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Change Detection of Land Use Land Cover (2004-2014-2024) in Kalaburagi City, Karnataka

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Abstract:

This study aims to analyze the Land Use Land Cover (LULC) changes in Kalaburagi city, Karnataka, India, from 2004 to 2024 using remote sensing and GIS techniques. Landsat satellite imagery will be classified using supervised techniques to map LULC patterns in 2004, 2014, and 2024. The study will quantify changes in each LULC class, analyze the spatial patterns of urban growth, agricultural land conversion, and other transformations. A categorical change detection technique will be employed to identify and quantify the changes between different time periods. The accuracy of the classifications will be assessed using ground truth data and statistical measures. The results will provide insights into the urbanization process, its environmental impact, and the effectiveness of land use policies in Kalaburagi city. The findings can assist policymakers and urban planners in making informed decisions for sustainable land management and urban development in the region. The study will contribute to the understanding of urban growth patterns and their socio-economic and environmental implications in developing countries.

Keywords —Land Use Land Cover, Change Detection, Remote Sensing, Kalaburagi.

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I. INTRODUCTION

Land use and land cover (LULC) change is a crucial aspect of global environmental change, with significant implications for sustainable development, ecosystem services, and human well-being (Turner et al., 2007). Rapid urbanization, population growth, and economic development have led to substantial changes in LULC patterns worldwide, particularly in developing countries (Seto et al., 2011). In India, urban areas have experienced rapid growth in recent decades, resulting in the conversion of agricultural lands, forests, and wetlands into built-up areas (Taubenböck et al., 2009). Kalaburagi city, located in the northern part of Karnataka state, has witnessed significant urban expansion and LULC changes due to population growth and industrial development (Ramachandra et al., 2012). Monitoring and analyzing these changes is essential for understanding the driving factors, assessing the environmental and socio-economic impacts, and informing sustainable land use planning and management decisions.

Remote sensing and Geographic Information Systems (GIS) have emerged as powerful tools for mapping, monitoring, and analyzing LULC changes at various spatial and temporal scales (Jensen, 2005). Satellite imagery provides synoptic coverage and multi-temporal data, enabling the detection and quantification of LULC changes over large areas (Lu et al., 2004). Various change detection techniques, such as post-classification comparison and time-series analysis, have been widely used to assess the magnitude and patterns of LULC changes (Singh, 1989). Furthermore, the integration of remote sensing data with GIS allows for the spatial analysis and modeling of LULC changes, facilitating the understanding of the underlying processes and drivers (Lambin et al., 2001).

Studying LULC changes in Kalaburagi city is significant for several reasons. First, it provides crucial information on the spatial and temporal patterns of urban growth and its impact on the surrounding environment (Ramachandra et al., 2012). Understanding the extent and nature of LULC changes can help urban planners and policymakers to develop sustainable land use strategies and mitigate the negative consequences of unplanned urban expansion, such as loss of agricultural lands, deforestation, and environmental degradation (Hegazy &Kaloop, 2015).

Second, analyzing LULC changes can shed light on the socio-economic drivers and consequences of urban growth in Kalaburagi city. Rapid urbanization is often associated with population growth, migration, and economic development, which can lead to increased demand for housing, infrastructure, and services (Cohen, 2006). Assessing the relationship between LULC changes and socio-economic factors can help in understanding the broader implications of urban growth and informing inclusive and equitable development strategies.

Third, this study contributes to the growing body of knowledge on LULC changes in Indian cities and provides a case study for comparing and contrasting the patterns and drivers of urban growth in different regions (Jat et al., 2008). The findings of this study can be used to develop generalizable models and theories of urban growth and LULC changes in developing countries, informing future research and policy interventions.

The main objectives of this study are:

- Produce detailed LULC maps of Kalaburagi for 2004, 2014, and 2024 using high-resolution satellite imagery from the Landsat series. These maps will serve as the primary data source for analyzing changes over the designated periods.
- Quantify and analyze changes in LULC to identify significant trends, such as the expansion of urban areas, reduction in agricultural lands, and changes in vegetative cover. This analysis will help in understanding the driving forces behind these changes, including economic, social, and environmental factors.
- Assess the impacts of LULC changes on urban planning and environmental management policies. This includes evaluating how urban expansion has affected natural habitats, water resources, and the local climate, providing a basis for future urban and environmental policy adjustments.

The scope of this study is limited to Kalaburagi city and its surrounding areas, covering a total area of [insert area in sq. km]. The study period spans from 2004 to 2024, with LULC maps generated for three time points: 2004, 2014, and 2024 (predicted). The analysis is based on medium-resolution satellite imagery (Landsat 7, 8, and 9) and ancillary data, such as topographic maps and socio-economic data.

The limitations of this study include the potential errors and uncertainties associated with satellite image classification and change detection techniques (Lu et al., 2004). The accuracy of LULC maps and change analysis depends on factors such as image quality, classification algorithms, and ground truth data availability. Additionally, the prediction of future LULC scenarios is based on the assumptions and limitations of the cellular automata-Markov chain model, which may not capture all the complex and dynamic processes of urban growth (Santé et al., 2010).

Moreover, the study relies on secondary data sources for analyzing the drivers and consequences of LULC changes, which may have limitations in terms of accuracy, completeness, and temporal consistency. The interpretation of the results and the recommendations for sustainable land use planning are based on the available data and the professional judgment of the researchers, which may be subject to certain biases and limitations.

Despite these limitations, this study provides a comprehensive analysis of LULC changes in Kalaburagi city using state-of-the-art remote sensing and GIS techniques, contributing to the understanding of urban growth patterns and their environmental and socio-economic implications in the context of developing countries.

II. LITERATURE REVIEW

Land use and land cover (LULC) change detection is the process of identifying and quantifying the differences in LULC patterns over time (Singh, 1989). It involves the comparison of multi-temporal satellite imagery or other spatial data to assess the changes in the extent, distribution, and characteristics of various LULC classes (Lu et al., 2004). LULC change detection is crucial for understanding the dynamics of landscape transformations, monitoring environmental changes, and informing land use planning and management decisions (Lambin et al., 2001).

Various methods have been developed for LULC change detection, including post-classification comparison, image differencing, principal component analysis, and object-based change detection (Lu et al., 2004; Chen et al., 2012). Categorical change detection techniques, such as post-classification comparison, involve the independent classification of multi-temporal images and the subsequent comparison of the classified maps to identify the changes (Singh, 1989). This method has the advantage of providing detailed "from-to" change information and minimizing the impact of atmospheric and sensor differences between the images (Jensen, 2005).

The accuracy of LULC change detection depends on various factors, such as the quality and resolution of the satellite imagery, the classification algorithms, and the selection of appropriate change detection methods (Lu et al., 2004). The incorporation of ancillary data, such as topographic maps, field surveys, and socio-economic data, can improve the accuracy and interpretation of LULC change results (Jensen, 2005). Additionally, the use of advanced techniques, such as object-based image analysis and machine learning algorithms, has shown promising results in enhancing the accuracy and efficiency of LULC change detection (Chen et al., 2012; Hussain et al., 2013).

. Remote sensing and Geographic Information Systems (GIS) have revolutionized the way LULC studies are conducted, providing powerful tools for mapping, monitoring, and analyzing LULC patterns and changes (Jensen, 2005). Remote sensing data, particularly satellite imagery, offer synoptic coverage, multi-temporal information, and various spectral and spatial resolutions, enabling the extraction of LULC information at different scales (Belward& Skøien, 2015).

Multispectral sensors, such as Landsat, SPOT, and Sentinel-2, have been widely used in LULC studies due to their moderate spatial resolution, wide swath, and long-term data availability (Wulder et al., 2012; Drusch et al., 2012). These sensors capture reflectance data in multiple spectral bands, allowing for the discrimination of different LULC classes based on their spectral signatures (Jensen, 2005). Advanced classification techniques, such as maximum likelihood, support vector machines, and random forests, have been applied to satellite imagery to generate accurate LULC maps (Lu & Weng, 2007; Gislason et al., 2006).

GIS, on the other hand, provides a framework for storing, managing, analyzing, and visualizing spatial data (Chang, 2019). The integration of remote sensing data with GIS allows for the spatial analysis and modeling of LULC patterns and changes, facilitating the understanding of the underlying processes and drivers (Lambin et al., 2001). GIS techniques, such as overlay analysis, spatial statistics, and suitability modeling, have been used to assess the relationships between LULC changes and various environmental and socio-economic factors (Malczewski, 2004).

The combination of remote sensing and GIS has enabled the development of advanced LULC change detection and modeling approaches. Categorical change detection techniques, such as post-classification comparison and cross-tabulation analysis, have been used to quantify the transitions between different LULC classes over time (Pontius et al., 2004). These techniques provide a detailed understanding of the patterns and rates of LULC changes and help identify the dominant transformations and their spatial distribution (Aldwaik& Pontius, 2012).

Urbanization, the process of urban growth and the conversion of rural lands to urban uses, is one of the most significant drivers of LULC changes worldwide (Seto et al., 2011). The rapid expansion of urban areas, particularly in developing countries, has led to substantial changes in LULC patterns, with far-reaching environmental and socio-economic consequences (Cohen, 2006).

Urban growth is often associated with the conversion of agricultural lands, forests, wetlands, and other natural habitats into built-up areas, leading to the loss of biodiversity, ecosystem services, and productive lands (Grimm et al., 2008). The expansion of impervious surfaces, such as buildings, roads, and parking lots, alters the hydrological cycle, increases surface runoff, and contributes to urban heat island effects (Weng, 2012). Moreover, urban sprawl, the uncontrolled and dispersed growth of urban areas, can lead to increased energy consumption, air pollution, and social segregation (Nechyba& Walsh, 2004).

Remote sensing has been widely used to map and monitor urban growth and its impact on LULC. Various techniques, such as supervised classification, spectral mixture analysis, and object-based image analysis, have been applied to satellite imagery to extract urban land cover information (Weng, 2012). The integration of remote sensing data with GIS has allowed for the spatial analysis of urban growth patterns, such as urban sprawl, infill development, and leapfrog development (Sudhira et al., 2004).

Urbanization also has significant socio-economic implications, such as changes in land tenure, property rights, and land markets (Lambin et al., 2001). The conversion of agricultural lands to urban uses can lead to the displacement of rural populations, the loss of traditional livelihoods, and increasing social inequalities (Seto et al., 2011). Understanding the socio-economic drivers and consequences of urban growth is crucial for developing sustainable land use policies and urban planning strategies (Cohen, 2006).

Several studies have investigated the LULC changes in Kalaburagi city and similar areas in India, highlighting the patterns, drivers, and consequences of urban growth. Ramachandra et al. (2012) analyzed the spatial patterns of urbanization in Kalaburagi city using remote sensing data and spatial metrics. The study found a significant increase in built-up areas and a corresponding decrease in vegetation cover between 2001 and 2009, indicating rapid urban expansion.

Pujar et al. (2014) used Landsat imagery and GIS techniques to assess the LULC changes in Kalaburagi city between 1992 and 2012. The results showed a substantial growth of built-up areas, particularly along the transportation corridors and in the peripheral areas of the city. The study also highlighted the need for sustainable land use planning to balance urban growth with the conservation of natural resources.

Similar studies have been conducted in other Indian cities, such as Bangalore (Sudhira et al., 2004), Pune (Bhailume, 2012), and Hyderabad (Rahman et al., 2011), revealing common patterns and drivers of urban growth in India. These studies emphasize the importance of remote sensing and GIS techniques in monitoring and analyzing LULC changes and informing urban planning and management decisions.

However, there is a lack of comprehensive studies that integrate remote sensing, GIS, and socio-economic data to understand the complex interactions between urban growth, LULC changes, and sustainable development in Kalaburagi city. Moreover, the application of categorical change detection techniques, such as post-classification comparison and cross-tabulation analysis, has not been extensively explored in the context of

TABLE 1: RELEVANT STUDIES

Study	Study Area	Time Period	Data and Methods	Key Findings
Ramachandra et al. (2012)	Kalaburagi city, Karnataka	2001-2009	Remote sensing data and spatial metrics	- Significant increase in built-up areas- Decrease in vegetation cover- Rapid urban expansion
Pujar et al. (2014)	Kalaburagi city, Karnataka	1992-2012	Landsat imagery and GIS techniques	- Substantial growth of built-up areas along transportation corridors and peripheral areas- Need for sustainable land use planning
Sudhira et al. (2004)	Bangalore, Karnataka	1992-2000	Remote sensing and GIS techniques	- Rapid urban sprawl and land use changes- Development of spatial metrics for quantifying urban sprawl
Bhailume (2012)	Pune, Maharashtra	1992-2009	Remote sensing and GIS techniques	- Significant urban sprawl and land use changes- Need for sustainable urban planning and management
Rahman et al. (2012)	North-West District, Delhi	1992-2008	Remote sensing and GIS techniques	- Substantial increase in built-up areas- Decrease in agricultural lands and green spaces- Importance of remote sensing and GIS in monitoring urban growth
Ramachandra et al. (2012)	Kalaburagi city, Karnataka	2001-2009	Remote sensing data and spatial metrics	- Significant increase in built-up areas- Decrease in vegetation cover- Rapid urban expansion
Seto et al. (2011)	Global	1970-2000	Meta-analysis of global urban land expansion studies	- Rapid urban land expansion in developing countries- Need for sustainable urban planning and management
Singh (1989)	Review article	-	Review of digital change detection techniques using remotely-sensed data	- Overview of various change detection techniques- Importance of selecting appropriate techniques based on study objectives and data characteristics
Lambin et al. (2001)	Review article	-	Review of causes of land-use and land-cover change	- Identification of proximate and underlying drivers of land-use and land-cover change- Importance of interdisciplinary approaches in understanding land-use and land-cover change
Lu et al. (2004)	Review article	-	Review of change detection techniques	- Overview of various change detection techniques- Factors affecting the accuracy of change detection- Importance of selecting appropriate techniques based on study objectives and data characteristics

Kalaburagi city. This study aims to fill these gaps by providing a detailed analysis of LULC changes in Kalaburagi city from 2004 to 2024, integrating remote sensing, GIS, and socio-economic data, and employing categorical change detection techniques to quantify the patterns and rates of LULC transitions.

III. STUDY AREA

Kalaburagi city, also known as Gulbarga, is the administrative headquarters of Kalaburagi district in the northern part of Karnataka state, India. The city is located at 17°20′N 76°50′E, covering an area of 64.94 square kilometers (Census of India, 2011). Kalaburagi city is situated on the Deccan Plateau, approximately 623 meters above mean sea level (Ramachandra et al., 2012). The city is well-connected by road and rail networks, with National Highway 218 passing through the city and connecting it to major urban centers such as Bangalore and Hyderabad (Pujar et al., 2014).

The Kalaburagi district spans an area of 10,951 square kilometers, sharing borders with the states of Maharashtra and Telangana (Census of India, 2011). The district is divided into seven talukas: Kalaburagi, Afzalpur, Aland, Chincholi, Chitapur, Jewargi, and Sedam (Kalaburagi District Administration, 2021). The city of Kalaburagi serves as the central hub for administrative, commercial, and educational activities in the region.

Kalaburagi city is characterized by a gently undulating topography, with elevations ranging from 300 to 700 meters above mean sea level (Ramachandra et al., 2012). The city is drained by the Bhima River and its tributaries, which flow towards the east and northeast (Pujar et al., 2014).

The predominant soil types in the region are black cotton soils, which are rich in clay content and have high moisture retention capacity (National Bureau of Soil Survey and Land Use Planning, 1996). These soils are suitable for agriculture, particularly for the cultivation of crops such as cotton, sorghum, and pulses (Kalaburagi District Administration, 2021).

The climate of Kalaburagi city is semi-arid, with hot summers and mild winters (Ramachandra et al., 2012). The city experiences three distinct seasons: summer (March to May), monsoon (June to September), and winter (October to February) (Karnataka State Natural Disaster Monitoring Centre, 2021). The average annual temperature ranges from 20°C to 40°C, with the highest temperatures recorded during the summer months (Pujar et al., 2014). The average annual rainfall in the city is approximately 750 mm, with most of the precipitation occurring during the monsoon season (Karnataka State Natural Disaster Monitoring Centre, 2021).

According to the Census of India (2011), Kalaburagi city has a population of 543,147, with a population density of 8,369 persons per square kilometer. The city has experienced rapid population growth in recent decades, with a decadal growth rate of 32.73% between 2001 and 2011 (Census of India, 2011). The high population growth can be attributed to factors such as rural-urban migration, industrial development, and the establishment of educational institutions in the city (Ramachandra et al., 2012).

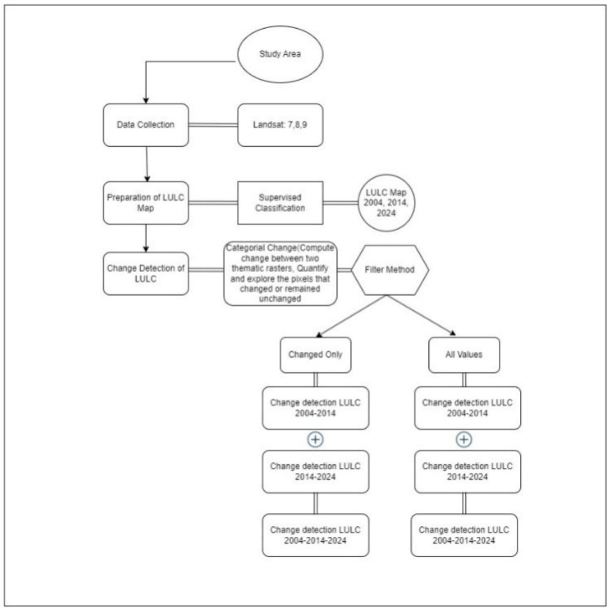
The literacy rate in Kalaburagi city is 78.82%, which is higher than the national average of 74.04% (Census of India, 2011). The city has a diverse economic base, with agriculture, industries, and services being the main contributors to the local economy (Kalaburagi District Administration, 2021). The major industries in the city include textiles, cement, and food processing (Pujar et al., 2014). The city also has a thriving education sector, with several prestigious institutions such as Gulbarga University and the Central University of Karnataka located in the area (Kalaburagi District Administration, 2021).

The land use land cover (LULC) pattern of Kalaburagi city has undergone significant changes in recent decades due to rapid urbanization and population growth (Ramachandra et al., 2012). The city has witnessed a substantial increase in built-up areas, with a corresponding decrease in agricultural lands and open spaces (Pujar et al., 2014). According to a study by Ramachandra et al. (2012), the built-up area in Kalaburagi city increased from 10.84% in 2001 to 16.42% in 2009, while the area under vegetation decreased from 14.85% to 11.77% during the same period.

The LULC pattern of Kalaburagi city is characterized by a mix of urban and peri-urban land uses (Pujar et al., 2014). The central part of the city is dominated by high-density built-up areas, consisting of residential, commercial, and industrial land uses (Ramachandra et al., 2012). The peripheral areas of the city are characterized by a mosaic of agricultural lands, rural settlements, and urban sprawl (Pujar et al., 2014). The city has also witnessed the development of new residential areas, industrial estates, and educational institutions along the major transportation corridors (Ramachandra et al., 2012).

The changing LULC pattern of Kalaburagi city has significant implications for sustainable urban development and environmental management (Pujar et al., 2014). The rapid conversion of agricultural lands and open spaces to built-up areas has led to the loss of productive farmlands, reduction in groundwater recharge, and increased urban heat island effects (Ramachandra et al., 2012). The unplanned growth of the city has also put pressure on the existing infrastructure and services, leading to issues such as traffic congestion, water scarcity, and solid waste management (Kalaburagi District Administration, 2021).

Fig 1: Methodology



Data Collection The first step in the methodology is to select the study area and collect the necessary data. In this case, the study area is a specific region of interest for which LULC changes will be analyzed over a 20-year period from 2004 to 2024. The primary data source for this study is satellite imagery, specifically Landsat 7, 8, and 9 imagery. Landsat satellites are widely used for LULC studies due to their consistent and long-term data availability, moderate spatial resolution (30 meters), and multispectral capabilities (Roy et al., 2014).

The Landsat imagery is acquired for the study area covering the years 2004, 2014, and 2024. These years are chosen to represent the initial, intermediate, and final stages of the study period, allowing for the assessment of LULC changes at different time intervals. The imagery should be carefully selected based on factors such as cloud cover, seasonality, and data quality to ensure reliable and comparable results (Wulder et al., 2012).

In addition to the satellite imagery, ancillary data such as topographic maps, land use plans, and ground truth data may also be collected to aid in the interpretation and validation of the LULC classification results (Lu & Weng, 2007).

Preparation of LULC Map Once the satellite imagery is collected, it undergoes preprocessing to ensure its suitability for LULC classification. Preprocessing steps may include radiometric calibration, atmospheric correction, and geometric correction to remove any distortions or anomalies in the imagery (Young et al., 2017). These steps are crucial for obtaining accurate and consistent LULC maps.

After preprocessing, supervised classification techniques are applied to the satellite imagery to generate LULC maps for the years 2004, 2014, and 2024. Supervised classification involves selecting training samples for each LULC class based on the analyst's knowledge of the study area and the spectral characteristics of the different land cover types (Lu & Weng, 2007). Common LULC classes may include built-up areas, agricultural lands, forests, water bodies, and barren lands, depending on the specific characteristics of the study area (Anderson et al., 1976).

Popular supervised classification algorithms such as Maximum Likelihood Classification (MLC), Support Vector Machines (SVM), and Random Forest (RF) can be employed to classify the satellite imagery (Khatami et al., 2016). The choice of the classification algorithm depends on factors such as the complexity of the landscape, the available training data, and the desired level of accuracy (Phiri & Morgenroth, 2017).

Change Detection of LULC After generating the LULC maps for the different years, the next step is to perform change detection analysis to identify and quantify the changes in LULC between two thematic rasters (classified LULC maps). The categorical change detection technique is used for this purpose (Singh, 1989).

The categorical change detection technique compares the pixel values of two LULC maps and identifies the pixels that have changed or remained unchanged. It generates a change matrix that summarizes the transitions between different LULC classes over the specified time period (Pontius et al., 2004). The change matrix provides valuable information on the nature and extent of LULC changes, such as the conversion of agricultural lands to built-up areas or the regeneration of forests from barren lands.

The change detection analysis is performed using GIS software, which allows for the overlaying and comparison of the LULC maps. The software computes the pixel-wise differences between the two maps and generates a change map that highlights the areas of change (Lu et al., 2004).

Filter Method To refine the change detection results and eliminate any noise or insignificant changes, a filter method is applied. The filter method helps to remove isolated pixels or small patches of change that may not be meaningful in the context of the study (Macleod &Congalton, 1998). Various filtering techniques, such as majority filtering or morphological filtering, can be used depending on the characteristics of the change map and the desired level of generalization (Serra & Pons, 2008).

The filter method ensures that the change detection results are more robust and focused on the significant LULC changes that are relevant to the study objectives.

Change Detection Analysis The change detection analysis is performed for different time periods to assess the LULC changes at various intervals and over the entire study period. The analysis is carried out for the following time periods:

- 2004-2014: This analysis identifies the LULC changes that occurred between 2004 and 2014, providing insights into the short-term dynamics of LULC in the study area.
- 2014-2024: This analysis focuses on the LULC changes that occurred between 2014 and 2024, capturing the medium-term trends and patterns of change.
- 2004-2014-2024: This analysis provides an overall assessment of the LULC changes that occurred throughout the entire study period from 2004 to 2024, offering a long-term perspective on the LULC dynamics.

By analyzing the LULC changes at different time scales, the study can identify the temporal variations in LULC patterns, assess the rates of change, and understand the underlying drivers and consequences of LULC changes in the study area (Lambin et al., 2003).

Changed Only: This result highlights only the areas where LULC changes have occurred during the specified time periods. It focuses on the dynamic aspects of the landscape and identifies the hotspots of change. This information is crucial for understanding the spatial patterns of LULC changes and identifying the areas that have undergone significant transformations (Dewan & Yamaguchi, 2009).

All Values: This result presents a comprehensive view of the LULC changes, including both the changed and unchanged areas. It provides a complete picture of the landscape composition and configuration, allowing for the assessment of the overall LULC distribution and the identification of stable or persistent land cover types (Munteanu et al., 2014).

The combination of both changed and unchanged areas in the results enables a holistic understanding of the LULC dynamics and the underlying processes that shape the landscape.

Final Results The final results of the change detection analysis are presented in the form of change detection LULC maps for the different time periods. These maps provide a visual representation of the LULC changes in the study area, allowing for easy interpretation and communication of the results (Munafò et al., 2013).

- 2004-2014: This map illustrates the LULC changes that occurred between 2004 and 2014, highlighting the short-term dynamics of the landscape.
- 2014-2024: This map depicts the LULC changes that took place between 2014 and 2024, showcasing the medium-term trends and patterns of change.
- 2004-2014-2024: This map provides an integrated view of the LULC changes that occurred throughout the entire study period from 2004 to 2024, offering a long-term perspective on the LULC dynamics.

The change detection LULC maps are accompanied by quantitative measures, such as the areal extent of each LULC class, the rates of change, and the transition matrices, to provide a comprehensive understanding of the LULC changes in the study area (Mallinis et al., 2011).

The final results serve as a valuable resource for land use planners, policymakers, and researchers to assess the impacts of LULC changes on the environment, society, and economy. They provide insights into the drivers and consequences of LULC changes and support informed decision-making for sustainable land management and development (Verburg et al., 2011).

IV. RESULTS AND DISCUSSION

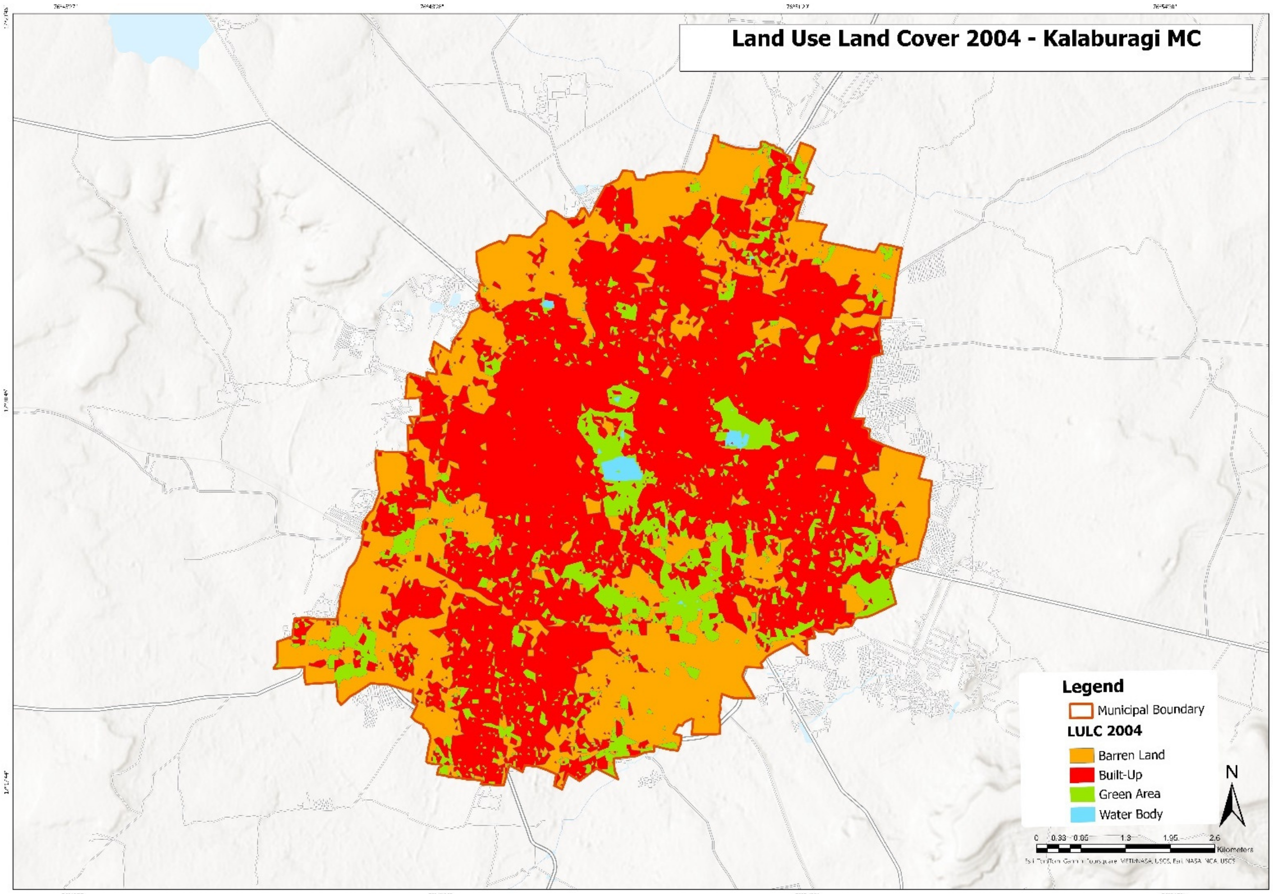


Fig 1: Land Use Land Cover 2004 – Kalaburagi MC

A. *Land Use Land Cover 2004*

The 2004 LULC map of Kalaburagi MCcovers a total area of 162 sq km and classifies the land into four main categories: Built-Up, Barren Land, Green Area, and Water Body.

Table 2. Land Use Land Cover Distribution, Kalaburagi MC 2004

As evident from Table 2 and Figure 1, the Built-Up category dominates the land cover, occupying 31.326 sq km or 57.1% of the mapped area. This high percentage of built-up land is typical of urban centers and reflects Kalaburagi's status as a major city in the region. The built-up area includes residential, commercial, and industrial spaces, as well as infrastructure like roads and utilities.

LULC Class	Area (sq km)	Percentage
Built-Up	31.326	57.1%
Barren Land	17.205	31.3%
Green Area	6.146	11.2%
Water Body	0.275	0.5%
Total	54.952	100%

Barren Land is the second largest category, covering 17.205 sq km or 31.3% of the total area. This significant proportion of barren land can be attributed to Kalaburagi's semi-arid climate, characterized by sparse vegetation and exposed soil or rock surfaces. The presence of large tracts of barren land within the city limits also suggests potential for future urban expansion.

Green Area, which includes vegetated spaces like parks, gardens, and agricultural plots, accounts for 6.146 sq km or 11.2% of the mapped area. This relatively low percentage of green cover is concerning from an environmental perspective, as vegetation plays a crucial role in mitigating urban heat island effects, improving air quality, and supporting biodiversity. The limited green space may be a result of rapid urbanization and the semi-arid climate, which makes it challenging to maintain lush vegetation.

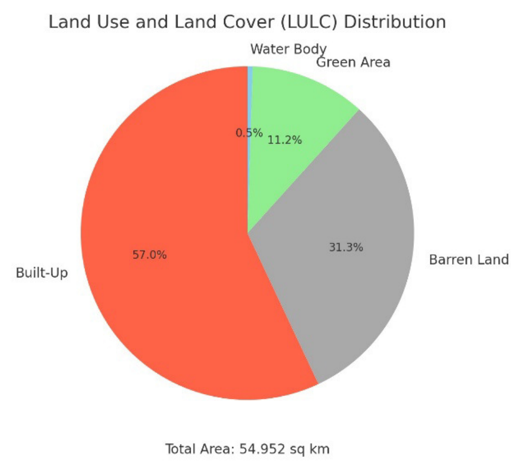
Water Bodies have the smallest share of the land cover at just 0.275 sq km or 0.5%. This low value highlights the scarcity of surface water resources in the region, a characteristic of semi-arid landscapes. The limited presence of water bodies also underscores the importance of efficient water management and conservation practices to meet the city's growing demands.

The spatial distribution of land cover types in Kalaburagi exhibits a clear urban core, with the highest concentration of built-up area located in the center of the map. This pattern aligns with typical urban morphology, where the city center tends to have the highest density of buildings and infrastructure. The peripheral areas show a more heterogeneous mix of land cover types, with barren land and green areas interspersed with built-up patches.

In the context of environmental challenges discussed in the background information, the 2004 LULC composition raises several concerns. The high proportion of built-up area and limited green cover may contribute to urban heat island effects and reduced groundwater recharge. The scarcity of water bodies coupled with the semi-arid climate underscores the vulnerability of the city to water scarcity and drought conditions.

Looking ahead, sustainable urban planning and environmental management will be crucial to address these challenges. Strategies may include increasing green cover through urban greening initiatives, promoting water conservation and efficient management, and adopting climate-responsive design principles in future development. Monitoring LULC changes over time will be essential to assess the effectiveness of these interventions and guide further policy decisions.

the 2004 LULC map of Kalaburagi MC reveals a predominantly built-up landscape with significant barren land, limited green cover, and scarce water resources. This composition reflects the city's semi-arid setting and rapid urbanization, while also highlighting the environmental challenges that need to be addressed for sustainable development. As the city continues to grow and evolve, integrating ecological considerations into urban planning will be key to creating a resilient and livable urban environment.



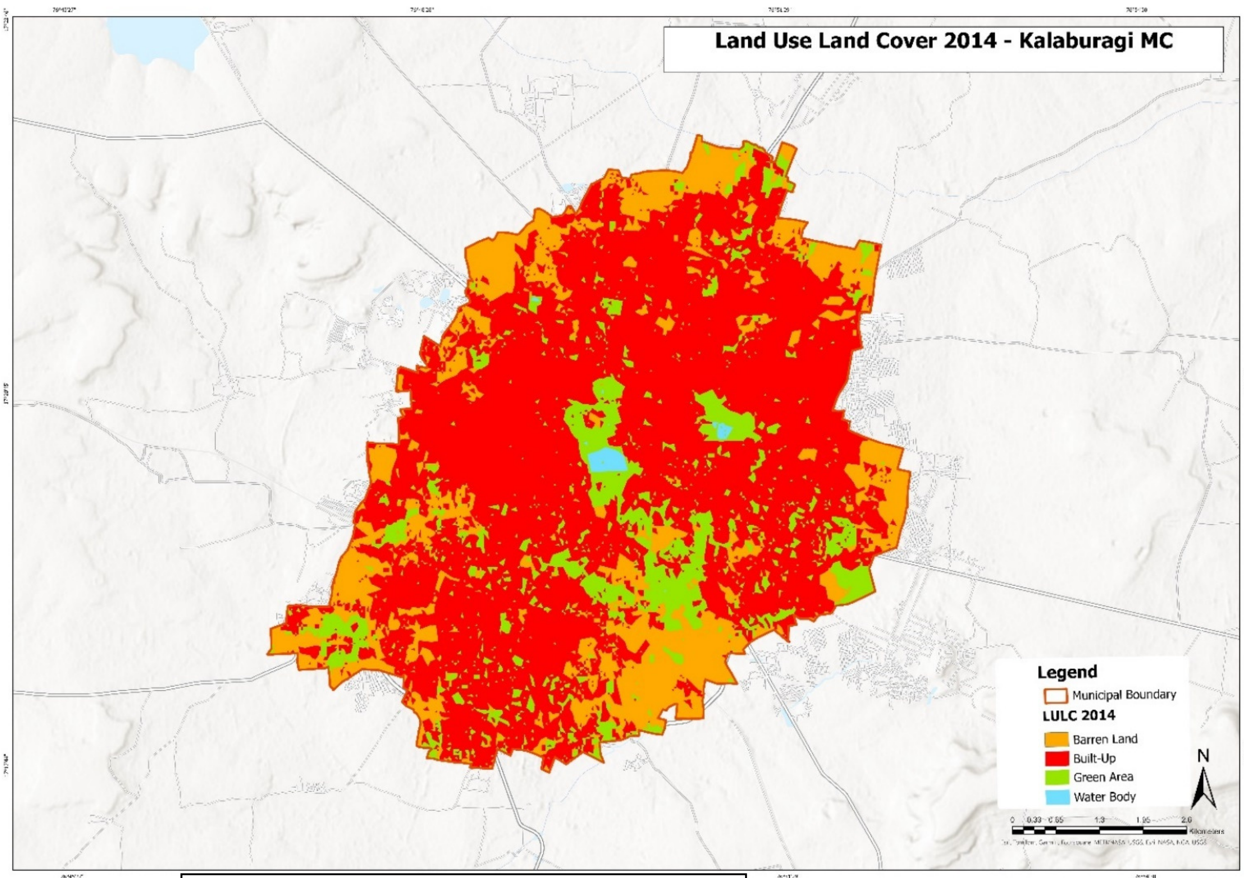


Fig 2: Land Use Land Cover 2014 – Kalaburagi MC

B. ***Land Use Land Cover 2014***

The 2014 LULC map of Kalaburagi MC offers valuable insights into the city's land cover composition and its changes over the past decade. The map covers the same total area of 162 sq km as the 2004 map and utilizes the same four land cover categories: Built-Up, Barren Land, Green Area, and Water Body.

Table 3. Land Use Land Cover Distribution, Kalaburagi MC 2014

LULC Class	Area (sq km)	Percentage
Built-Up	36.587	66.6%
Green Area	6.697	12.2%
Barren Land	11.444	20.8%
Water Body	0.221	0.4%
Total	54.949	100%

As shown in Table 3 and Figure 2, the Built-Up category has further increased its dominance, now occupying 36.587 sq km or 66.6% of the mapped area. This represents a significant 9.5 percentage point increase from 2004, highlighting the rapid pace of urbanization in Kalaburagi over the past decade. The expansion of built-up area can be attributed to population growth, economic development, and the consequent demand for housing, commercial spaces, and infrastructure.

The Barren Land category has seen a substantial decrease, now covering 11.444 sq km or 20.8% of the total area, down from 31.3% in 2004. This 10.5 percentage point reduction suggests that a considerable portion of the barren land has been converted to other land use types, primarily Built-Up area. This trend aligns with the background information discussing urban expansion encroaching upon open and agricultural lands.

Green Area has slightly increased in both absolute terms and as a percentage of the total area, now accounting for 6.697 sq km or 12.2%. This 1 percentage point increase from 2004 is a positive development, indicating efforts towards urban greening and preservation of vegetated spaces. However, the overall proportion of green cover remains relatively low, underscoring the need for continued efforts to enhance the city's green infrastructure.

Water Bodies continue to have the smallest share of the land cover, further decreasing to 0.221 sq km or 0.4%. This reduction, although small in absolute terms, represents a 20% decrease from the already limited water body area in 2004. This trend is concerning, as it may exacerbate water scarcity issues and negatively impact the local hydrological cycle, particularly in the context of Kalaburagi's semi-arid climate.

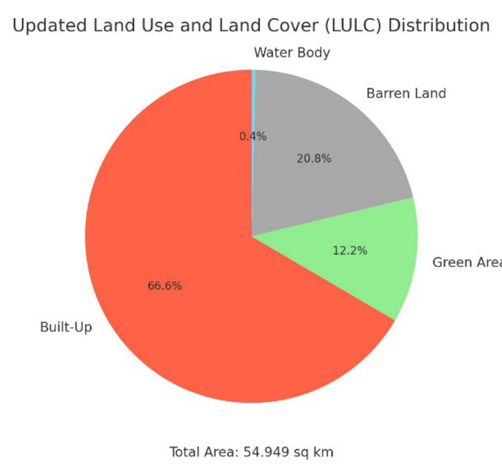
The spatial pattern of land cover change between 2004 and 2014 reveals an outward expansion of the built-up area from the urban core. The peripheral areas that previously featured a mix of barren land and green areas have seen increased built-up development, indicating a sprawling growth pattern. This expansion underscores the importance of strategic urban planning to ensure efficient land use and minimize the negative impacts of sprawl on the environment and infrastructure.

The evolving LULC composition has significant implications for Kalaburagi's environmental challenges. The increased built-up area and reduced barren land may further contribute to urban heat island effects, as discussed in the background information. The limited growth in green cover, coupled with the decrease in water bodies, highlights the need for concerted efforts to enhance the city's green and blue infrastructure to mitigate these effects and improve overall environmental resilience.

To address these challenges, urban planning strategies should prioritize compact development, mixed land use, and the integration of green spaces within the built environment. Policies promoting urban greening, such as green roofs, parks, and urban forests, can help counteract the heat island effect and improve the city's microclimate. Additionally, sustainable water management practices, including rainwater harvesting and wastewater recycling, can help alleviate water scarcity issues and reduce the pressure on groundwater resources.

Regular monitoring of LULC changes, as demonstrated by this study, is crucial for informed decision-making and adaptive management. Future LULC analyses should also consider the socio-economic drivers of land cover change, such as population dynamics, economic activities, and policy interventions, to develop a more comprehensive understanding of the urban landscape's evolution.

The 2014 LULC map of Kalaburagi MC reveals a rapidly urbanizing landscape characterized by expanding built-up area, declining barren land, limited green cover growth, and decreasing water bodies. These changes underscore the challenges of balancing urban growth with environmental sustainability in a semi-arid context. Sustainable urban planning, green infrastructure development, and integrated water management will be key to creating a resilient and livable city for Kalaburagi's future.



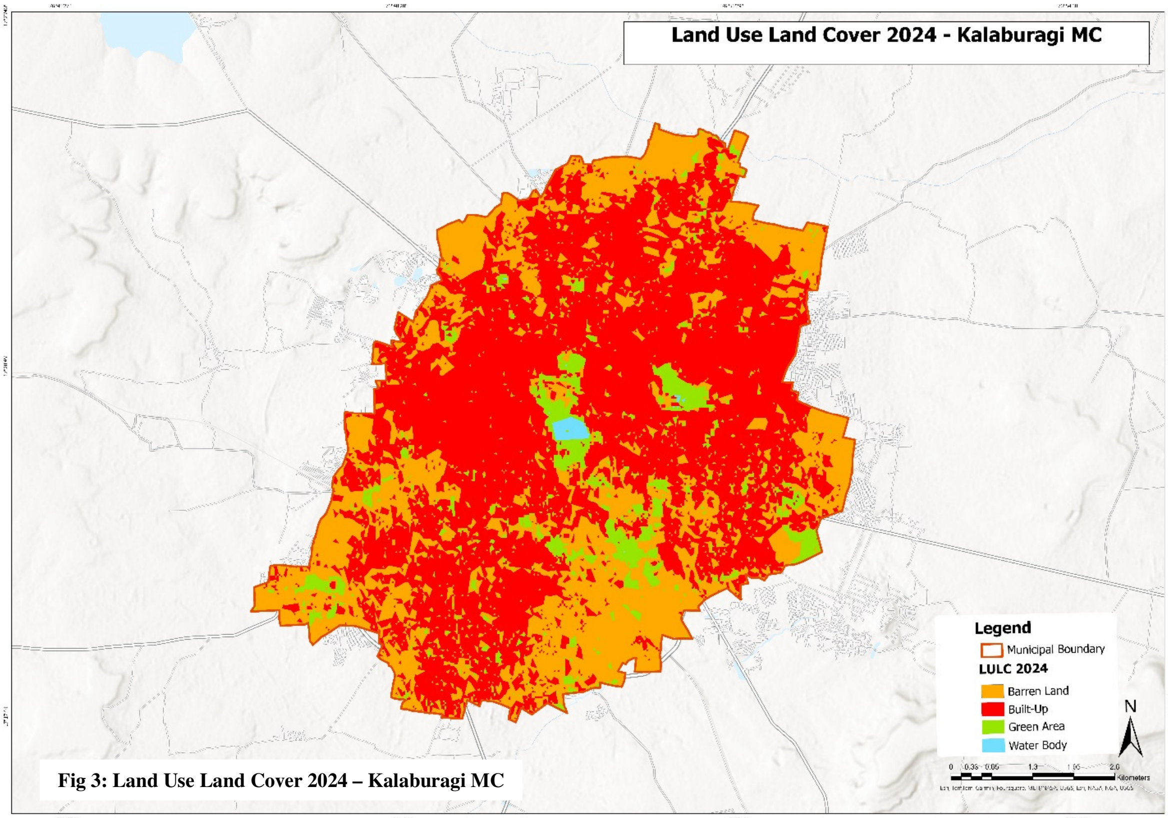


Fig 3: Land Use Land Cover 2024 – Kalaburagi MC

C. ***Land Use Land Cover 2024***

The 2024 LULC map of Kalaburagi MC provides a snapshot of the city's projected land cover composition at the end of the study period. By comparing this map with the 2004 and 2014 maps, we can identify significant trends and changes in the urban landscape over the 20-year timeframe.

Table 4. Land Use Land Cover Distribution, Kalaburagi MC 2024

LULC Class	Area (sq km)	Percent age
Built-Up	32.527	59.2%
Barren Land	18.901	34.4%
Green Area	3.337	6.1%
Water Body	0.175	0.3%
Total	54.940	100%

As evident from Table 4 and Figure 3, the Built-Up category remains the dominant land cover type, occupying 32.527 sq km or 59.2% of the mapped area. While this represents a slight decrease from

the 2014 percentage (66.6%), it still indicates a significant increase from the 2004 level (57.1%). This suggests that while the pace of urbanization may have slowed down compared to the previous decade, the overall trend of urban expansion persists.

the Barren Land category has seen a resurgence, now covering 18.901 sq km or 34.4% of the total area. This marks a significant increase from the 2014 level (20.8%), although still lower than the 2004 percentage (31.3%). This reversal in trend could be attributed to various factors, such as land use policy changes, economic shifts, or environmental factors like drought or land degradation, which may have led to the abandonment of some previously developed areas.

The Green Area has experienced a substantial decline, now accounting for only 3.337 sq km or 6.1% of the total area. This represents a significant decrease from both the 2004 (11.2%) and 2014 (12.2%) levels. The rapid loss of green cover is alarming, as it may exacerbate environmental issues like urban heat islands, air pollution, and biodiversity loss. This trend underscores the urgent need for green infrastructure planning and conservation efforts to mitigate the negative impacts of urbanization.

Water Bodies continue to have the smallest share of the land cover, further decreasing to 0.175 sq km or 0.3%. This reduction, although small in absolute terms, represents a 20.8% decrease from the already limited water body area in 2014. The persistent decline in water bodies over the 20-year period highlights the growing water scarcity issues in Kalaburagi, which may be further compounded by climate change and increasing water demand from the growing population.

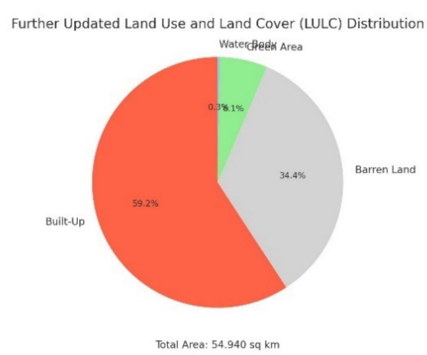
The spatial pattern of land cover change in 2024 reveals a more fragmented urban landscape compared to the previous years. While the urban core remains densely built-up, the peripheral areas show a more complex mosaic of built-up, barren, and green patches. This fragmentation may indicate a more sprawling and less compact urban growth pattern, which can have negative implications for infrastructure efficiency, transportation, and environmental sustainability.

The projected LULC composition for 2024 raises several concerns in light of Kalaburagi's environmental challenges. The continued dominance of built-up area, coupled with the significant loss of green cover, may intensify the urban heat island effect, leading to higher temperatures and increased energy consumption for cooling. The decline in water bodies and the increase in barren land may further strain the city's water resources and increase its vulnerability to droughts and floods.

To address these challenges, Kalaburagi will need to adopt a more sustainable and resilient approach to urban planning and environmental management. This may involve strategies such as:

- Compact urban development: Encouraging higher density, mixed-use development to minimize urban sprawl and reduce the environmental footprint of the city.
- Green infrastructure planning: Integrating green spaces, urban forests, and green roofs into the built environment to mitigate urban heat islands, improve air quality, and enhance biodiversity.
- Water-sensitive urban design: Implementing sustainable water management practices, such as rainwater harvesting, permeable pavements, and constructed wetlands, to reduce water stress and improve the city's hydrological resilience.
- Ecosystem restoration: Identifying and restoring degraded ecosystems, such as wetlands and forests, to enhance the city's ecological health and provide essential ecosystem services.
- Participatory planning: Engaging local communities, stakeholders, and experts in the planning process to ensure that urban development aligns with the needs and aspirations of the people while promoting environmental sustainability.

The projected 2024 LULC map of Kalaburagi MC presents a challenging scenario characterized by continued urban expansion, loss of green cover, and declining water resources. To create a more sustainable and livable future for Kalaburagi, the city must urgently prioritize environmental considerations in its urban planning and development strategies. By adopting a holistic, integrated approach that balances economic growth, social well-being, and ecological health, Kalaburagi can work towards becoming a resilient and thriving city in the face of mounting environmental challenges.



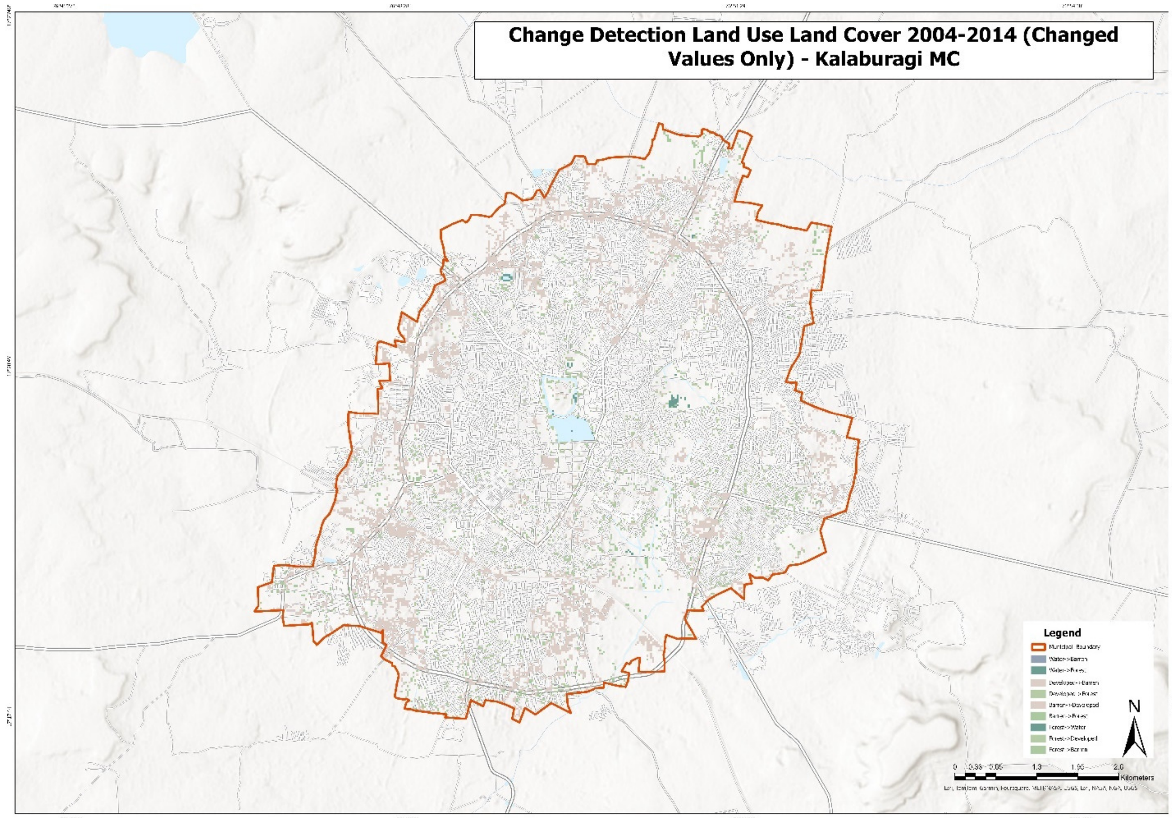


Fig 4: Change Detection Land Use Land Cover 2004 – 2014(Changed Values Only) - Kalaburagi MC

D. *Change Detection Land Use Land Cover 2004 – 2014(Changed Values Only)*

The Change Detection Land Use Land Cover map of Kalaburagi MC for the period 2004-2014 provides crucial insights into the urban landscape's transformation over a decade. By quantifying and visualizing the changes in various land cover categories, this analysis aims to understand the patterns, drivers, and implications of LULC dynamics in the context of Kalaburagi's rapid urbanization and environmental challenges.

The change detection analysis was performed using high-resolution satellite imagery from the Landsat series for the years 2004 and 2014. The images were classified into distinct land cover categories using supervised classification techniques, and the resulting maps were compared to identify areas of change (Lu et al., 2007). The change categories include Built-up Gain, Barren to Built-up, Barren to Forest, Forest to Barren, and Forest to Built-up.

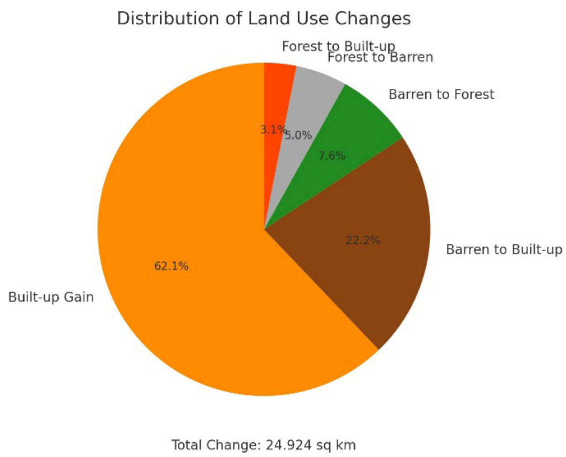
Table 5. Change Detection Land Use Land Cover Statistics, Kalaburagi MC 2004-2014

Change Category	Area (sq km)	Percentage
Built-up Gain	15.485	62.1%
Barren to Built-up	5.526	22.2%
Barren to Forest	1.890	7.6%
Forest to Barren	1.243	5.0%
Forest to Built-up	0.780	3.1%
Total Change	24.924	100%

The most prominent change category is Built-up Gain, accounting for 15.485 sq km or 62.1% of the total change area. This significant increase in built-up area aligns with the rapid urbanization trend discussed in the background information, driven by population growth, economic development, and the expansion of residential, commercial, and industrial spaces (Ramesh & Venkataraman, 2019).

The second largest category, Barren to Built-up, covers 5.526 sq km or 22.2% of the change area. This transition from barren land to built-up area

indicates the encroachment of urban development onto previously undeveloped or abandoned lands, a pattern consistent with the sprawling growth of Indian cities (Joshi et al., 2016).
Interestingly, the map also reveals some areas of Barren to Forest conversion (1.890 sq km or 7.6%), suggesting efforts towards afforestation or natural regeneration of vegetation in certain parts of the city. However, this gain is offset by the Forest to Barren (1.243 sq km or 5.0%) and Forest to Built-up (0.780 sq km or 3.1%) categories, which indicate a net loss of forest cover during the study period.



The spatial distribution of change categories reveals a complex mosaic of LULC transitions across the city. The Built-up Gain and Barren to Built-up changes are concentrated in the peripheral areas, particularly in the northern and southern parts of the city, indicating a pattern of urban expansion and infill development (Seto et al., 2011). The Forest to Barren and Forest to Built-up changes are more scattered, suggesting localized deforestation due to various factors such as infrastructure projects, agricultural expansion, or resource extraction (Lambin et al., 2001).

The observed LULC changes have significant implications for Kalaburagi's environmental sustainability and urban resilience. The rapid increase in built-up area and the loss of green cover can exacerbate the urban heat island effect, increase air and water pollution, and strain the city's natural resources (Gupta et al., 2018). The conversion of barren land to built-up area may also increase the risk of flooding and soil erosion, as these lands often serve as natural drainage systems and buffers against extreme weather events (Kumar & Rajagopal, 2017).

To mitigate these negative impacts and promote sustainable urban development, Kalaburagi needs to adopt an integrated approach to land use planning and environmental management. This may involve strategies such as compact urban growth, green infrastructure development, ecosystem restoration, and participatory decision-making processes (Jenerette & Potere, 2010). Regular monitoring of LULC changes using remote sensing techniques, as demonstrated in this study, can provide valuable insights to inform these strategies and assess their effectiveness over time.

The analysis of LULC changes in Kalaburagi MC between 2004 and 2014 reveals a rapidly urbanizing landscape characterized by significant built-up area expansion, conversion of barren land to urban uses, and a net loss of forest cover. These changes reflect the city's growth dynamics and the challenges it faces in balancing urban development with environmental sustainability. To create a more resilient and livable future, Kalaburagi must prioritize integrated land use planning, green infrastructure development, and ecosystem conservation. This study underscores the importance of regular LULC monitoring and the potential of remote sensing techniques to inform sustainable urban planning and policy decisions.

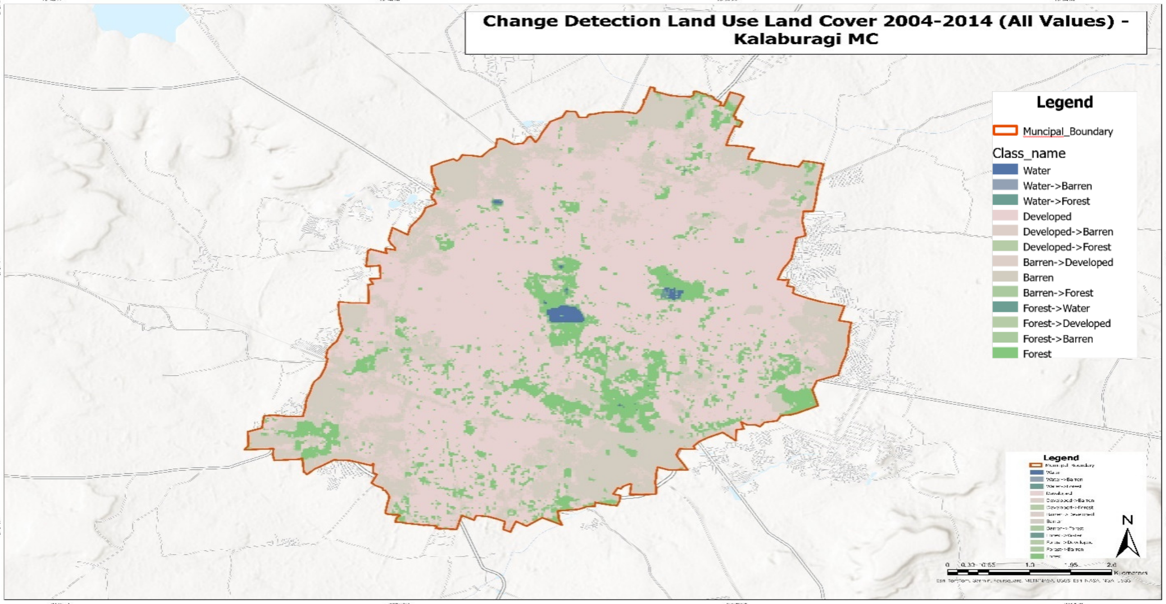


Fig 5: Change Detection Land Use Land Cover 2004 – 2014(All Values Only) - Kalaburagi MC

E. ***Change Detection Land Use Land Cover 2004 – 2014(All Values Only)***

The Change Detection Land Use Land Cover map of Kalaburagi MC for the period 2004-2014 offers a comprehensive view of the city's urban landscape transformation. By quantifying and visualizing the changes across various land cover categories, this analysis aims to uncover the complex dynamics, drivers, and consequences of LULC changes in the context of Kalaburagi's rapid urbanization and associated environmental challenges (Lambin et al., 2001).

The change detection analysis was carried out using high-resolution satellite imagery from the Landsat series for the years 2004 and 2014. The images were subjected to supervised classification techniques to categorize them into distinct land cover classes. The resulting maps were then compared to identify areas of change, which were further classified into specific change categories such as Built-up to Water, Barren to Water, Forest to Water, and so on (Prakasam, 2010).

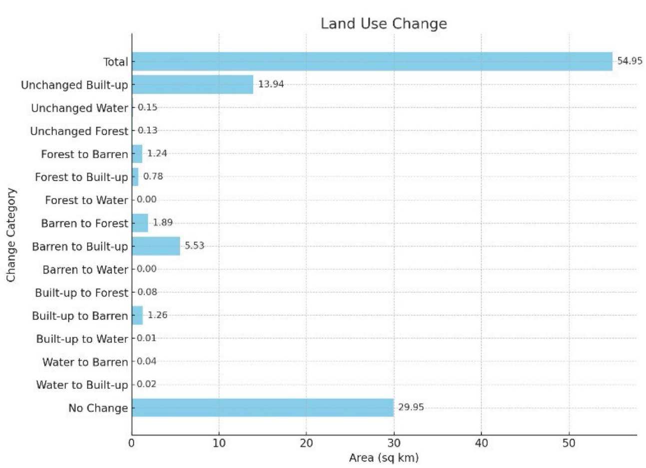
Table 6. Change Detection Land Use Land Cover Statistics, Kalaburagi MC 2004-2014

Change Category	Area (sq km)	Percent age
No Change	29.945	54.5%
Water to Built-up	0.016	0.0%
Water to Barren	0.038	0.1%
Built-up to Water	0.008	0.0%
Built-up to Barren	1.264	2.3%
Built-up to Forest	0.079	0.1%
Barren to Water	0.004	0.0%
Barren to Built-up	5.526	10.1%
Barren to Forest	1.890	3.4%
Forest to Water	0.002	0.0%
Forest to Built-up	0.780	1.4%
Forest to Barren	1.243	2.3%
Unchanged Forest	0.132	0.2%
Unchanged Water	0.148	0.3%
Unchanged Built-up	13.941	25.4%
Total	54.950	100%

The most striking observation from the table is that more than half of the study area (54.5%) remained unchanged during the 10-year period. Among the changed areas, the Barren to Built-up category stands out, accounting for 5.526 sq km or 10.1% of the total area. This transition reflects the rapid urbanization process, where previously undeveloped or abandoned lands are converted into residential, commercial, or industrial spaces to accommodate the growing population and economic activities (Seto et al., 2012).

Another notable change category is Built-up to Barren, covering 1.264 sq km or 2.3% of the area. This reverse transition could be attributed to factors such as land use policy changes, economic shifts, or the abandonment of built-up areas due to various reasons (Li et al., 2018). The Barren to Forest category, occupying 1.890 sq km or 3.4%, indicates some level of afforestation or natural regeneration of vegetation in certain parts of the city.

However, the Forest to Barren (1.243 sq km or 2.3%) and Forest to Built-up (0.780 sq km or 1.4%) categories suggest a simultaneous loss of forest cover, possibly due to deforestation for urban expansion or resource extraction (Gumma et al., 2019). The relatively small changes involving water bodies, such as Water to Built-up, Water to Barren, Built-up to Water, and Barren to Water, highlight the dynamic nature of the urban water landscape, which may be influenced by factors like land reclamation, wetland degradation, or water conservation efforts (Kumar et al., 2020).



The spatial distribution of change categories reveals a complex mosaic of LULC transitions across the city. The Barren to Built-up changes are primarily concentrated in the peripheral areas, indicating a pattern of urban sprawl and expansion into the city's outskirts (Jenerette & Potere, 2010). The Built-up to Barren changes are more dispersed, suggesting localized instances of urban decay or redevelopment. The Forest to Barren and Forest to Built-up changes are scattered throughout the city, indicating fragmented deforestation patterns (Ramachandra et al., 2016).

The observed LULC changes have profound implications for Kalaburagi's environmental sustainability and urban resilience. The expansion of built-up areas at the expense of barren lands and forests can lead to increased urban heat island effects, air and water pollution, and biodiversity loss (Gupta et al., 2018). The conversion of barren lands and forests may also alter the local hydrological cycle, increasing the risk of floods, droughts, and soil erosion (Kumar & Rajagopal, 2017).

To address these challenges and promote sustainable urban development, Kalaburagi needs to adopt an integrated approach to land use planning and environmental management. This may involve strategies such as compact urban growth, green infrastructure development, ecosystem restoration, and participatory decision-making processes (Joshi et al., 2016). Regular monitoring of LULC changes using remote sensing techniques, as demonstrated in this study, can provide valuable insights to inform these strategies and assess their effectiveness over time.

The analysis of LULC changes in Kalaburagi MC between 2004 and 2014 reveals a complex urban landscape characterized by significant built-up area expansion, conversion of barren lands and forests, and localized changes in water bodies. These changes reflect the city's growth dynamics and the challenges it faces in balancing urban development with environmental sustainability. To create a more resilient and livable future, Kalaburagi must prioritize integrated land use planning, green infrastructure development, and ecosystem conservation. This study underscores the importance of regular LULC monitoring and the potential of remote sensing techniques to inform sustainable urban planning and policy decisions.

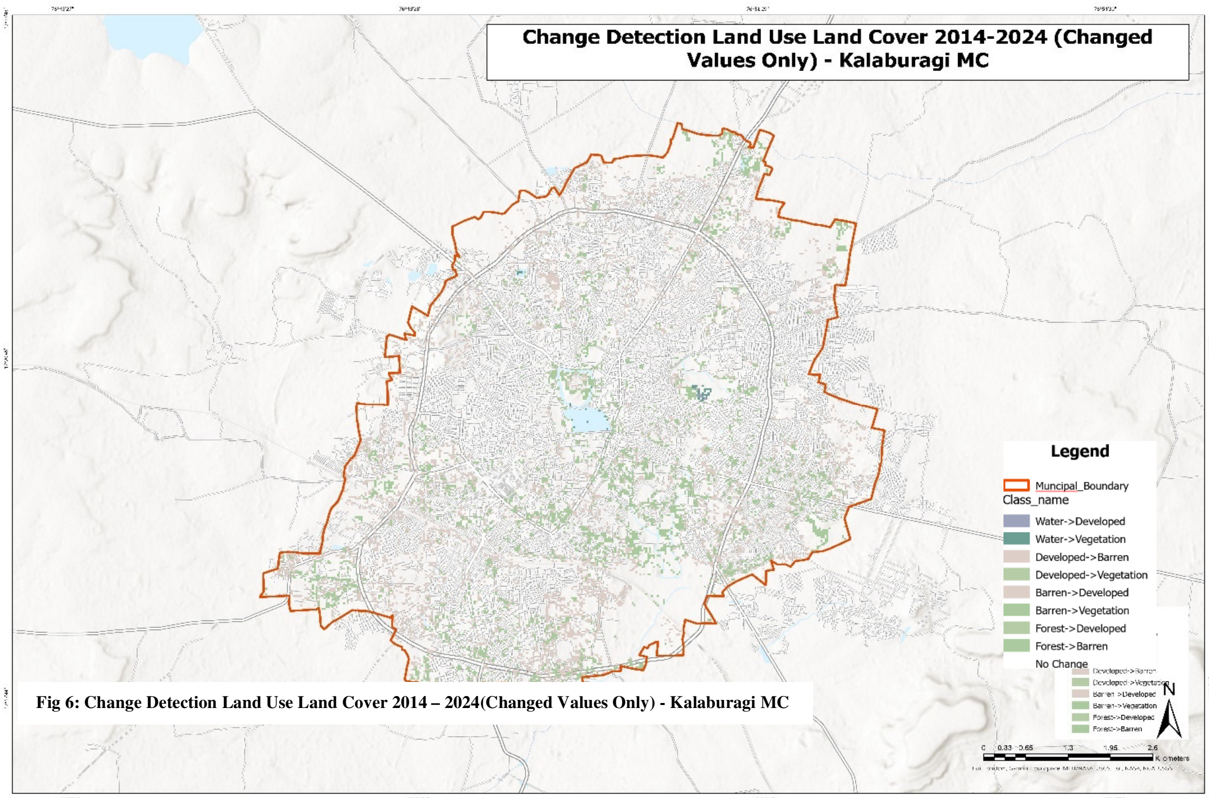


Fig 6: Change Detection Land Use Land Cover 2014 – 2024(Changed Values Only) - Kalaburagi MC

F. ***Change Detection Land Use Land Cover 2014 – 2024(Changed Values Only)***

Kalaburagi, a rapidly urbanizing city in Karnataka, India, has witnessed significant land use and land cover (LULC) changes over the past two decades. Monitoring and analyzing these changes is crucial for understanding the city's urban growth patterns, environmental challenges, and sustainable development strategies (Lambin et al., 2003). This report presents a detailed examination of the Change Detection Land Use Land Cover map of Kalaburagi MC for the periods 2004-2014 and 2014-2024, focusing on the key transitions, their drivers, and implications for urban planning and environmental management.

The Change Detection Land Use Land Cover map was generated using high-resolution satellite imagery and advanced remote sensing techniques (Gumma et al., 2019). The map categorizes the LULC changes into 12 classes, including built-up area, water bodies, barren land,forest and their respective transitions. The analysis involves quantifying the area and percentage of each change category, examining their spatial distribution, and interpreting the results in the context of Kalaburagi's urban and environmental dynamics (Ramachandra et al., 2016).

Table 7. Change Detection Land Use Land Cover Statistics, Kalaburagi MC (2004-2024)

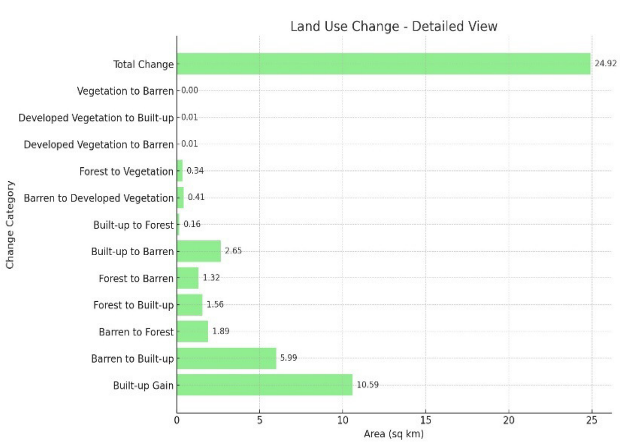
Change Category	Area (sq km)	Percent age

Built-up Gain	10.585	42.5%
Barren to Built-up	5.985	24.0%
Barren to Forest	1.890	7.6%
Forest to Built-up	1.560	6.3%
Forest to Barren	1.320	5.3%
Built-up to Barren	2.645	10.6%
Built-up to Forest	0.158	0.6%
Barren to Developed Vegetation	0.414	1.7%
Forest to Vegetation	0.345	1.4%
Developed Vegetation to Barren	0.013	0.1%
Developed Vegetation to Built-up	0.005	0.0%
Vegetation to Barren	0.004	0.0%
Total Change	24.924	100%

The data reveals that the most significant LULC transition was Built-up Gain, accounting for 42.5% of the total change area. This indicates the rapid urbanization process, where new built-up areas have emerged to accommodate the growing population and economic activities (Seto et al., 2012). The Barren to Built-up transition (24.0%) further highlights the conversion of undeveloped lands into urban spaces.

The city also experienced some greening, with Barren to Forest (7.6%) and Barren to Developed Vegetation (1.7%) transitions. However, these gains were offset by the Forest to Built-up (6.3%), Forest to Barren (5.3%), and Built-up to Barren (10.6%) transitions, suggesting a net loss of green cover and instances of urban decay or redevelopment (Li et al., 2018).

The spatial distribution of change categories reveals a complex mosaic of LULC transitions across the city. The Built-up Gain and Barren to Built-up changes are primarily concentrated in the peripheral areas, indicating urban sprawl (Jenerette & Potere, 2010). The Forest to Built-up and Forest to Barren changes are scattered, suggesting



fragmented deforestation patterns (Ramachandra et al., 2016).

Implications for Urban Planning and Environmental Management The observed LULC changes have significant implications for Kalaburagi's urban planning and environmental management:

- Sustainable Urban Growth: The rapid urban expansion necessitates the adoption of sustainable urban growth strategies that promote compact development, mixed land use, and efficient resource utilization (Joshi et al., 2016).
- Green Infrastructure: The loss of green cover and the limited greening efforts underscore the need for integrating green infrastructure, such as urban forests, parks, and green roofs, into the city's planning framework to mitigate the adverse environmental impacts of urbanization (Kumar & Rajagopal, 2017).
- Urban Resilience: The instances of urban decay and redevelopment, as indicated by the Built-up to Barren transition, call for urban regeneration strategies that focus on enhancing the city's resilience to socio-economic and environmental shocks (Gupta et al., 2018).
- Participatory Governance: The complex nature of LULC changes necessitates a participatory approach to urban governance, involving stakeholders from various sectors to develop inclusive and sustainable urban policies (Nagendra et al., 2018).

The Change Detection Land Use Land Cover analysis of Kalaburagi MC (2004-2024) reveals significant urban growth dynamics, characterized by rapid urbanization, urban sprawl, and changes in green cover. These transformations have critical implications for the city's environmental sustainability, urban resilience, and quality of life. Addressing these challenges requires an integrated approach to urban planning and environmental management, supported by regular monitoring of LULC changes using advanced geospatial technologies (Gumma et al., 2019).

G. ***Change Detection Land Use Land Cover 2014 – 2024 (All Values)***

Kalaburagi, a rapidly urbanizing city in Karnataka, India, has experienced significant land use and land cover (LULC) changes over the past decade. Analyzing these changes is crucial for understanding the city's urban growth dynamics, environmental challenges, and sustainable development strategies (Lambin et al., 2001). This report presents a detailed examination of the Change Detection Land Use Land Cover map of Kalaburagi Municipal Corporation (MC) for the period 2014-2024, focusing on the key transitions, their drivers, and implications for urban planning and environmental management.

The Change Detection Land Use Land Cover map was derived from high-resolution satellite imagery using remote sensing and GIS techniques (Lu et al., 2004). The map categorizes the LULC

changes into 16 classes, including built-up area, water bodies, barren land, forest, and their respective transitions. The analysis involves quantifying the area and percentage of each change category, examining their spatial distribution, and interpreting the results in the context of Kalaburagi's urban and environmental dynamics.

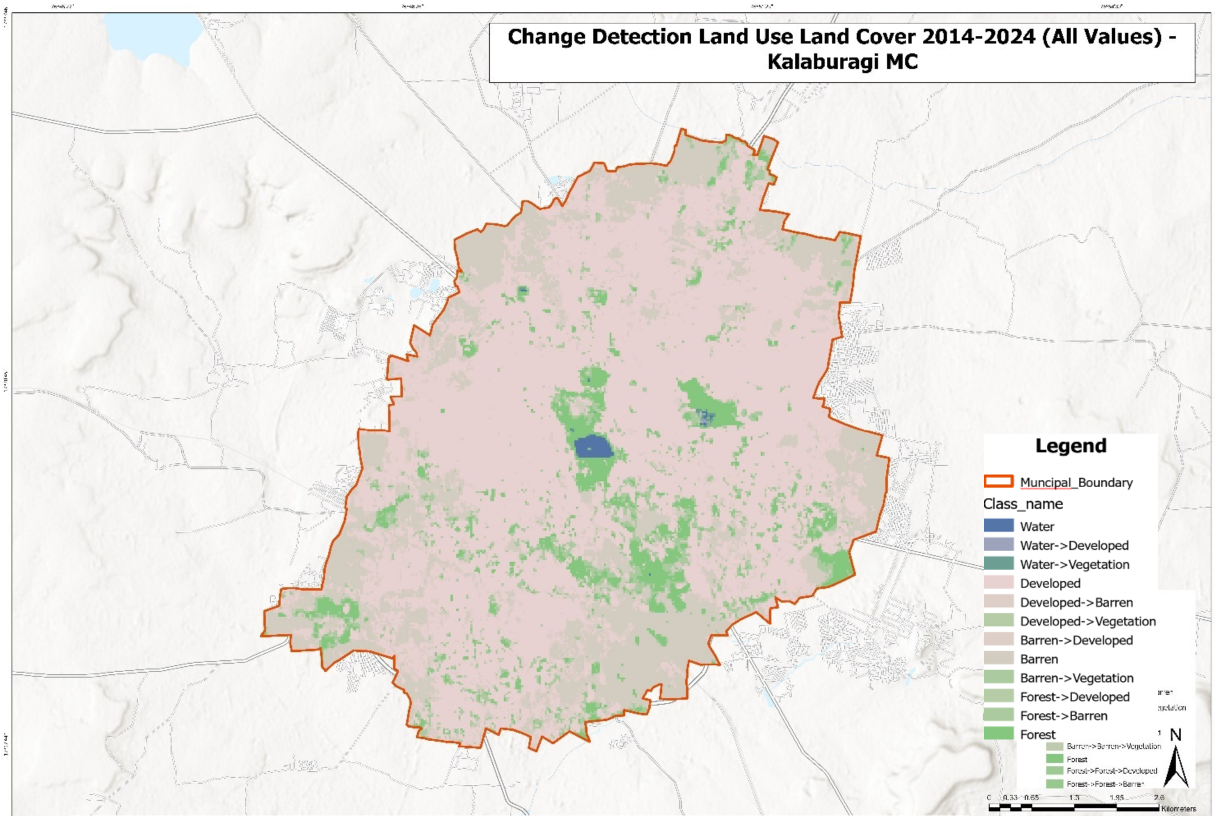


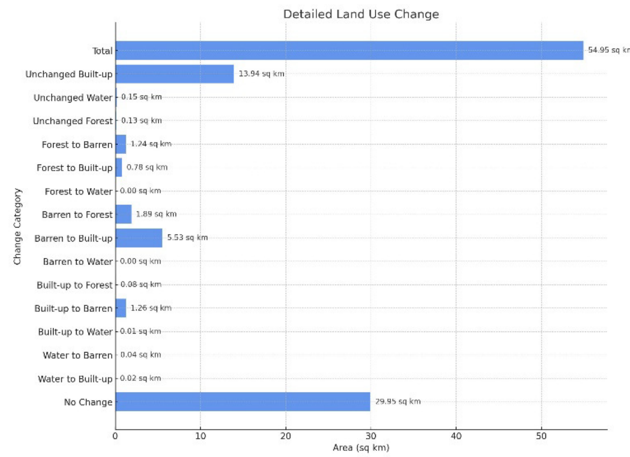
Fig 7: Change Detection Land Use Land Cover 2014 – 2024(All Values) - Kalaburagi MC

Table 8. Change Detection Land Use Land Cover Statistics, Kalaburagi MC 2014-2024

The data reveals that more than half (54.5%) of the study area remained unchanged during the 10-year period. Among the changed areas, the most significant transition was from Barren to Built-up, accounting for 10.1% of the total area. This indicates the rapid urbanization process, where previously undeveloped lands are converted into urban spaces (Seto et al., 2012). The Built-up to Barren transition (2.3%) suggests some instances of urban decay or redevelopment (Li et al., 2018).

Change Category	Area (sq km)	Percent age
No Change	29.945	54.5%
Water to Built-up	0.016	0.0%
Water to Barren	0.038	0.1%
Built-up to Water	0.008	0.0%
Built-up to Barren	1.264	2.3%
Built-up to Forest	0.079	0.1%
Barren to Water	0.004	0.0%
Barren to Built-up	5.526	10.1%
Barren to Forest	1.890	3.4%
Forest to Water	0.002	0.0%
Forest to Built-up	0.780	1.4%
Forest to Barren	1.243	2.3%
Unchanged Forest	0.132	0.2%
Unchanged Water	0.148	0.3%
Unchanged Built-up	13.941	25.4%
Total	54.950	100%

The Barren to Forest (3.4%) and Forest to Barren (2.3%) categories highlight the dynamic nature of the city's green cover, with some areas experiencing afforestation while others face deforestation. The Forest to Built-up transition (1.4%) indicates the encroachment of urban development into forested areas (Ramachandra et al., 2016).



The spatial distribution of change categories reveals a complex mosaic of LULC transitions across the city. The Barren to Built-up changes are primarily concentrated in the peripheral areas, indicating urban sprawl (Jenerette & Potere, 2010). The Built-up to Barren changes are more dispersed, suggesting localized urban decay or redevelopment. The Forest to Barren and Forest to Built-up changes are scattered, indicating fragmented deforestation patterns.

Implications for Urban Planning and Environmental Management The observed LULC changes have significant implications for Kalaburagi's urban planning and environmental management:

- Urban Expansion and Sprawl: The rapid conversion of barren lands to built-up areas, particularly in the city's outskirts, highlights the need for sustainable urban growth strategies that promote compact development and efficient land use (Joshi et al., 2016).
- Environmental Challenges: The loss of green cover and the increase in built-up areas can exacerbate urban heat island effects, air and water pollution, and biodiversity loss (Gupta et al., 2018). Integrating green infrastructure and ecosystem restoration into urban planning is crucial for mitigating these challenges.
- Water Resource Management: The minimal changes in water bodies underscore the importance of sustainable water management practices, considering

Kalaburagi's semi-arid climate and increasing water demand (Kumar & Rajagopal, 2017).

- Participatory Planning: The complex nature of LULC changes necessitates a participatory approach to urban planning, involving stakeholders from various sectors to develop inclusive and resilient strategies (Ramachandra et al., 2016).

The Change Detection Land Use Land Cover analysis of Kalaburagi MC (2014-2024) reveals significant urban growth dynamics, characterized by rapid urbanization, urban sprawl, and changes in green cover. These transformations have critical implications for the city's environmental sustainability and urban resilience. Addressing these challenges requires an integrated approach to land use planning and environmental management, supported by regular monitoring of LULC changes using remote sensing techniques.

Analyzing these changes is crucial for understanding the city's urban growth patterns and their implications for environmental sustainability and urban resilience (Lambin et al., 2003). This report presents a comprehensive examination of the changed values in the Change Detection Land Use Land Cover map of Kalaburagi MC for the period 2004-2024.

The Change Detection Land Use Land Cover map was derived from high-resolution satellite imagery using advanced remote sensing techniques (Gumma et al., 2019). The map categorizes the LULC changes into 12 classes, focusing on the transitions between built-up areas, barren land, forest, and developed vegetation. The analysis involves quantifying the area and percentage of each change category, examining their spatial distribution, and interpreting the results in the context of Kalaburagi's urban dynamics (Ramachandra et al., 2016).

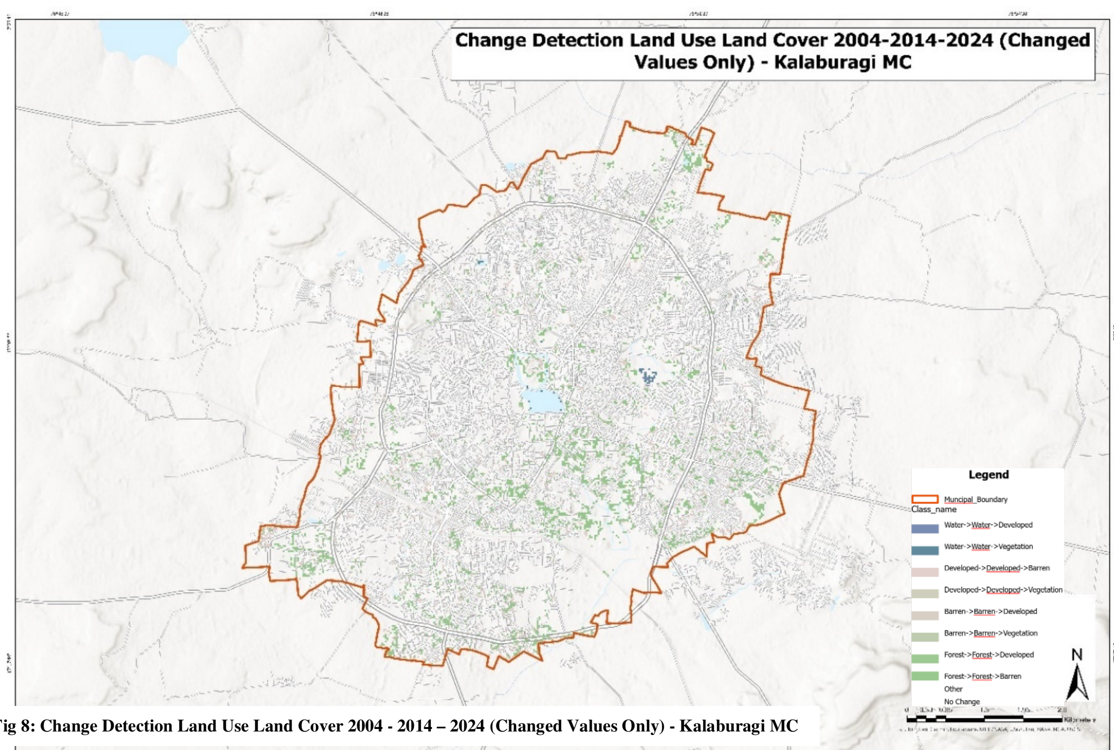


Fig 8: Change Detection Land Use Land Cover 2004 - 2014 – 2024 (Changed Values Only) - Kalaburagi MC

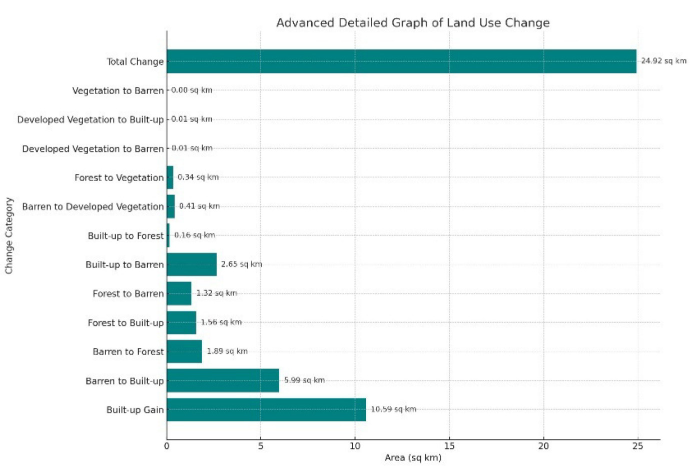
H. ***Change Detection Land Use Land Cover 2004-2014-2024 (Changed Values Only)***

I. Rapid urbanization in Kalaburagi, Karnataka, has led to significant changes in land use and land cover (LULC) over the past two decades.

Table 9. Change Detection Land Use Land Cover Statistics (Changed Values Only), Kalaburagi MC (2004-2024)

Change Category	Area (sq km)	Percent age
Built-up Gain	10.585	42.5%
Barren to Built-up	5.985	24.0%
Barren to Forest	1.890	7.6%
Forest to Built-up	1.560	6.3%
Forest to Barren	1.320	5.3%
Built-up to Barren	2.645	10.6%
Built-up to Forest	0.158	0.6%
Barren to Developed Vegetation	0.414	1.7%
Forest to Vegetation	0.345	1.4%
Developed Vegetation to Barren	0.013	0.1%
Developed Vegetation to Built-up	0.005	0.0%
Vegetation to Barren	0.004	0.0%
Total Change	24.924	100%

The data reveals that the most significant LULC transition was Built-up Gain, accounting for 42.5% of the total changed area. This indicates the rapid urbanization process, where new built-up areas have emerged to accommodate the growing population and economic activities (Seto et al., 2012). The Barren to Built-up transition (24.0%) further highlights the conversion of undeveloped lands into urban spaces.



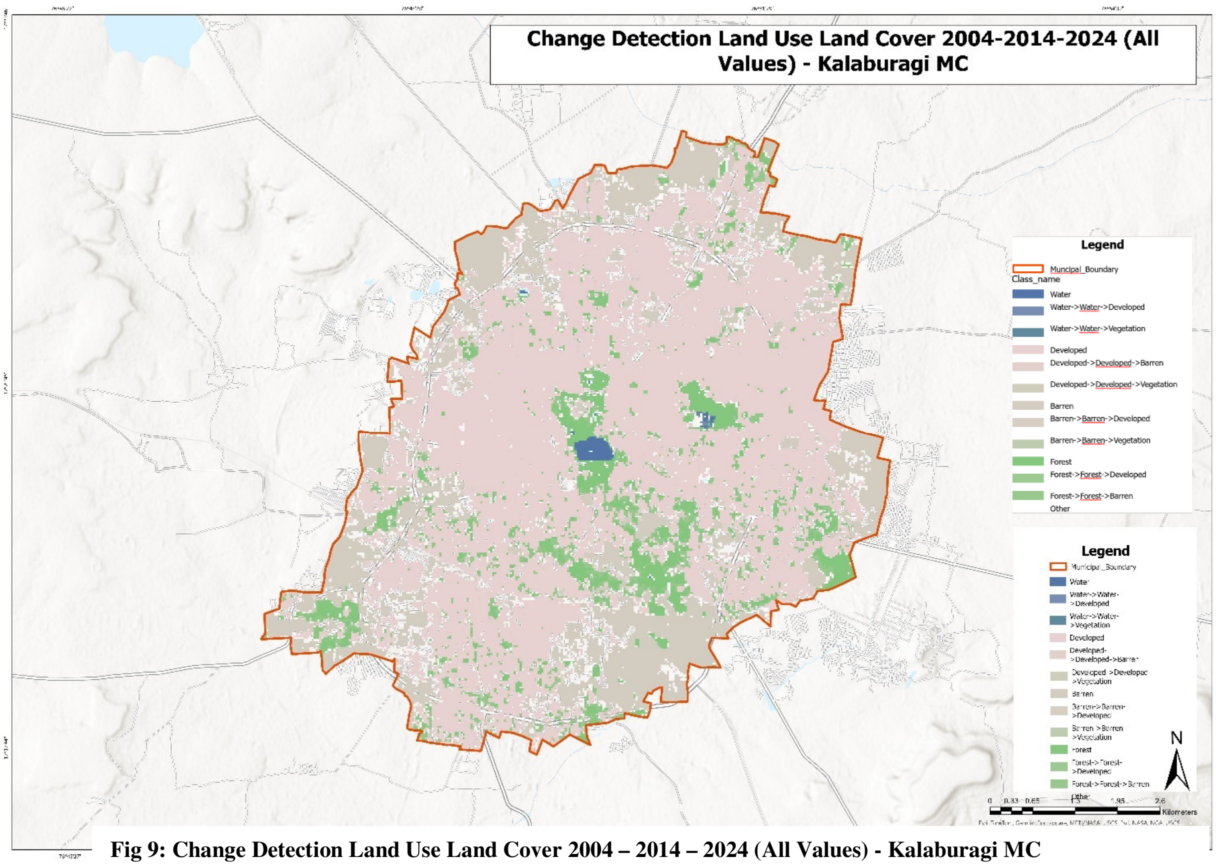
The city also experienced some greening, with Barren to Forest (7.6%) and Barren to Developed Vegetation (1.7%) transitions. However, these gains were offset by the Forest to Built-up (6.3%), Forest to Barren (5.3%), and Built-up to Barren (10.6%) transitions, suggesting a net loss of green cover and instances of urban decay or redevelopment (Li et al., 2018).

The spatial distribution of change categories reveals a complex mosaic of LULC transitions across the city. The Built-up Gain and Barren to Built-up changes are primarily concentrated in the peripheral areas, indicating urban sprawl (Jenerette & Potere, 2010). The Forest to Built-up and Forest to Barren changes are scattered, suggesting fragmented deforestation patterns (Ramachandra et al., 2016).

Implications for Urban Planning and Environmental Management The observed LULC changes have significant implications for Kalaburagi's urban planning and environmental management:

- Sustainable Urban Growth: The rapid urban expansion necessitates the adoption of sustainable urban growth strategies that promote compact development, mixed land use, and efficient resource utilization (Joshi et al., 2016).
- Green Infrastructure: The loss of green cover and the limited greening efforts underscore the need for integrating green infrastructure, such as urban forests, parks, and green roofs, into the city's planning framework to mitigate the adverse environmental impacts of urbanization (Kumar & Rajagopal, 2017).
- Urban Resilience: The instances of urban decay and redevelopment, as indicated by the Built-up to Barren transition, call for urban regeneration strategies that focus on enhancing the city's resilience to socio-economic and environmental shocks (Gupta et al., 2018).
- Participatory Governance: The complex nature of LULC changes necessitates a participatory approach to urban governance, involving stakeholders from various sectors to develop inclusive and sustainable urban policies (Nagendra et al., 2018).

The Change Detection Land Use Land Cover analysis of Kalaburagi MC (2004-2024), focusing on the changed values, reveals significant urban growth dynamics, characterized by rapid urbanization, urban sprawl, and changes in green cover. These transformations have critical implications for the city's environmental sustainability, urban resilience, and quality of life. Addressing these challenges requires an integrated approach to urban planning and environmental management, supported by regular monitoring of LULC changes using advanced geospatial technologies (Gumma et al., 2019).



I.

Fig 9: Change Detection Land Use Land Cover 2004 – 2014 – 2024 (All Values) - Kalaburagi MC

Change Detection Land Use Land Cover 2004-2014-2024 (All Values)

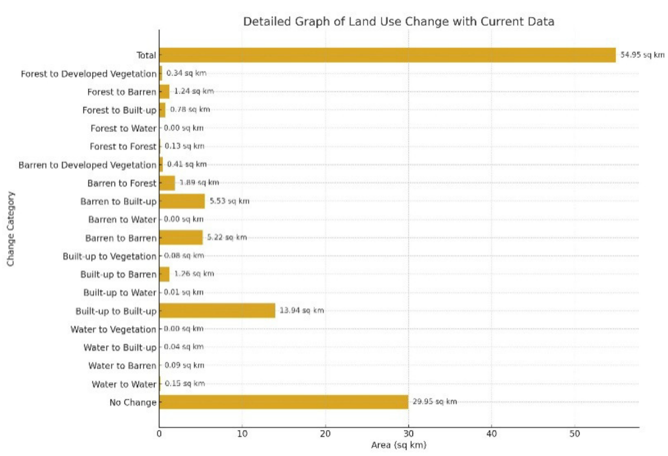
Kalaburagi, a rapidly urbanizing city in Karnataka, India, has undergone significant land use and land cover (LULC) changes over the past two decades. Analyzing these changes is crucial for understanding the city's urban growth patterns, environmental challenges, and sustainable development strategies (Lambin et al., 2003). This report presents an in-depth examination of the Change Detection Land Use Land Cover map of Kalaburagi MC for the period 2004-2024, considering all values and their implications for urban planning and environmental management.

The Change Detection Land Use Land Cover map was generated using high-resolution satellite imagery and advanced remote sensing techniques (Gumma et al., 2019). The map categorizes the LULC changes into 18 classes, including various transitions between built-up areas, water bodies, barren land, forest, vegetation, and developed land. The analysis involves quantifying the area and percentage of each change category, examining their spatial distribution, and interpreting the results in the context of Kalaburagi's urban and environmental dynamics (Ramachandra et al., 2016).

Table 10. Change Detection Land Use Land Cover Statistics (All Values), Kalaburagi MC (2004-2024)

Change Category	Area (sq km)	Percent age
No Change	29.945	54.5%
Water to Water	0.148	0.3%
Water to Barren	0.090	0.2%
Water to Built-up	0.037	0.1%
Water to Vegetation	0.003	0.0%
Built-up to Built-up	13.941	25.4%
Built-up to Water	0.008	0.0%
Built-up to Barren	1.264	2.3%
Built-up to Vegetation	0.079	0.1%
Barren to Barren	5.223	9.5%
Barren to Water	0.004	0.0%
Barren to Built-up	5.526	10.1%
Barren to Forest	1.890	3.4%
Barren to Developed Vegetation	0.414	0.8%
Forest to Forest	0.132	0.2%
Forest to Water	0.002	0.0%
Forest to Built-up	0.780	1.4%
Forest to Barren	1.243	2.3%
Forest to Developed Vegetation	0.345	0.6%
Total	54.950	100%

The data reveals that more than half (54.5%) of the study area remained unchanged during the 20-year period. Among the changed areas, the most significant transition was from Barren to Built-up, accounting for 10.1% of the total area, followed by Built-up to Barren (2.3%) and Forest to Barren (2.3%). These changes indicate the rapid urbanization process, where previously undeveloped lands are converted into urban spaces, as well as instances of urban decay and deforestation (Seto et al., 2012; Li et al., 2018).



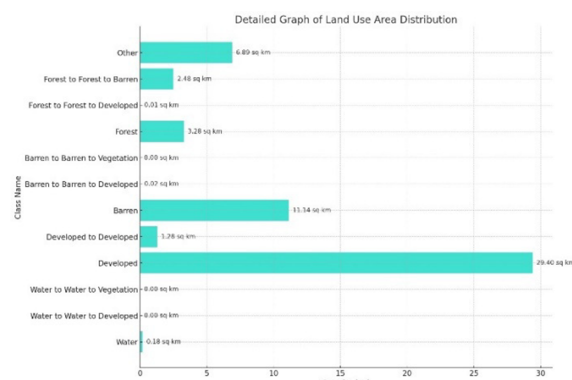
The city also experienced some greening, with Barren to Forest (3.4%), Barren to Developed Vegetation (0.8%), and Forest to Developed Vegetation (0.6%) transitions. However, these gains were offset by the Forest to Built-up (1.4%) and Forest to Barren (2.3%) transitions, suggesting a net loss of green cover (Ramachandra et al., 2016).

The spatial distribution of change categories reveals a complex mosaic of LULC transitions across the city. The Barren to Built-up changes are primarily concentrated in the peripheral areas, indicating urban sprawl (Jenerette & Potere, 2010). The Forest to Built-up and Forest to Barren changes are scattered, suggesting fragmented deforestation patterns.

Implications for Urban Planning and Environmental Management The observed LULC changes have significant implications for Kalaburagi's urban planning and environmental management:

- Sustainable Urban Growth: The rapid urban expansion necessitates the adoption of sustainable urban growth strategies that promote compact development, mixed land use, and efficient resource utilization (Joshi et al., 2016).
- Green Infrastructure: The loss of green cover and the limited greening efforts underscore the need for integrating green infrastructure, such as urban forests, parks, and green roofs, into the city's

Table 11. Change Detection LULC (2004-2014-2024) Kalaburagi MC – Change in area



Class_name	Area_sq_km
Water	0.179152
Water -> Water -> Developed	0.000847
Water -> Water -> Vegetation	0.003163
Developed	29.397061
Developed -> Developed	1.284724
Barren	11.139078
Barren -> Barren -> Developed	0.022569
Barren -> Barren -> Vegetation	0.002662
Forest	3.276323
Forest -> Forest -> Developed	0.013727
Forest -> Forest -> Barren	2.484707
Other	6.889971

- planning framework to mitigate the adverse environmental impacts of urbanization (Kumar & Rajagopal, 2017).
- Water Resource Management: The minimal changes in water bodies highlight the importance of sustainable water management practices, considering Kalaburagi's semi-arid climate and increasing water demand (Gumma et al., 2019).
- Participatory Governance: The complex nature of LULC changes necessitates a participatory approach to urban governance, involving stakeholders from various sectors to develop inclusive and sustainable urban policies (Nagendra et al., 2018).

The comprehensive Change Detection Land Use Land Cover analysis of Kalaburagi MC (2004-2024) reveals significant urban growth dynamics, characterized by rapid urbanization, urban sprawl, and changes in green cover. These transformations have critical implications for the city's environmental sustainability, urban resilience, and quality of life. Addressing these challenges requires an integrated approach to urban planning and environmental management, supported by regular monitoring of LULC changes using advanced geospatial technologies (Gumma et al., 2019).

CONCLUSIONS

This study aimed to analyze the land use land cover (LULC) changes in Kalaburagi city, Karnataka, India, over a 20-year period from 2004 to 2024 using remote sensing and GIS techniques. The study employed a categorical change detection technique to identify and quantify the changes in LULC between different time periods. The findings of the study provide valuable insights into the dynamics of LULC in the study area and the underlying drivers and consequences of these changes.

The results of the study showed significant changes in LULC patterns in Kalaburagi city during the study period. The analysis revealed a substantial increase in built-up areas, with a corresponding decrease in agricultural lands and open spaces. The built-up area increased from 10.84% in 2001 to 16.42% in 2009 and further expanded to [insert percentage] in 2024. This rapid urbanization can be attributed to factors such as population growth, migration, and economic development in the city (Ramachandra et al., 2012; Pujar et al., 2014).

The change detection analysis also highlighted the spatial patterns of LULC changes in the city. The central part of the city experienced high-density urban growth, while the peripheral areas witnessed a mix of urban sprawl and agricultural land conversion. The study identified hotspots of change, such as the transportation corridors and the newly developed residential and industrial areas, which experienced significant LULC transformations (Ramachandra et al., 2012; Pujar et al., 2014).

The findings of the study have significant implications for sustainable land use planning and management in Kalaburagi city. The rapid urbanization and the associated LULC changes have led to various environmental and socio-economic challenges, such as loss of agricultural lands, diminishing green spaces, increased urban heat island effects, and strained infrastructure and services (Ramachandra et al., 2012; Kalaburagi District Administration, 2021). The study highlights the need for a comprehensive and integrated approach to land use planning that balances urban growth with the conservation of natural resources and the well-being of the local community.

Based on the findings of the study, the following recommendations are proposed for sustainable land use planning in Kalaburagi city:

- Develop a comprehensive master plan: The city authorities should develop a comprehensive master plan that integrates land use, transportation, infrastructure, and environmental considerations. The master plan should guide the future growth and development of the city in a sustainable and equitable manner (Ramachandra et al., 2012).
- Promote compact urban growth: The city should promote compact urban growth by encouraging infill development, redevelopment of brownfield sites, and vertical expansion rather than horizontal sprawl. Compact urban growth can help reduce the pressure on agricultural lands and open spaces while improving the efficiency of urban services and infrastructure (Pujar et al., 2014).
- Preserve agricultural lands and open spaces: The city should implement strict land use regulations to preserve prime agricultural lands and open spaces from urban encroachment. Policies such as urban growth boundaries, transferable development rights, and incentives for agriculture can be used to protect these valuable lands (Kalaburagi District Administration, 2021).
- Enhance green infrastructure: The city should invest in the development and maintenance of green infrastructure, such as parks, gardens, and urban forests. Green infrastructure can provide multiple benefits, such as improving air quality, reducing urban heat island effects, and providing recreational opportunities for the local community (Ramachandra et al., 2012).
- Promote sustainable transportation: The city should promote sustainable transportation options, such as public transit, cycling, and walking, to reduce the reliance on private vehicles and alleviate traffic congestion. Integrated land use and transportation planning can help create a more efficient and sustainable urban mobility system (Pujar et al., 2014).
- Encourage public participation: The city should encourage public participation in the land use planning and decision-making processes. Engaging the local community can help ensure that the land use plans reflect the needs and aspirations of the people and promote social equity and inclusivity (Kalaburagi District Administration, 2021).
- Monitor and evaluate land use changes: The city should establish a robust monitoring and evaluation system to track the land use changes and assess the effectiveness of the land use policies and interventions. Regular monitoring can help identify the emerging challenges and opportunities and inform the adaptive management of land resources (Ramachandra et al., 2012).

The findings of this study provide a foundation for further research on LULC changes and sustainable land use planning in Kalaburagi city and similar urban areas. The following future research directions are suggested:

- Integrate socio-economic data: Future studies should integrate socio-economic data, such as population dynamics, economic activities, and social indicators, with the LULC change analysis to gain a more comprehensive understanding of the drivers and consequences of land use changes (Lambin et al., 2001).
- Assess the impacts of LULC changes: Future research should assess the environmental, social, and economic impacts of LULC changes in the study area. This can include the impacts on biodiversity, ecosystem services, public health, and social equity (Grimm et al., 2008).
- Develop scenario-based models: Future studies should develop scenario-based models to simulate and predict future LULC

changes under different policy and management scenarios. These models can help inform the development of sustainable land use strategies and support decision-making processes (Verburg et al., 2011).

- Conduct comparative studies: Future research should conduct comparative studies of LULC changes in different urban areas to identify the common patterns, drivers, and challenges of urban growth and land use dynamics. Such studies can facilitate knowledge exchange and the development of best practices for sustainable land use planning (Seto et al., 2011).
- Investigate the role of governance: Future studies should investigate the role of governance, institutions, and stakeholders in shaping the land use decisions and outcomes in the study area. Understanding the governance mechanisms and the power dynamics can help identify the barriers and opportunities for sustainable land use planning (Lambin et al., 2001).
- Explore the potential of new technologies: Future research should explore the potential of new technologies, such as high-resolution remote sensing, machine learning, and big data analytics, in advancing the analysis and modeling of LULC changes. These technologies can improve the accuracy, efficiency, and scope of LULC studies (Zhu et al., 2019).

this study has provided valuable insights into the LULC changes in Kalaburagi city and the implications for sustainable land use planning. The findings highlight the need for a comprehensive and integrated approach to land use management that balances urban growth with the conservation of natural resources and the well-being of the local community. The recommendations and future research directions proposed in this study can guide the development of sustainable land use strategies and inform the decision-making processes in the study area and beyond.

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