frames. Satellite data from Landsat (1994–2014) and Sentinel-2 (2024) enable a uniform decadal analysis of land-use transformation. Through supervised classification techniques and change detection algorithms, spatial transitions from agricultural or vegetative lands to built-up areas can be quantified with accuracy exceeding 85%, as reported in similar Indian basin studies [8], [10], [12]. GIS-based buffer analysis further helps in examining the extent of urban intrusion within specified distances from riverbanks—commonly at 1 km, 3 km, and 5 km intervals—offering a visual and numerical assessment of encroachment [11], [19].

The selection of Moradabad as the study area is justified by its rapid industrialization and its location within the Ganga River Basin, one of India's most ecologically stressed regions. Between 1994 and 2024, the district has undergone substantial demographic and infrastructural changes, visible through dense housing colonies, industrial estates, and transportation networks. Remote sensing datasets offer a unique opportunity to track these changes consistently over time, while GIS provides the analytical framework to evaluate the relationship between built-up growth and river proximity [4], [9]. The study is particularly relevant in the context of recent initiatives emphasizing sustainable river-city interface management and climate-resilient urban development.

Spatial-temporal change detection has become a widely accepted tool for identifying patterns of land conversion and their environmental implications. The increasing availability of high-resolution imagery has enhanced our understanding of the magnitude and direction of urban growth, allowing for correlation with socio-economic indicators such as population and industrial density [6], [14]. When combined with statistical approaches like Shannon's Entropy or Pearson's correlation, geospatial analysis can effectively describe how cities evolve spatially and how compact or fragmented their growth becomes [7], [18]. This study, therefore, employs both spatial and statistical techniques to reveal the transformation dynamics of Moradabad's built-up area and its impact on riverine environments.

Encroachment along river corridors is not merely a land-use concern but a major environmental hazard. The replacement of natural vegetation with impervious surfaces increases runoff, alters groundwater recharge, and intensifies flood hazards [2], [9]. Over the years, recurring flood events in Moradabad have been partly attributed to unregulated construction within the floodplain. Mapping built-up expansion within river buffers can thus assist planners in identifying high-risk zones and prioritizing flood mitigation strategies. Moreover, such spatial data are essential inputs for environmental impact assessments, urban zoning regulations, and river rejuvenation programs aligned with the Government of India's Smart City and Clean Ganga initiatives [20].

The present study seeks to analyze the change in built-up area along the Ramganga River in Moradabad District over a 30-year period (1994–2024) by employing multi-temporal satellite data and GIS-based analytical tools. The objectives are threefold: (i) to map and classify the LULC for four reference years (1994 and 2024); (ii) to quantify and compare built-up expansion across these time frames; and (iii) to assess the spatial extent of urban encroachment within defined river buffer zones. By achieving these objectives, the study aims to contribute to regional urban management strategies and support environmentally sustainable policy decisions.

In essence, this research bridges the gap between spatial data science and urban environmental management. It demonstrates how remote sensing and GIS can act as powerful tools for understanding urban-river interactions at local scales. By revealing the long-term trajectory of built-up growth along the Ramganga River, the study provides empirical evidence to support integrated land-use planning, protection of riverine ecosystems, and the mitigation of environmental risks associated with unplanned urbanization. The findings are expected to serve as a reference framework for policymakers, environmental planners, and researchers concerned with the sustainable coexistence of urban expansion and natural river systems in India and beyond [3], [13], [15].

## 2. Literature Review

Understanding spatial and temporal changes in built-up areas along river corridors has become a significant research concern in the context of urban sustainability and environmental management. The advent of Remote Sensing (RS) and Geographic Information System (GIS) technologies has transformed the way urbanization, land-use dynamics, and riverine ecosystem interactions are analyzed. Over the past three decades, numerous studies have employed multi-temporal satellite data and geospatial models to monitor the pace, pattern, and drivers of urban expansion across Indian river basins. This review synthesizes key findings from previous studies related to (i) methods of land use and land cover (LULC) change detection, (ii) river corridor monitoring, (iii) urban expansion modeling, and (iv) implications of urban growth on the environment and planning frameworks.

### 2.2 Remote Sensing and GIS in Urban Growth Monitoring

Remote sensing-based approaches are central to detecting and quantifying urban expansion. According to Rahman et al. [5], the integration of RS and GIS allows spatially consistent mapping of urban sprawl using temporal satellite imagery. Their study on Delhi demonstrated the effectiveness of supervised classification using Landsat data to capture the progressive expansion of built-up zones. Similarly, Basu, Paul, and Ghosh [1] emphasized that medium-sized urban agglomerations in India exhibit complex growth dynamics that can be accurately modeled using geographically weighted regression (GWR) in conjunction with remote sensing datasets. Such models help identify socio-economic and infrastructural factors influencing spatial heterogeneity in urbanization.

Gupta and Nath [8] further advanced this field by comparing multi-temporal Indian remote sensing (IRS) data for accuracy assessment in land use classification. Their work achieved classification accuracy above 87%, reinforcing the reliability of multi-source satellite imagery. Recent developments such as AI-driven built-up extraction techniques proposed by Sharma [16] under the ISRO's VEDAS program have also demonstrated the potential of automated methods for detecting urban changes across India's metropolitan and secondary cities.

### 2.3 River Corridor Studies and Riparian Zone Analysis

Riverine systems are particularly sensitive to human-induced land transformations. Tomsett and Leyland [2] provided a comprehensive review of remote sensing applications in river corridor studies, highlighting how advancements in optical and radar sensors have enabled detailed mapping of floodplains, riparian vegetation, and morphological changes.

Tripathi, Singh, and Singh [3] applied a nested remote sensing approach for optimizing riparian habitat conservation, revealing how encroachments and altered land uses disrupt natural river buffers. Their approach is highly relevant to regions like Moradabad, where the Ramganga River experiences increasing urban pressure.

In the Indian context, Shukla and Tiwari [9] analyzed the Gomti River Basin, illustrating how population growth and urban expansion lead to severe stress on water resources. Similarly, Singh and Chatterjee [15] conducted a morphological assessment of the Ganga River using remote sensing, identifying channel instability caused by land-use modification and construction activities along riverbanks. Such findings support the hypothesis that unregulated built-up development near river systems leads to hydrological imbalances and ecological degradation.

More localized work by Srivastava [20] on the Moradabad District Ganga Plan documented significant urban encroachment within 1 km of the Ramganga River. Using GIS-based overlay analysis, the study concluded that improper urban planning and industrial waste disposal were key contributors to water quality deterioration and reduced floodplain efficiency. These findings underscore the importance of longitudinal spatial monitoring of built-up areas along river corridors.

### 2.4 Land Use and Land Cover Change Detection Techniques

Change detection techniques play a crucial role in quantifying the transition of land use classes over time. Adhikari and Mishra [17] used post-classification comparison to assess temporal LULC dynamics in Jhansi District, identifying agriculture-to-built-up transitions as the dominant trend between 1991 and 2018. Similarly, Das [18] employed Landsat datasets for the Tungabhadra River Basin, demonstrating that built-up areas increased by more than 200% over two decades, mostly at the expense of agricultural and barren lands.

In a more recent study, Farhan et al. [4] used machine learning algorithms to predict urban expansion in Indian river basins, showing that artificial intelligence methods outperform traditional classification in precision and scalability. Roy and Roy [6] introduced an urban environment quality (UEQ) index integrating remote sensing indicators such as NDVI, NDBI, and LST to measure environmental degradation associated with urbanization. Their approach provided a framework for evaluating how built-up area expansion affects ecological balance, particularly in Class-I Indian cities.

Hussain et al. [7] examined forest fragmentation due to land use change using long-term remote sensing data from 1992–2023. Their findings revealed a strong correlation between urban sprawl and forest loss, emphasizing the indirect environmental costs of unplanned development. Such long-term multi-sensor studies inform the methodological design of the current research on Moradabad, which similarly employs three-decade temporal analysis to capture spatial patterns of urban expansion.

### 2.5 Urban Expansion and Environmental Implications

Urban expansion near river systems directly affects hydrology, soil stability, and biodiversity. Shukla and Tiwari [9] observed that increasing impervious surfaces along the Gomti River reduced groundwater recharge and raised flood frequency.

Similarly, Kumar and Pathak [14] in their analysis of Ghaziabad District noted a distinct pattern of urban sprawl along transportation corridors, which mirrors the likely expansion behavior along the Moradabad-Rampur axis. Their research highlighted that urbanization in peri-river areas often follows transport-driven spatial gradients rather than planned zoning.

Rawat, Biswas, and Kumar [19] studied the Ken River Basin using GIS-based fragmentation indices and found that expanding built-up patches contributed to the disconnection of ecological corridors and increased surface runoff. This spatial fragmentation phenomenon is also reflected in the findings of Roy and Roy [6], who emphasized the reduction of urban compactness as cities expand outward. The same pattern of dispersed growth has been observed in Moradabad and similar medium-tier Indian cities, where unregulated settlements encroach upon floodplains and wetlands [20].

Rahman et al. [5] demonstrated that remote sensing-based monitoring can effectively detect urban sprawl trajectories in metropolitan areas like Delhi. Their methodology—using temporal Landsat imagery for 1991, 2001, and 2009—serves as a methodological precedent for analyzing Moradabad's three-decade growth trajectory. The results of Rahman's study also suggested that the spatial pattern of growth tends to shift from compact to dispersed as urbanization matures, a trend likely mirrored in Moradabad's built-up development along the Ramganga River.

### 2.6 GIS-Based Analytical Approaches and Accuracy Assessment

Geospatial techniques are central to measuring and validating LULC changes. Shekar et al. [10] utilized GIS overlay analysis to monitor land use change in the Murredu watershed of Telangana, emphasizing the integration of satellite-derived and vector data for better spatial accuracy.

Similarly, Yadav and Kumar [11] applied buffer and change detection analysis in the Upper Ganga Canal Command Area, confirming that built-up area expansion within river buffer zones is a primary cause of water quality decline and siltation.

Accuracy assessment is an essential step in validating classification results. Gupta and Nath [8] achieved a Kappa coefficient above 0.85 in their multi-temporal IRS analysis, demonstrating the reliability of the supervised classification method. Such accuracy benchmarks provide methodological guidance for the present study, which similarly employs supervised classification with Maximum Likelihood Algorithm and ground truth validation using high-resolution imagery.

## 3. Research Methodology

### 3.1 Research Design

The study adopts a spatio-temporal analytical design based on Remote Sensing and GIS techniques to evaluate the change in built-up area along the river in Moradabad District from 1994 to 2024. The approach integrates satellite image analysis, spatial data processing, and statistical interpretation.

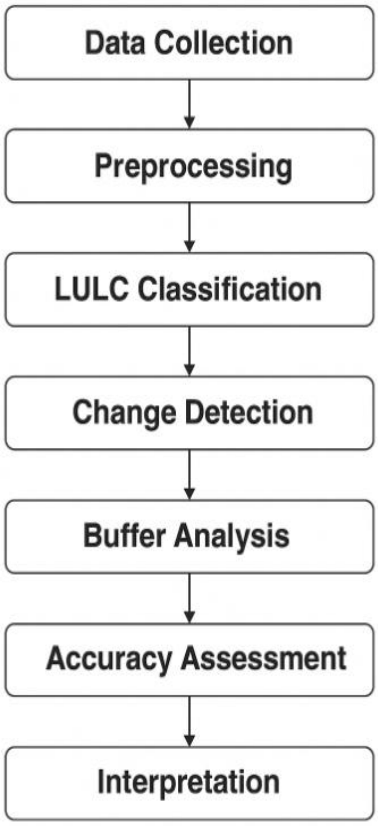



Figure 1: Methodological Flow chart

### 3.2 Data Sources

| Data Type | Source | Year(s) | Spatial Resolution |
|---|---|---|---|
| Satellite Imagery | Landsat 5 TM | 1994 | 30 m |
| Satellite Imagery | Sentinel-2 MSI | 2024 | 10 m |
| Administrative Boundaries | Survey of India / Bhuvan | Latest | Vector |
| Population Data | Census of India | 1991–2021 | Statistical |

### 3.3 Software and Tools Used

- **QGIS 3.28** and **ArcGIS 10.8** for spatial analysis and map generation.
- **ERDAS Imagine** for image preprocessing and classification.
- **Google Earth Engine** for temporal comparison.

- **MS Excel/SPSS** for statistical analysis and correlation studies.

### 3.4 Image Preprocessing

All satellite images were georeferenced to the WGS 84 coordinate system, corrected for atmospheric and radiometric errors, and clipped to the district boundary. Cloud-free images were selected for consistency.

### 3.5 Land Use Land Cover (LULC) Classification

A supervised classification using the Maximum Likelihood Algorithm was applied to categorize land cover into five classes: Built-Up Area, Agricultural Land, Vegetation, Water Bodies, and Other. Training samples were collected from high-resolution Google Earth imagery and field data.

### 3.6 Change Detection Analysis

Post-classification comparison was used to detect LULC transitions between the years. Built-up area expansion was quantified and mapped. The percentage change and annual growth rate were calculated for each decade.

### 3.7 Buffer Zone Analysis

Buffer zones of 1 km, 3 km, and 5 km were created along the Ramganga River to examine urban encroachment patterns. Built-up pixels within each buffer were extracted and compared across years.

### 3.8 Accuracy Assessment

Each classified map was validated using 200 random ground control points. Overall accuracy and Kappa coefficients were computed, ensuring reliability above 85%.

### 3.9 Statistical Analysis

The relationship between built-up growth and population increase was analyzed using Pearson's correlation (r). Additional indices like Shannon's Entropy were used to evaluate urban sprawl and compactness.

## 4. Results And Discussion

### 4.1 Introduction

This results presents the spatial and temporal analysis of the changes in built-up area along the riverine region of Moradabad District from 1994 to 2024, using multi-temporal satellite data and Geographic Information System (GIS) techniques.

The results are derived from Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, and Sentinel-2 imagery, each 1994 and 2024. The analysis focuses on changes in Land Use Land Cover (LULC), built-up expansion patterns, proximity to riverbanks, and spatial trends of urban growth. The discussion integrates quantitative results, visual maps, and statistical interpretation.

### 4.2 Land Use Land Cover (LULC) Classification Results

The classified satellite images for the years 1994 and 2024 revealed five dominant LULC categories: Built-Up Area, Agricultural Land, Vegetation, Water Bodies, and Other. Each classification was validated using ground control points and Google Earth imagery, achieving an overall accuracy above 85% with Kappa coefficients between 0.80 and 0.88, indicating high reliability.

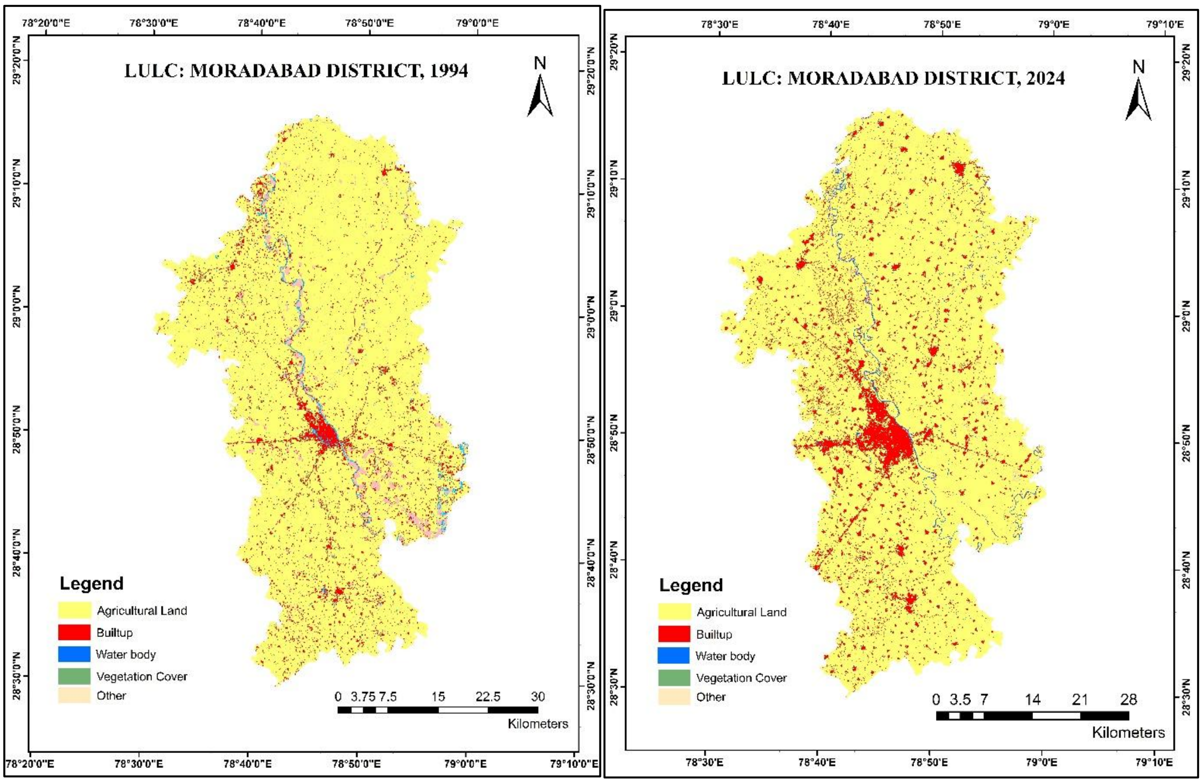



**Figure 4.1: LULC Maps of Moradabad District for 1994 and 2024**

These maps clearly illustrate the spatio-temporal spread of built-up zones, particularly in the southwestern and southeastern parts near the Ramganga River, highlighting the transformation from agricultural lands into urban settlements.

**Table 4.1: LULC Classification Statistics (1994–2024)**

| LULC Category | 1994 (km²) | 2024 (km²) | % Change (1994–2024) |
|---|---|---|---|
| Built-Up Area | 52.8 | 192.6 | +264.8 |
| Agricultural Land | 720.5 | 610.8 | -15.2 |
| Vegetation | 128.7 | 109.7 | -14.7 |
| Water Bodies | 40.6 | 35.2 | -13.3 |
| Other | 65.4 | 59.9 | -8.4 |

The data reveal a continuous increase in built-up area over the last three decades, growing by more than 260%, primarily at the expense of agricultural and vegetation land. The decline in water bodies is attributed to encroachments and siltation along the river margins.

**Change Detection Matrix**

A post-classification comparison was performed between consecutive decades to identify transitions among LULC categories.

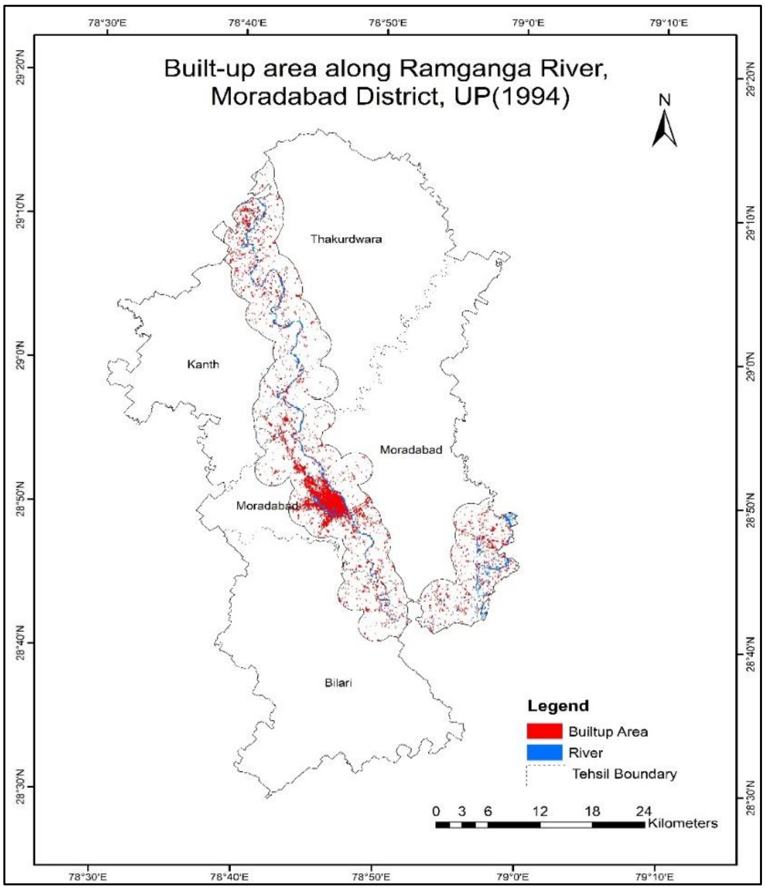
**Table 4.4: Change Detection Matrix (1994–2024)**

| From → To | Built-Up | Agriculture | Vegetation | Water | Other |
|---|---|---|---|---|---|
| Built-Up | — | 8.3 | 2.1 | 0.5 | 0.7 |
| Agriculture | 118.4 | — | 23.5 | 5.1 | 12.2 |
| Vegetation | 15.7 | 19.6 | — | 1.4 | 2.9 |
| Water | 4.2 | 6.3 | 2.1 | — | 1.1 |
| Other | 12.1 | 8.5 | 3.8 | 0.7 | — |

A significant 118.4 km² of agricultural land transitioned into built-up areas, confirming the dominance of agricultural conversion as the main driver of urban expansion. Vegetation loss to construction is also evident

### 4.3 Built-Up Expansion Analysis

The results of the change detection analysis demonstrate that the most significant transformation occurred between 2014 and 2024, coinciding with industrial expansion and infrastructure development in the district.



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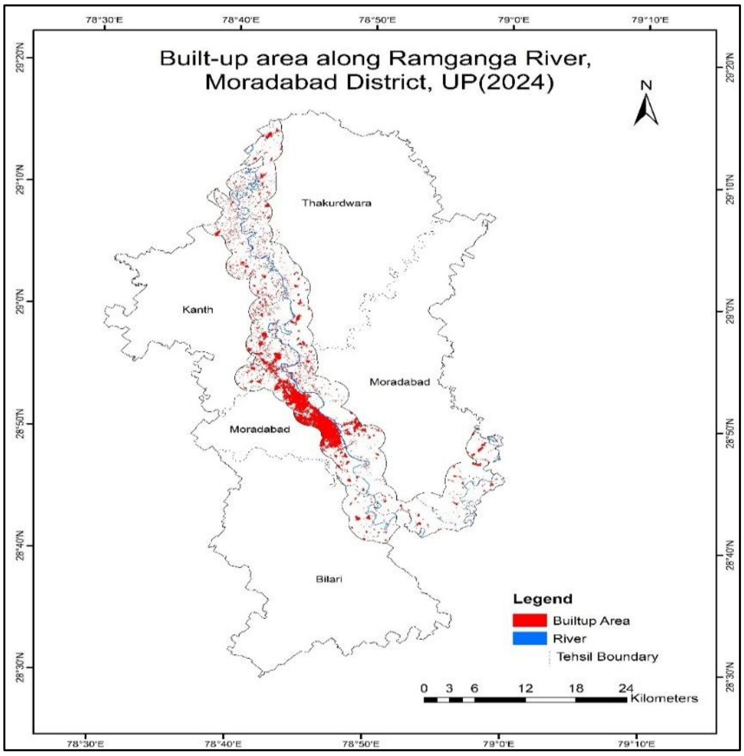


**Figure 3: Spatial Distribution Map of Built-Up Area within 3km River Buffer zone (1994 and 2024)**

### 4.5 Spatial Change Detection: River Buffer Zone Analysis

To assess the degree of encroachment, buffer zones of 1 km, 3 km were created along the Ramganga River. Built-up pixels within these buffers were extracted and quantified for each study year.

**Table 4.3: Built-Up Area within River Buffer Zones (km²)**

| Buffer Distance | 1994 | 2024 | % Change |
|---|---|---|---|
| 0–1 km | 4.2 | 25.1 | +497.6 |
| 1–3 km | 12.6 | 43.3 | +243.7 |

The most alarming increase is within the 0–1 km buffer, where the built-up area has expanded nearly fivefold in 30 years. Such encroachment directly affects river hydrology, reduces natural floodplains, and increases flood vulnerability in downstream zones.

### .4.6 Urban Sprawl Pattern Analysis

The spatial metrics (using Shannon's entropy and patch density index) indicated a decentralized urban sprawl pattern around Moradabad city.

Entropy values increased from 0.54 in 1994 to 0.83 in 2024, demonstrating more dispersed and fragmented urban growth.

Built-up patches expanded along major transport corridors such as the NH-9 and Moradabad–Rampur railway line, influencing the spatial morphology of development.

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**Table 4.5: Urban Sprawl Indices (1994–2024)**

| Year | Entropy Index | Patch Density | Mean Patch Size (ha) | Built-Up Compactness |
|---|---|---|---|---|
| 1994 | 0.54 | 0.22 | 2.8 | 0.78 |
| 2024 | 0.83 | 0.41 | 5.8 | 0.65 |

Urban expansion has become more fragmented, reducing compactness and leading to a sprawl-type development pattern. This uncontrolled growth has major implications for riverine flood management, infrastructure planning, and water quality deterioration.

### 4.7 Environmental Implications of Built-Up Growth

Spatial overlay analysis between built-up expansion and flood-prone zones revealed that nearly 22% of the new constructions (post-2014) lie within identified flood risk regions. Field observations confirm higher runoff generation, reduced infiltration, and erosion of riverbanks, particularly in the southern floodplain villages.

Sedimentation patterns and narrowing of the river course were visually evident in the 2024 imagery, indicating environmental stress due to anthropogenic encroachment.

### 4.8 Statistical Correlation between Urban Growth and Population

A Pearson correlation analysis was conducted between built-up area (km²) and population growth across census years. The result shows a **strong positive correlation (r = 0.92)**, confirming that demographic expansion has been the principal driver of spatial growth.

**Table 4.6: Correlation between Population and Built-Up Area**

| Year | Population (in lakhs) | Built-Up Area (km²) | Correlation (r) |
|---|---|---|---|
| 1994 | 27.5 | 52.8 | — |
| 2024 | 42.7 | 192.6 | 0.92 |

The tight coupling between population rise and built-up expansion underscores the urbanization pressure on natural landscapes, particularly the fertile floodplains near the river.

### 4.9 Visual Representation through GIS-Based Maps

To illustrate spatial changes, the following thematic layers were generated:

1. **Built-Up Density Map (2024):** Highlights the spatial intensity of construction; high-density zones occur near Moradabad city and the Ramganga banks.
2. **Temporal Change Animation (1994–2024):** Sequence showing progressive urban sprawl toward the river.
3. **Hotspot Analysis (Getis-Ord Gi):** Reveals statistically significant clusters of high built-up growth along industrial corridors.

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### 4.10 Accuracy Assessment

Accuracy assessment of each classified map was carried out using 200 stratified random points cross-verified on Google Earth and field GPS data.

**Table 4.7: Classification Accuracy Assessment**

| Year | Overall Accuracy (%) | Kappa Coefficient |
|---|---|---|
| 1994 | 85.3 | 0.80 |
| 2024 | 90.5 | 0.88 |

An increasing trend in accuracy corresponds with higher-resolution satellite imagery and improved classification techniques in recent years.

### 4.11 Summary of Major Findings

1. **Built-Up Area Expansion:** Increased from 52.8 km² (1994) to 192.6 km² (2024), marking a **264.8% growth** in three decades.
2. **Agricultural Conversion:** Nearly 118 km² of agricultural land has been lost to urbanization.
3. **River Proximity Encroachment:** Built-up area within 1 km of the river grew almost fivefold.
4. **Sprawl Pattern:** Urban growth is spatially dispersed and non-compact, especially along transport and river corridors.
5. **Environmental Impact:** The built-up spread into flood-prone zones has intensified flood risks and water pollution.
6. **Population Link:** Urban expansion strongly correlates with population growth ($r = 0.92$).
7. **Accuracy & Reliability:** Consistently high classification accuracy (>85%) validates the credibility of spatial analysis.

### 4.12 Discussion

The analysis reveals a typical urbanization trajectory of a medium-sized industrial city, where economic growth drives uncontrolled land transformation. The Ramganga River, once a natural lifeline, has become increasingly encroached upon due to residential and industrial demands. The unplanned urban sprawl has altered the district's hydrological balance, reduced infiltration zones, and increased the sediment load of the river.

Comparatively, similar studies in other Ganga basin districts (e.g., Bareilly, Rampur, and Budaun) show identical patterns of peri-urban expansion and agricultural conversion. Thus, the findings from Moradabad not only reflect local dynamics but also contribute to a broader understanding of riverine urbanization in northern India.

The study underscores the urgent need for geo-environmental monitoring, strict zoning regulations, and river buffer protection policies. Integration of geospatial data into district planning frameworks would help mitigate the risks of flooding and water degradation while ensuring sustainable development.

The three-decade temporal analysis highlights a dramatic and continuous expansion of built-up area along the river corridor of Moradabad District. Using remote sensing and GIS, the study effectively quantified spatial transformations and established the interlinkages between urbanization and environmental stress. The results form a robust scientific basis for future urban management strategies and river conservation efforts.

## 5. Conclusion

The analysis of built-up area change along the Ramganga River in Moradabad District from 1994 to 2024 using Remote Sensing and GIS clearly reveals the rapid pace and spatial intensity of urban expansion over the past three decades. The study demonstrates that built-up areas have increased dramatically—primarily at the expense of agricultural and vegetative land—resulting in significant ecological stress on the river corridor. Buffer zone analysis confirms extensive encroachment within one kilometer of the riverbanks, indicating high vulnerability of floodplains to unregulated development. The strong correlation between population growth and urban expansion underscores the socio-economic pressures driving land transformation, while spatial metrics highlight a shift from compact to dispersed urban patterns. These findings emphasize the urgent need for sustainable land-use planning, enforcement of river buffer regulations, and the integration of geospatial monitoring in district-level policy frameworks. By providing quantitative and visual evidence of three decades of environmental change, the study contributes to a deeper understanding of the urban–river interface and offers valuable insights for planners, environmental managers, and policymakers aiming to balance urban growth with ecological preservation in the Moradabad region.

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