



DETECTING URBAN EXPANSION AND ENVIRONMENTAL CHANGE THROUGH REMOTE SENSING AND GIS: CASE OF GULBARGA CITY

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ABSTRACT

Geoinformatics based approach is used to detect the long-term spatio-temporal dynamics of land use/land cover (LULC), environmental indices, land surface temperature (LST), and air quality in Gulbarga city. For the assessment of integrated analysis, multi-temporal satellite-derived indices were utilized which was the primary objective. The various factors like, environmental impacts of urban expansion, including NDVI, NDBI, and NDWI, along with thermal and air pollution parameters were evaluated. The overall impact of change was detected by comparing multi-year remote sensing data for vegetation cover, built-up areas, and surface water bodies, which was further correlated with surface temperature and atmospheric conditions.

There was a substantial increase in built-up areas with a consistent decline in vegetation cover and surface water extent. There were prominent changes during the recent decade, and the transformations were strongly associated with rising land surface temperatures. The comparative analysis showcased higher thermal intensity in built-up regions when compared to vegetated and water-covered areas. This created an inverse relationship between vegetation and temperature which was clearly observed. Lastly, particulate matter and gaseous pollutants showed elevated levels in an annual air quality analysis, due to the influence of urban activities such as traffic, industrial emissions, and dust.

In conclusion, there has been noticeable environmental degradation due to increased thermal stress caused by the rapid urbanization which also affected the ecological balance, and air quality. The advancement in multi-temporal geospatial techniques helped in tracking in-depth tangible understanding about urban environmental changes with regards to urban growth. This study reflects the high demand for sustainable planning strategies for urban growth management.

KEYWORDS: Geoinformatics, Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Urbanization, Air Pollution

1. INTRODUCTION

Rapid urban expansion now drives environmental change in Indian cities, especially in semi-arid regions with limited natural resources. Over the past few decades, the population and infrastructure in Gulbarga City, Karnataka, has grown substantially. These forces have transformed land use/land cover (LULC), altered vegetation patterns,

reduced surface water availability, and changed thermal characteristics. Such changes intensify environmental stress, raise land surface temperatures (LST), and increase urban air pollution levels.

Remote sensing and Geographic Information Systems (GIS) form an effective framework to monitor long-term urban environmental changes. To assess

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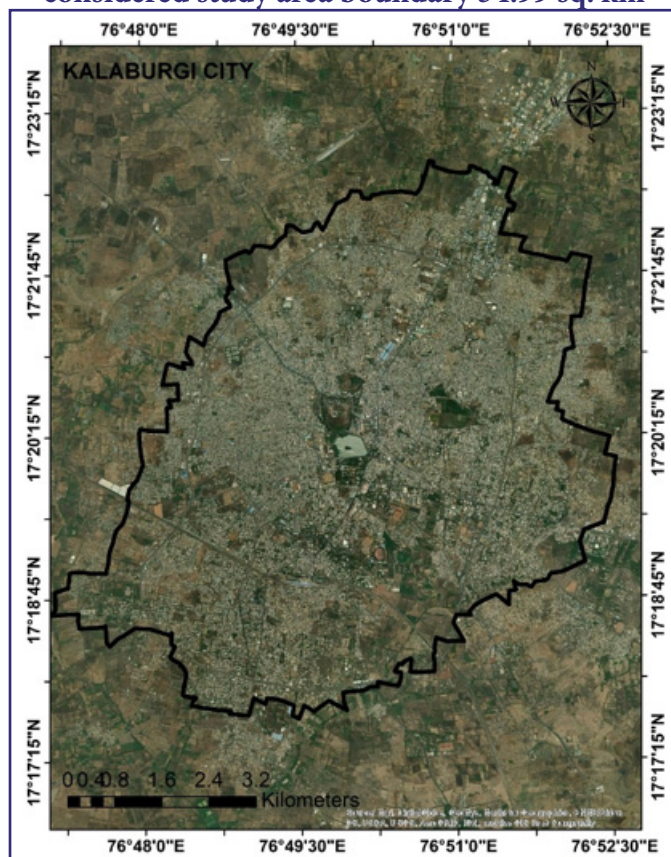
the land-cover dynamics and their environmental impacts, multi- temporal satellite data is obtained. Vegetation health and density is evaluated by Normalized Difference Vegetation Index (NDVI) and for the urban expansion patterns LULC classification method is practiced. Thermal infrared bands are considered critical indicators to derive Land Surface Temperature (LST) to detect urban heat island effects which are always linked to impervious surfaces and reduced green cover. In addition to land-cover and thermal changes, air quality is also influenced by urbanization. Expansion of built-up areas is always linked with increased vehicular emissions and industrial activities and causes reduced vegetation. It all collectively contributes to elevated concentrations of atmospheric pollutants such as nitrogen dioxide (NO₂), carbon monoxide (CO), Sulphur dioxide (SO₂), ozone (O₃), and particulate matter (PM_{2.5} and PM₁₀). Due to the advancement in geo-informatics, we can now conduct spatial assessments remotely through Satellite-based atmospheric observations and verify it with traditional ground-based monitoring for city-scale pollution analysis.

Existing remote sensing and GIS studies in this domain are often limited to short-term analyses with narrow temporal scales, restricting a comprehensive understanding of complex, interconnected factors. These factors span environmental, socio-economic, and spatial dimensions, making them inherently interdisciplinary. Therefore, there is a strong need for integrated, long-term analyses that effectively capture interactions and provide a cumulative assessment of multiple variables.

This study was conducted to assess urban expansion and its environmental impacts on Gulbarga City through a multi-temporal analysis of LULC, NDVI, LST, and air pollution. Multi temporal satellite data dating from the year 2000–2025 was considered for the analysis. The results detected the land-cover dynamics, vegetation changes, surface temperature variations, and pollutant distributions. The study highlights the causes and gives the reason behind long-term urban environmental change. These findings help guide sustainable urban planning, heat mitigation strategies, and pollution management in rapidly growing cities like Gulbarga.

1.1. Study Area

Fig. 1: Gulbarga city satellite image with considered study area boundary 54.99 sq. km



Gulbarga city also known as Kalburgi is in northeastern Karnataka, India, and experiences a semi-arid climate. The city has undergone rapid urban growth in recent decades. The study area includes urban, peri-urban, agricultural, and water-covered regions, resulting in land-use transformation from agricultural and open land to built-up areas, making it suitable for analyzing land-cover changes and surface temperature variations. The region is characterized by; Semi-arid climate, Seasonal vegetation cover, Expanding built-up areas, Limited surface water resources.

2. MATERIALS AND METHODS:

2.1 Satellite Data

Multi-temporal satellite datasets were used to analyze LULC, NDVI, for the years 2000, 2010, 2020, and 2025 and for the Land surface temperature (LST). For the air pollution check, and years data of 2025 on monthly basis was conducted.

The different data sources and their technical specifications are mentioned below in table 1 which

are used in this study. Multiple satellites were referred to analyzing each variable. for land use, thermal patterns, and air quality. Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI with a spatial resolution of 30 m was used to determine Land Use/Land Cover (LULC) and vegetation dynamics (NDVI). Daytime Land Surface Temperature (LST) was obtained from Landsat thermal bands (originally 100 m, resampled to 30 m), while nighttime LST was derived from MODIS (MOD11A2) at 1 km resolution. Atmospheric pollutants including NO₂, CO, SO₂, and O₃ were retrieved from Sentinel-5P (TROPOMI) data at an approximate spatial resolution of 7 km. Lastly, Particulate matter concentrations (PM_{2.5} and PM₁₀) were estimated using Aerosol Optical Depth (AOD)-based approaches. All datasets were projected to the WGS 84 / UTM Zone 43N coordinate system to ensure consistency and comparability and they were processed within the ArcGIS environment.

Parameter	Satellite / Sensor	Resolution
LULC, NDVI	Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI	30 m
LST (Day)	Landsat Thermal Bands	100 m (resampled to 30 m)
LST (Night)	MODIS (MOD11A2)	1 km
Air Pollution (NO ₂ , CO, SO ₂ , O ₃)	Sentinel-5P (TROPOMI)	~7 km
PM _{2.5} , PM ₁₀	AOD-based estimation	Variable

2.2 Image Pre-Processing

Satellite images were pre-processed to ensure consistency across sensors and time periods. The steps included:

In the first step radiometric and atmospheric correction is applied to remove sensor noise and atmospheric distortions, converting raw digital numbers into reliable surface reflectance values. In the second step, Cloud and shadow masking is performed to eliminate contaminated pixels to improve the data quality. Thirdly, Image is subset using KRSAC city boundary to define the study area boundary this step helps in reducing the volume to be more precise and to increase the focus. To maintain uniformity among datasets with varying resolutions, spatial resolution harmonization was performed, resampling all images to a common scale.

Finally, geometric correction and reprojection were carried out to align all datasets within a consistent coordinate system to ensure accurate spatial overlay and analysis in a GIS environment.

2.3 Methodology

This study followed the multi-source geospatial integrated methodology to assess urban environmental changes from 2000 to 2025. Satellite datasets from Landsat, MODIS, and Sentinel-5P compiled for land cover–thermal analysis and air pollution analysis. Firstly, Land Use/Land Cover (LULC) classification is performed using supervised methods (MLC) and then the NDVI–Land Surface Temperature (LST) analysis day and night are done separately to evaluate urban expansion, vegetation dynamics, and thermal patterns. In the second step, atmospheric pollutants (NO₂, CO, SO₂, O₃) and particulate matter (PM_{2.5}, PM₁₀) are analyzed to assess the variations in air quality. All the above extracted data will then be examined for spatial and temporal variability. Lastly, all the variables are integrated to provide a final comprehensive urban environmental assessment report highlighting all the influencing factors such as urban growth, vegetation loss, rising LST, and pollution-induced thermal hotspots.

3. RESULTS AND DISCUSSION

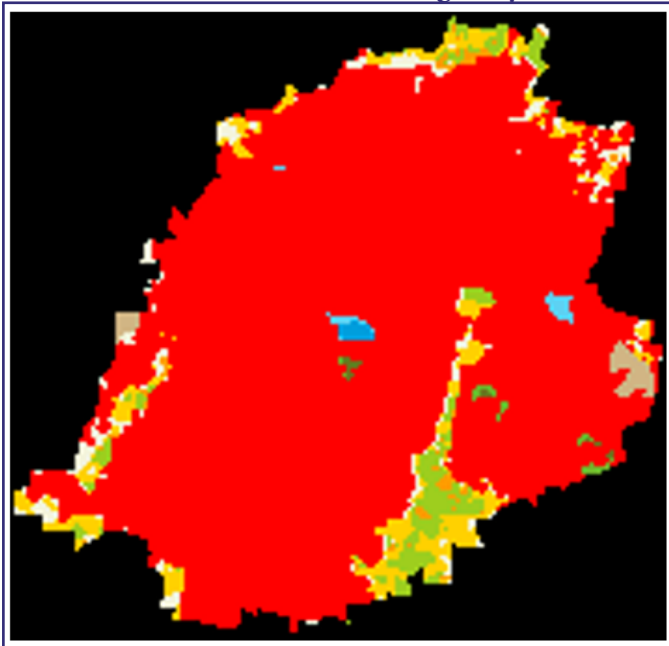
3.1 Land Use / Land Cover (LULC) Classification

LULC maps were generated using a supervised classification approach with the Maximum Likelihood Classifier. Four LULC classes were identified:

1. Water bodies
2. Built-up land
3. Vegetation
4. Soil / Road

Class-wise area and percentage cover were calculated for each year with a 5 years difference starting from 2000, 2005, 2010, 2015, 2020, 2025 using the

**Fig. 2: Land Use / Land Cover (LULC)
Classification Gulbarga city**



Tabulate Area tool in ArcGIS. Multi-temporal LULC change analysis was performed to quantify urban expansion and loss of natural land covers. The total area which was considered for the analysis is 54.99 sq. km – KRSRAC City Boundary

**Table 2: Land Use/Land Cover (LULC)
Distribution for the Year 2000**

2000	LULC	Area in sq km	% Cover
	Water bodies	5.7	5.1
	Builtup land	20.1	41.2
	Vegetation	25.8	48.1
	Soil /Road	5.1	6.1
	LULC	56.7	100.5

**Table 3: Land Use/Land Cover (LULC)
Distribution for the Year 2005**

2005	LULC	Area in sq km	% Cover
	Water bodies	4.1	3.5
	Builtup land	22.6	45.2
	Vegetation	21.8	41.1
	Soil /Road	6.9	9.1
	LULC	55.4	98.9

**Table 4: Land Use/Land Cover (LULC)
Distribution for the Year 2010**

2010	LULC	Area in sq km	% Cover
	Water bodies	3.1	2.9
	Builtup land	26.6	55.1
	Vegetation	18.8	31.1
	Soil /Road	7.2	10.1
	LULC	55.7	99.2

**Table 5: Land Use/Land Cover (LULC)
Distribution for the Year 2015**

2015	LULC	Area in sq km	% Cover
	Water bodies	2.1	2.2
	Builtup land	29.6	65.1
	Vegetation	15.8	20.1
	Soil /Road	8.9	11.1
	LULC	56.4	98.5

**Table 6: Land Use/Land Cover (LULC)
Distribution for the Year 2020**

2020	LULC	Area in sq km	% Cover
	Water bodies	1.3	1.4
	Builtup land	32.2	69.1
	Vegetation	12.8	18.1
	Soil /Road	8.3	10.8
	LULC	54.6	99.4

**Table 7: Land Use/Land Cover (LULC)
Distribution for the Year 2025**

2025	LULC	Area in sq km	% Cover
	Water bodies	1.2	1.4
	Builtup land	35.3	71.3
	Vegetation	9.8	15.7
	Soil /Road	7.3	11.6
	LULC	53.6	100

3.2 Vegetation Analysis (NDVI)

NDVI was computed to assess spatial and temporal changes in vegetation using

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

NDVI values were categorized into dense vegetation, sparse vegetation, and non-vegetated areas. Declining NDVI values were interpreted as indicators of vegetation loss and reduced pollution absorption

capacity.

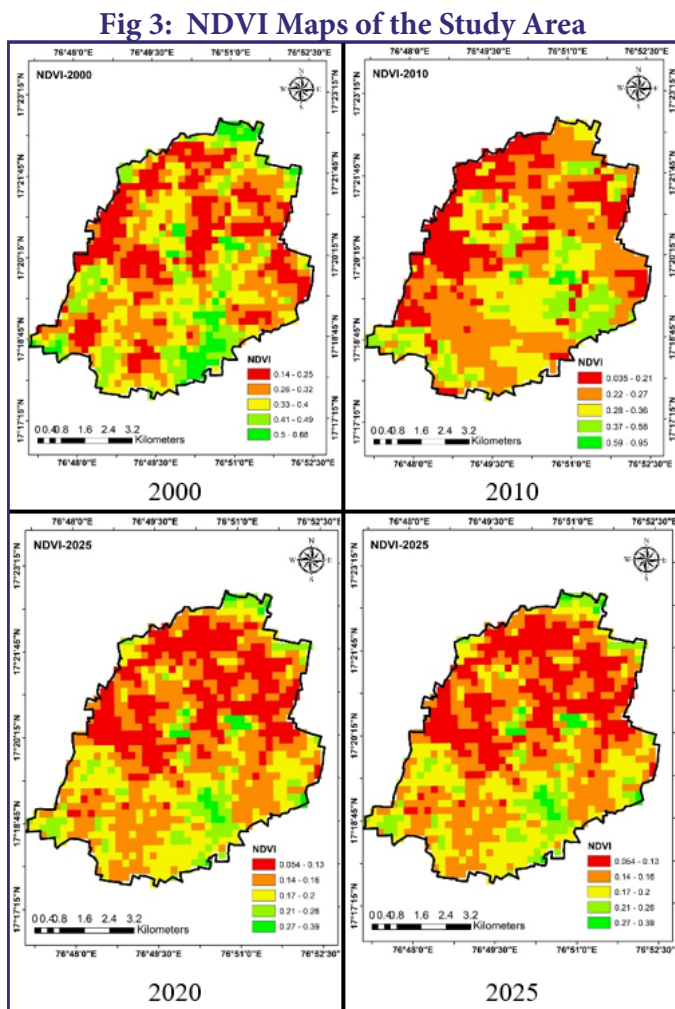
3.3 Land Surface Temperature (LST) Analysis

Daytime LST

Daytime LST was derived from Landsat thermal bands through:

1. Conversion of digital numbers to spectral radiance
2. Radiance to brightness temperature
3. Emissivity correction using NDVI-based method

LST maps were classified into temperature zones to identify urban heat island regions on monthly basis for the year 2025.



Night-time LST

Night-time LST data were obtained from MODIS MOD11A2 products. Temporal averaging was applied to analyze nocturnal heat retention associated with dense built-up areas on monthly basis for the year 2025.

Fig: 4 Day time LST analysis

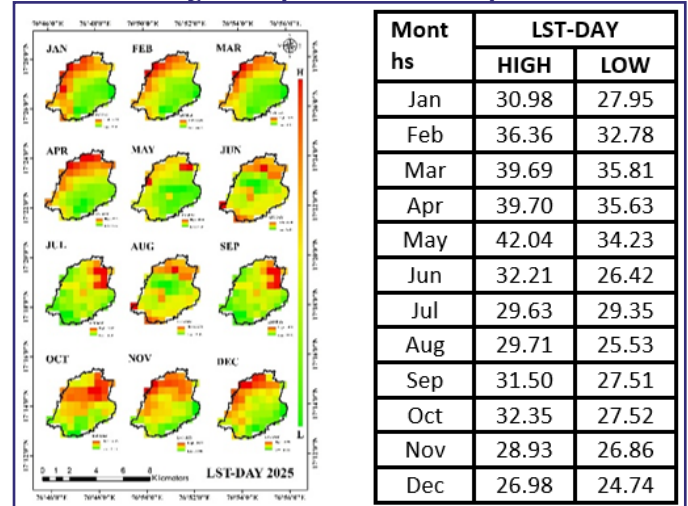
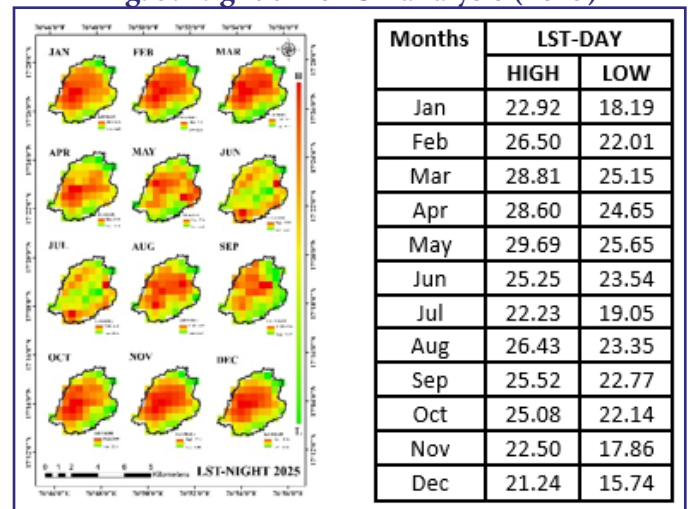


Fig: 5: Night time LST analysis (2025)



3.5. Air Pollution Analysis

Air pollution assessment focused on the following pollutants:

- Nitrogen Dioxide (NO_2)
- Carbon Monoxide (CO)
- Sulphur Dioxide (SO_2)
- Ozone (O_3)
- Particulate Matter ($\text{PM}_{2.5}$ and PM_{10})

Satellite-based pollutant concentration maps were generated using Sentinel-5P TROPOMI data. $\text{PM}_{2.5}$ and PM_{10} concentrations were estimated using aerosol optical depth (AOD), NDVI, and LST relationships. Pollutant levels were classified into low, moderate, and high concentration zones.

Fig. 6: Nitrogen Dioxide (NO₂) analysis (2025)

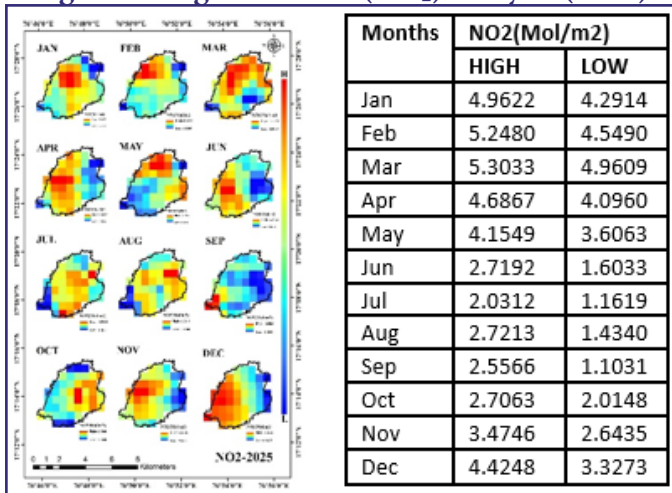


Fig. 8: Sulphur Dioxide (SO₂) analysis (2025)

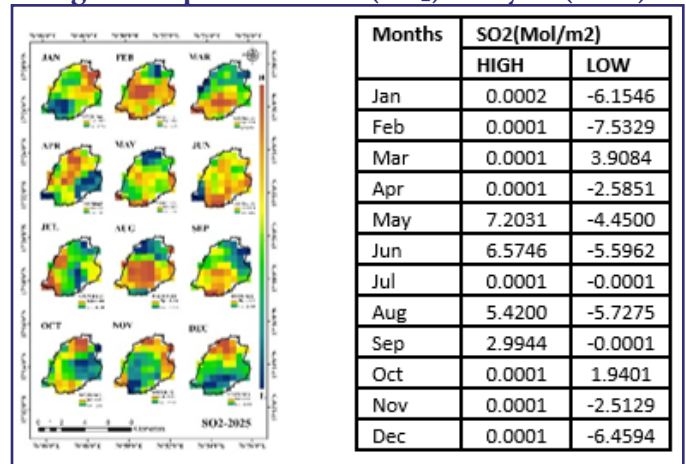


Fig. 7: Carbon Monoxide (CO) analysis (2025)

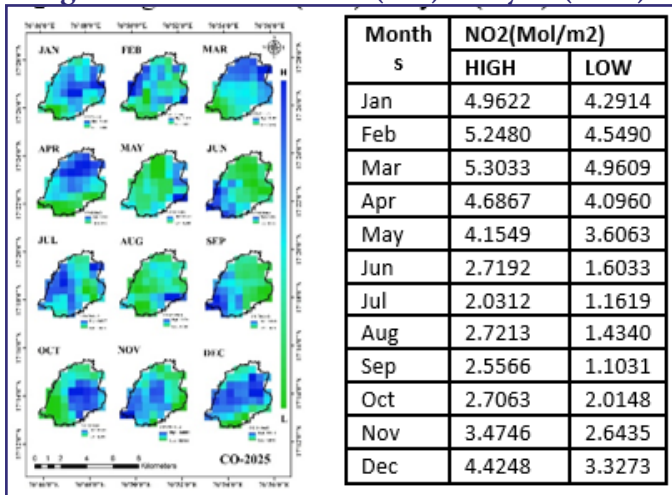


Fig. 9: Ozone (O₃) analysis (2025)

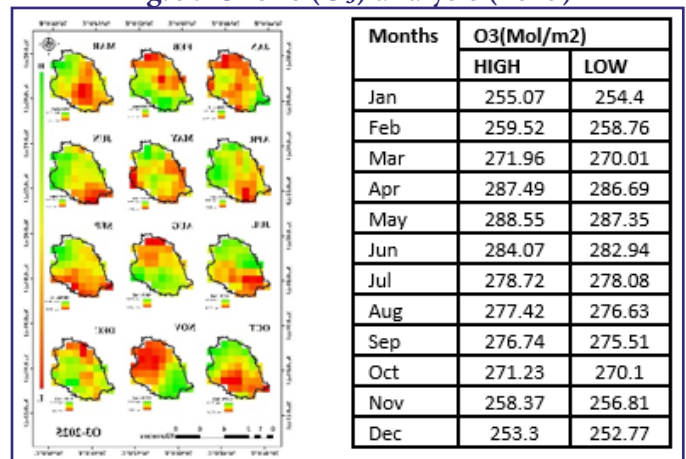
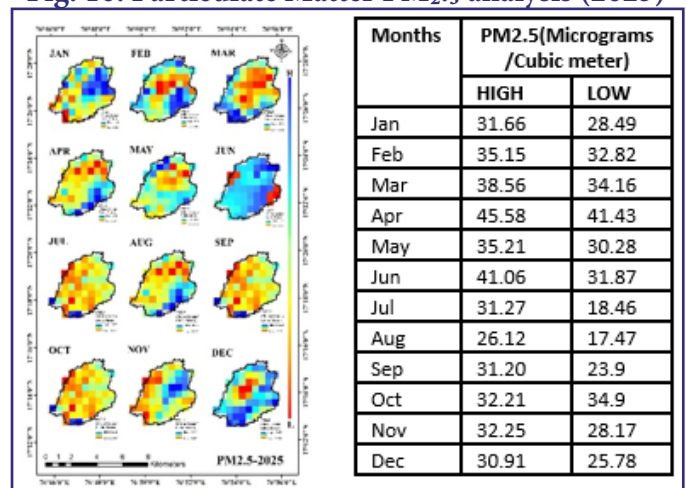


Fig. 10: Particulate Matter PM_{2.5} analysis (2025)

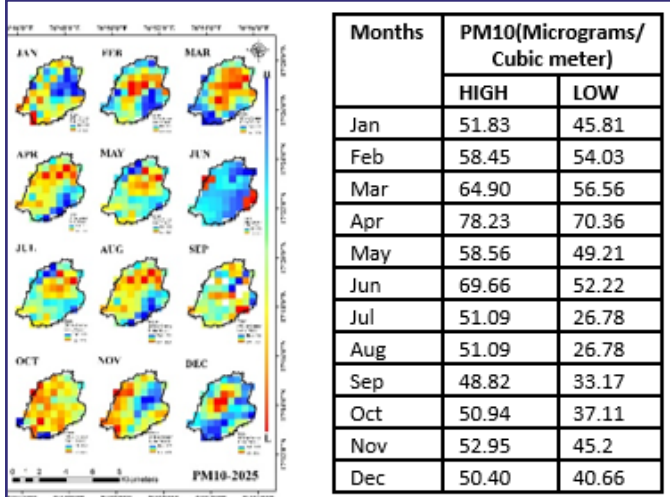


3.6 Integrated Urban–Environmental Analysis

Spatial overlay and correlation analyses were conducted to examine relationships among:

- Built-up land and pollutant concentration
- NDVI and particulate matter
- LST (day and night) and air pollution

This integrated analysis helped identify urban heat and pollution hotspots.

Fig. 11: Particulate Matter PM₁₀ analysis (2025)

2.7 Accuracy Assessment

Classification accuracy was evaluated using confusion matrices and kappa statistics based on reference data from high-resolution imagery and secondary sources.

2.8 Output Generation

The final outputs included:

- Multi-temporal LULC maps
- NDVI and LST (day and night) maps
- Air pollution distribution maps
- Change detection and hotspot map

These outputs provide a comprehensive assessment of urban expansion and environmental change in Kalaburagi City.

3. CONCLUSIONS

The findings of this study clearly demonstrate that rapid urban expansion in Gulbarga city has significantly altered the environmental landscape over the study period. The consistent decline in vegetation cover has been noticed alongside the marked increase in built-up areas. There was a significant shift in land-use patterns driven by urban growth. This transformation has also contributed to a noticeable reduction in surface water extent, resulting in a concurrent rise in land surface temperatures. The most significant change was within densely developed zones. The inverse relationship between vegetation indices and surface temperature was observed. A positive association between built-up areas and thermal intensity was also detected, highlighting the role of land-cover changes in intensifying urban heat. Additionally, there was deterioration in air quality—

primarily influenced by particulate matter and urban emissions. This could be due to the environmental pressures associated with unplanned urbanization. Overall, the study emphasizes that the combined effects of land use change, thermal variation, and air pollution are closely interconnected and collectively contribute to environmental degradation in Gulbarga. These findings reinforce the need for integrated geoinformatics-based planning approaches to support smart, stable and sustainable urban development, which can be enhanced through green cover, and also mitigate urban heat and pollution impacts.

REFERENCES

1. Anderson J. R. et al. (1976). A Land Use and Land Cover Classification System for Use with Remote Sensor Data. USGS Professional Paper 964.
2. United States Geological Survey (USGS). Landsat Data Users Handbook.
3. Rouse J. W. et al. (1974). Monitoring vegetation systems in the Great Plains with ERTS. NASA SP-351.
4. Tucker C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8(2), 127–150.
5. Weng Q. (2004). Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. *Remote Sensing of Environment*, 89(4), 467–483.
6. Voogt J. A. & Oke T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*, 86(3), 370–384.
7. Seto K. C. et al. (2012). Global forecasts of urban expansion to 2030 and impacts on biodiversity. *PNAS*, 109(40), 16083–16088.
8. Dewan A. M. & Yamaguchi Y. (2009). Land use and land cover change in Greater Dhaka. *Remote Sensing of Environment*, 113(3), 625–638.
9. Carlson T. N. et al. (1994). Satellite estimation of surface energy balance and soil moisture. *Journal of Applied Meteorology*, 33, 138–146.
10. Gillies R. R. et al. (1997). A method for estimating surface soil moisture using NDVI and LST. *Remote Sensing of Environment*, 59, 139–154.
11. European Space Agency (2018). Sentinel-5P TROPOMI User Guide.
12. Veefkind J. P. et al. (2012). TROPOMI on Sentinel-5 Precursor: A GMES mission for global atmospheric composition monitoring. *Remote Sensing of Environment*, 120, 70–83.
13. van Donkelaar A. et al. (2010). Global estimates of ambient fine particulate matter concentrations from satellite-based aerosol optical depth. *Environmental Health Perspectives*, 118(6), 847–855.
14. Gupta P. & Christopher S. A. (2009). Particulate matter air quality assessment using satellite data. *Journal of Geophysical Research*.
15. Jensen J. R. (2005). *Introductory Digital Image Processing*. Prentice Hall.
16. Lillesand T. et al. (2015). *Remote Sensing and Image Interpretation*. Wiley.
17. Central Pollution Control Board (CPCB). *National Air Quality Reports*.
18. Indian Space Research Organisation. *Bhuvan & satellite data resources*.