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Land Use and Land Cover Analysis of Hyderabad Metropolitan Development Authority (HMDA) Using Remote Sensing and GIS Techniques

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Abstract: Rapid urbanization in the Hyderabad Metropolitan Development Authority (HMDA) region has resulted in significant transformations of land use and land cover (LULC) over the past 15 years. These changes, primarily characterized by the expansion of built-up areas at the expense of vegetation and water bodies, pose challenges to environmental sustainability and urban resilience.

This study employs multi-temporal satellite imagery from 2009, 2014, 2019, and 2024 to map and quantify LULC dynamics using remote sensing and Geographic Information System (GIS) techniques. Supervised classification, supported by accuracy assessments exceeding 85%, was applied to delineate five key classes: built-up, vegetation, dense vegetation, barren soil, and water bodies. The results reveal a 33% increase in built-up land alongside substantial declines in vegetation (−240 km²) and water bodies (−87 km²).

Spatial analysis highlights radial urban growth concentrated around Hyderabad's core and outward expansion into surrounding districts. These findings demonstrate the ecological pressures of urban sprawl and emphasize the need for integrating geospatial monitoring into urban planning. By providing evidence-based insights, the study supports strategies aimed at conserving ecological resources, mitigating urban heat island effects, and promoting sustainable land management in rapidly growing metropolitan regions.

Keywords: Land Use Land Cover (LULC), Remote Sensing, GIS, Hyderabad Metropolitan Development Authority (HMDA), Urbanization, Environmental Sustainability

I. INTRODUCTION

Urbanization is rapidly transforming landscapes in many developing regions, including the Hyderabad Metropolitan Development Authority (HMDA) area in Telangana, India. Over the past 15 years, HMDA has experienced significant land use and land cover (LULC) changes, driven by population growth, infrastructure development, and economic expansion. These changes often lead to the reduction of vegetation, fragmentation of agricultural land, and shrinking of water bodies, which pose challenges to environmental sustainability.

Accurate monitoring of LULC changes is essential for effective urban planning and natural resource management. Remote sensing and Geographic Information System (GIS) technologies provide powerful tools to analyze spatial and temporal variations in land cover.

This study uses multi-temporal satellite imagery from 2009, 2014, 2019, and 2024, applying the Maximum Likelihood Classification (MLC) method to classify and quantify key land cover types in the HMDA region.

The findings aim to inform sustainable urban development strategies and future ecological impact assessments in this rapidly changing metropolitan area.

A. Objectives

The main objectives of the work are

To perform landuse and landcover analysis in the study area of HMDA from 2009 to 2024.

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II. STUDY AREA

Fig. 1 India Map

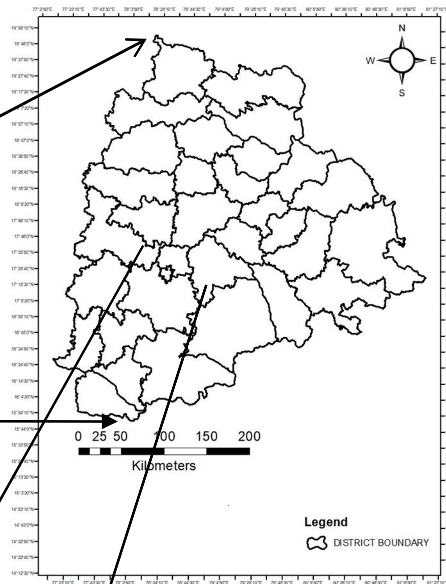

Fig. 2 Telangana Map

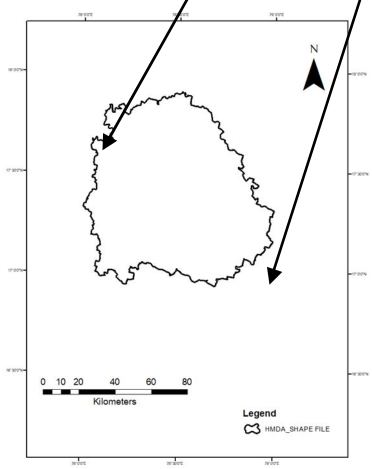

Fig. 3 Study Area Boundary Map

The Hyderabad Metropolitan Development Authority (HMDA) region is located in the state of Telangana, India, covering an area of approximately 7,257 square kilometers. It includes the city of Hyderabad along with its adjoining districts such as Medchal–Malkajgiri, Rangareddy, Sangareddy, Medak, Siddipet, and Yadadri Bhuvanagiri. The region spans geographical coordinates from 16°55′N to 17°53′N latitude and 78°00′E to 78°59′E longitude.

The region lies in the semi-arid Deccan Plateau and experiences a tropical wet and dry climate. Summers are generally hot, with temperatures exceeding 40°C, while winters remain mild. Annual rainfall averages between 750 mm and 850 mm, largely driven by the southwest monsoon. The topography includes undulating terrain, rocky outcrops, low-lying valleys, and several minor rivers, making the area ecologically diverse and hydrologically significant.

Land use within HMDA is heterogeneous, encompassing dense urban development, peri-urban zones, agricultural fields, forest patches, and water bodies. Due to Hyderabad's role as a commercial and IT hub, built-up areas have rapidly expanded, replacing natural landscapes. The region's dynamic transformation makes it an ideal case for LULC monitoring, especially to inform urban planning and sustainable land management practices.

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III. DATA AND METHODOLOGY

1) Data Sources: Satellite imagery for the years 2009, 2014, 2019, and 2024 was acquired from open-access platforms such as Landsat and Sentinel. These images were chosen based on spatial resolution, cloud cover, and seasonal comparability.
2) Preprocessing: Preprocessing steps included geometric correction, atmospheric correction, and image enhancement to ensure consistency and accuracy across datasets.
3) Classification Techniques

- Supervised Classification: Training samples were collected for each land cover class using field data and high-resolution imagery. Algorithms such as Support Vector Machine (SVM) and Maximum Likelihood Classification (MLC) were employed.
- Unsupervised Classification: Clustering methods like K-means were tested for comparison but were not used for final mapping due to lower accuracy.

4) Land Cover Classes The study classified the land into five primary categories:

- Built-up Area
- Vegetation
- Dense Vegetation
- Barren Soil
- Water Bodies

5) Accuracy Assessment The classification results were validated using ground truth data and confusion matrices, achieving an overall accuracy of over 85% for each time period.

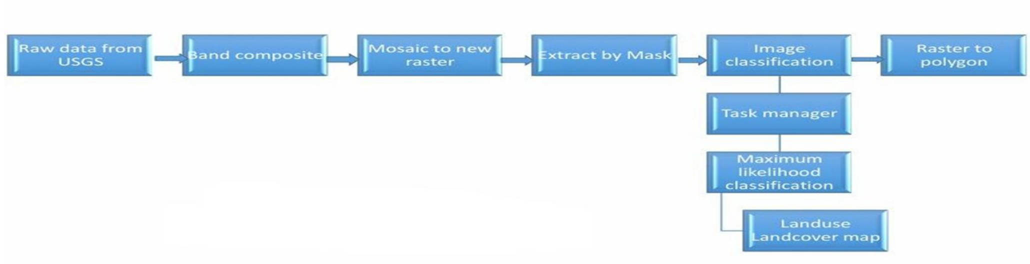
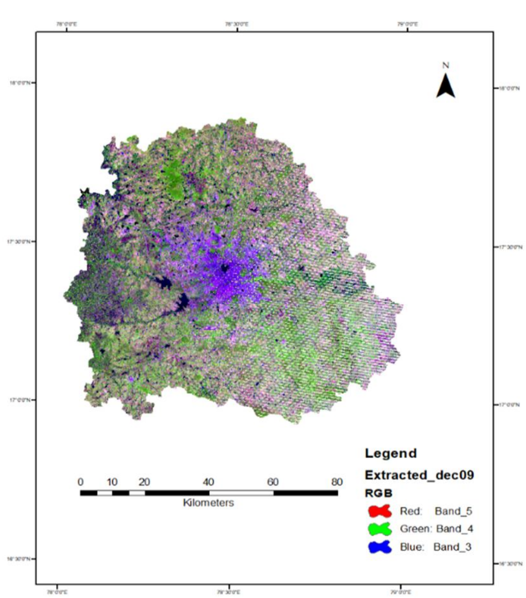


Fig.04 Flow chart for LULC

IV. RESULTS AND DISCUSSION

A. LULC Analysis



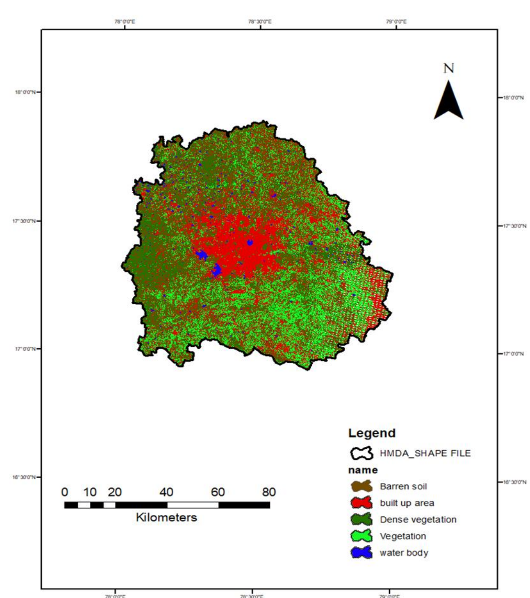


Fig: 05 Satellite Imagery of the study area 2009

Fig: 06 LULC map for the study area 2009

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Table no: 01

LULC_Classification	Area(km^2)
Barren land	1886.38
Built up area	2421.46
Dense vegetation	932.98
Vegetation	1810.57
Water body	205.73
Total	7257.12

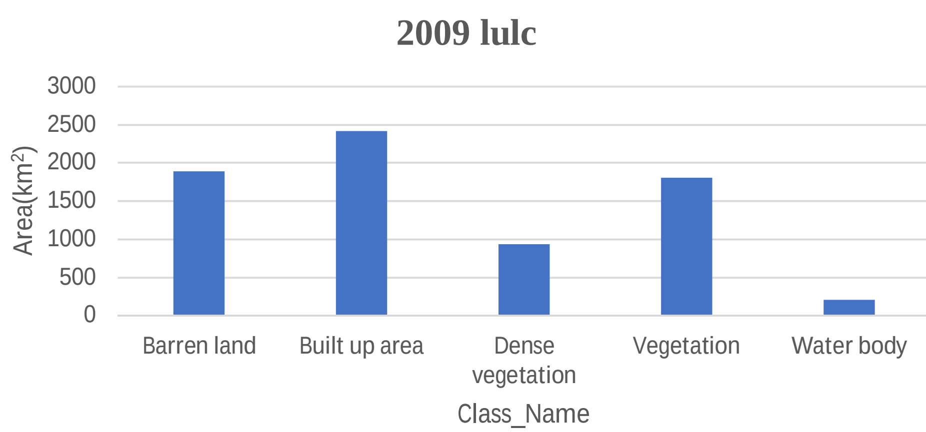
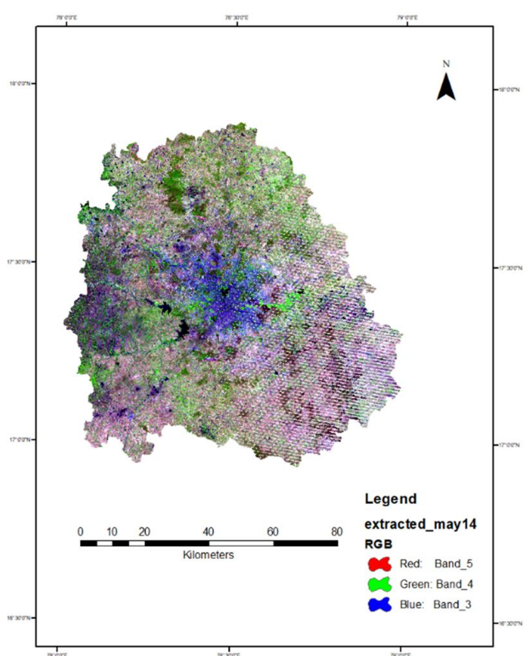


Fig 07: 2009 LULC



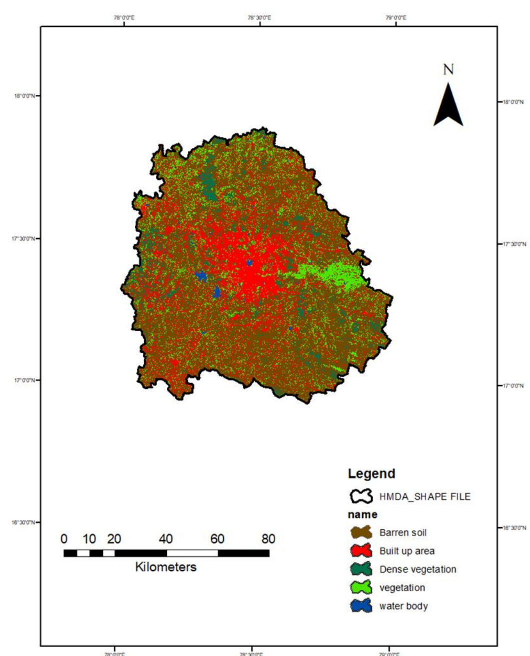


Fig: 08 Satellite Imagery of the study area 2014

Fig: 09 LULC map for the study area 2014

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Table no: 02

LULC_Classification	Area(km^2)
Barren land	1618.08
Built up area	2874.37
Dense vegetation	899.59
Vegetation	1701.49
Water body	164.26
Total	7257.79

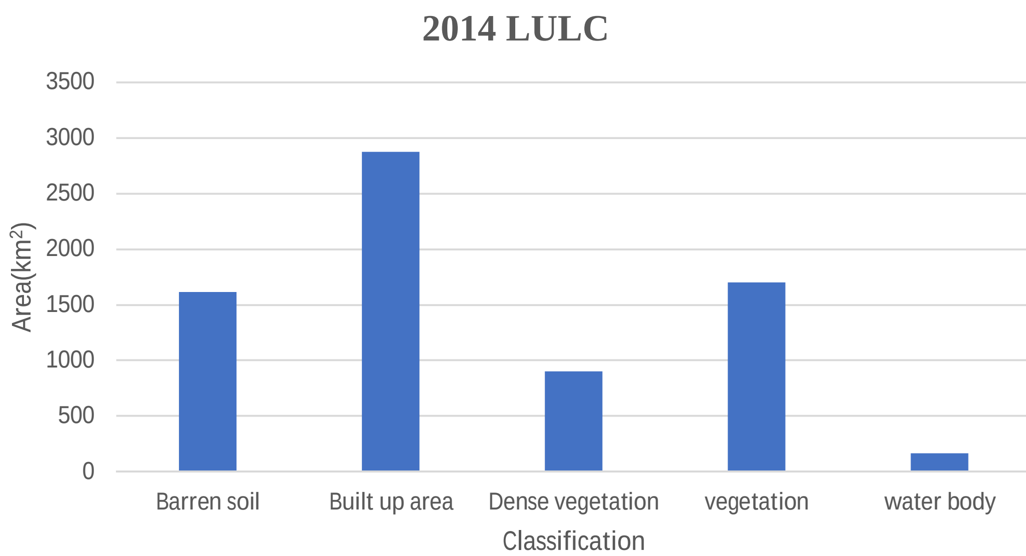
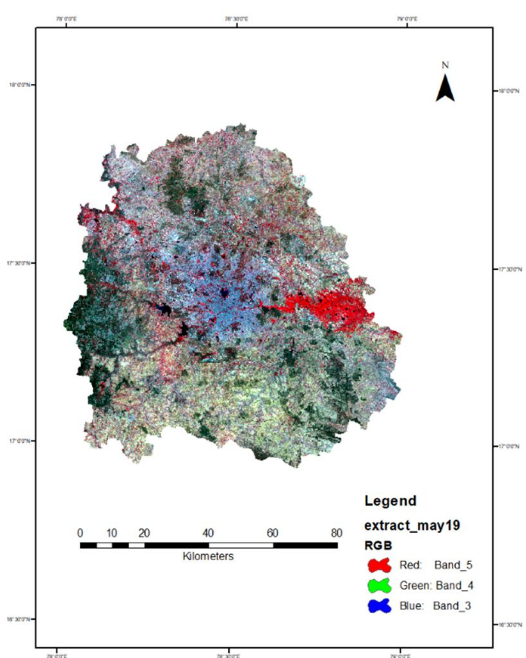


Fig10: 2014 LULC



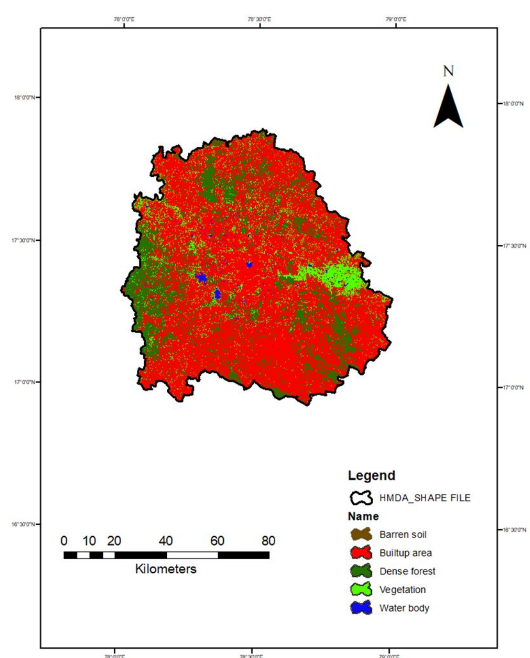


Fig: 11 Satellite Imagery of the study area 2019

Fig: 12 LULC map for the study area 2019

Table no: 03

LULC_Classification	Area(km^2)
Barren land	1568.83
Built up area	3038.72
Dense vegetation	878.31
Vegetation	1646.38
Water body	124.89
Total	7257.91

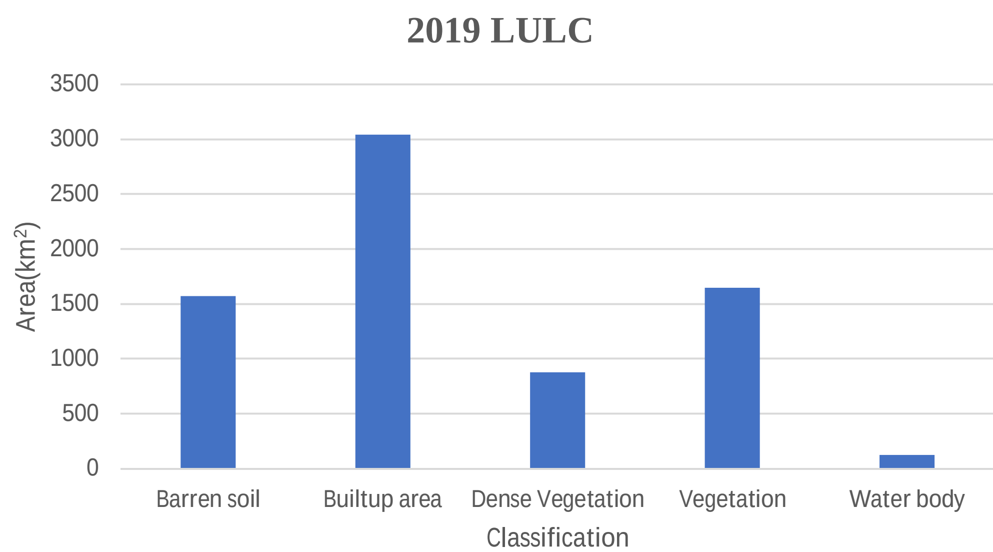


Fig13: 2019LULC

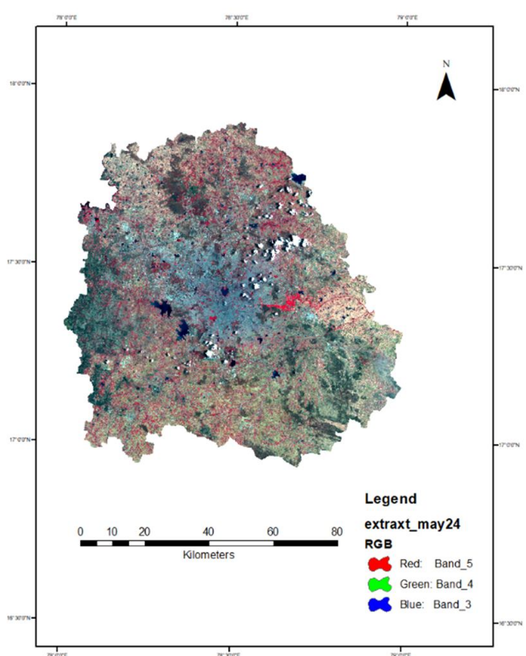


Fig: 14 Satellite Imagery of the study area 2024

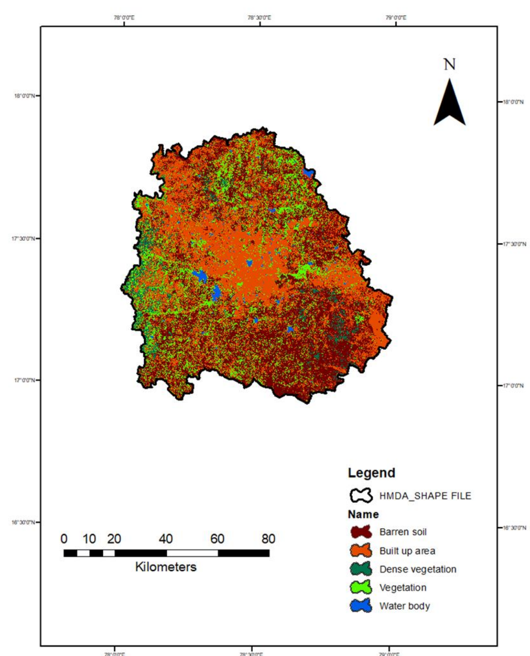


Fig: 15 LULC map for the study area 2024

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Table no: 04

LULC_Classification	Area(km^2)
Barren land	1491.66
Built up area	3223.98
Dense vegetation	867.67
Vegetation	1561.37
Water body	113.23
Total	7257.13

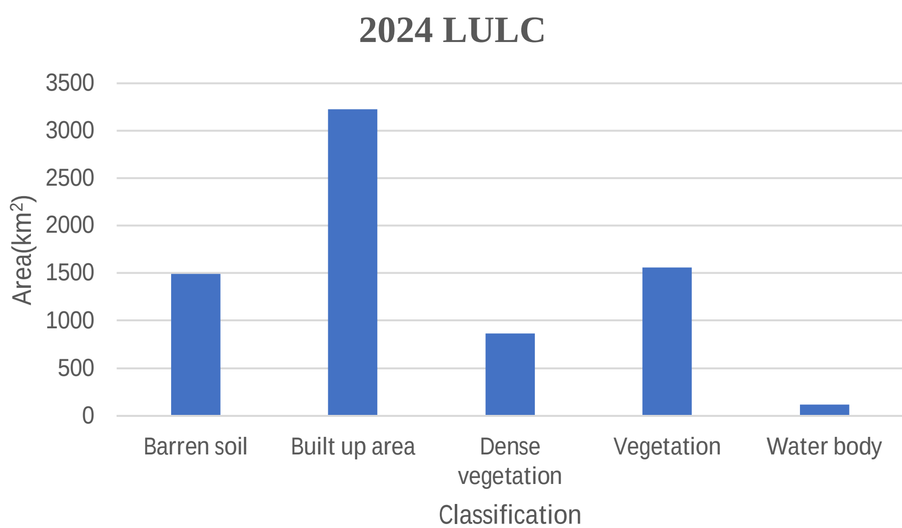

Fig16: 2024 LULC

A. *Temporal Changes in Land Cover (2009–2024)*

Table no: 05

Year	Built-Up (km^2)	Vegetation (km^2)	Dense Vegetation (km^2)	Barren Soil (km^2)	Water Body (km^2)
2009 May	2,421.46	1,810.57	932.98	1,886.38	205.73
2014 May	2,874.37	1,701.49	899.59	1,618.08	164.26
2019 May	3,038.72	1,646.38	878.31	1,568.83	124.89
2024 May	3,223.98	1,561.37	867.67	1,491.66	113.23

B. *Observations*

- Built-up Area: Increased by 806.52 km^2 (33%) over 15 years, reflecting rapid urbanization.
- Vegetation: Declined by 240.71 km^2 due to conversion to urban infrastructure.
- Dense Vegetation: Slight but continuous decrease, indicating pressure on forested areas.
- Barren Soil: Reduced by over 400 km^2, mainly due to urban construction and reforestation efforts.
- Water Bodies: Decreased by 87.5 km^2, raising concerns about groundwater recharge and urban flooding.

C. Spatial Patterns

The core urban areas of Hyderabad have expanded radially, with notable growth towards Medchal and Rangareddy districts. Peripheral rural areas show gradual conversion into residential and industrial zones.

V. DISCUSSION

The LULC analysis underscores the urgent need for balanced development. The alarming rise in built-up areas at the cost of vegetation and water bodies can exacerbate environmental challenges. Integrating LULC data into urban planning can help mitigate adverse effects such as the Urban Heat Island (UHI) and enhance resilience to climate change. Furthermore, GIS-based LULC monitoring can aid in zoning regulations, green space conservation, and infrastructure planning.

VI. CONCLUSION

This study provides a focused assessment of Land Use and Land Cover (LULC) changes in the HMDA region for the month of May, examining spatial shifts from 2009 to 2024. The results indicate a substantial and consistent increase in built-up areas, driven by urban expansion, which is paralleled by a decline in vegetative cover and water bodies. These transformations underscore the growing pressure urbanization places on the region's natural resources.

Through the use of remote sensing and GIS techniques, the research effectively maps these changes, offering valuable insights for urban planners and policymakers. The study emphasizes the need for proactive land use policies that promote sustainable development while conserving critical green and blue spaces. If such trends continue unchecked, the region could face severe environmental consequences including reduced groundwater recharge, loss of biodiversity, and increased vulnerability to climate-induced risks. In conclusion, the findings call for a more integrated approach to urban planning—one that leverages geospatial intelligence to ensure balanced growth. Preserving ecological assets alongside infrastructure development is key to securing a livable and resilient future for the HMDA region.

VII. ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my guide, Dr. M. V. S. S. Giridhar, Professor, Department of Civil Engineering, JNTU Hyderabad, for his continuous guidance, encouragement, and valuable feedback throughout the duration of this work. His insights and motivation have been instrumental in shaping the quality of this study.

I also extend my thanks to the Department of Civil Engineering and the University College of Engineering, Science and Technology, JNTUH, for providing the necessary facilities and resources for the completion of this project.

Lastly, I am grateful to my family and friends for their constant support and encouragement during my academic journey.

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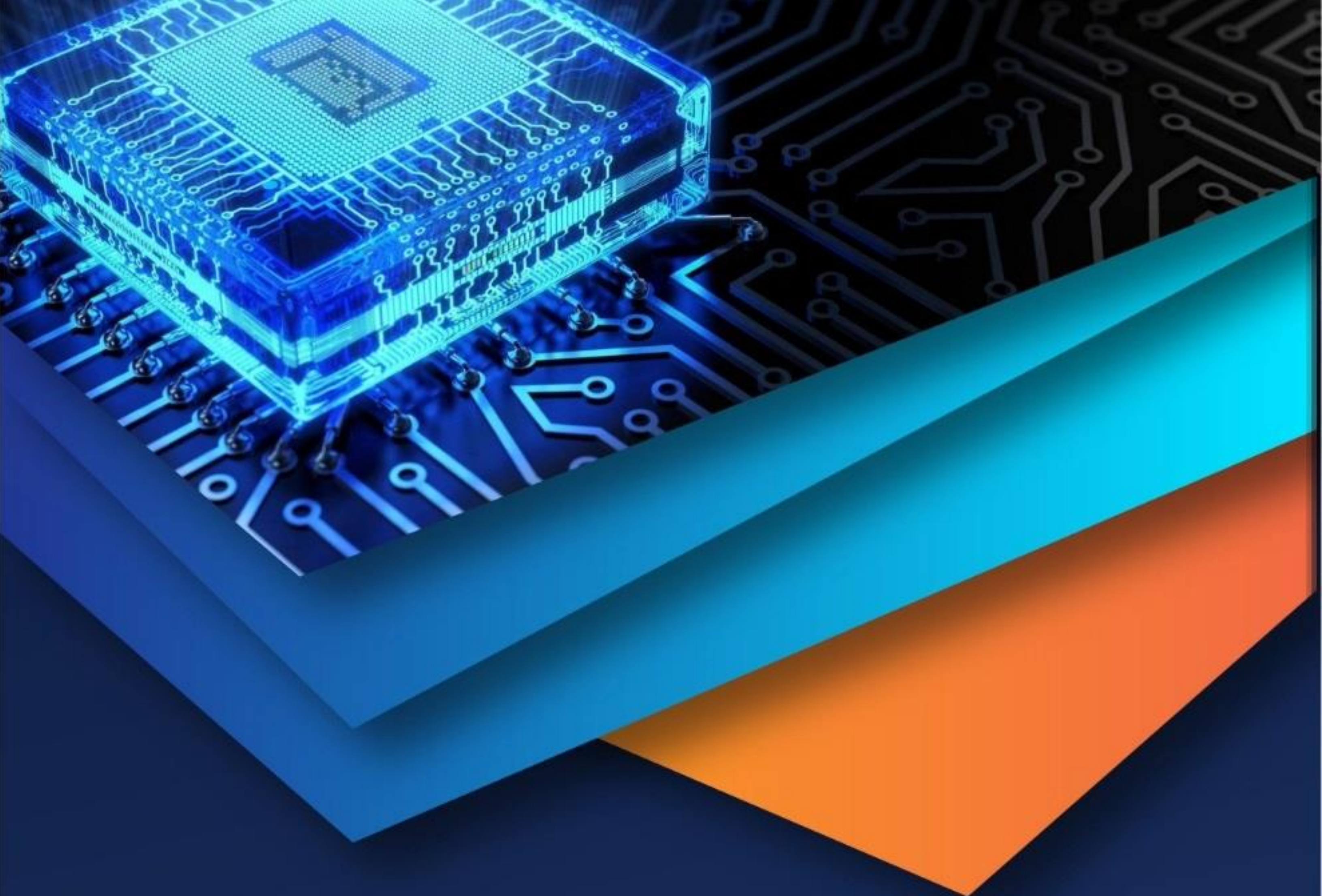

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