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Urban Growth Dynamics of Meerut City Using Remote Sensing and GIS

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ARTICLE DETAILS

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ABSTRACT

The spatio-temporal dynamics of LULC changes in Meerut city from 2000 to 2024 have been explored using remote sensing and GIS methods in this study. Urbanization and its environmental effects were evaluated using high-resolution (Landsat 7 ETM+ and Landsat 8 OLI) satellite data. The findings raise serious concerns built-up 50.06% (from 65.33% to 81.7% of the land), while water bodies contracted by 75%, vegetation by 82.05% and wetland by 76.36% respectively. This is an unsustainable growth model that can detract from an equitable environmental quality of life and long-term livability for Meerut city. The research methods combined multi-temporal satellite data analysis with validation at ground level, to obtain the true characteristics of land uses and land covers, offering reference for urban planning. The article ends with urgent recommendations for urban development policies that are sustainable, proposing a balanced strategy of growth that preserves the remaining natural resources but also allows for the expansion of urban activities.

1. Introduction:

If India has a rapidly changing urban-scape, Meerut city occupies an important place. Meerut, a significant industrial and educational center of Uttar Pradesh state, has experienced dramatic land use and land cover (LULC) transitions over last decades as a result of urbanization and population increase. Growing population, industrial development, transport facilities and increase in residential colonies have always been putting pressure on agricultural land and natural resources of Meerut city. Understanding how a city grows is very important. It helps us see why the city looks the way it does today. It is also essential for planning a sustainable future and managing the city's resources wisely.The traditional surveying techniques used for monitoring urban development and land use displacement are typically not only time consuming but also limited in spatial extent. On the other hand, remote sensing supplies precise and updated data at different temporal and spatial scales, for example multi-temporal and multi-spectral satellite data. On the other hand, Geographic Information Systems (GIS) are used as a tool to analyze and visualize such information that allow addressing the trends, rates, and spatial distribution of this land use changes. By combining the two technologies it creates a much higher potential of quantitative and qualitative analysis of urban dynamics.

It is noteworthy that many scholars have done research work on this subject so far. Previous research on urbanization and land use/land cover (LULC) changes has clearly demonstrated the effectiveness of remote sensing and GIS technologies in monitoring and analyzing urban expansion. Sudhira et al. (2003) established a framework for understanding urban development trends through Spatio-Temporal data analysis. Bhatta (2009) illustrated, using the case of Kolkata Metropolitan Area, how the integration of remote sensing and GIS enables in-depth analysis of urban growth patterns. Similarly, studies on Indian cities like Ranchi (Kumar et al., 2011), Pune (Sivakumar, 2014), and Gandhinagar (Badlani et al., 2017) have strengthened the methodologies for measuring urban expansion and land cover changes. In a cross-border perspective, Safder and Babar (2019) assessed urbanization and urban sprawl in Faisalabad, Pakistan, providing comparative insights. Recent studies on Mangaluru (Dhanaraj & Angadi, 2021, 2022), Raiganj (Roy & Kasemi, 2021), and Jalpaiguri (Barman et al., 2024) highlight the growing use of advanced techniques such as landscape metrics and Shannon's entropy model to evaluate urban growth. Collectively, these studies conclude that remote sensing and GIS

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provide a strong scientific basis for monitoring urban dynamics, assessing land use changes, and supporting sustainable urban planning. However, the biggest research gap in all these works is the lack of high-resolution data. To fill this research gap, the researchers have used data from high resolution satellites Landsat 7_ETM and Landsat 8_OLI in their research, which has added more truth and objectivity to the results of this research. This study is highly relevant for rapidly urbanizing cities like Meerut, where unplanned development, shrinking fallow and agricultural lands, declining water bodies, and rapid expansion of built-up areas have significantly impacted environmental balance, resource management, and urban infrastructure. Against this backdrop, the researcher has analyzed the urban expansion of Meerut city over the past 24 years (2000–2024) in this study using remote sensing and GIS applications.

The primary objective of this research is to analyze the spatio-temporal dynamics of urban development in Meerut city using high-resolution remote sensing data and GIS applications, thereby enabling evidence-based recommendations for urban planning and sustainable development.

2. Materials and method

2.1 Study Area

This city is situated in the western part of the state of Uttar Pradesh; Meerut city lies between 28°32' to 29°18' North latitude and in 77°07' to 78°14' East longitude. City wise, the city area is considerably large at 450 square kilometers, acting as a major urban centre of the National Capital Region (NCR). Administration and politics Meerut is divided into 70 wards, which is looked after by Nagar Nigam (Municipal Corporation), and own mayor post for the city and own commissioner for the district. Its topographical coverage consists of high populated urban areas, peri-urban areas and the agricultural hinterland, characterizing a fast changeover pattern from an agrarian to modern industrial and commercial city.The researcher has included not only area under the administration of Meerut Municipal Corporation but also its peripheral areas in this research, so that the horizontal expansion of the city can be assessed with greater clarity.

2.2 Material and Data Used

The following datasets have been used to accomplish the stated objectives:

1. Survey of India Topographical Sheets: Used sheets numbered 53G/4, 8, 12, 16 and 53H/9, 13. These were surveyed for Meerut city and its surrounding areas between 1966-67 and 1972 at scales of 1:25,000 and 1:50,000.
2. Guide Map: A guide map of Meerut city at a 1:20,000 scale was also used.
3. Satellite Imagery:
    a. Landsat 7_ETM satellite data with a 30-meter resolution.
    b. Landsat 8_OLI satellite data with a 30-meter resolution.
4. Ground truth data collected from study area.

2.3 Methodology

This study analyzed urban development in Meerut by integrating remote sensing, GIS, and GPS. The process began with acquiring and georeferencing high-resolution Landsat 7 ETM and Landsat 8 OLI satellite imagery. Using ArcGIS and ERDAS Imagine, researchers digitally mapped various features, including Agriculture land, Vegetations, Fallow Lands and Built-Up Land. A crucial step was ground truthing, where field surveys using GPS devices were conducted to verify the mapped features and their attributes. All collected data was then integrated into a GIS database. The final output was a 1:110,000 scale land use map that reflected all field-verified corrections. This integrated approach ensured a high degree of accuracy, providing a reliable dataset for future urban planning in Meerut.

3. Result and Discussion

Information regarding LULC in Meerut city Table-1 and Fig.-1 & 2 show the LULC of Meerut city in the year 2000. The city is primarily made up of built-up areas (633.70 sq km), which is the largest share with 65.33% of the total area of 970 square kilometers. Open and agricultural land accounted for 199.53 sq km (20.57%), while the left-out land was 57.23 sq km (5.9%) and natural vegetation was 75.66 sq km (7.8%). The water bodies are only 3.88 sq km (0.4%). The data depicts that in 2000 the majority of land in Meerut had already been converted into urban built-up areas because of the rapid expansion, whereas agricultural land, fallow areas, and natural vegetation were present in small proportions, and water bodies had become extremely scarce.

Table-1: Land Use/Land Cover (LULC) Status of Meerut City, 2000

S. No	LULC Category	Area in sq. KM	% of total Area
1	water	3.88	0.4
2	Vegetation	75.66	7.8
3	Fallow land	57.23	5.9
4	Agriculture	199.53	20.57
5	Built-Up Area	633.70	65.33
6	Total	970.00	100

Source of Data:Landsat 7_ETM satellite data with a 30-meter resolution. Acquired, August, 2025

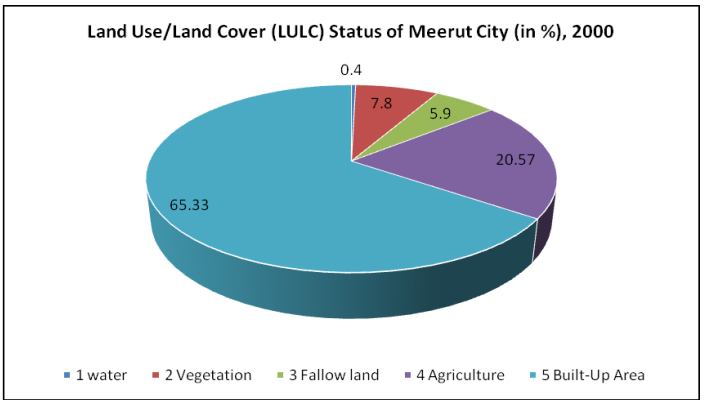

Fig.-1: Land Use/Land Cover (LULC) Status of Meerut City (in %), 2000

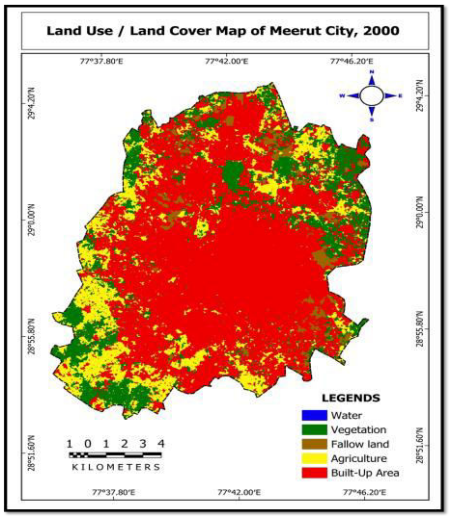

Fig.-2: Land Use/Land Cover Map of Meerut City, 2000. *Source of Data: Landsat 7_ETM satellite data with a 30-meter resolution. Acquired, August, 2025*

Urban Sprawl of Meerut City In contrast, based on table 2 and Fig-3 & 4, Meerut city demonstrates an intriguing pattern of rapid urbanization over the 970 sq km area. The built-up areas are the most significant feature of the geography of the city, as they cover an area of 792.49 sq km (81.7%) and thus, indicate the impressive urban sprawl of the city. Such a development has affected the environmental aspect significantly: the area under agriculture has been reduced to 144.53 sq km (14.9%), that under the fallow land to 18.43 sq km (1.9%), and natural vegetation to 13.58 sq km (1.4%). Most distressing is the reduction of water bodies to 0.97 sq km (0.1%), which indicates severe hydrological stress.

Table-2: Land Use/Land Cover (LULC) Status of Meerut City, 2024

S. No	LULC Category	Area in sq. KM	% of Total Area
1	water	0.97	0.1
2	Vegetation	13.58	1.4
3	Fallow land	18.43	1.9
4	Agriculture	144.53	14.9
5	Built-Up Area	792.49	81.7
6	Total	970.00	100

Source of Data: Landsat 8_OLI satellite data with a 30-meter resolution. Acquired, August, 2025

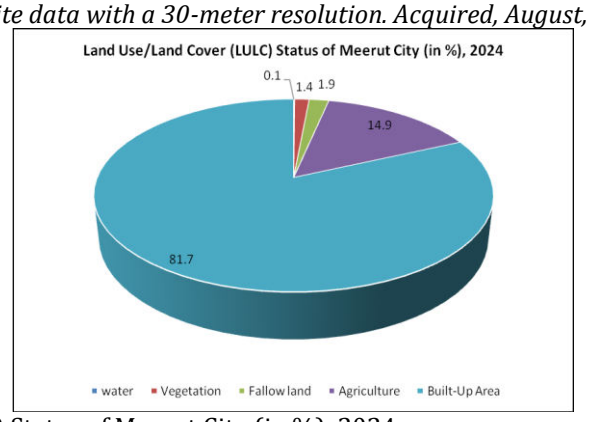

Fig.-3: Land Use/Land Cover (LULC) Status of Meerut City (in %), 2024

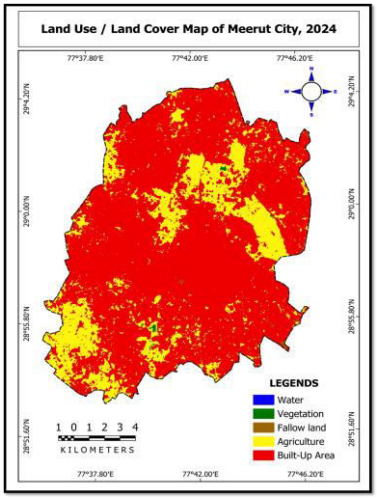

Fig.-4: Land Use/Land Cover Map of Meerut City, 2024. *Source of Data: Landsat 8_OLI satellite data with a 30-meter resolution. Acquired, August, 2025*

According to table-3 and Fig.-5 & 6 the comparative Land Use/Land Cover (LULC) analysis of Meerut city between 2000 and 2024 reveals significant transformations while maintaining a constant total area of 970 sq km. The most alarming decline occurred in water bodies, shrinking by 75% from 3.88 sq km to just 0.97 sq km. Natural vegetation suffered the most drastic reduction, plummeting by 82.05% from 75.66 sq km to a mere 13.58 sq km. Fallow land decreased substantially by 67.80%, reducing from 57.23 sq km to 18.43 sq km. Agricultural land also diminished by 27.56%, contracting from 199.53 sq km to 144.53 sq km. In stark contrast, built-up areas expanded remarkably by 25.06%, growing from 633.70 sq km to 792.49 sq km. This comprehensive analysis clearly demonstrates Meerut's rapid urbanization over 24 years, characterized by aggressive conversion of natural features and agricultural land into urban infrastructure.

Table-3: The Comparative Analysis of Meerut City's Land Use/Land Cover (LULC) Patterns Between 2000 and 2024

S. No	LULC Category	2000 Area in sq. KM	2024 Area in sq. KM	Change in %
1	water	3.88	0.97	-75.00%
2	Vegetation	75.66	13.58	-82.05%
3	Fallow land	57.23	18.43	-67.80%
4	Agriculture	199.529	144.53	-27.56%
5	Built-Up Area	633.701	792.49	25.06%
6	Total	970	970	0.00%

Source of Data: L7_ETM and L8_OLI satellite data with a 30-meter resolution. Acquired, August, 2025

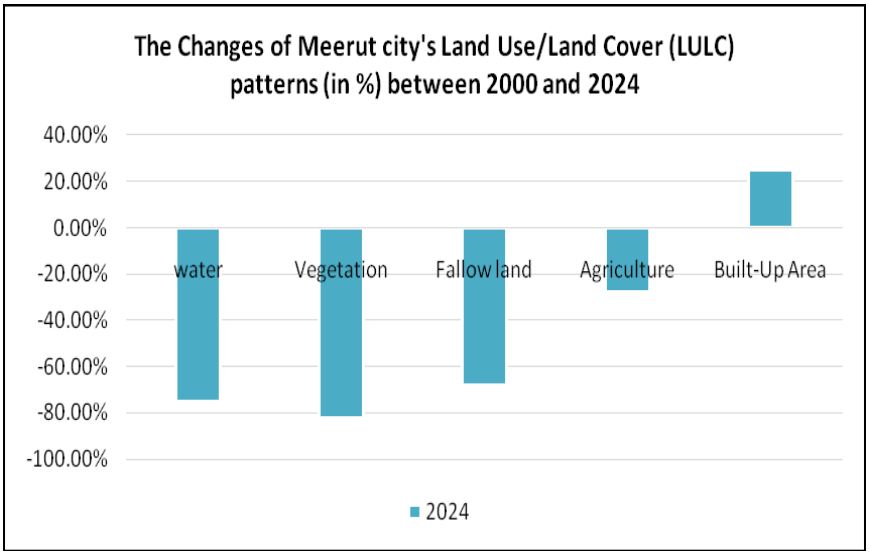

Fig.-5: The Changes of Meerut city's Land Use/Land Cover (LULC) patterns (in %) between 2000 and 2024

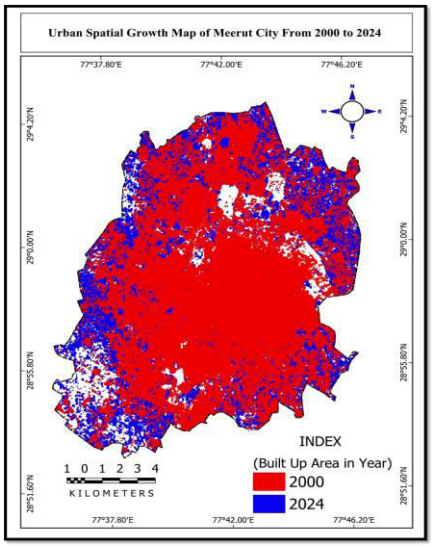

Fig.-6: Urban Spatial Growth Map of Meerut City From 2000 to 2024**.** *Source of Data: Landsat 7_ETM and Landsat 8_OLI satellite data with a 30-meter resolution. Acquired, August, 2025*

It is noteworthy, that in Fig.6, the built-up layer of year 2000 is overlapping the built-up layer of year 2024, due to which here the red color represents the built-up area of year 2000 and 2024both, while the blue color of 2024 represents the change in the built-up area between 2000 and 2024.

4. Discussion

The findings of this study clearly highlight the unsustainable pattern of urban expansion in Meerut city. Between 2000 and 2024, built-up areas increased by more than 25%, while water bodies, vegetation, fallow land, and agriculture have drastically declined. These results are consistent with earlier studies conducted in other Indian cities (Sudhira et al., 2003; Bhatta, 2009; Kumar et al., 2011), which also observed rapid urban sprawl at the cost of natural and agricultural land. However, unlike many previous works, this study used higher-resolution Landsat 7 ETM+ and Landsat 8 OLI data, providing more reliable and precise estimates of land cover transitions. The sharp decline in water bodies (75%) and vegetation (82%) indicates severe ecological stress, which may aggravate urban heat island effects, groundwater depletion, and biodiversity loss. Therefore, the study underscores the urgent need for sustainable urban planning strategies that balance urban growth with conservation of natural resources.

5. Conclusion

Analysis of LULC change in Meerut from 2000 to 2024 documents the change to be remarkable, one that was largely urban-driven. The study reveals that the city has seen a 25.06% increase in the areas of the built-up in the last 24 years and these areas now cover 81.7% of the city's total area. This growth, however, has been at the expense of nature and local food; water bodies have been reduced in size by 75%, natural vegetation has declined by 82.05%, fallow land by 67.80%, and agriculture land by 27.56% pointing towards an alarming trend of losing ecological balance and the land productive potential. The revelation of the study stresses the non-sustainability of Meerut's urban sprawl where the rise of the city's hardware has been at the sacrifice of water security, green cover, and farmlands. The extremely minimal remaining water bodies (0.1%) and very low levels of vegetation (1.4%) aggravated by the city's continuous growth not only threaten the inhabitants' health but also increase the chances of the city experiencing urban heat island effects, depletion of groundwater, and loss of biodiversity.

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