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Analysis of Land Use and Land Cover Change Detection for Indore District of Malwa Plateau Region Using Supervised Machine Learning

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Abstract: The main aim of this work is to find out LULC classes for the Indore region. For the last seven years, Indore has been crowned the cleanest city in India according to the latest ranking of 2023. In the Indian state of Madhya Pradesh, the city and district of Indore are situated on the southern edge of the Malwa plateau. The municipalities of the Indore district majorly cover Manpur, Depalpur, Goutampura, Mhow, Hatod, Betma, Rau and Sanwer, with an area of approximately 3900 square kilometers. In contrast, Indore covers a land area of approximately 530 square kilometres. It is in charge of the nation's slow but steady industrialization and population growth found in the last three decades. The city was much smaller and had a far smaller population thirty years ago. However, to evaluate the changes and decide on Indore city's future planning, Indore has taken over responsibility for the city's economic activities in recent years. New appropriate patterns should be recommended based on local factors like topography characteristics. The satellite image with multiple spectrums was used for the investigation. ArcGIS is based on pixel-by-pixel supervised classification using the maximum likelihood approach of Landsat satellite images from 2003 and 2023. The ground area, agriculture, and urbanization are linked to the LULC features. The various categories of classified land use and land cover features include the area of built-up regions, water bodies, cropland, forest, and barren land taken to predict the broad changes. Remotely sensed Landsat 5 images of 2003 and 8 images of 2023 were utilized to identify changes to accomplish this goal. This work clarifies the comparison of LULC classes for the Indore region.

Introduction

Ecosystem services like food, water, and air are essential to human survival, as is the supply of materials for building and development. Although the value of ecosystems and the services they provide cannot be overstated, various human and natural processes have changed how they operate, decreasing their ability to provide these essential ecosystem services for human welfare. The wetland environment is changing more quickly due to human activity (urbanization, deforestation, reclamation of agricultural land, etc.) as external stress factors brought about by the growth of the social economy (Gao and Zhang, 2009). This includes shrinking the area, fragmenting the landscape, and degrading ecological functions. More than just trees, forests are intricate, dynamic systems of interacting, frequently interrelated biological, physical, and chemical elements. This complexity produces combinations of climate, soils, tree species, and plant life. LULC is a key strategy that manages natural resources, including water and forests, as well as construction, planning, and climate considerations. The population and size of the city are among the most significant criteria.

One can attribute the gradual population rise to the direct or indirect expansion of the city (Li et al., 2016; Mittermeier et al., 1998; Tavares et al., 2019). A city's

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territory expands with living people, resulting in a sharp rise in settlements and a decline in agricultural land, fallow land, marsh, barren land, and vegetative land. Remote sensing (RS) and geographic information systems (GIS) are the best tools for identifying changes in land cover and usage from space-borne system images (Das and Dandapath, 2016a, 2016b; Das, 2017; Derdouri et al., 2021). A variety of methods and specific algorithms can be used to perform the change detection analysis. Created LULC modeling by the incorporation of remote sensing data (Kafi et al., 2014). The most popular city in Madhya Pradesh, India, Indore, has been identified as a hotspot for the forest environment. The study's main focus is Indore, known for its forests and expanding commercial and industrial activity.

The Indore District of the Malwa Plateau Region is a miniature of the world, an area where the changes are being quickly brought about by its urbanization and environmental changes. This article looks into the intricate details of space use and space cover changes of the kinetic region to fully streamline the accuracy of supervised machine learning methods. By basing on essential ideas from Xue and Wang (2011), and Zhi and Woodcock (2014) which portray the varied temporal-spatial movement of urban green spaces in connection with rapid urbanization and the implementation of greening policies and placement of a methodology that the places that continuously undergo change such as land cover can be detected and classified Through the integration of findings of first-mover studies, in our study, we aspire to add to the comprehension of the complex liaison between human interactions, policy interventions, and environment changes, which in turn are a base for sustainable land management practices in our region.

In the recent past, the consideration of land use and land-cover change detection has been one of the areas producing very serious attention due to the weighty impacts it makes in the areas of sustainable development and environmental management. The current research aims to investigate the factors behind the fluctuations in the land use and land cover (LU/LC) in the Malwa plateau area around Indore, thus using the supervised machine learning methods for the analysis. Trying to be motivated and inspired by scholars such as Abdullah et al. (2019) and Adon et al. (2018), which confirmed temperature/spatial trends and land-use dynamics by means of remote sensing and GIS, the present paper will eventually support research concerning the landscape changes in highly urbanized parts of the world. Incorporating cutting-edge geospatial technologies and controlled machine learning algorithms, our objective is to supply the necessary information on how various natural phenomenon get transformed into processes that steer the land use dynamics. This way, our findings will help with the making of informed decisions for sustainable land management and regional planning.

Given the rapid engine of urbanization and the ecological issues accompanying it, the dynamics regarding the operation of land-use and land-cover change tend to become important in the process of carbon-sensitive sustainability. Here this article cautiously observes the role of such changes in the Indore District of the Malwa Plateau Region while using the sophisticated machine learning classifiers framework as its tool. The fascinating research done by Hasan et al. (2022), which sheds light on the intricate set of factors behind urban green spaces and their impacts on land surface temperature in growing regions, has been the driving force behind this study. So, it is expected to unfold the complexities of the transformation of the landscape in rapidly growing regions. Through integrating state-of-the-art geospatial packages with machine learning algorithms (Mishra et al., 2020), the study attempts to unveil thoroughly the land use changes spurring the decision-making process vibrant for planning strategies and technologies.

With respect to the area of land use change and detection of land cover, the supervised machine learning strategies could provide an impeccable performance which could be through the exploitation of their power. This article focuses on alterations of an area around the city of Indore, located on the territory of Malwa Plain Region and applies the current achievements of science in this area. Using an interdisciplinary lens, which is the fruit of broad scholarship, including Lohare et al. (2023) study on smart sensors for greenhouse production, the research aims to unmask the hidden secrets of environmental systems. Moreover, lessons are taken from some guidance-making experiments like those of Chen et al. in (2018), which have established the effectiveness of satellite monitoring and GIS technologies in predicting and monitoring land-use change in different terrains. Attempting a global outlook on the matter evokes dialogues stemming from pivotal works reflecting various spatial contexts. This research presents a comprehensive picture, which informs various land use management actions aimed at improving the environmental status (Monserud and Leemans, 1992).

The flourish field of land use and land cover changes monitoring, in turn, is relentlessly twinned with robust techniques so as to pry more subtle dynamics that tend to affect the landscape. Through this article, we will examine the impacts of such transformations in Indore District around the Malwa plateau Area with the help of the supervised machine learning framework which has strong robust basis. The novel topic of this study was fostered by outstanding papers that are promising such as Vivekananda et al. (2020) which illustrate the power of the multi-temporal image analysis for land use and land cover classification and change detection and Yang et al. (2017) which strongly encourages an innovative regional mapping strategy of combining earth observations on the Open Street Map. The objective of this study is to shed light on the intricate dynamics of land use by comprehending how various vectored research endeavours impact these processes. This important work will form the basis for sustainable land management practice in the region.

Materials and Methods

Study Area

Indore District is located at DMS Lat 22°43'10.445" North and 75°51'27.817" East. In terms of geographical extension, Indore is the major city of the Indian state of Madhya Pradesh.

Indore is the central province's most densely inhabited city, with approximately 3900 square kilometres, as shown in Figure 1.

This LULC categorization includes vegetation, built-up areas, agricultural, waterbodies, and barren land. Lakes and other water streams developed areas such as towns, highways, factories, barren areas, and vegetation like evergreen forests.

LULC Classification Approach

Using ArcGIS software, atmospherically corrected tiles were first pre-processed to create a false colour composite image of the research region reflectance files. Following atmospheric correction, band-2 (colour blue), band-3 (colour green), and band-4 (colour red) were subsequently used to create the RGB composite image for each tile. The FCC (False Colour Composite) image was successfully produced by altering the band combination of the RGB composite image. A synthetic colour picture, or FCC, is one in which the wavelengths of the colours red, green, and blue are allocated to which they do not occur naturally. Figures 2 and 3 display the research area's false colour composite image for the years 2003 and 2023. Using on-screen visual interpretation principles, previous knowledge-based logic rules, available auxiliary data, sufficient ground reference data, and Google Earth Pro satellite data, the study region's FCC image helped prepare the AOI (A of Interest) files of distinct LULC classes.

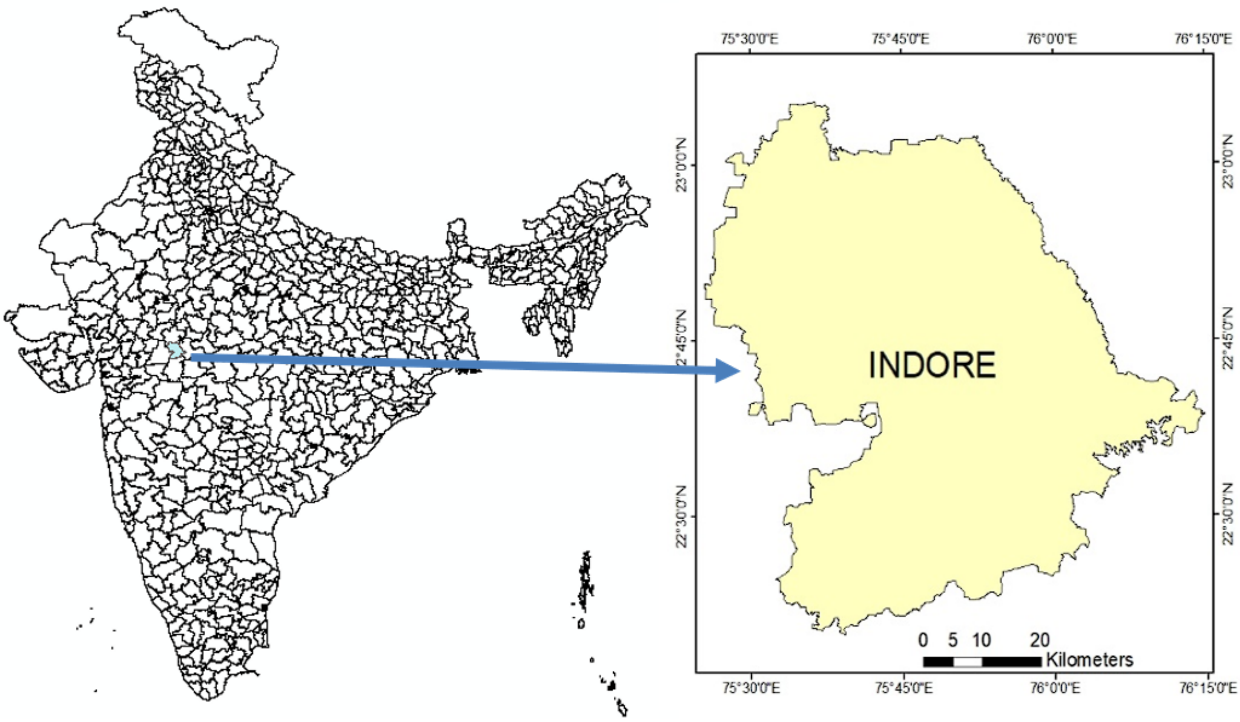

Figure 1. Location and Geometry of study area of Indore.

Data Sources

The present data sources used for this study are shown (Table 1).

The different LULC Classes are categorized using a Level 1 approach to make change detection analysis easier.

Following the creation of AOIs, an FCC image was used for supervised classification, producing large LULC classes in the classed image. The acquired image was reclassified to well-known LULC classes that differed in tone, texture, form, association, and pattern of different items in the satellite data.

The AOI (Area of Interest) files were then further superimposed on a supervised categorized image to obtain a thematically recoded raster image. Finally, the area that each LULC class covered was computed. Figure 4 depicts the methodological framework adopted in the categorization technique.

Table 1. Data Sources used for change detection.

LULC Data Source	Year	Type of Spatial Resolution	LULC Source
Landsat - 5	2003	30m	"https://earthexplorer.usgs.gov"
Landsat - 8	2023	30m	"https://earthexplorer.usgs.gov"

Five significant LULC classifications were discovered during the classification process, including Water Bodies, Built Up, Cropland, Forest and Barren Land.

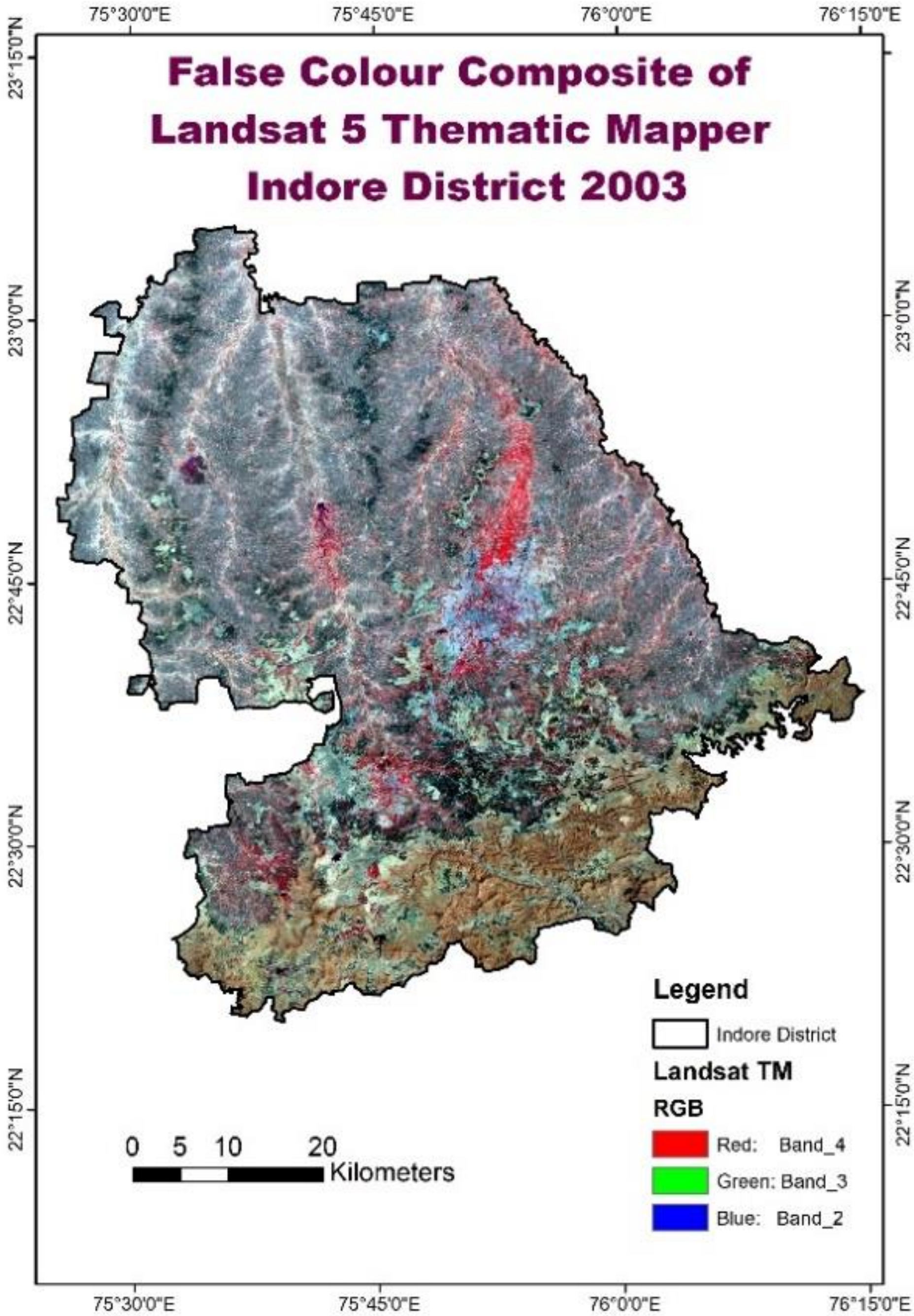

Figure 2. FCC image of the study area year 2003.

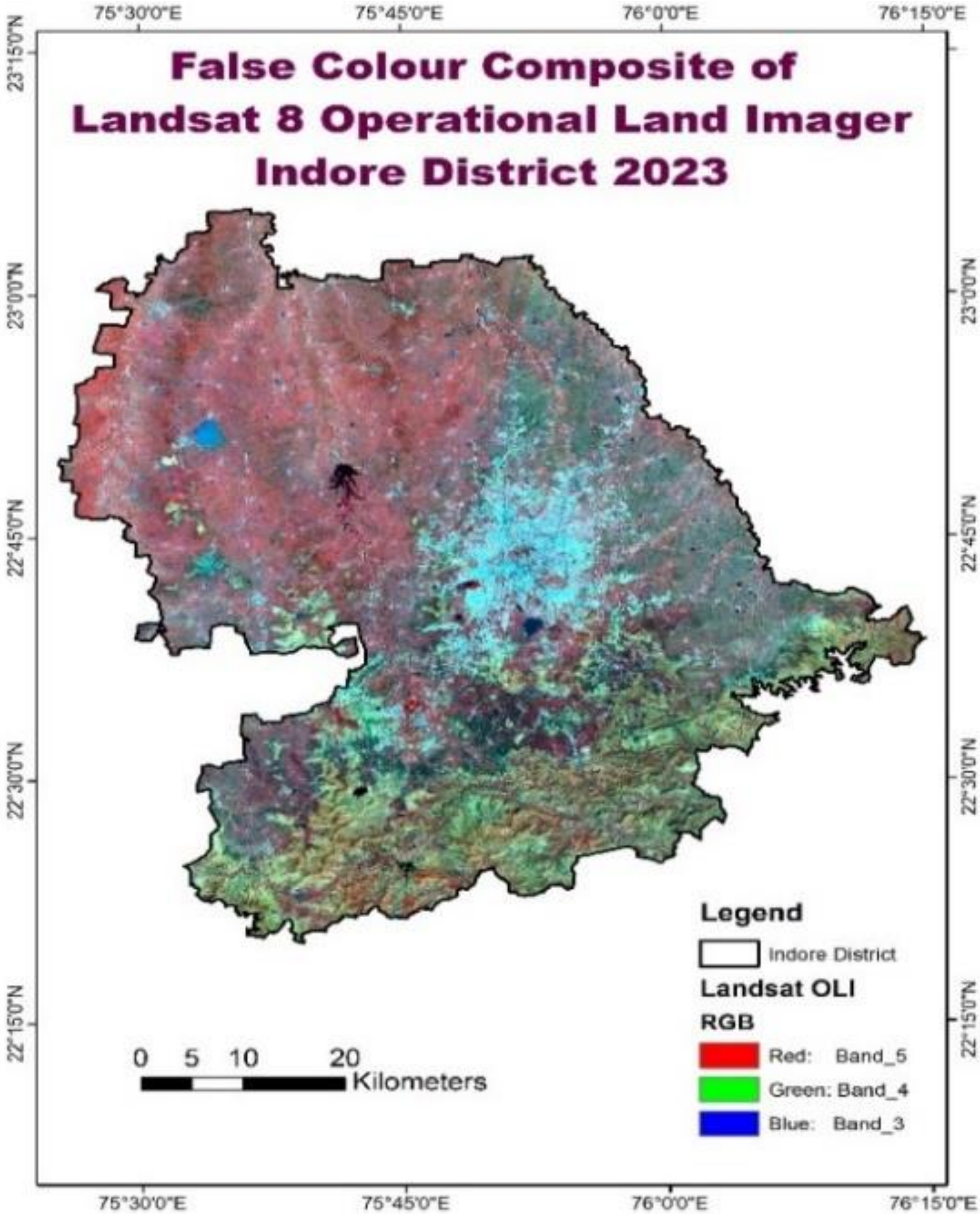

Figure 3. FCC image of the study area year 2023.

Evaluation of Accuracy

Processing remote sensing data involves accuracy assessment or validation (Thenkabail et al., 2005). When comparing a classified image's accuracy to reference data, or "ground truth," it is most commonly expressed as a percentage of the map area that has been correctly classified (Story and Congalton, 1986). According to Congalton and Green (2019), the error matrix is a square array of values arranged in rows and columns expressing the ratio of sample units allotted to a specific class in one classification to the same class in another. Making LULC maps and identifying modifications were part of the post-interpretation step. This work used the post-classification comparison as the change detection technique. ArcGIS software created the overlay between the LULC maps from 2003 to 2023. A table between the changes in 2003

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and 2023 land use/cover overlays was created for comparison.

Table 2. Five LULC classes areas and rates of change from 2003 to 2023.

LULC Class	2003 LULC Area		2023 LULC Area		Change between 2003 and 2023	
	Area (Sq. Km)	%	Area (Sq. Km)	%	Area (Sq. Km)	%
Water Bodies	2.922478	0.0748	7.0708	0.1810	+4.1483	+0.1062
Built-Up	63.5309	1.6265	218.6876	5.5990	+155.1567	+3.9725
Cropland	3052.5570	78.1551	2999.12	76.7869	-53.4369	-1.3681
Forest	235.2904	6.0241	99.9146	2.5581	-135.376	-3.4660
Barren Land	551.4655	14.1192	580.9731	14.8747	+29.5077	+0.7554
Total	**3905.7663**	**100**	**3905.7664**	**100**	**0.00**	**0.00**

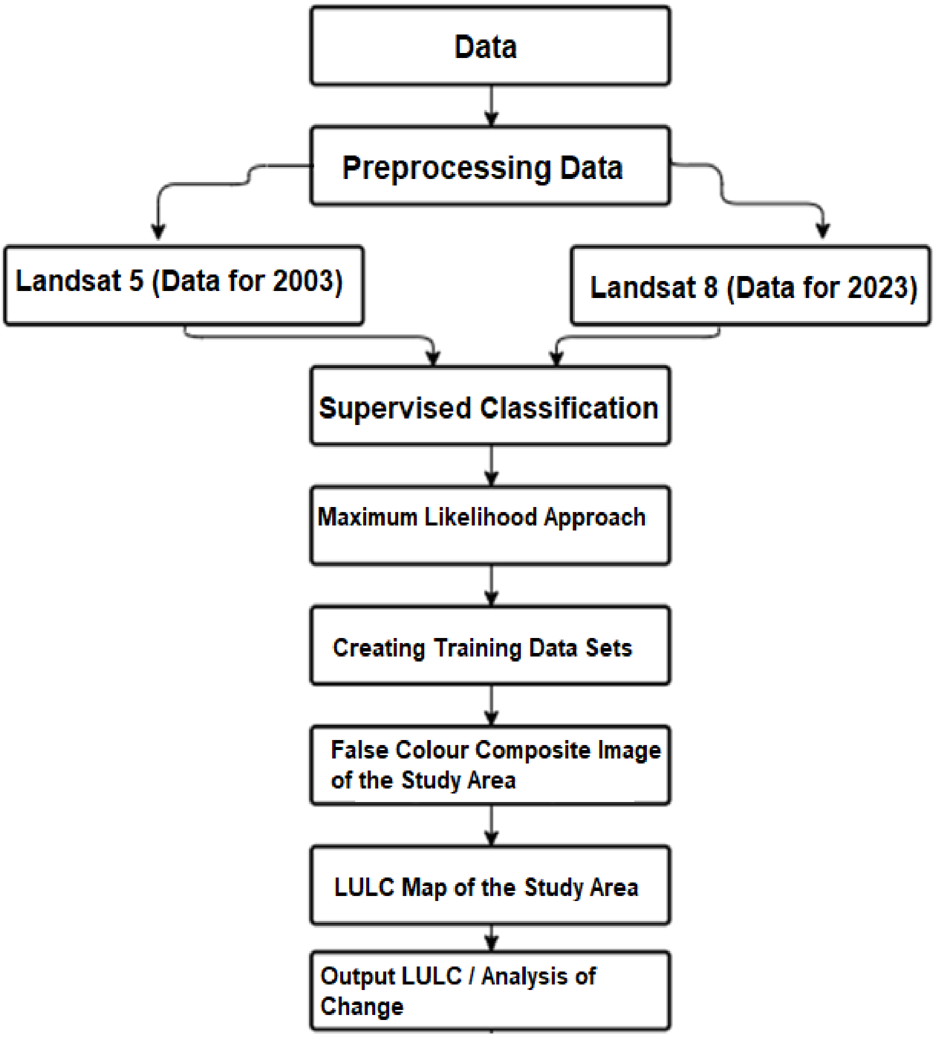

Figure 4. Flow Chart for the Research Methodology.

Indore district, a total of five major land-use and land-cover classes (LULCs) were identified. These comprised

Results and Discussion

Landowners, researchers, and decision-makers rely on the large-scale (district-level) land use and land cover (LULC) classification, which is a computationally demanding task that helps them make informal judgments for a variety of purposes (Thenkabail et al., 2005). In the forest (i.e., dense/closed and open category of evergreen forest), built-up land (habitation, rural), open/barren/wasteland (i.e., barren rocky, scrubland), and agricultural land (cropland, agricultural plantation).

Figures 5 and 6 display the research area's classified LULC map for 2003 and 2023, respectively, and Table 2 displays the district of Indore's LULC data.

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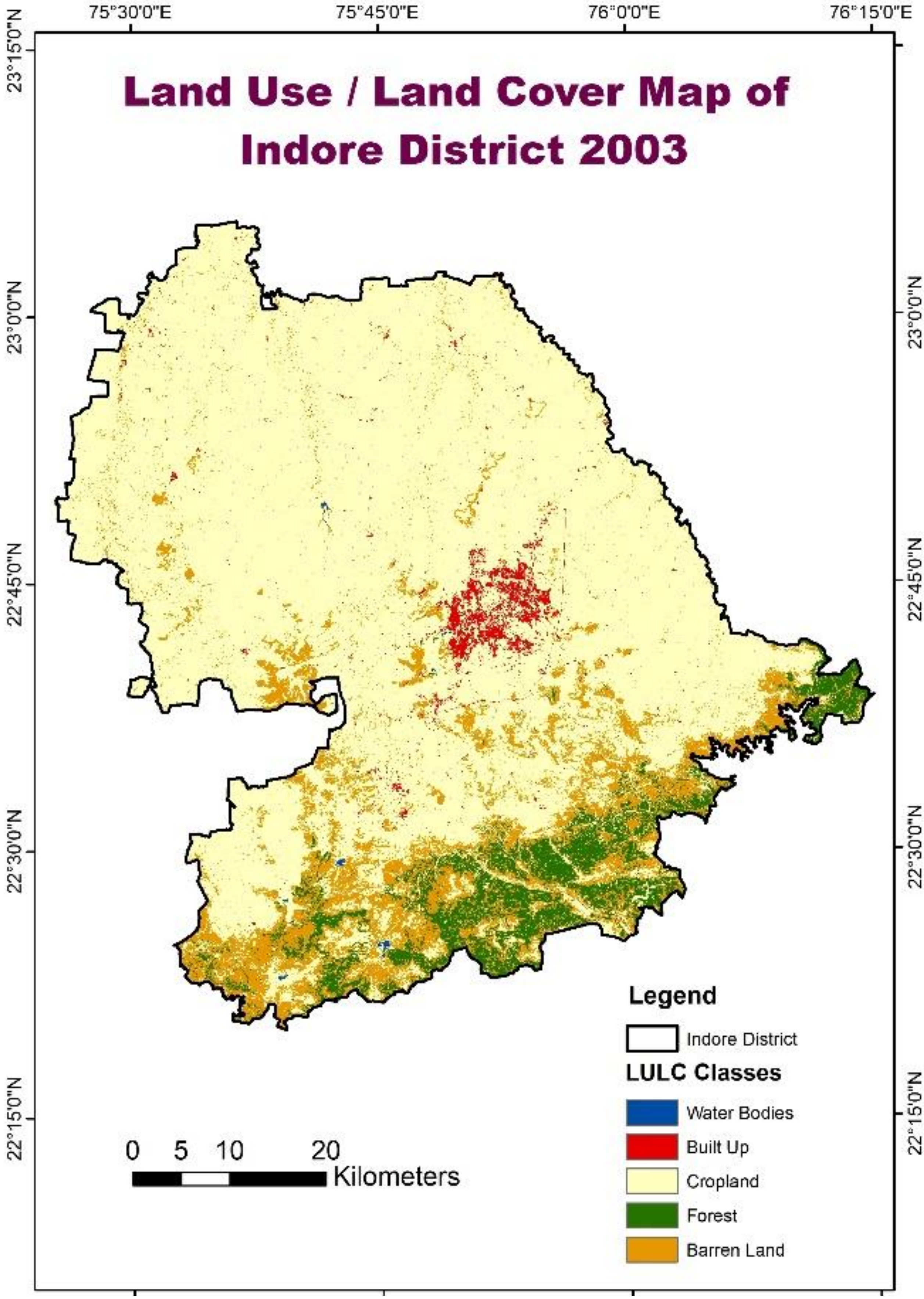

Figure 5. LULC map for the year 2003.

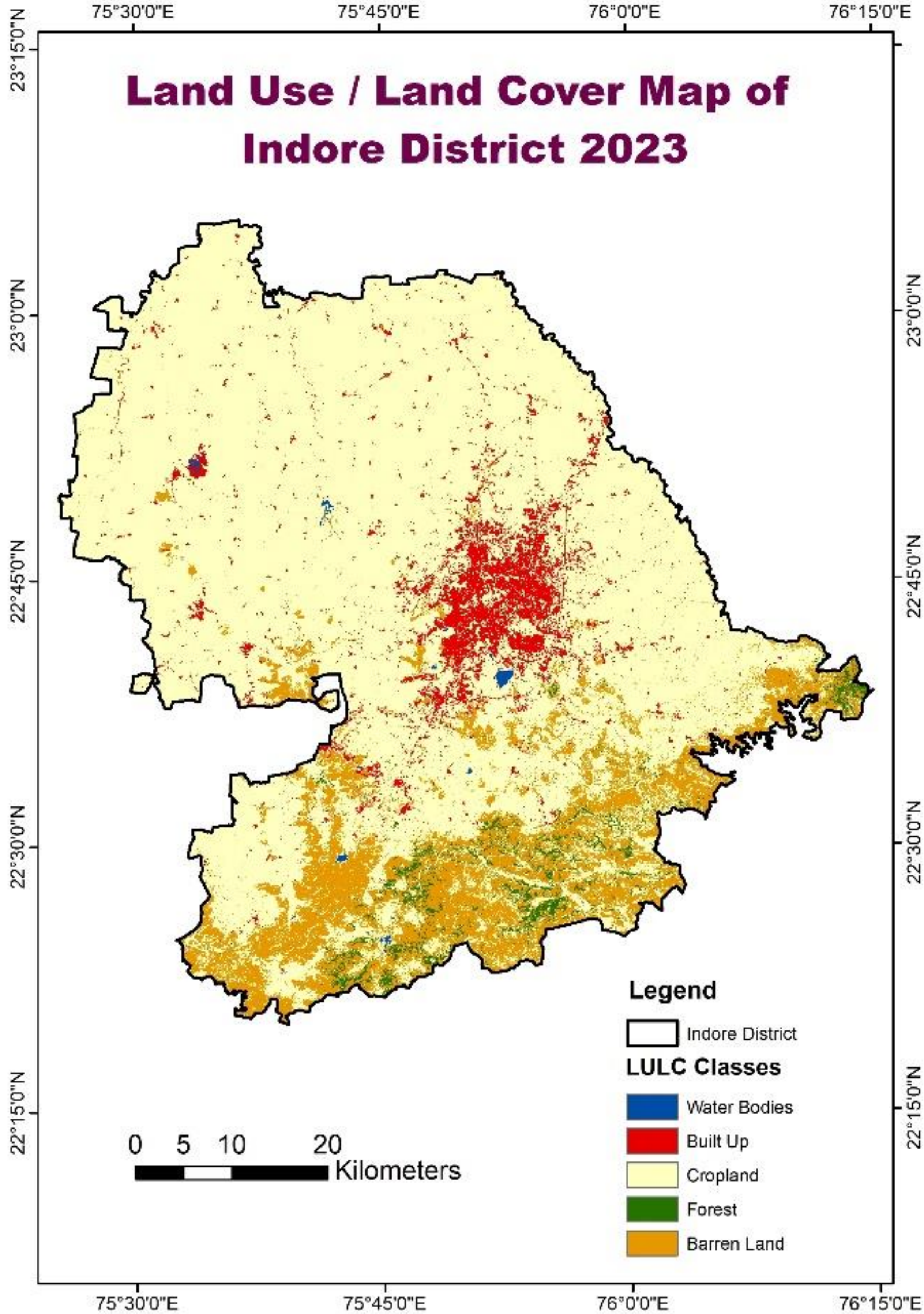

Figure 6. LULC map for the year 2023.

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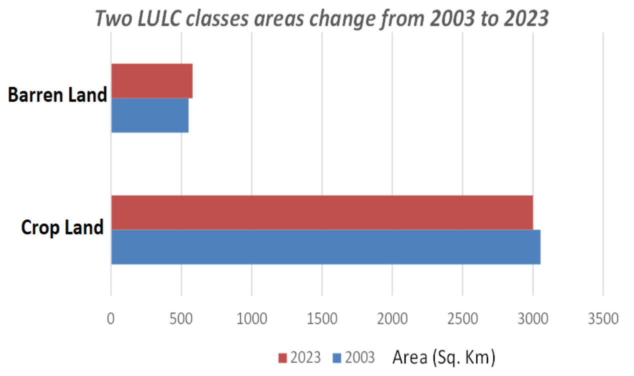

Figure 7. Plot for Two LULC class areas and rates of change from 2003 to 2023.

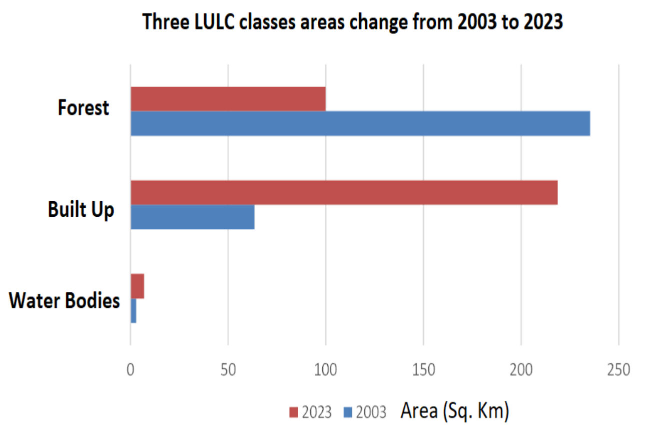

Figure 8. Plot for Three LULC class areas and rates of change from 2003 to 2023.

Conclusion

This study showed how powerful tools for mapping and identifying land use and cover changes may be obtained with the latest developments in remote sensing (RS) and geographic information system (GIS) technologies. This study, which combined field observations with contemporary technology to be conducted in the Indore district of Madhya Pradesh, India, revealed both changes and conversions of the land cover. The current study found that the built-up land (habitation) area has grown at a rate of 3.9725 % in the last two decades, while the agricultural area has decreased by 1.3681 %, as plotted in Figure 7 and Figure 8. The growing trend in built-up areas suggests that human intervention activities should be limited for policymakers. The study's conclusions emphasize the necessity of thoroughly evaluating human activity and modifying appropriate policies accordingly.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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