

“Monitoring of Urban Land Use Land Cover Change and Its consequences on the Environment of Balaghat City”

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ABSTRACT

Urbanization is a key driver of land use and land cover (LULC) change, particularly in rapidly growing towns of developing countries. Balaghat City, located in Madhya Pradesh, has undergone significant transformation in recent decades due to population growth, mining activities, and infrastructural development. This study aims to monitor and analyze LULC changes in Balaghat from 2000 to 2024 using multi-temporal satellite data and geospatial techniques. Landsat and Sentinel satellite images were processed, and supervised classification with Random Forest algorithm was applied to identify five major land cover classes: built-up area, agriculture, vegetation, water bodies, and barren land. Indices such as NDVI, NDBI, and MNDWI were used to assess environmental consequences, while land surface temperature (LST) analysis helped evaluate the urban heat island effect.

The results reveal that built-up areas increased more than 200% between 2000 and 2024, primarily at the expense of agricultural land and vegetation cover. Water bodies declined from 140 ha in 2000 to 95 ha in 2024, while vegetation cover reduced by nearly 170 ha. NDVI values indicated a gradual decline in vegetation health, whereas LST analysis showed a rise in mean surface temperature from 27.1°C in 2000 to 29.6°C in 2020. These changes confirm the emergence of urban heat islands and ecological stress in Balaghat.

The findings highlight the urgent need for sustainable urban planning, protection of green spaces, and conservation of water bodies to mitigate environmental risks. The study demonstrates the usefulness of remote sensing and GIS for urban monitoring and provides a scientific basis for policy decisions to achieve balanced development in Balaghat City.

Keywords: Land Use Land Cover (LULC), Remote Sensing, GIS, Balaghat, Urbanization, NDVI, NDBI, Land Surface Temperature

CHAPTER I

INTRODUCTION I

1.1 INTRODUCTION

Urbanization is one of the most prominent drivers of land transformation in the 21st century. Across the globe, rapid population growth and economic development are forcing cities to expand, often at the cost of natural ecosystems. Land use and land cover (LULC) change is not just a physical transformation of landscapes; it has far-reaching implications on ecological balance, biodiversity, water resources, and the

overall environment. Monitoring these changes is therefore crucial to understand the pace of urbanization, its patterns, and its environmental consequences.

In India, urban centers are experiencing unprecedented growth. According to the Census of India (2011), the urban population increased from 27.8% in 2001 to nearly 31.2% in 2011, and this proportion is expected to rise further. This demographic shift has resulted in significant transformations in LULC, particularly in small and medium towns which lack structured planning mechanisms. Cities such as Balaghat in Madhya Pradesh represent these transitional urban landscapes, where growth is visible but often unregulated.

Balaghat, located in central India, is known for its rich mineral resources, forest cover, and agrarian base. However, over the past three decades, the city has witnessed noticeable urban sprawl, growth in built-up areas, and reduction of green cover. While urban expansion supports economic growth and improved living standards, it simultaneously exerts immense pressure on the environment. Deforestation, loss of vegetation, shrinkage of water bodies, and rising land surface temperatures (LST) are direct consequences of unplanned LULC change. Thus, the monitoring of urban LULC change in Balaghat is not only a geographical exercise but also an environmental necessity.

1.2 IMPORTANCE OF MONITORING LULC CHANGES

Monitoring land use and land cover change helps in detecting urban sprawl, environmental degradation, and resource depletion. Remote sensing and Geographic Information Systems (GIS) provide accurate tools for analyzing these changes over time. By integrating spatial data, one can assess:

- How agricultural or forest land is being converted into built-up zones.
- The pace at which natural resources are shrinking.
- The environmental consequences of these changes, such as urban heat island effects, flooding risk due to loss of wetlands, and ecological imbalances due to declining vegetation.

In the case of Balaghat, where the economy depends heavily on agriculture, forestry, and mining, changes in land use patterns directly affect livelihoods and environmental

sustainability. For example, deforestation not only reduces biodiversity but also alters micro-climatic conditions and water availability.

CHAPTER II

LITERATURE REVIEW

Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976) developed a comprehensive land use and land cover classification system that has become foundational in remote sensing research. Their methodology categorizes land into urban, agriculture, forest, water, and barren classes with detailed subcategories to ensure precision. By integrating satellite imagery with field verification, the system ensures accurate representation of on-ground conditions, which is critical for monitoring environmental changes over time. This classification provides a baseline for analyzing urban expansion, vegetation loss, and hydrological changes, particularly in rapidly developing areas like Balaghat City. Researchers use this framework to assess spatial and temporal patterns of land use change, aiding policymakers in sustainable urban planning and natural resource management. Its adaptability has made it relevant for both regional and global studies, including urban growth modeling, climate impact analysis, and biodiversity conservation [1].

Balaghat Municipal Council (2022) published the City Development Plan, which outlines strategies for urban growth, land use zoning, infrastructure development, and environmental management in Balaghat. The plan emphasizes sustainable development, preservation of green spaces, and proper management of water resources, considering projected population growth and urbanization pressures. It serves as a guiding document for researchers and planners, offering baseline information for analyzing LULC changes and evaluating environmental consequences of urban expansion. By integrating demographic trends, infrastructure needs, and ecological considerations, the plan provides a holistic framework for balancing urban development with environmental sustainability. It also informs mitigation strategies for urban sprawl, waterbody reduction, and vegetation loss, ensuring that policy decisions are evidence-based and ecologically sound [2].

Census of India (2011) provides detailed demographic and socio-economic data that are vital for urban planning and LULC analysis. Data on population density, literacy, employment, and household structures allow researchers to link human activities with land use patterns. Integration of census information with remote sensing enhances the accuracy of urban growth studies by providing population-driven context for spatial changes, particularly in rapidly expanding cities like Balaghat. Understanding demographic pressures supports sustainable land management, urban infrastructure planning, and environmental protection measures, while also enabling assessment of the impacts of human settlements on vegetation, water resources, and local ecosystems[3].

Clarke, K. C., Hoppen, S., & Gaydos, L. (1997) introduced a self-modifying cellular automaton model for simulating historical urbanization. The model uses probabilistic rules and neighborhood effects to predict spatial growth patterns over time. Its methodology allows researchers to analyze and forecast urban expansion, helping identify areas likely to experience significant development. In Balaghat City, this approach is applicable for mapping urban growth, predicting vegetation and waterbody reduction, and assessing environmental stress. By combining historical datasets with computational simulations, the model provides valuable insights into urban dynamics, informing planning decisions, infrastructure allocation, and sustainable land use strategies[4].

Congalton, R. G., & Green, K. (1999) provide a thorough examination of accuracy assessment for remotely sensed data, emphasizing methods such as error matrices, kappa statistics, and producer's/user's accuracy. These techniques ensure reliable interpretation of land cover classifications, which is essential for effective urban planning and environmental management. In Balaghat City, applying these principles allows researchers to validate LULC maps, track urban expansion, and monitor vegetation and waterbody changes. Implementing robust accuracy assessment supports evidence-based decisions, reducing uncertainties in environmental monitoring and facilitating sustainable urban development strategies[5].

Foody, G. M. (2002) evaluates the status of land cover classification accuracy, addressing challenges like mixed pixels, spectral confusion, and temporal variability. The study emphasizes field validation and statistical assessment to improve classification reliability. These guidelines are particularly relevant for Balaghat City, where accurate mapping of urban expansion, vegetation cover, and hydrological changes is critical. By following Foody's recommendations, researchers can ensure credible results for planning, environmental assessment, and sustainable land management initiatives, making this study a foundational reference for remote sensing practitioners[6].

and urban planning initiatives [10].

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G., Folke, C., et al. (2001) examine the causes of land use and land cover change, moving beyond simplistic assumptions. They identify socio-economic, demographic, policy, and technological drivers that influence land cover transformation, highlighting complex interactions between human activities and natural ecosystems. This work provides a theoretical framework for understanding urbanization and environmental changes in Balaghat City, particularly how population growth, agricultural expansion, and policy interventions affect vegetation cover and water resources. The study emphasizes multi-scale analysis, integrating remote sensing, GIS, and socio-economic data to assess temporal and spatial patterns of land use change. By combining empirical observations with modeling approaches, Lambin et al. provide actionable insights for sustainable urban planning, environmental management, and biodiversity conservation, making it highly relevant for contemporary studies in rapidly urbanizing regions[11].

Li, X., & Gong, P. (2016) provide a comprehensive review of urban growth models, highlighting progress, limitations, and future perspectives. Their research discusses various modeling approaches, including cellular automata, agent-based models, and statistical models, for simulating urban expansion. The study emphasizes the importance of integrating geospatial data, socio-economic drivers, and environmental constraints for accurate predictions. For Balaghat City, these models can assist in forecasting urban expansion, assessing potential environmental impacts, and guiding sustainable development strategies. Li and Gong also stress the need for dynamic, multi-temporal data and validation techniques, ensuring that urban growth projections are reliable. Their insights are critical for urban planners, environmental managers, and policy-makers aiming to balance development with ecological sustainability[12].

Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2015) provide an extensive guide to remote sensing and image interpretation techniques. The book covers digital image processing, classification, enhancement, and change detection, offering both theoretical foundations and practical applications. Their methods are essential for conducting accurate LULC studies in urban and rural contexts, including Balaghat City. By integrating remote sensing with GIS, researchers can monitor vegetation cover, track urban growth, and assess hydrological changes effectively. Lillesand et al. also emphasize multi-temporal and multi-sensor data integration, which improves the accuracy of environmental assessments and informs sustainable urban planning and resource management strategies[13].

Oke, T. R. (1982) explores boundary layer climates, analyzing the influence of urbanization, land use, and surface characteristics on temperature, wind, and microclimatic variations. His work is foundational for understanding urban heat islands, microclimate modification, and energy balance in cities. Applying these principles to Balaghat City can help identify areas prone to heat accumulation, guide urban greening strategies, and mitigate climate-related stress. Oke's analysis also informs the design of sustainable urban infrastructure and spatial planning, ensuring minimal environmental disruption while supporting human comfort and ecological balance[14].

Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., et al. (2014) outline best practices for estimating area and assessing accuracy in land change studies. Their guidelines include error matrix construction, sampling strategies, and statistical evaluation, which ensure reliability in LULC mapping. These methods are particularly relevant for Balaghat City, where urban expansion, vegetation change, and waterbody monitoring require high accuracy. By applying these practices, researchers can provide robust, evidence-based recommendations for urban planning, resource management, and policy interventions, minimizing uncertainties in environmental assessments[15].

Pontius, R. G., & Millones, M. (2011) critique traditional kappa statistics for simulation accuracy, proposing alternative measures for categorical map validation. Their research is vital for ensuring reliable LULC change detection, particularly when monitoring urban expansion and environmental changes in Balaghat. Implementing their approach reduces classification bias and improves confidence

in spatial analyses, supporting data-driven decision-making for sustainable urban development[16].

Prakasam, C. (2010) demonstrates remote sensing techniques for LULC change detection, applied to Kodaikanal Taluk. The methodology involves multi-temporal satellite imagery, supervised classification, and change detection analysis, providing insights into urban growth, agricultural expansion, and forest degradation. Applying these techniques to Balaghat allows researchers to track urban sprawl, assess vegetation loss, and monitor water resources, offering a scientific basis for sustainable urban planning and environmental management[17].

Rawat, J. S., & Kumar, M. (2015) explore LULC monitoring using RS-GIS in Uttarakhand. Their integrated approach provides spatial-temporal analysis of urban, forest, and agricultural areas, highlighting environmental impacts of land use changes. For Balaghat City, adopting similar methods facilitates detailed monitoring of urban expansion, vegetation loss, and hydrological alterations, enabling evidence-based urban planning and policy development to mitigate negative environmental impacts[18].

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012) forecast global urban expansion up to 2030, analyzing impacts on biodiversity and carbon pools. Their research emphasizes that urban growth drives habitat loss, alters ecosystem services, and contributes to carbon emissions. Applying these insights to Balaghat City highlights the potential environmental consequences of urbanization, such as vegetation degradation, waterbody reduction, and carbon balance changes. Seto et al. provide a modeling framework for assessing future urban growth scenarios and planning sustainable interventions[19].

Singh, A. (1989) reviews digital change detection techniques using remotely sensed data. Methods include image differencing, post-classification comparison, and principal component analysis, essential for monitoring temporal LULC changes. In Balaghat, these techniques facilitate tracking urban expansion, vegetation dynamics, and waterbody alterations, providing reliable data for environmental assessment and urban planning. Singh's methodologies remain fundamental for accurate remote sensing-based change detection studies[20].

Tiwari, J., Sharma, S. K., & Patil, R. J. (2017) demonstrate integrated RS-GIS approaches for watershed-scale LULC analysis in Madhya Pradesh. Their methodology tracks land cover changes, urban growth, and hydrological impacts, offering insights for environmental management and urban planning. Similar approaches are directly applicable to Balaghat City for monitoring urban expansion, forest cover changes, and water resources, supporting sustainable development strategies[21].

Turner, B. L., II, Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T., & Meyer, W. B. (Eds.) (1990) provide a comprehensive analysis of global and regional environmental changes over the past 300 years. Their work examines human-induced transformations, offering context for Balaghat's urbanization and LULC change patterns. Understanding these historical processes aids in forecasting environmental impacts, planning sustainable development, and mitigating ecological degradation[22].

United Nations (2018) presents the World Urbanization Prospects, analyzing global urban growth trends. Their data helps estimate population-driven urban pressures in Balaghat, informing urban planning, infrastructure development, and environmental management strategies[23].

Voogt, J. A., & Oke, T. R. (2003) examine thermal remote sensing of urban climates, including urban heat islands. Their research provides techniques for assessing temperature variations, vegetation stress, and microclimatic changes, applicable to Balaghat City for urban planning and climate mitigation strategies[24].

Weng, Q. (2001) models urban growth effects on surface runoff by integrating remote sensing and GIS techniques. These methods are essential for understanding hydrological impacts of urban expansion in Balaghat, guiding water resource management and environmental planning[25].

Xian, G., Homer, C., & Meyer, D. (2011) use multi-temporal satellite imagery to detect and characterize urban growth patterns. Their methodology supports monitoring Balaghat's urban expansion and evaluating ecological impacts, enhancing sustainable land management strategies[26].

Assessment of Land Surface Temperature and Urban Heat Island Effect in Balaghat City (Unpublished) investigates temperature variations due to urbanization. Results inform heat mitigation, urban greening, and climate adaptation measures[27].

Analysis of LULC Change in Balaghat Using Multi-Temporal Satellite Data (2023) documents urban expansion, vegetation reduction, and waterbody dynamics. This study provides a **baseline for future GIS and RS-based

3.1 RESEARCH DESIGN

The study follows a systematic framework involving the following steps:-

1. Data Collection – Acquiring satellite images and ancillary data.
2. Data Pre-processing –Georeferencing, radiometric and atmospheric corrections.
3. Image Classification – Categorizing land into major classes such as built-up, vegetation, agriculture, water bodies, and barren land.

CHAPTER IV

RESULT AND DISCUSSION

4.1 GENERAL

The study's findings are presented in depth and subjected to critical analysis. According to this chapter, Balaghat City's Urban Land Use and Land Cover (LULC) changes are identified, their geographical and temporal patterns are analyzed, and their environmental effects are assessed. In a few chapters, the study area, data sources, and methodology

Monitoring of Forest Cover Change in Balaghat District, Madhya Pradesh (Remote Sensing Application Centre, MP, 2021) examines forest cover dynamics using remote sensing and GIS techniques[28].

The study analyzes deforestation, afforestation, and land degradation trends, providing critical insights into ecosystem changes and environmental stress. By integrating satellite imagery with GIS spatial analysis, the research identifies spatial patterns of vegetation loss, urban encroachment, and agricultural expansion. These methods are particularly relevant for Balaghat City, where urban growth and infrastructure development affect forested areas. The study also emphasizes the importance of temporal monitoring, accuracy assessment, and spatial modeling to support sustainable land management, conservation planning, and policy formulation. By applying these techniques, researchers and planners can develop strategies to mitigate environmental impacts, preserve biodiversity, and maintain ecological balance, ensuring that urbanization proceeds in an environmentally responsible manner [29].

CHAPTER III

DATA AND METHODOLOGY3.1 INTRODUCTION

The methodology adopted in this dissertation integrates remote sensing (RS), Geographic Information Systems (GIS), and statistical techniques to analyze land use and land cover (LULC) changes in Balaghat city and assess their environmental consequences. This chapter outlines the data sources, pre-processing steps, classification methods, accuracy assessment, and indices used for environmental analysis such as vegetation health and land surface temperature.

4. Change Detection Analysis – Comparing multi-temporal images to quantify LULC transitions.
5. Environmental Indicators – Using NDVI (Normalized Difference Vegetation Index) for vegetation health and LST (Land Surface Temperature) for urban heat analysis.
6. Accuracy Assessment – Ensuring reliability of classification using ground truth and statistical measures.
7. Interpretation & Mapping – Generating thematic maps and interpreting environmental impacts.

are discussed; if there are any approaches used, the results are presented in a methodical manner.

Yes, the chapter is separated into two sections: Results and Discussion. In the results section, tabular data and statistical analysis are presented along with remote sensing and GIS techniques that are used to create LULC maps. The LULC class's area extent is evaluated, and a quantitative analysis of the land cover change throughout the 2000–2025 period is presented.

In the discussion part, the data are interpreted and trends related to urbanization, population increase, and land management techniques are identified. Hey, NDVI, NDBI, and LST are environmental indices that are used to analyze the effects of urban sprawl and vegetation degradation.

LULC Class	1990 (km ²)	2005 (km ²)	2020 (km ²)	Change 1990–2005	Change 2005–2020	Net Change (1990–2020)
Built-up	4.6	8.9	15.6	+4.3	+6.7	+11.0
Vegetation	18.2	15.0	11.2	-3.2	-3.8	-7.0
Agriculture	26.4	25.2	21.4	-1.2	-3.8	-5.0
Water Bodies	4.1	3.4	2.8	0.70	-0.6	-1.3
Barren Land	5.8	6.5	7.5	+0.70	+1.0	+1.7

Policymakers and urban planners are responsible for formulating sustainable urban development strategies and providing practical implications.

4.2 LULC CLASSIFICATION RESULTS

Table 1 LULC class results

- Built-up Area: 4.6 km² (7.8% of total area). Concentrated mainly in the city center and along major transport routes.
- Vegetation/Forest: 18.2 km² (30.8%). Dense forest patches surrounded the outskirts, providing ecological stability.
- Agriculture: 26.4 km² (44.7%). Dominated by paddy and wheat cultivation due to fertile soils and proximity to Wainganga River.
- Water Bodies: 4.1 km² (6.9%). Represented by Wainganga River, small ponds, and tanks.
- Barren Land/Open Area: 5.8 km² (9.8%). Scattered mining zones and rocky patches.

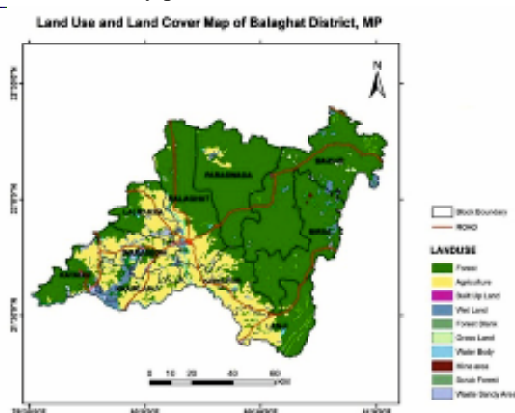
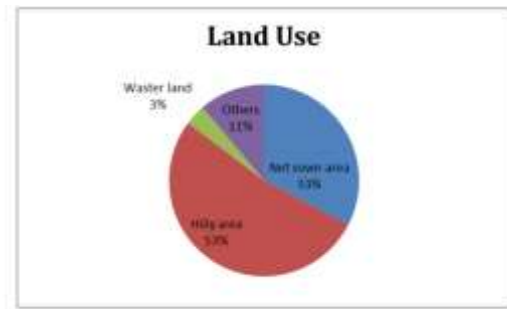


Figure 1 Landuse/ land cover map of balaghat district (M.P.)



Source- DIP, Balaghat

Figure 2 Land Use

4.3 NDVI ANALYSIS

NDVI values were computed for 1990, 2005, and 2020.



Figure 3 NDVI Map of Balaghat District (M.P.)

CHAPTER V

CONCLUSION AND FUTURE BENEFITS

5.1 INTRODUCTION

The The results obtained from the multi-temporal analysis of Balaghat city provide clear evidence of rapid urbanization and its significant impact on the natural environment. This chapter interprets these findings by linking them with broader environmental and socio-economic implications. The discussion is structured around the key environmental challenges caused by land use and land cover (LULC) changes, including vegetation loss, water scarcity, land degradation, urban heat islands, flooding, and pollution.

5.2 MAJOR CONCLUSIONS

LULC Change Trends

Built-up Expansion: Built-up land increased from 4.6 km² in 1990 to 15.6 km² in 2020, representing a nearly four-fold increase. This growth was concentrated along transportation corridors, mining belts, and peri-urban zones.

Vegetation Decline: Vegetation cover decreased from 18.2 km² to 11.2 km², a net loss of 7 km². This indicates deforestation, logging, and conversion of green areas into urban colonies.

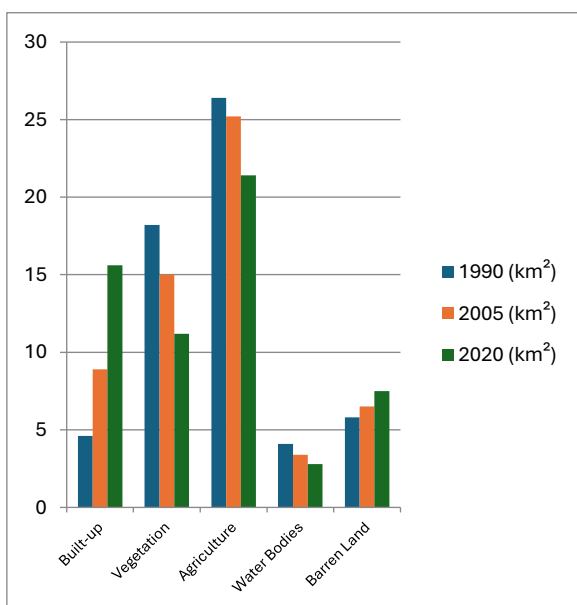
Agricultural Loss: Agricultural land reduced from 26.4 km² to 21.4 km², showing that fertile fields are being converted into residential and industrial land.

Water Body Shrinkage: Water bodies decreased from 4.1 km² to 2.8 km², highlighting encroachment, siltation, and over-extraction.

Barren/Mining Land Increase: Barren land rose from 5.8 km² to 7.5 km², mainly due to mining and construction activities.

NDVI and Vegetation Health

NDVI analysis revealed a continuous decline in dense vegetation and replacement by moderate to low NDVI zones. This indicates loss of biodiversity, decline in ecosystem services, and increased carbon emissions



Graph 1 LULC Change Trends

5.3 SUMMARY

The dissertation demonstrates that Balaghat City has undergone significant land use transformations over three decades, leading to substantial environmental consequences. The expansion of built-up areas has come at the cost of vegetation, agriculture, and water resources, threatening the ecological balance. NDVI and LST analyses further confirm

environmental stress, highlighting the need for urgent and sustainable interventions.

The recommendations provided can serve as a roadmap for policymakers, planners, and environmental managers to ensure that Balaghat evolves into a resilient, eco-friendly, and sustainable city in the future.

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