Spatio-Temporal Dynamics of Urban Green Spaces and Built-Up Expansion in Mysuru City, India: An Integrated LULC, NDVI, and NDBI-Based Geospatial Assessment

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Abstract
Rapid urbanization has significantly altered land use patterns and ecological conditions in many Indian cities, resulting in the reduction and fragmentation of urban green spaces. Assessing the spatial and temporal dynamics of vegetation and built-up areas is essential for sustainable urban planning and environmental management. This study investigates changes in urban green spaces in Mysuru City, Karnataka, India, between 2001 and 2025 using an integrated geospatial approach based on Land Use/Land Cover (LULC) classification, Normalized Difference Vegetation Index (NDVI), and Normalized Difference Built-up Index (NDBI). Multi-temporal Landsat satellite imagery was processed using Remote Sensing and Geographic Information System (GIS) techniques to evaluate urban expansion, vegetation dynamics, and land-cover transformations. The results reveal a substantial increase in built-up area from 52.4 km² in 2001 to 57.9 km² in 2025, accompanied by a significant reduction in open land from 15.6 km² to 5.4 km². Although the overall vegetation class increased from 17.6 km² to 22.0 km², NDVI analysis indicates a considerable decline in dense green spaces from 2.06 km² to 0.34 km², suggesting increasing vegetation fragmentation and degradation. Change detection analysis further demonstrates that 15.31 km² of open land and 4.63 km² of vegetation were converted into built-up areas during the study period. The NDBI results confirm the progressive expansion of urban infrastructure and impervious surfaces across the city. The findings highlight the growing pressure of urban development on ecological resources and emphasize the importance of integrating geospatial technologies into urban planning frameworks. This study provides valuable insights for policymakers and urban planners in developing strategies for green space conservation, sustainable land management, and environmentally resilient urban growth..

Keywords: Urban Green Spaces, Land Use/Land Cover (LULC), NDVI, NDBI, Remote Sensing, GIS, Urban Expansion, Mysuru City, Sustainable Urban Planning.

1. Introduction

Urbanization is one of the most significant drivers of land transformation worldwide, resulting in substantial modifications to natural ecosystems and urban landscapes. The continuous expansion of cities due to population growth, economic development, industrialization, and infrastructure improvement has accelerated the conversion of natural and semi-natural land covers into built-up areas. While urban development contributes to socio-economic progress, it often exerts considerable pressure on environmental resources, particularly urban green spaces, leading to ecological degradation, habitat fragmentation, and deterioration of environmental quality.

Urban green spaces, including parks, urban forests, gardens, wetlands, institutional campuses, and roadside vegetation, play a critical role in maintaining ecological balance and enhancing urban sustainability. These green areas provide multiple ecosystem services such as air purification, carbon sequestration, temperature regulation, biodiversity conservation, stormwater management, and recreational opportunities for urban residents. Numerous studies have demonstrated that the preservation and effective management of urban green spaces are essential for mitigating the adverse impacts of rapid urban growth and improving the quality of life in cities.

Advances in Remote Sensing (RS) and Geographic Information Systems (GIS) have significantly improved the ability to monitor and assess urban environmental changes. Multi-temporal satellite imagery enables continuous observation of land-use and land-cover dynamics over large spatial and temporal scales. Among the widely adopted geospatial techniques, Land Use/Land Cover (LULC) classification provides valuable information on the spatial distribution of different land categories, while spectral indices such as the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) facilitate the assessment of vegetation health and urban development intensity. The integration of these approaches provides a comprehensive framework for evaluating urban growth patterns and their impacts on urban ecosystems.

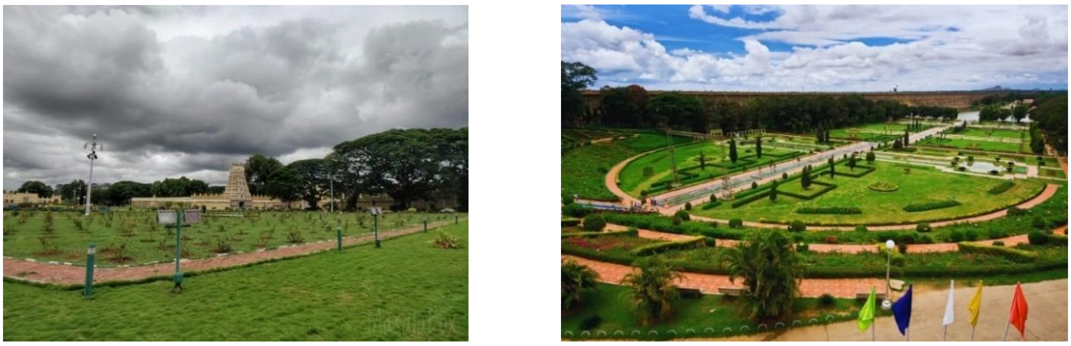


Fig 1.1: Urban green areas in Mysuru – Kukkarahalli Lake Park and Brindavan Gardens

Mysuru City, one of the rapidly developing urban centers in southern India, has experienced considerable urban expansion during the last two decades. Population growth, tourism development, infrastructure modernization, and increasing demand for residential and commercial land have transformed the city's landscape. Although Mysuru is recognized for its cultural heritage, planned urban structure, and environmental significance, continuous urban growth has increasingly affected the distribution and quality of urban green spaces. Understanding these changes is essential for supporting sustainable urban planning and environmental conservation efforts.

Several studies have examined urban expansion and vegetation dynamics using remote sensing and GIS techniques. However, most investigations have focused either on land-use change or vegetation assessment independently. Limited studies have integrated LULC classification with NDVI and NDBI analyses to evaluate urban green space dynamics comprehensively, particularly within Mysuru City. Furthermore, long-term assessments that quantify the combined effects of urban expansion on vegetation distribution, density, and ecological condition remain scarce.

To address this research gap, the present study employs an integrated geospatial approach using multi-temporal Landsat imagery acquired for the years 2001 and 2025. The study combines LULC classification, NDVI analysis, NDBI analysis, and change detection techniques to investigate the spatial and temporal dynamics of urban green spaces in Mysuru City. The primary objectives are to assess changes in vegetation cover and built-up areas, identify patterns of urban expansion, and evaluate the implications of these changes for sustainable urban development.

The outcomes of this study contribute to a better understanding of urban landscape transformation and provide scientifically informed insights for policymakers, planners, and environmental managers. The findings may support the development of effective strategies for green space conservation, sustainable land-use planning, and climate-resilient urban growth in rapidly expanding cities.

2. INTRODUCTION (Literature Integrated)

2.1 Urban Green Spaces and Sustainable Urban Development

Urban green spaces are recognized as essential components of sustainable urban environments due to their ecological, social, and economic benefits. Green infrastructure contributes to air quality improvement, urban heat mitigation, biodiversity conservation, carbon sequestration, stormwater regulation, and recreational opportunities. As urban populations continue to increase, maintaining adequate green space has become a major challenge for city planners worldwide.

Anguluri and Narayanan (2017) emphasized that urban vegetation plays a vital role in reducing air and noise pollution while enhancing environmental quality and human well-being. Similarly, Bolcárová and Kološta (2015) demonstrated that the availability of green spaces is strongly associated with urban sustainability indicators and recommended integrating green infrastructure into long-term urban planning strategies. These studies collectively highlight the importance of preserving urban green spaces for sustainable city development.

2.2 Application of Remote Sensing and GIS in Urban Green Space Assessment

Remote Sensing (RS) and Geographic Information Systems (GIS) have become indispensable tools for monitoring urban environmental changes. The availability of multi-temporal satellite imagery enables researchers to assess vegetation dynamics, urban expansion, and land-use transformation over extended periods.
Aryal et al. (2022) utilized Sentinel-2 imagery and NDVI thresholding techniques to map urban green spaces in Victoria, Australia, demonstrating the effectiveness of vegetation indices for green space assessment. Lotfata (2021) applied NDVI and NDBI for evaluating urban vegetation and built-up areas in Iran and reported that densely urbanized regions generally exhibit lower vegetation density and higher ecological stress. However, these studies primarily focused on vegetation mapping and did not extensively investigate long-term urban growth patterns.

The integration of RS and GIS technologies provides a robust framework for analyzing urban ecosystems, supporting evidence-based planning and environmental management. The capability of geospatial technologies to monitor spatial and temporal changes has made them widely applicable in urban sustainability studies.

2.3 Land Use/Land Cover Change and Urban Expansion

Land Use/Land Cover (LULC) analysis is widely employed to evaluate landscape transformation resulting from human activities. Urbanization is one of the primary drivers of LULC change, often resulting in the conversion of vegetation and open land into built-up surfaces.

Lambin et al. (2001) reported that population growth, economic development, and infrastructure expansion significantly influence land transformation processes. Similarly, Seto et al. (2011) identified urban expansion as a major contributor to vegetation loss and environmental degradation at both regional and global scales. These studies emphasize the importance of monitoring LULC dynamics for understanding the environmental consequences of urban growth.

In the Indian context, rapid urbanization has substantially altered land-use patterns in many cities. Expanding residential, commercial, and transportation infrastructure has resulted in increasing pressure on urban ecosystems and green spaces, highlighting the need for continuous monitoring and sustainable land management practices.

2.4 NDVI and NDBI for Urban Environmental Analysis

Spectral indices derived from satellite imagery are extensively used for environmental assessment and urban studies. Among these, the Normalized Difference Vegetation Index (NDVI) is one of the most widely adopted indicators for evaluating vegetation density and health.

Running et al. (2004) demonstrated the effectiveness of NDVI in monitoring vegetation productivity and temporal changes in ecosystem conditions. Huete et al. (2002) further improved vegetation monitoring by reducing atmospheric and soil background effects, thereby enhancing the reliability of vegetation assessments.

For urban studies, NDVI is commonly used to distinguish vegetated areas from built-up and barren surfaces. Conversely, the Normalized Difference Built-up Index (NDBI) serves as an effective indicator for identifying urbanized areas and monitoring built-up expansion. Weng (2001) demonstrated that NDVI and NDBI can be effectively combined to evaluate urban growth patterns and their environmental impacts. The integrated use of these indices enables a comprehensive assessment of vegetation dynamics and urban expansion.

2.5 Urban Green Space Dynamics in Mysuru

Mysuru has experienced substantial urban growth during recent decades due to population increase, tourism development, and infrastructure modernization. Existing planning reports and administrative documents emphasize the importance of preserving ecological resources and urban green infrastructure within the city.

Recent studies have reported a decline in vegetation cover and increasing urban expansion across Mysuru. Sushmitha and Chandrashekara (2024) observed considerable green space loss associated with residential and commercial development. However, their analysis primarily focused on general urbanization trends and did not comprehensively integrate LULC classification, NDVI, and NDBI analyses for long-term green space assessment.

Although several studies have investigated urban growth and vegetation changes in Indian cities, detailed geospatial assessments focusing specifically on Mysuru remain limited. Consequently, there is a need for a comprehensive evaluation of urban green space dynamics using integrated geospatial techniques.

2.6 Research Gap

The review of previous studies reveals that most investigations have focused either on land-use change analysis or vegetation assessment independently. Limited research has integrated LULC classification, NDVI, and NDBI within a unified framework to evaluate urban green space dynamics comprehensively. Furthermore, long-term assessments of urban green space transformation in Mysuru City remain scarce.

Existing studies also provide limited information regarding the relationship between built-up expansion, vegetation fragmentation, and green space quality. Consequently, there remains a significant knowledge gap concerning the spatial and temporal interactions between urban growth and ecological resources within the city.
To address these limitations, the present study integrates multi-temporal Landsat imagery, LULC classification, NDVI analysis, NDBI analysis, and change detection techniques to evaluate urban green space dynamics in Mysuru City between 2001 and 2025. The study provides a comprehensive geospatial assessment of vegetation change, built-up expansion, and landscape transformation, contributing valuable insights for sustainable urban planning and environmental management.

3.EXPERIMENTAL (Study Area)

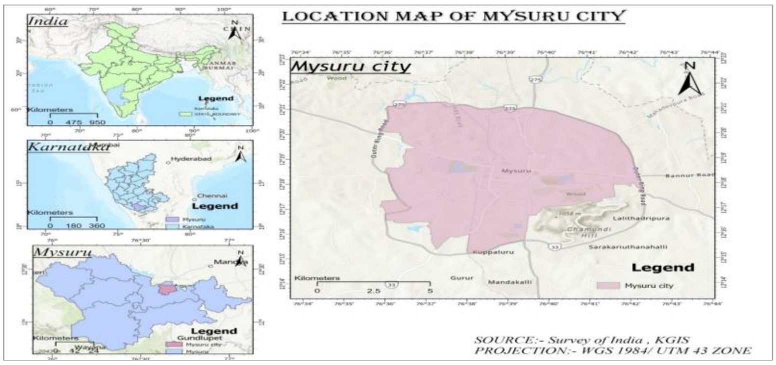


Fig: Location map of study area (Mysuru)

Mysuru City, formerly known as Mysore, is one of the prominent urban centers in southern Karnataka, India. The city is widely recognized for its cultural heritage, tourism, educational institutions, and planned urban development. In recent decades, Mysuru has experienced substantial urban expansion driven by population growth, economic development, infrastructure improvement, and increasing demand for residential and commercial land. These developments have significantly influenced land-use patterns and the distribution of urban green spaces, making Mysuru an appropriate case study for assessing urban landscape transformation through geospatial techniques.

Geographically, Mysuru is situated on the southern part of the Deccan Plateau between 12°18′–12°30′ N latitude and 76°38′–76°45′ E longitude. The city lies approximately 140 km southwest of Bengaluru and occupies an area of about 128.42 km². The region is located within the Cauvery River basin and is influenced by the Kaveri and Kabini river systems, which contribute to the hydrological and ecological characteristics of the area.

The topography of Mysuru is characterized by an undulating plateau landscape consisting of gently rolling plains interspersed with isolated hillocks and granite outcrops. One of the most prominent physiographic features is Chamundi Hill, located to the southeast of the city, which rises to an elevation of approximately 1000 m above mean sea level. The average elevation of the city is about 770 m, contributing to relatively moderate climatic conditions compared to many other urban centers in southern India.

Mysuru experiences a tropical savanna climate with distinct summer, monsoon, and winter seasons. The city receives an average annual rainfall of approximately 750–850 mm, with the southwest monsoon contributing the majority of precipitation between June and September. Additional rainfall occurs during the northeast monsoon and pre-monsoon periods. Temperatures typically range from 15°C during winter to about 38°C during summer, providing favorable conditions for vegetation growth and urban green space development.

The drainage network of Mysuru comprises rivers, lakes, tanks, canals, and reservoirs associated with the Cauvery basin. Notable water resources include the Krishna Raja Sagara (KRS) reservoir and several urban lakes that play a significant role in maintaining ecological balance and supporting urban water requirements. The relatively gentle terrain and moderate climate have facilitated urban growth; however, rapid expansion has increasingly transformed natural and vegetated landscapes into built-up areas.

Given its rapid urbanization, environmental significance, and availability of multi-temporal satellite data, Mysuru provides an ideal setting for investigating the spatial and temporal dynamics of urban green spaces. The study area offers valuable insights into the interactions between urban growth, vegetation change, and sustainable land management in medium-sized Indian cities.

4. EXPERIMENTAL

4.1 Data Sources

This study employed multi-temporal Landsat satellite imagery to investigate the spatio-temporal dynamics of urban green spaces and built-up expansion in Mysuru City between 2001 and 2025. Landsat imagery was selected because of its long-term historical archive, moderate spatial resolution, and suitability for urban environmental studies.

A Landsat 5 Thematic Mapper (TM) image acquired on 23 February 2001 and a Landsat 8 Operational Land Imager (OLI) image acquired on 25 February 2025 were obtained from the United States Geological Survey (USGS) Earth Explorer platform. Both images were selected during the dry season with minimal cloud cover to ensure temporal comparability and minimize atmospheric interference. Administrative boundary data for Mysuru City were obtained from open-source GIS databases and used for image clipping and spatial analysis.

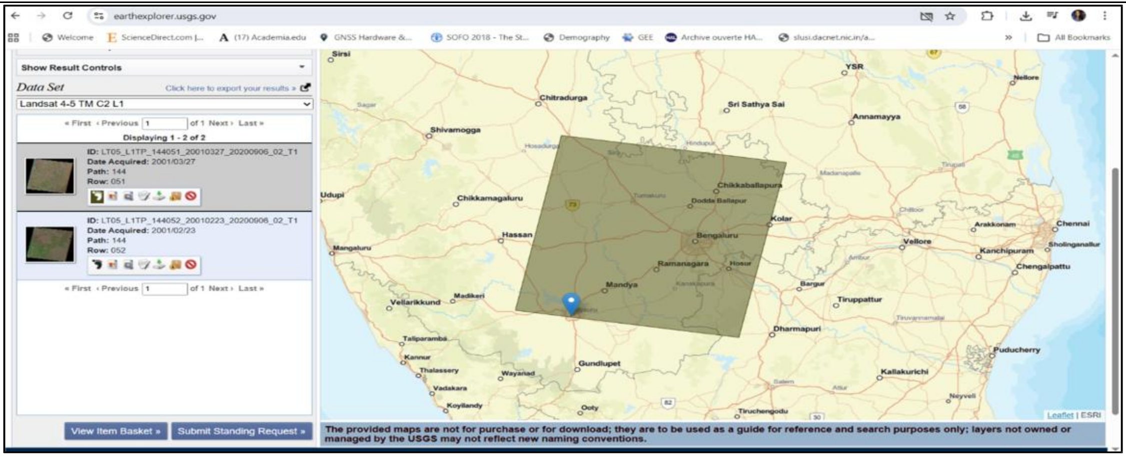


Fig: USGS Earth Explorer for satellite images download

Table 1. Data Sources Used in the Study

Sl. No.	Data Type	Source	Sensor/Tool	Resolution	Purpose
1	Satellite Imagery (2001)	United States Geological Survey	Landsat 5 TM	30 m	LULC classification & NDVI calculation
2	Satellite Imagery (2025)	United States Geological Survey	Landsat 8 OLI	30 m15m	Change detection & index analysis
3	Administrative Boundary	Open-source K-GIS portals	Shapefile	—	Clipping & masking study area
4	GIS Software	ArcGIS Pro	—	—	Spatial analysis & mapping
5	Statistical Tool	Microsoft Excel	—	—	Graphs & data analysis

4.2 Image Pre-Processing

Prior to analysis, the satellite images underwent several pre-processing procedures to enhance data quality and ensure consistency between datasets. The preprocessing workflow included radiometric correction, atmospheric correction, layer stacking, and image clipping.

Radiometric correction was applied to minimize sensor-related errors and normalize pixel reflectance values. Atmospheric correction was performed to reduce the effects of haze, aerosols, and atmospheric scattering. Individual spectral bands were subsequently stacked to generate multispectral composite images.

False Color Composite (FCC) images were generated using Bands 4-3-2 for Landsat 5 TM (2001) and Bands 5-4-3 for Landsat 8 OLI (2025). The stacked images were clipped using the Mysuru administrative boundary to restrict analysis to the study area.

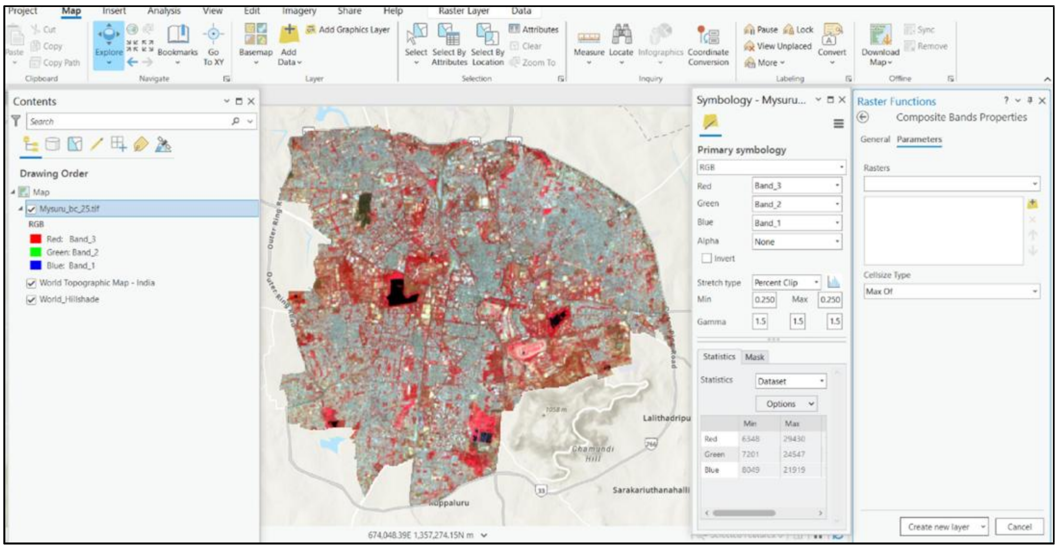


Fig: Band composite of satellite images in GIS using RGB bands

4.3 Land Use/Land Cover Classification

Land Use/Land Cover (LULC) classification was performed to identify and quantify major land-cover categories within Mysuru City. A supervised classification approach was adopted using the Maximum Likelihood Classification (MLC) algorithm in ArcGIS Pro.

Training samples were selected based on visual image interpretation, field knowledge, and reference data. Four major land-cover classes were identified:

- Built-up Area
- Vegetation
- Open Land
- Water Bodies

The Maximum Likelihood Classifier assigns each pixel to the class with the highest statistical probability based on spectral characteristics. The classified maps generated for 2001 and 2025 were subsequently used for change detection and urban growth analysis.

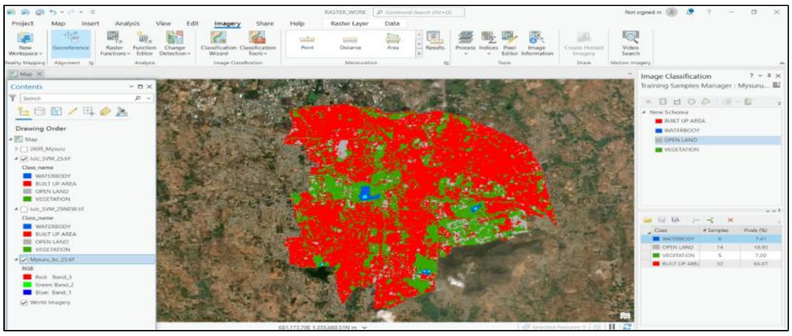


Fig: Collection of reference samples for supervised image classification in ArcGIS pro

4.4 NDVI-Based Vegetation Assessment

The Normalized Difference Vegetation Index (NDVI) was employed to evaluate vegetation distribution, density, and health across the study area. NDVI is a widely used spectral index that exploits the contrast between vegetation reflectance in the Near Infrared (NIR) and Red bands.

The NDVI was calculated using:
NDVI = (NIR − Red) / (NIR + Red)
For Landsat 5 TM imagery, Band 4 (NIR) and Band 3 (Red) were used, while Landsat 8 OLI imagery utilized Band 5 (NIR) and Band 4 (Red).
The resulting NDVI values were categorized into vegetation density classes:
Vegetation density maps were generated for both years to assess changes in urban green spaces over time.

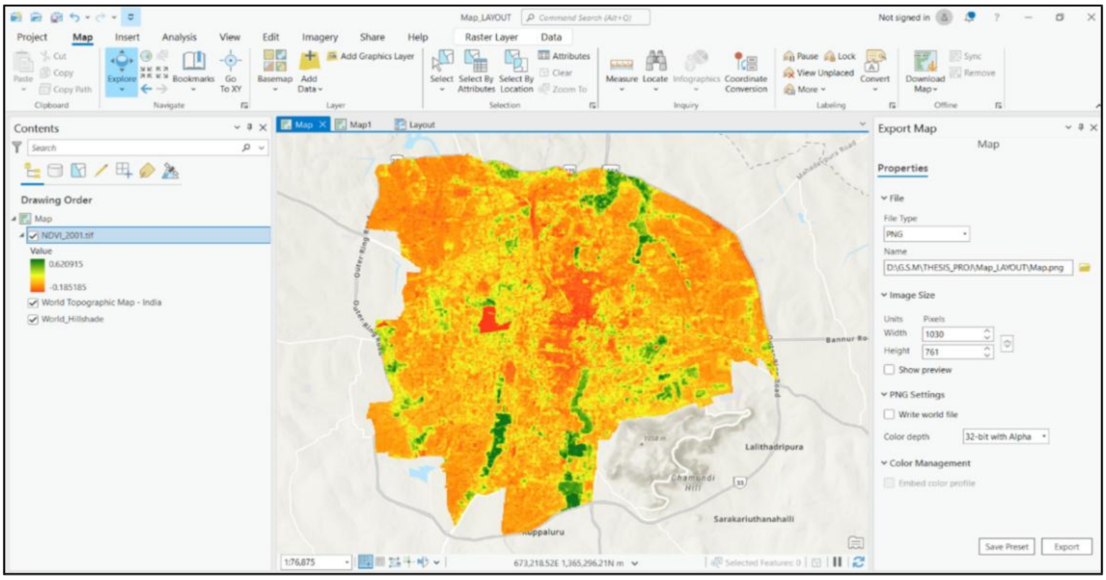


Fig: NDVI calculation using NIR and Red band

4.5 NDBI-Based Built-Up Area Assessment

The Normalized Difference Built-up Index (NDBI) was used to identify built-up surfaces and evaluate urban expansion patterns. NDBI utilizes the spectral contrast between the Short-Wave Infrared (SWIR) and Near Infrared (NIR) bands.

The NDBI was calculated as:

NDBI=(SWIR-NIR)/(SWIR+NIR)

Positive NDBI values generally indicate built-up areas, whereas negative values correspond to vegetation and water bodies.

The classified NDBI categories were:

NDBI maps were generated for both study years to analyze the intensity and spatial distribution of urban development.

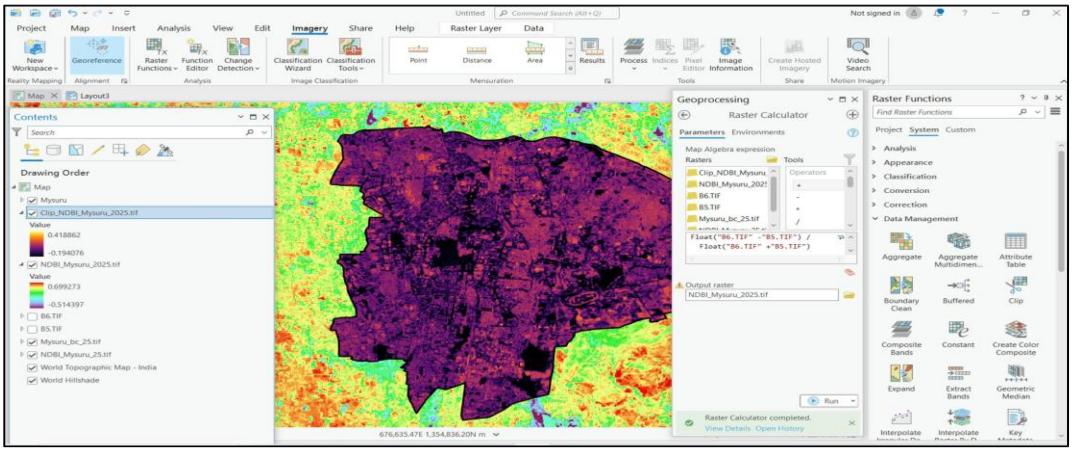


Fig: NDBI calculation using SWIR and NIR band

4.6 Urban Green Space Extraction and Vegetation Density Mapping

Urban green spaces were delineated through the integration of LULC classification results and NDVI thresholds. Vegetation areas identified through supervised classification were combined with NDVI-derived vegetation classes to improve the representation of urban green spaces.

Vegetation density was categorized into four classes:

- High Density Vegetation (NDVI > 0.30)
- Moderate Vegetation (NDVI 0.20–0.30)
- Sparse Vegetation (NDVI 0.10–0.20)
- Non-Vegetation (NDVI < 0.10)

This classification enabled assessment of both vegetation extent and vegetation quality across the urban landscape.

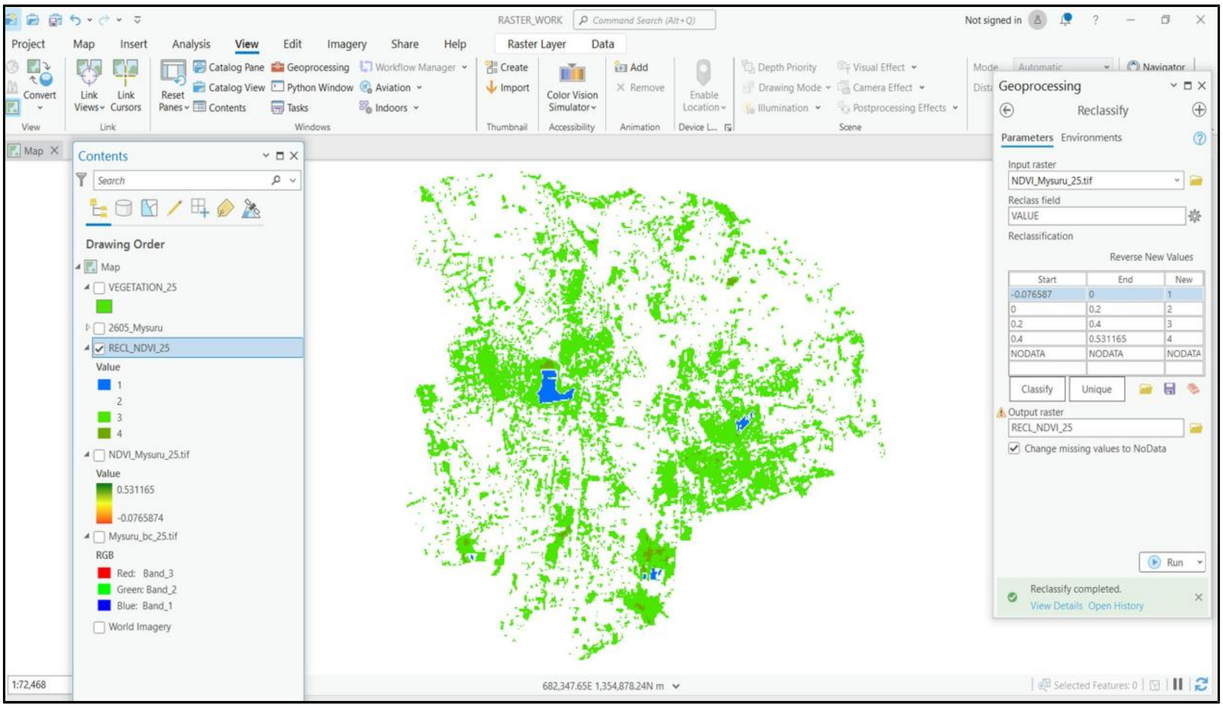


Fig: Extraction of Urban Green Space from reclassified NDVI and LULC

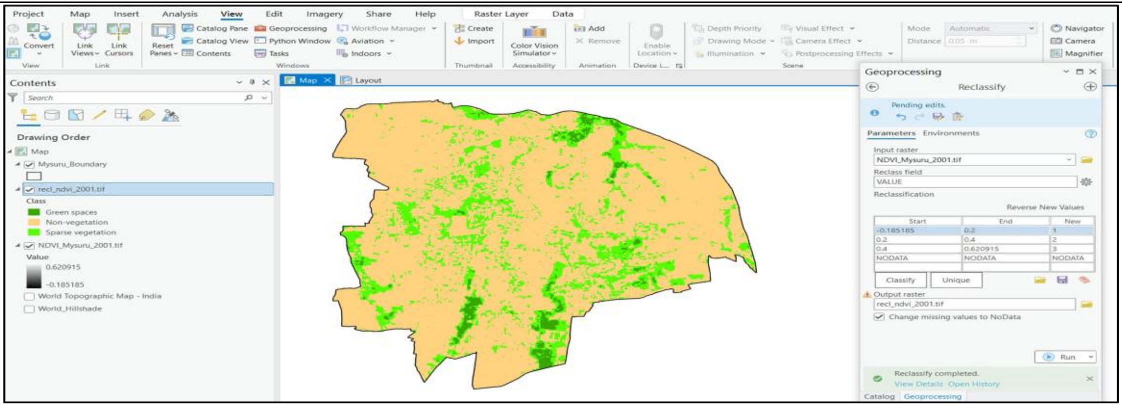


Fig: Vegetation density mapping from threshold of vegetation range

4.7 Change Detection Analysis

Post-classification change detection was performed to identify land-cover transitions between 2001 and 2025. The classified LULC maps for both years were overlaid to generate a change matrix representing land-cover conversions.

Major transition categories analyzed included:

- Open Land to Built-up Area
- Vegetation to Built-up Area
- Vegetation to Open Land
- Stable Land-Cover Classes

The area associated with each transition was calculated and used to evaluate the magnitude and direction of urban growth and green space transformation.

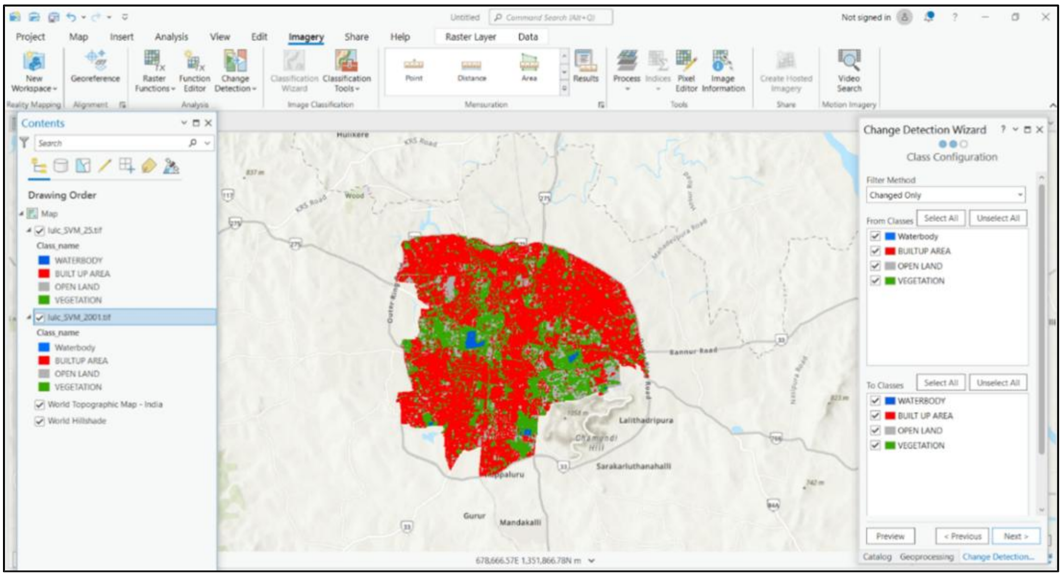


Fig: Change detection analysis of different LULC areas

4.8 Zonal Statistics Analysis

To evaluate vegetation characteristics within individual land-cover classes, zonal statistics analysis was conducted using the classified LULC maps as zone layers and NDVI rasters as input datasets.

Mean NDVI values were calculated for each LULC category for both study years. The analysis facilitated comparison of vegetation conditions across built-up areas, vegetation zones, open land, and water bodies. Changes in mean NDVI values between 2001 and 2025 were subsequently used to assess vegetation degradation, fragmentation, and the influence of urban expansion on ecological conditions.

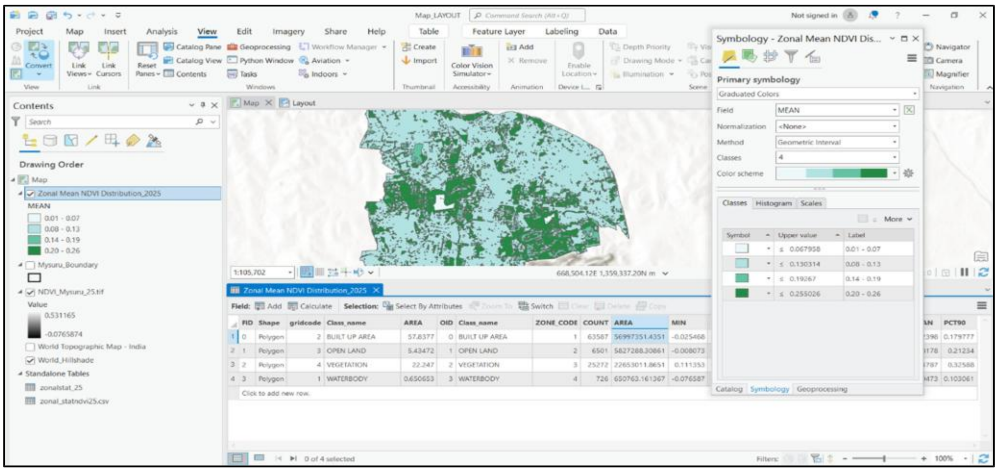


Fig: Zonal statistics calculation of different LULC areas

5. Results and Discussion

5.1 Land Use/Land Cover Dynamics (2001–2025)

The LULC analysis revealed substantial landscape transformation in Mysuru City between 2001 and 2025, primarily driven by urban expansion and infrastructure development. The classified maps indicate a continuous increase in built-up land accompanied by a decline in open land and modifications in vegetation distribution.

The built-up area increased from 52.4 km² in 2001 to 57.9 km² in 2025, representing an increase of approximately 10.5%. This growth reflects rapid urbanization resulting from population growth, economic activities, transportation development, and expansion of residential and commercial infrastructure. Urban growth was predominantly concentrated along the peripheral zones of the city and major transportation corridors, indicating outward urban sprawl.

Conversely, open land exhibited a substantial decline from 15.6 km² to 5.4 km² during the study period. This reduction suggests that open spaces served as the primary source of land for urban development. The conversion of vacant and transitional lands into built-up areas demonstrates increasing developmental pressure on available land resources.

Vegetation cover increased from 17.6 km² in 2001 to 22.0 km² in 2025. However, this apparent increase should be interpreted cautiously because NDVI analysis indicates that much of the vegetation consists of fragmented and low-density vegetation rather than dense ecological green spaces. Water bodies showed only a marginal increase from 0.5 km² to 0.7 km², contributing minimally to overall land-cover dynamics.

Overall, the LULC results indicate a dominant trend of urban expansion accompanied by significant changes in landscape composition and ecological structure.

Table 2. Spatio-Temporal Variation of LULC Classes

LULC Class	2001 (km²)	2025 (km²)
Built-up Area	52.4	57.9
Open Land	15.6	5.4
Vegetation	17.6	22.0
Water Body	0.5	0.7

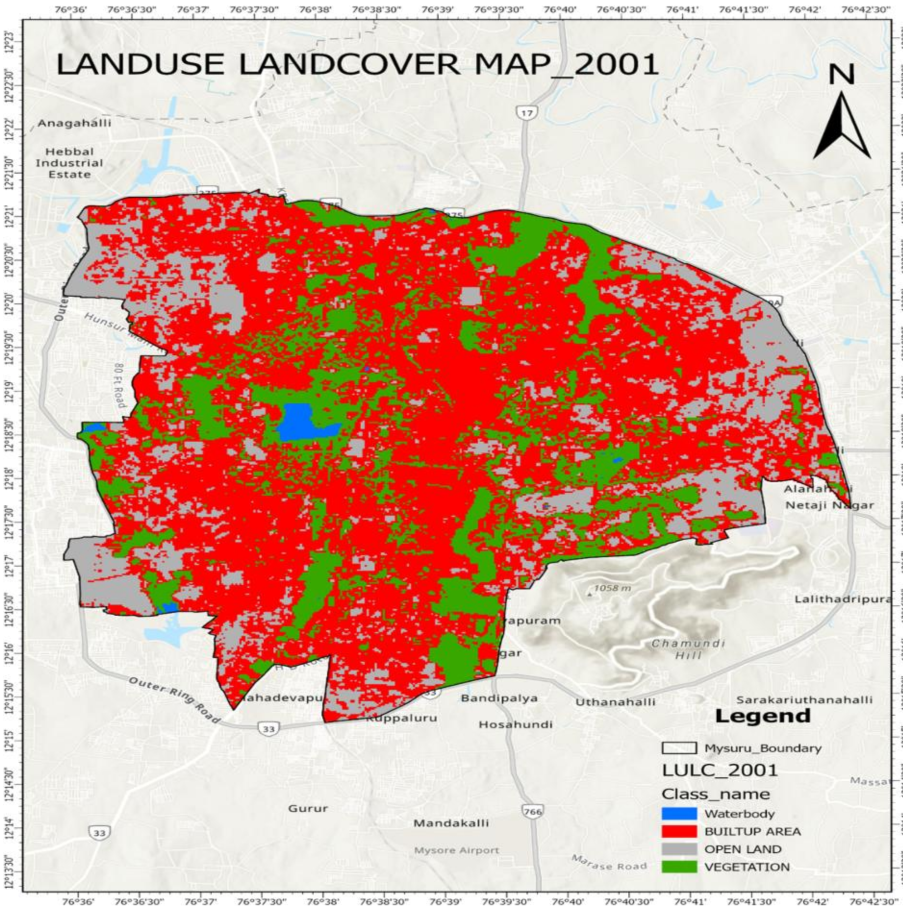


Fig: LULC map of 2001

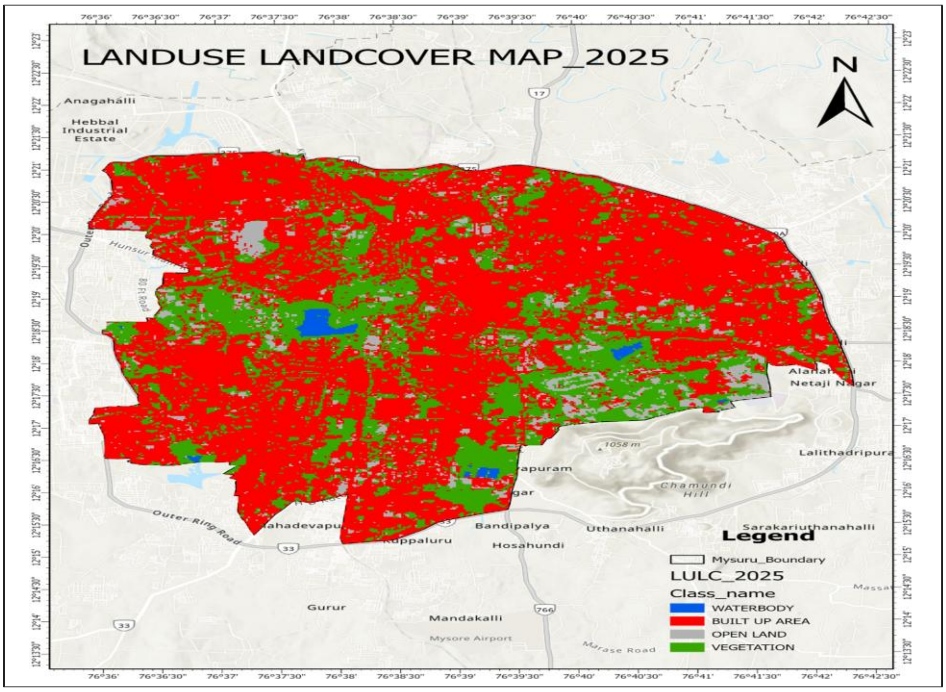


Fig: LULC map of 2025

5.2 NDVI-Based Vegetation Dynamics

NDVI analysis was performed to evaluate temporal changes in vegetation condition and density. The results indicate significant alterations in the quality and spatial distribution of urban green spaces between 2001 and 2025.

Dense green areas experienced a pronounced decline from 2.06 km² in 2001 to only 0.34 km² in 2025. This reduction suggests considerable degradation of healthy vegetation cover due to urban expansion and land-use conversion. The fragmentation of previously continuous vegetation patches indicates increasing ecological stress within the urban landscape.

In contrast, sparse vegetation increased from 13.93 km² to 21.91 km². Although this increase may initially appear positive, it largely reflects the replacement of dense vegetation with fragmented and lower-quality vegetation cover. Such vegetation often consists of roadside plantations, isolated trees, institutional landscapes, and peri-urban vegetation patches.

The reduction of non-vegetated surfaces from 70.19 km² to 63.92 km² further indicates landscape modification. However, the decline in dense vegetation highlights deterioration in ecological quality despite the apparent increase in total vegetation extent.

Table 3. NDVI Class Distribution

NDVI Class	2001 (km²)	2025 (km²)
Non-Vegetation	70.19	63.92
Sparse Vegetation	13.93	21.91
Dense Green Spaces	2.06	0.34

The NDVI results clearly demonstrate that urbanization has altered vegetation structure and reduced the ecological effectiveness of urban green spaces.

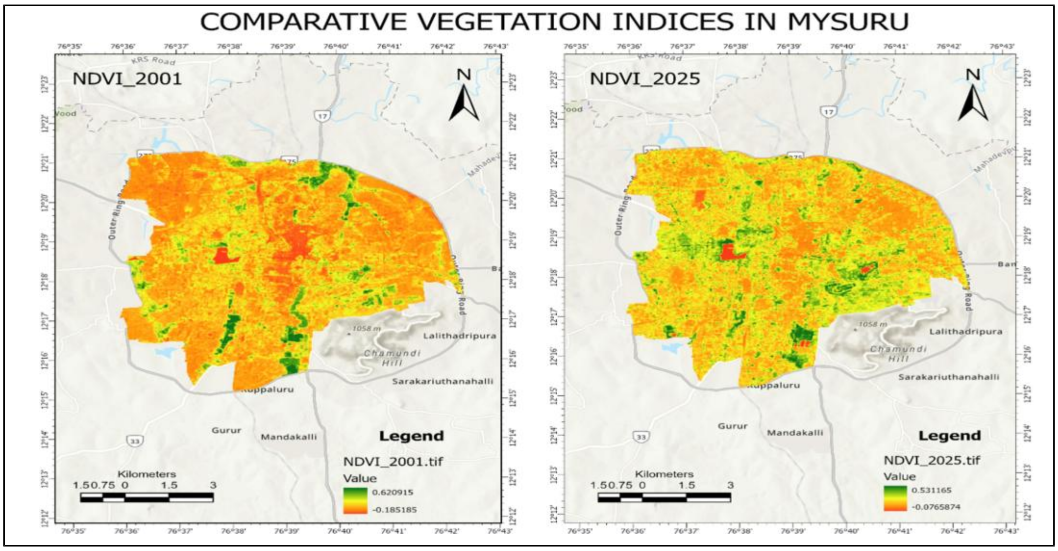


Fig: NDVI maps of 2001 & 2025

5.3 NDBI Analysis and Built-Up Expansion

The NDBI analysis confirms the increasing intensity of urban development within Mysuru City. Higher NDBI values observed in 2025 indicate expansion of impervious surfaces including residential zones, commercial developments, transportation infrastructure, and associated urban facilities.

The spatial distribution of positive NDBI values reveals significant built-up expansion around the city outskirts and along major road networks. The coexistence of negative NDBI values in some regions reflects the presence of vegetation and mixed land-cover conditions within the urban environment.

The NDBI results complement the LULC findings by demonstrating the increasing dominance of built-up surfaces and the gradual transformation of natural landscapes into urban land uses.

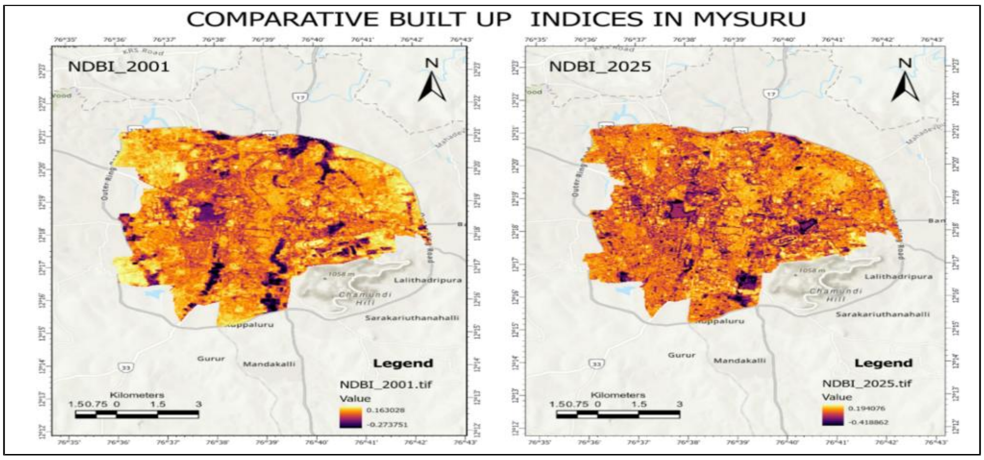


Fig: NDBI maps of 2001 & 2025

5.4 Land-Cover Change Detection Analysis

The change detection analysis provides detailed insights into the magnitude and direction of land-cover transitions between 2001 and 2025.

The most significant transition observed was the conversion of open land into built-up area, accounting for 15.31 km². This finding indicates that urban growth primarily occurred through the development of vacant and transitional lands. Additionally, 4.63 km² of vegetation was directly converted into built-up area, representing a substantial loss of urban green spaces.

A smaller transition of 0.64 km² from vegetation to open land was also identified, suggesting localized vegetation degradation and land clearing activities.

Table 4. Major Land-Cover Transitions (2001–2025)

Transition Category	Area (km²)
Open Land → Built-up Area	15.31
Vegetation → Built-up Area	4.63
Vegetation → Open Land	0.64
No Change	3.37
Other Changes	62.58

The low proportion of unchanged land indicates that a considerable portion of the city experienced some form of land-cover transformation during the study period.

5.5 Zonal Statistics of NDVI Across LULC Classes

The zonal statistics analysis revealed distinct variations in vegetation characteristics among different land-cover categories.

Vegetation areas consistently recorded the highest NDVI values, although mean NDVI decreased from 0.274 in 2001 to 0.255 in 2025. This decline suggests a reduction in vegetation density and health, likely resulting from fragmentation and urban encroachment.

Built-up areas showed a modest increase in mean NDVI from 0.105 to 0.125, which may be attributed to urban landscaping, roadside plantations, and institutional green spaces. Open land exhibited the largest increase in NDVI, increasing from 0.084 to 0.162, indicating the presence of sparse vegetation in previously barren areas.

Table 5. Mean NDVI Variation Across LULC Classes

LULC Class	NDVI 2001	NDVI 2025	Change
Built-up Area	0.105	0.125	+0.020
Open Land	0.084	0.162	+0.077
Vegetation	0.274	0.255	-0.019
Water Body	-0.042	0.006	+0.048

The decline in NDVI within vegetation zones confirms that urban growth has influenced vegetation quality despite the apparent increase in overall vegetated area.

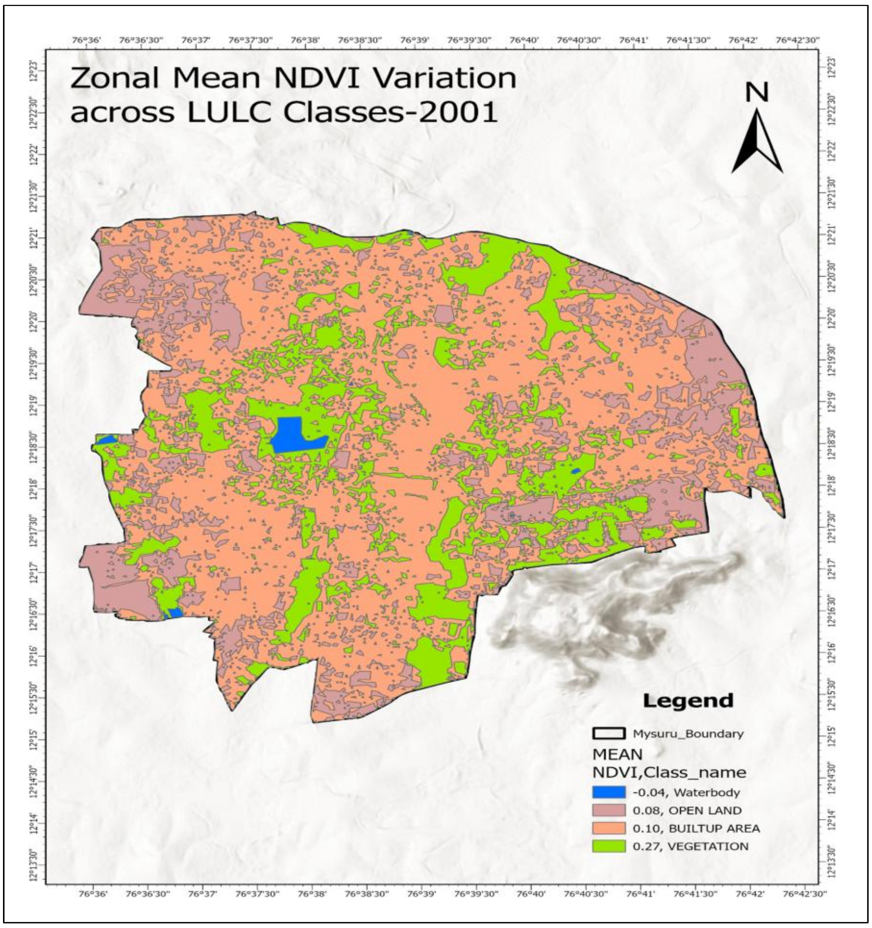


Fig: Zonal Mean NDVI Distribution Across LULC Classes (2001)

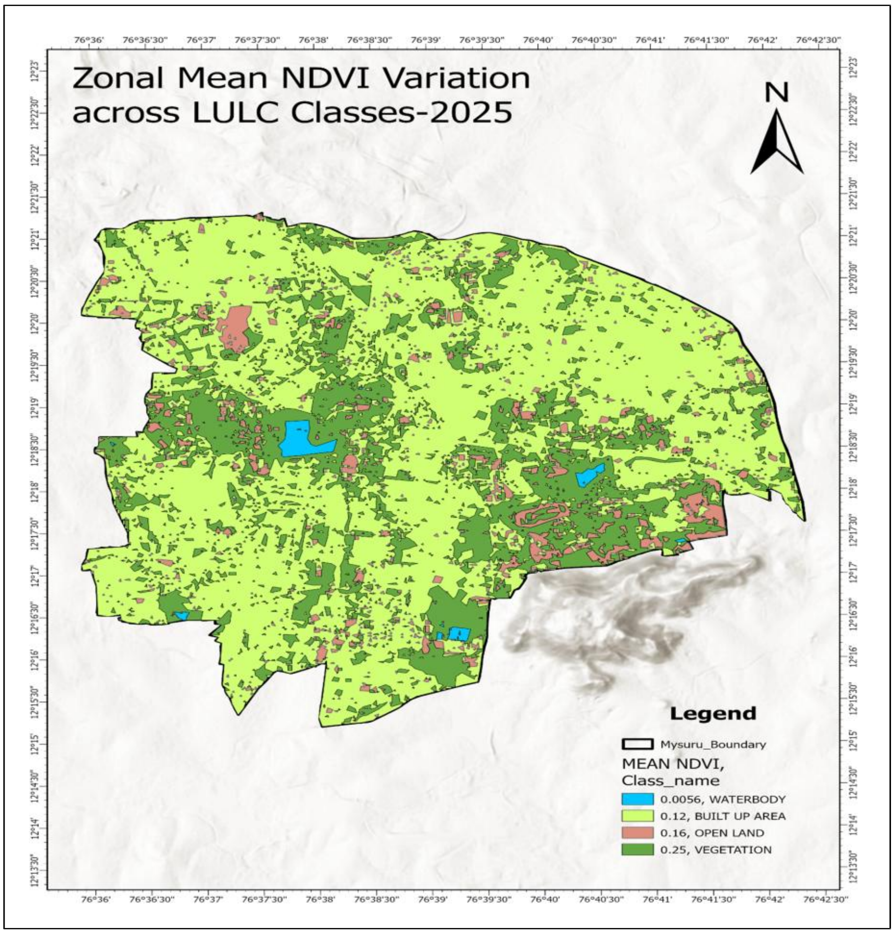


Fig: Zonal Mean NDVI Distribution Across LULC Classes (2025)

5.6 Implications for Sustainable Urban Planning

The integrated analysis of LULC, NDVI, NDBI, and change detection results demonstrates that urban expansion has significantly altered the ecological landscape of Mysuru City over the past two decades. Although vegetation area increased numerically, the substantial reduction in dense green spaces and declining NDVI values indicate increasing vegetation fragmentation and degradation.

These findings highlight the need for strategic urban planning measures aimed at preserving existing green spaces, promoting urban forestry initiatives, protecting ecologically sensitive zones, and integrating green infrastructure into future development plans. Sustainable management of urban green spaces is essential for maintaining ecological resilience, mitigating urban environmental problems, and improving the overall quality of life in rapidly growing cities.

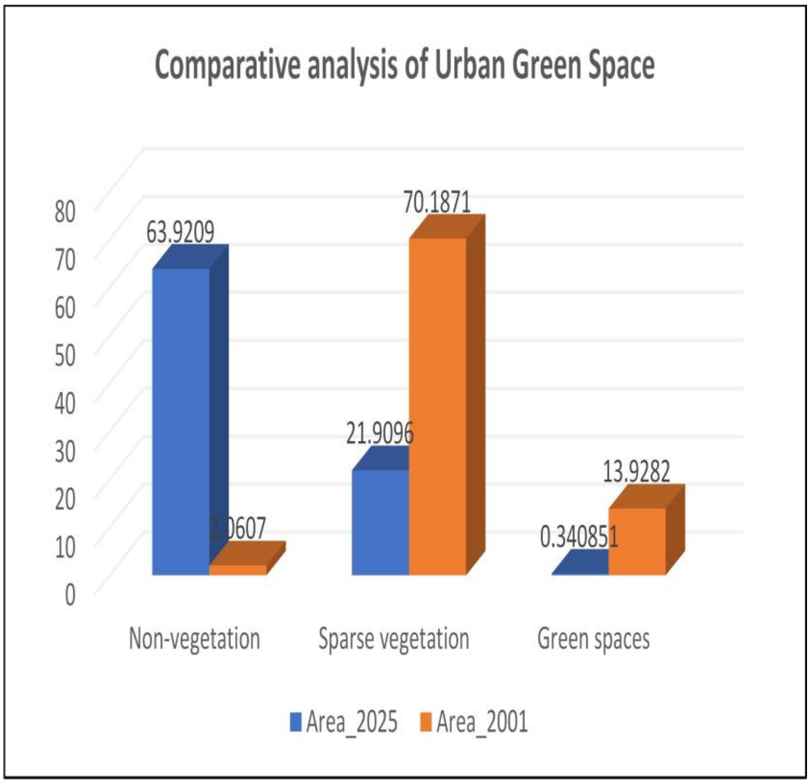


Fig: Comparative analysis of Urban Green space in Mysuru (2001 and 2025)

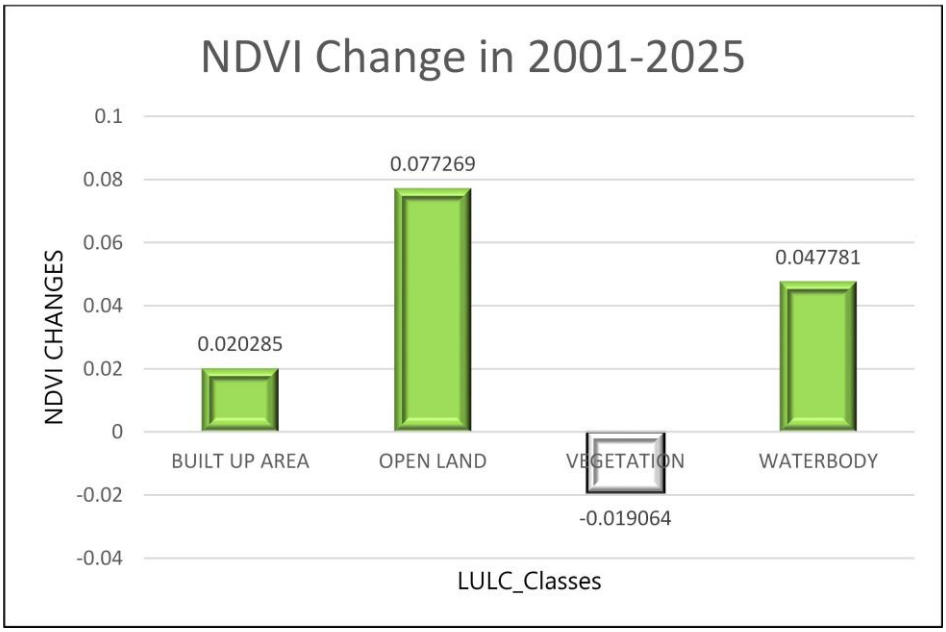


Fig: Comparative Analysis of Vegetation Classes Based on NDVI (2001–2025)

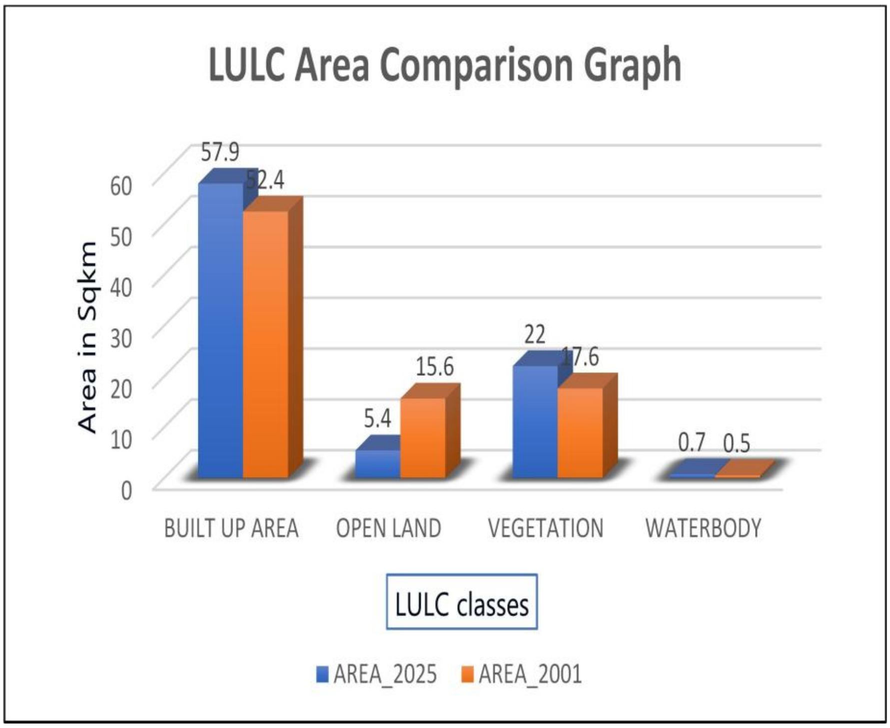
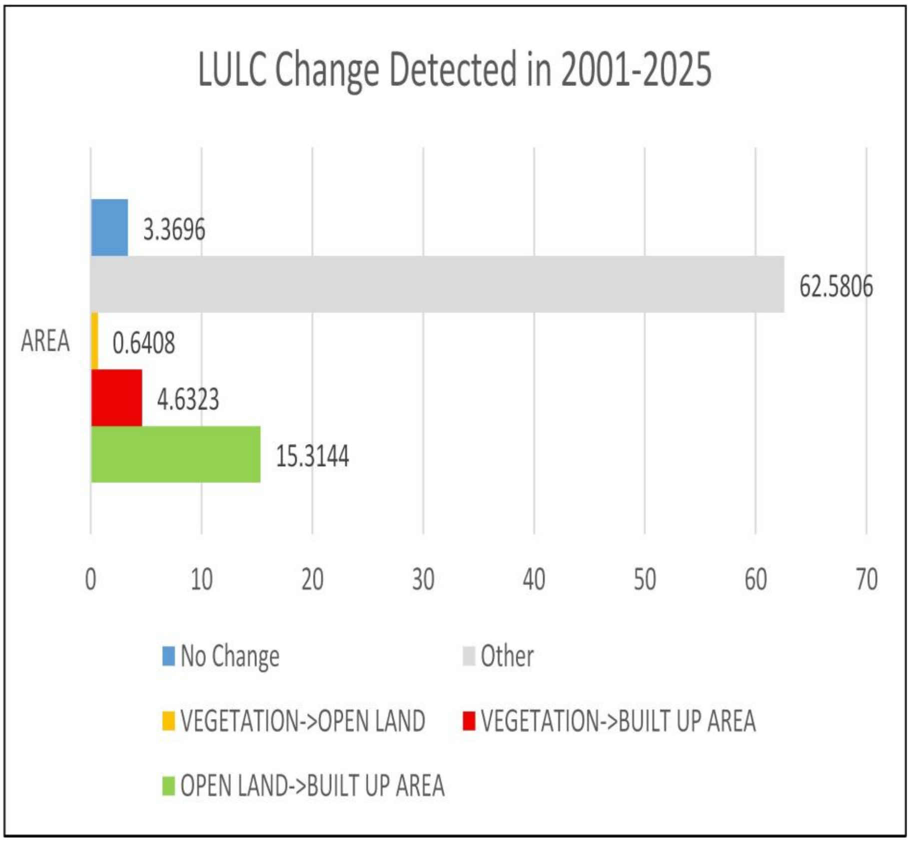


Fig: Area-wise Distribution of LULC Classes in Mysuru (2001 and 2025)



ig: Post-Classification Change Detection of LULC Classes (2001–2025)

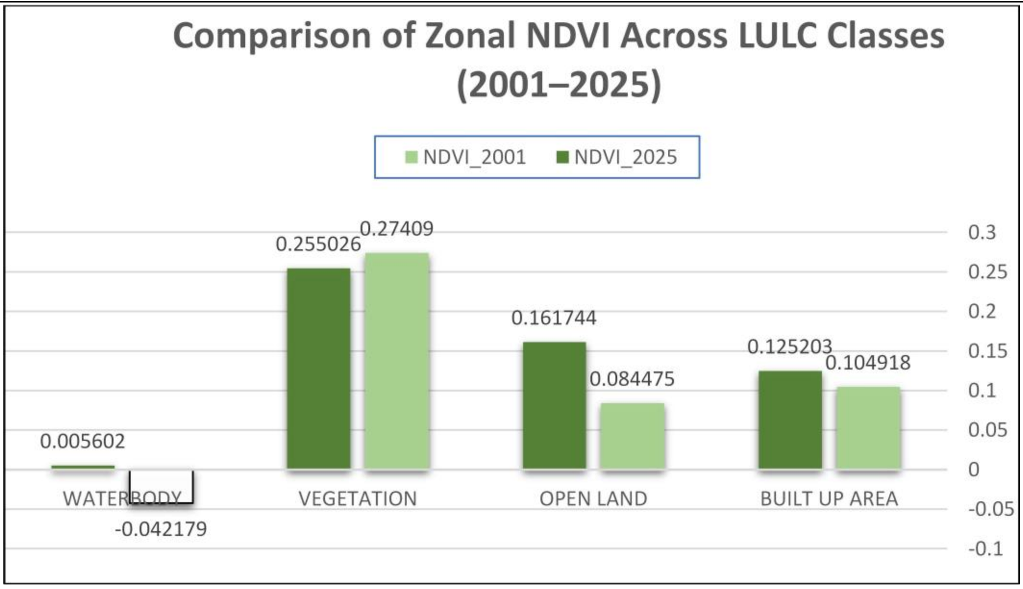


Fig: Temporal Change in Mean NDVI by Land Use Classes in Mysuru

6. Conclusion and Policy Implications

6.1 Conclusion

This study investigated the spatio-temporal dynamics of urban green spaces and built-up expansion in Mysuru City between 2001 and 2025 using an integrated geospatial approach based on Land Use/Land Cover (LULC) classification, Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), and change detection analysis. The integration of remote sensing and GIS techniques provided a comprehensive understanding of urban landscape transformation and its implications for environmental sustainability.

The findings indicate substantial urban expansion over the study period, evidenced by the increase in built-up area from 52.4 km² in 2001 to 57.9 km² in 2025. Simultaneously, open land declined considerably from 15.6 km² to 5.4 km², highlighting the conversion of vacant and transitional lands into urban infrastructure. Although the total vegetation area increased from 17.6 km² to 22.0 km², NDVI analysis revealed a significant decline in dense green spaces from 2.06 km² to 0.34 km², indicating fragmentation and degradation of ecologically valuable vegetation.

The change detection analysis further demonstrated that 15.31 km² of open land and 4.63 km² of vegetation were transformed into built-up areas during the study period. The decline in mean NDVI values within vegetation zones confirms that urbanization has adversely affected vegetation quality and continuity. The NDBI results corroborate the increasing dominance of impervious surfaces and built-up intensity throughout the city.

Overall, the study reveals that rapid urban growth has significantly altered the spatial distribution and ecological condition of urban green spaces in Mysuru. While vegetation remains present within the urban landscape, its increasing fragmentation and declining density may reduce its ecological effectiveness and capacity to provide ecosystem services. The integrated use of LULC, NDVI, NDBI, and change detection techniques proved effective for monitoring urban environmental change and can serve as a valuable framework for sustainable urban planning and environmental management.

6.2 Policy Implications

The results of this study provide important insights for urban planners, policymakers, and environmental managers seeking to achieve sustainable urban development in rapidly growing cities.

First, urban development policies should prioritize the protection and conservation of existing green spaces, particularly areas characterized by dense vegetation and high ecological value. The preservation of urban forests, parks, wetlands, and institutional green areas is essential for maintaining biodiversity, regulating microclimatic conditions, and enhancing environmental quality.

Second, city planning authorities should incorporate green infrastructure strategies into future urban development plans. Establishing green corridors, urban forestry programs, roadside plantations, and interconnected open spaces can help reduce vegetation fragmentation and improve ecological connectivity across the urban landscape.

Third, land-use planning regulations should be strengthened to minimize the conversion of environmentally sensitive areas into built-up land. Continuous monitoring of land-cover changes using geospatial technologies should be integrated into municipal planning frameworks to support evidence-based decision-making and sustainable resource management.

Fourth, urban greening initiatives should be promoted within residential, commercial, and institutional developments to compensate for the loss of natural vegetation and enhance urban resilience to climate change. Such measures can contribute to reducing urban heat island effects, improving air quality, and increasing the overall livability of urban environments.

Finally, the adoption of geospatial monitoring systems using satellite imagery and GIS can facilitate regular assessment of urban growth patterns and environmental changes. These technologies provide cost-effective and scientifically reliable tools for evaluating the effectiveness of urban planning policies and ensuring long-term sustainability.

6.3 Future Research Directions

Future studies may employ high-resolution satellite imagery, machine learning-based classification techniques, and advanced vegetation indices such as Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI), and Land Surface Temperature (LST) to improve analytical accuracy. Incorporating socio-economic, demographic, and climate-related datasets would further enhance understanding of the complex interactions between urbanization, environmental change, and urban sustainability. Additionally, investigating urban heat island effects and green space accessibility could provide valuable insights for developing climate-resilient and environmentally sustainable cities.

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