Analyzing the change in land cover dynamics: A case study of Delhi

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Abstract

land use/land cover change analysis is one of the key strategies for managing and tracking natural resources and monitoring as well as mapping the shift. The major contributor to such changes is urbanization. These types of changes are very prominent in metropolitan cities where the population load is high. The study area selected for the present study is Delhi, the National capital of India. This article compares the changes in land use and land cover from 2014 to 2023. To map the changes Landsat 8 data were used for 2014 and Landsat 9 was used for 2023. A total of five classes were selected for the analysis: vegetation, built-up, scrubland, waterbody, and agriculture for both datasets. The images were classified with a maximum likelihood algorithm and the overall accuracy attained was 86% (kappa 0.82) for 2014 and 90% (kappa 0.87) for 2023. The change detection suggested that there is an increase in land cover for built-up (+ 3.80) and also in the natural vegetation (+ 5.49) and a decline was observed in scrubland (-1.51) and agricultural areas (-7.91). Apart from the change detection map, a composite map for each class was also prepared for better understanding. In concluding remarks data on urban growth, land use, and land cover change studies are very important for local government and urban planners to create future plans for the sustainable development of the city.

Introduction

Most of the landscapes on the Earth's surface have been transformed to some extent as a consequence of expanding human environmental interference. As a result, the terrestrial ecosystem and its constituent parts are under extreme pressure. The features that are present on the land such as flora, rocks, or settlements, are referred to as land cover, which describes how a parcel of land is used for purposes like agriculture, habitation, or industrial (Lillesand et al., 2003). Studies of land use and land cover (LULC) have emerged as essential tools for managing natural resources and comprehending the varied effects that human activity has on the environment. The accelerating degree of urbanization is one of the main contributors to LULC transformation. The transformation of the rural area into an urban region due to economic growth and development, as well as individuals moving from rural to urban habitats, is what allows the urban-to-rural ratio to change. Between 1900 and 1999, the number of people living in cities increased by more than 10 folds, from 224 million to 2.9 billion. According to statistics from the United Nations, the percentage of people living in urban areas surpassed 50% in 2006 and will approach 60% in 2020. While it is anticipated that there would be a nearly 2 billion rise in urban populations over the next 30 years, there will actually be a little reduction in rural populations, from 3.3 billion in 2003 to 3.2 billion in 2030 (Jain et al., 2016). Hence, it is anticipated that metropolitan regions will absorb all anticipated population expansion in the near future. This expansion is primarily if not entirely occurring in developing nations. Hence, any return to rurality seems doubtful because urbanization is undoubtedly an irreversible transformation that, in most situations, is permanent. It is one of the main causes of a shift in a region's LULC and has contributed to the growth of many cities. The very tardy and yet extremely unfinished industrialization of agriculture is a significant component that contributes to urbanization. Population growth in the national capital has also been exponential. Delhi, one of the world's fastest-growing cities, has seen a remarkable increase in population from a meagre 405,800 in 1901 to 16,753,200 in 2011 (Census of India, 2011). Similarly, it is mentioned that Delhi's population density went from 6352 people per square kilometre in 1991 to 11,297 people per square kilometre in 2011. The primary reasons for the current trend of urbanization in emerging economies include rural-urban migration, the regional growth of urban zones through colonial expansion, and the transition and reorganization of rural regions into micro-urban towns. According to the data, 2.22 million immigrants visited Delhi between 1991 and 2001, a significant increase over the 1.64 million who did so between 1981 and 1991 (Delhi Human Development Report 2006). Both the influx of new immigrants and the suburbanization of the working class outside of the central city are the main drivers of the growth of the metropolitan periphery. Within and between regions and nations, there are differences in the relative weight given to each of these different drivers of urbanization and suburbanization. India experienced the same effects of urbanization and LULC shifts as the rest of the world. Further drive for urbanization in Indian metropolitan areas such as Mumbai, Delhi, Kolkata, and Chennai came from the nation's independence (Delhi Census Handbook, 1991). In contradiction to western urbanization, which was a gradual shift in the economic foundation from farming to industrialization and then to tertiary sector-driven economic progress, the rise of the service industry is what is propelling economic progress in Indian cities (Kumari et al., 2018). The Indian economy was made more accessible to the global market by the economic liberalization strategy of 1991, which resulted in a significant inflow of foreign direct investment (FDI) in major cities. Compared to other regions in the nation, Delhi received the highest share of FDI. The city is vulnerable to rapid urban growth as a result of the Indian government's acceptance of 100% FDI in real estate and infrastructure (Delhi Census Handbook, 1991). Reductions in agricultural and related activities, as a result, have decreased the primary sector's contribution to Delhi's economy (Sarkar, 2019). People from different states who've been seeking employment are drawn to the abundance of job opportunities offered by this predominant shift from agriculture to services. The exclusive cultural model is yet another aspect that draws individuals to the metropolitan area. For the intent of deciding, planning, and implementing land use plans to satisfy the growing demand for basic human necessities and welfare, knowledge of land use and land cover, as well as options for their best use, is vital. The dynamics of land use as a result of changing needs brought on by population growth are also tracked with the use of remote sensing technologies. Traditional methods for detecting changes in land cover are based on comparing successive remote sensing-derived land-cover maps, but ground surveys are often the conventional method of monitoring land use and urban growth. Ground surveys cannot be conducted in quick succession due to organizational issues and time constraints, hence they are unable to produce the necessary time series data. While this is going on, using data from remote sensing, this problem is readily fixed. As a result, the use of methods like image processing, remote sensing, and aerial photography becomes crucial. Over the past several decades, urban growth and dynamics have been documented in countless locations throughout the world using remote sensing and image processing. Planning, utilizing, and formulating policies and programs is a requirement for every developmental strategy, as is having current and accurate information on the distribution and evolution of the LULC pattern. When only a few reliable data resources can be found and government data frequently proves to be inadequate or out-of-date, using satellite imagery emerges as the most reliable solution. Landsat, IRS, Quickbird, MODIS, SPOT, and IKONOS are a few satellites that deliver data that is multi-temporal, multi-spectral, and multi-resolution. The objectives of the study are to analyze LULC changes in the Delhi region from 2014 to 2023 by utilizing Landsat 8 and 9 data, in addition, to evaluating change detection for the same.

Methodology

Initially, the collection of Toposheets from the Survey of India for preparing the study area boundary shapefile was done. The satellite images required for the study were downloaded from the USGS (United State Geological Survey) Earth Explorer. Further processing of the image and interpretation part was carried out in ERDAS Imagine software. The obtained data set (supervised images of both years) were analyzed for each and every individual class and the composite maps were prepared in ArcGIS software. The methodology followed is further explained in the flowchart mentioned (Fig. 2).

Study area

Delhi, the national capital territory of India lies in the region between 28^{0}24'17"-28^{0}53'00" N and 76^{0}50'24' '-77^{0}20'37" E with a total area of 1483 km^{2}. The area is divided into eleven districts namely: New Delhi, Central Delhi, West Delhi, North Delhi, North West Delhi, South Delhi, South West Delhi, South East Delhi, East Delhi, North East Delhi, and Shahdara. Some of the adjacent satellite cities, like Gurgaon, Noida, Faridabad, and Ghaziabad, were also flourishing eventually surrounding Delhi. The study area is located between the Himalayas in the north, the Aravalli mountains in the south, and the Yamuna River in the east from a wider geographical context. The mean sea level is between 213 and 290 meters above sea level. Due to the geographical extent mentioned the weather conditions are dry cold winters (1-3^{0}C) and extreme peak temperatures (45-47^{0}C) in summers. The average rainfall reported to be around 790mm and monsoons are the prime climatic factor on which most of the agriculture depend (Fig. 1).

Satellite data used

The data acquired from USGS were downloaded for the years 2014 and 2023. The images were selected on the basis of the minimum cloud cover possible. The images downloaded were of the same season for the years for better comparison. Further details were mentioned in the table given below (Table 1)

Table 1
Satellite dataset used in the study

Satellite	Sensor	Date of acquisition	Path/row	Cloud cover %
Landsat 8	OLI-TIRS	09-02-2014	146/040	4.83
Landsat 9	OLI-TIRS	10-02-2023	146/040	0.74

Delineating study area

The study area has been delineated using city plan maps received from Delhi Municipal Corporation and Survey of India Toposheets at a scale of 1:50000. The Landsat picture is sub-setted using the resulting base layer. This base layer is the study area shapefile which is helpful in masking the study area from the satellite imagery.

Classification

To create the composite image, stacking is done on 1–7 bands. Both supervised and unsupervised classification techniques were used to categorize the images. The ISODATA clustering algorithm, which is included in the ERDAS Imagine, will categorize under the unsupervised technique in accordance with the necessary number of classes and the available digital pixels (Naikoo et al., 2020). The user-provided training sites (signatures) and the maximum-likelihood algorithm used in the supervised classification technique will be used to classify the image. The user-provided training data instructs the software on the kinds of pixels that should be chosen for various forms of land cover. The unsupervised categorized image has been used as a reference to observe any anomaly in land use cover as it is based on spectral data. Finally, the classification provides an idea of land cover for the analysis of the study area. The classes identified for the present study were: vegetation, built-up, scrubland, waterbody, and agricultural areas. Thirty training regions (belonging to homogeneous pixels) were chosen for each category of LULC. A similar category of signatures was sorted as a new spectral signature class and the same step is repeated for each of the classes. Likewise, this categorization method was used to obtain changes in LULC categories for both years (Fig. 4).

Image post-processing

After creating the LULC maps for the calculation of the area of each class, vectorization of the layer was done. Then all the individual polygons were dissolved into their respective classes. After dissolving both layers, the comparison was made by intersecting the two. The final process was to create the change detection map out of the two layers (Fig. 6).

Accuracy assessment

The LULC classification and mapping process includes the post-classification accuracy assessment, which is used to evaluate the accuracy of the classified images. The categorization accuracy measures the output quality of maps and aids in determining whether a map is appropriately classified. Studies have already employed methods like the Kappa coefficient, error matrices, and index-based methodologies for evaluating the accuracy of created LULC maps (Naikoo et al., 2020; Prasad et al., 2021; Qadir et al., 2020; Sundarakumar et al., 2012; Tadese et al., 2020). Using 500 randomly chosen points (100 for each class) through stratified random sampling, the Kappa coefficient technique is employed in this study to assess the precision of the maps generated. The points were chosen to represent all areas of the research region and equally represent each LULC class. The reference data used were the Google Earth Pro domain and Bhuvan ISRO (Prasad et al., 2021). Both reference datasets offer a finer resolution to estimate the land cover. The estimated overall accuracy was observed to be 86% and 90% for 2014 and 2023 while kappa statistics were reported to be 0.825 and 0.875 respectively (Table 2).

Change detection analysis

Change detection analyses identify and quantify differences in satellite datasets taken at different times at a specific location (Fig. 6). This approach is highly useful in identifying various changes occurring in land use classes, such as increases or decreases in any set of classes that can be measured simultaneously. The final results can be shown in form of a map highlighting each and every change with different colors. These types of studies are highly useful when an area is observed for a specific timeline. In the last section composite maps showing the increase/decrease within the class area were also incorporated, which clearly depicts the changes (Fig. 5).

Results And Discussion

The discussion of LULC analysis and accuracy evaluation for each year was covered in the first section (Table 2). The changes were mentioned in terms of net percent change as well as area change is explained with the change detection map along with composite maps for each of the classes were also shown in detail below:

Land use/land cover

The LULC maps were shown in Fig. 4, which includes a total of 5 classes: vegetation, built-up, scrubland, waterbody, and agriculture. In a short span of time, the study area has shown significant changes in terms of land cover change in each class. Various studies have documented enormous percent changes in land use over a considerable amount of time. The north-eastern, west, and central region of the study area has reached saturation in terms of build-up cover. Some of the northern parts, Rohini and Dwarka were still in the developing phase and are nevertheless exhibiting evidence of continued expansion. The changes in the land use classes were provided in Table 3. For both years LULC maps were prepared with the help of FCC image (Fig. 3) and are shown in (Fig. 4).

The FCC is primarily produced as it is very beneficial for the identification of the land use classes in the study area (Sundarakumar et al., 2012). Due to the change of band combinations from TCC (true color composite, band combination 4,3,2) to FCC (band combination 5,4,3) the comparisons can be made.

In Fig. 4, on comparing the LULC maps the changes are clearly visible as encroachment of built-up area in the agricultural areas of the northern and southwestern regions of the study area. Less vegetation cover is observed in the central ridge, although overall the green cover can be observed to improve. Overall, scrub lands have also reduced to a certain extent. All this can be statistically validated through the corresponding table (Table 3).

Accuracy assessment

The accuracy assessment is a method in which the producer and user accuracy was compared and the total accuracy is computed.

Table 2
Accuracy assessment statistics

Land use classes	Accuracy for 2014		Accuracy for 2023	
	Producer's	User's	Producer's	User's
Vegetation	0.80	0.85	0.95	1
Built-up	0.78	0.9	0.9	0.85
Scrub land	0.82	0.7	0.95	0.76
Waterbody	1	0.95	0.75	1
Agriculture	0.9	0.9	0.95	0.95
Overall accuracy	0.86		0.90	
Kappa	0.825		0.875	

The number of accurately classified points determines the accuracy of the image. The result of the accuracy assessment is given in Table 2. The accuracy assessment method is the widely used method for determining the kappa coefficient.

Composite maps

The maps were prepared in ArcGIS software. These maps are the result of a combination of the two different LULC maps that were mentioned earlier (Fig. 4).

The composite maps clearly depict the difference in each land use class with the time interval. The color coding in these maps is just for understanding. These types of maps are very helpful for temporal studies as we can show the slightest variation efficiently. The detailed changes were further discussed with the change detection map.

Change detection analysis

The data from the five LULC classes of the study area served as the basis for the analysis of the land cover transformation that was provided in this research. The maximum relative changes were observed in agriculture (-7.9%) and scrubland (-1.5%) in terms of land cover area. Vegetation and built-up were the most positive changes (Table 3).

Table 3
Relative change percent of each land use class

Land use classes	Area_2014	Area in %	Area_2023	Area in %	Relative change %
Vegetation	162.502	10.940	244.158	16.438	5.497
Built-up	686.309	46.205	742.852	50.012	3.807
Scrub land	167.514	11.278	145.091	9.768	-1.510
Waterbody	19.736	1.329	21.513	1.448	0.120
Agriculture	449.287	30.248	331.747	22.334	-7.914

The change detection was evident with the To-and-From algorithm (Fig. 6 and Table 4). The "To and From" approach can be used to identify change areas in remote sensing data from two separate time periods by determining the shortest path between each pair of pixel pairs. The approach can be used to determine how the spectral characteristics of the same pixel location in two separate images differ from one another. The method involves creating a distance matrix that contains the spectral value differences between every pair of pixels in the two images. The matrix is initially filled with the spectral value difference between the relevant pixels in the two images. The algorithm then determines whether there is a shorter path between each pair of pixels by taking into account intermediate pixels. The distance matrix is updated if a shorter path is discovered. The areas with significant changes between the two time periods can be found using the distance matrix generated. The distance matrix's high-valued pixels represent regions where there have been large changes in spectral values.

Table 4
Change detection matrix for LULC (2014–2023)

Year	2023					
2014	Vegetation	Built-up	Scrub land	Waterbody	Agriculture	Total
Vegetation	106.129	96.477	17.563	2.42	21.513	244.102
Built-up	33.54	529.171	60.724	3.479	115.736	742.65
Scrub land	17.027	34.228	59.94	0.289	33.518	142.002
Waterbody	1.965	3.067	1.1	12.821	2.543	21.496
Agriculture	3.798	23.254	28.111	0.703	275.74	331.606
Total	162.459	686.197	167.438	19.712	449.05	1483.86

The "To and From" approach can effectively determine the difference in spectral values between all pairs of pixels in two images, making it helpful for change detection in remote sensing applications. It's crucial to keep in mind that the algorithm considers changes to be ongoing and progressive over time. The algorithm might not be successful in locating the change locations when the changes are abrupt.

Conclusion

Monitoring of changes has a whole new dimension with the availability of satellite data from which extraction of information is possible. The present study involves the land use land cover change analysis for the years 2014 and 2023. The study area is the national capital and being a metropolitan city, it is experiencing rapid urbanization in the last few decades. Generally, it was observed that this type of study includes a longer time span but studies like this are also necessary to map the current shift or to take any mitigation step right at the source of generation. Although estimating changes over a large area is a huge task that is now done with the help of remote sensing. This study is an attempt towards mapping the changes during 2014–2023. Here, Landsat 8 and 9 data were used for the different time periods. The LULC maps were prepared by supervised classification with 5 classes: vegetation, built-up, scrubland, waterbody, and agriculture. The overall accuracy was found to be 86% and 90% for 2014 and 2023 respectively. Change detection analysis results increase in vegetation cover (+ 5.4%) followed by build-up (+ 3.8%) and a decrease in scrubland areas (-1.5%) and agricultural areas (-7.9) was observed. The waterbody has shown a slight positive variation (+ 0.12). Similar kind of results was also reported by Qadir et al. (2020) and Naikoo et al. (2020). For each class, composite maps were prepared for a better understanding of the land use change within the respective class for this study.

Declarations

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Competing Interest None

Authors Contributions: The research work, collection of data, manuscript writing, and final interpretation were conducted by Sangita Singh (corresponding author) and the final editing was performed by Dr. Kiranmay Sarma (Professor) including the technical details of the software used.

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Figures

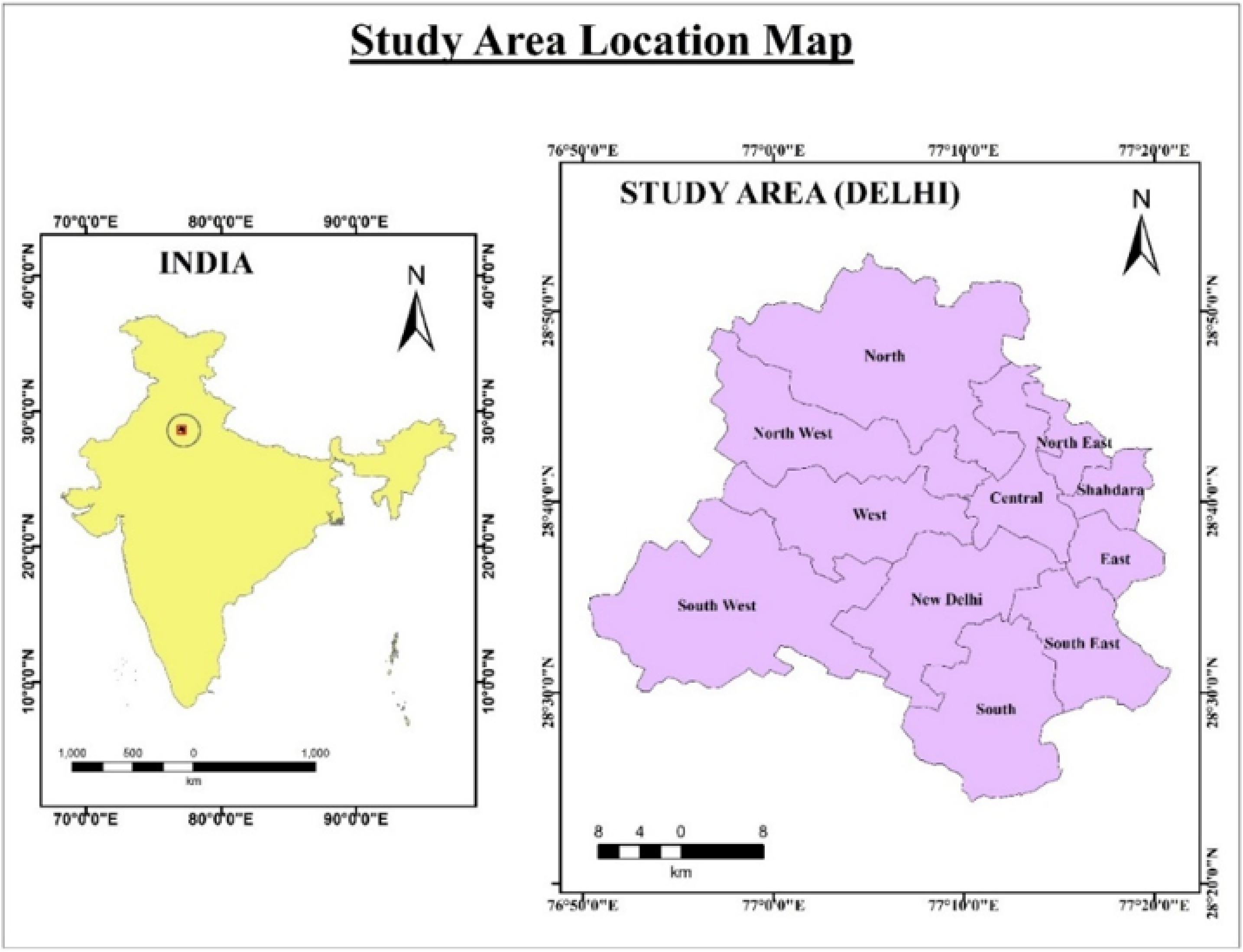

Figure 1

Study area location map of Delhi

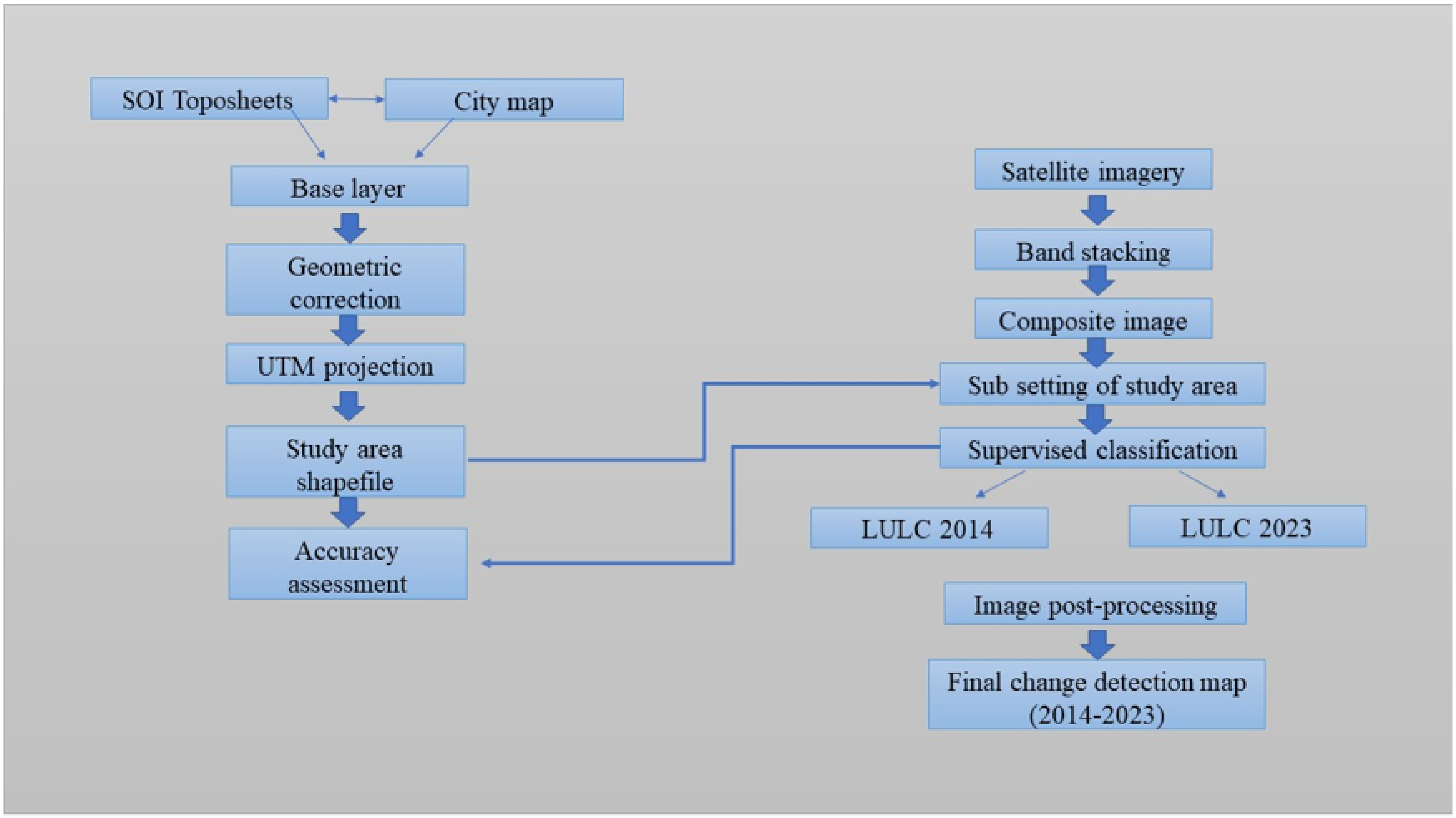

Figure 2

Flowchart of the methodology

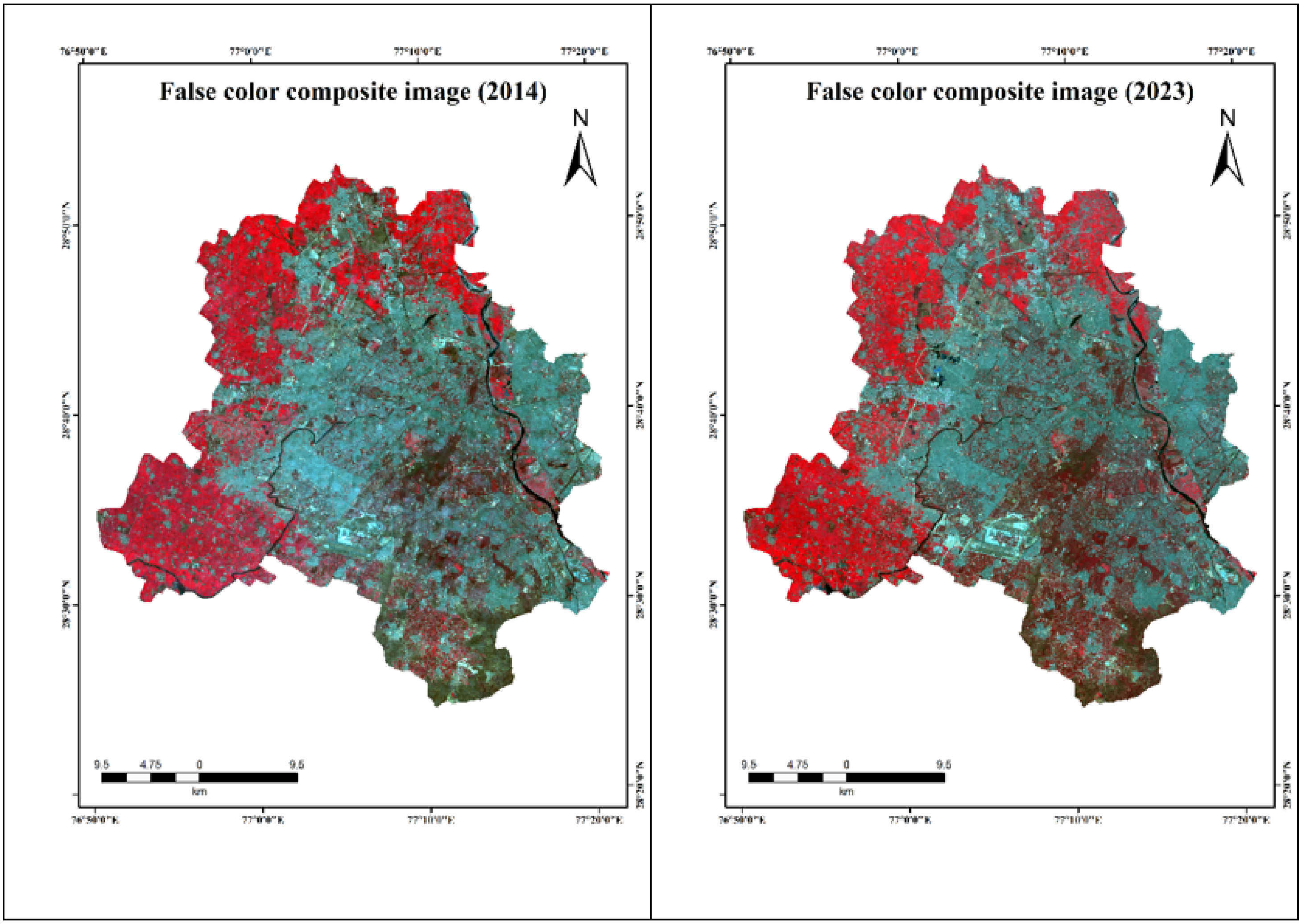

Figure 3

False color composite image for the years 2014 and 2023

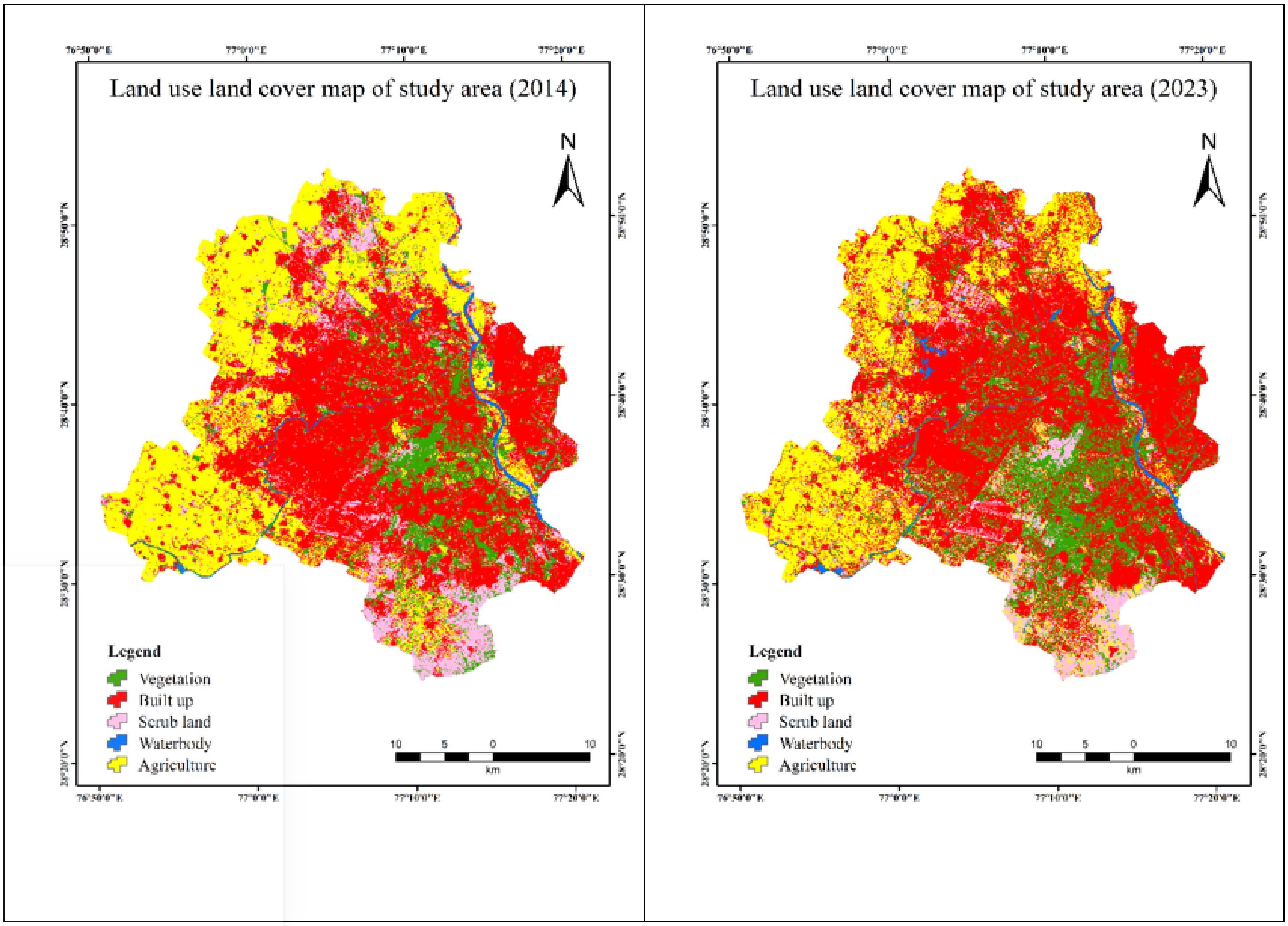

Figure 4

Land use land cover map of the study area for the years 2014 and 2023

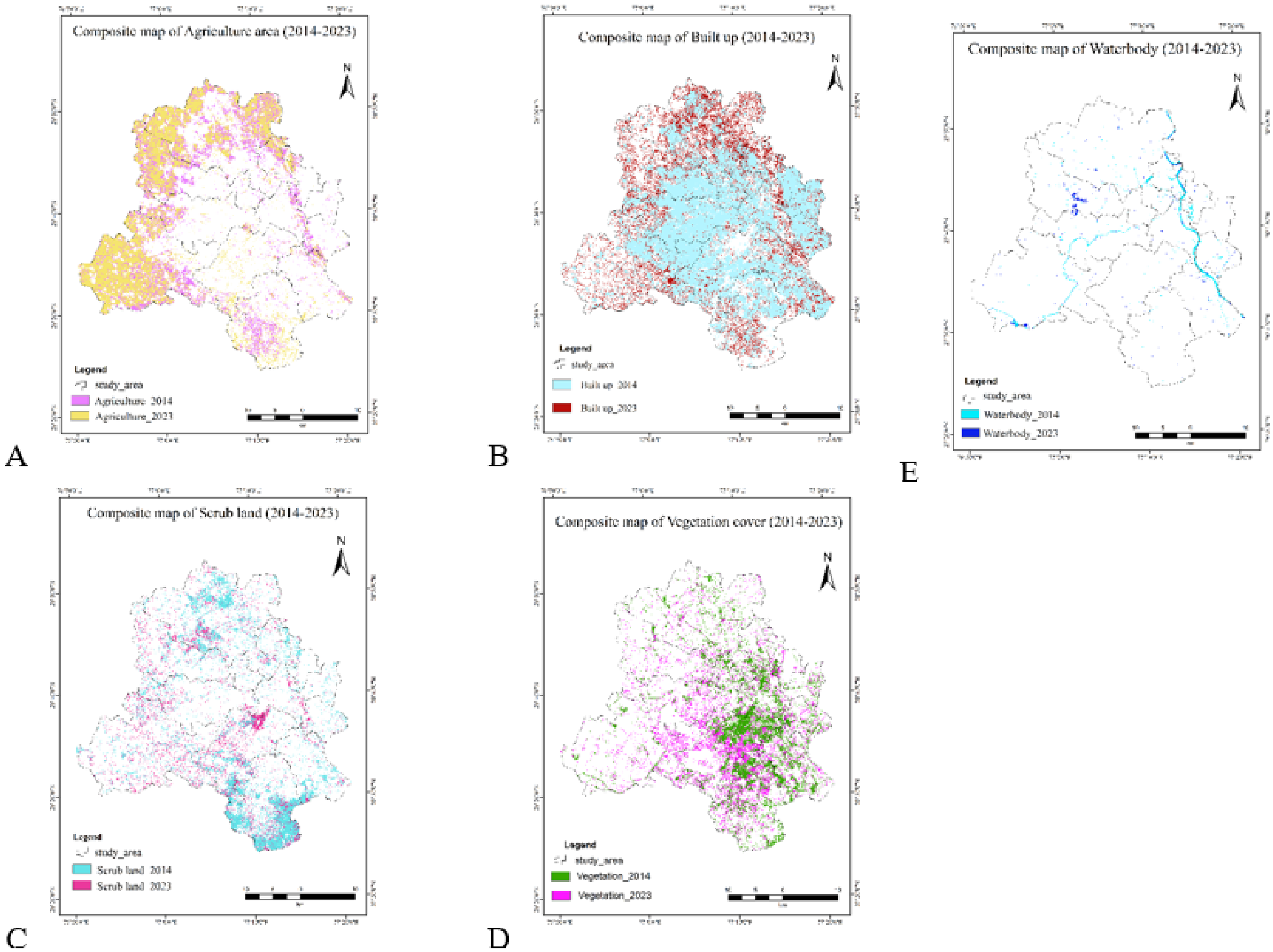

Figure 5

Composite maps of each land use class a) agriculture, b) built-up, c) scrubland, d) vegetation, and e) waterbody

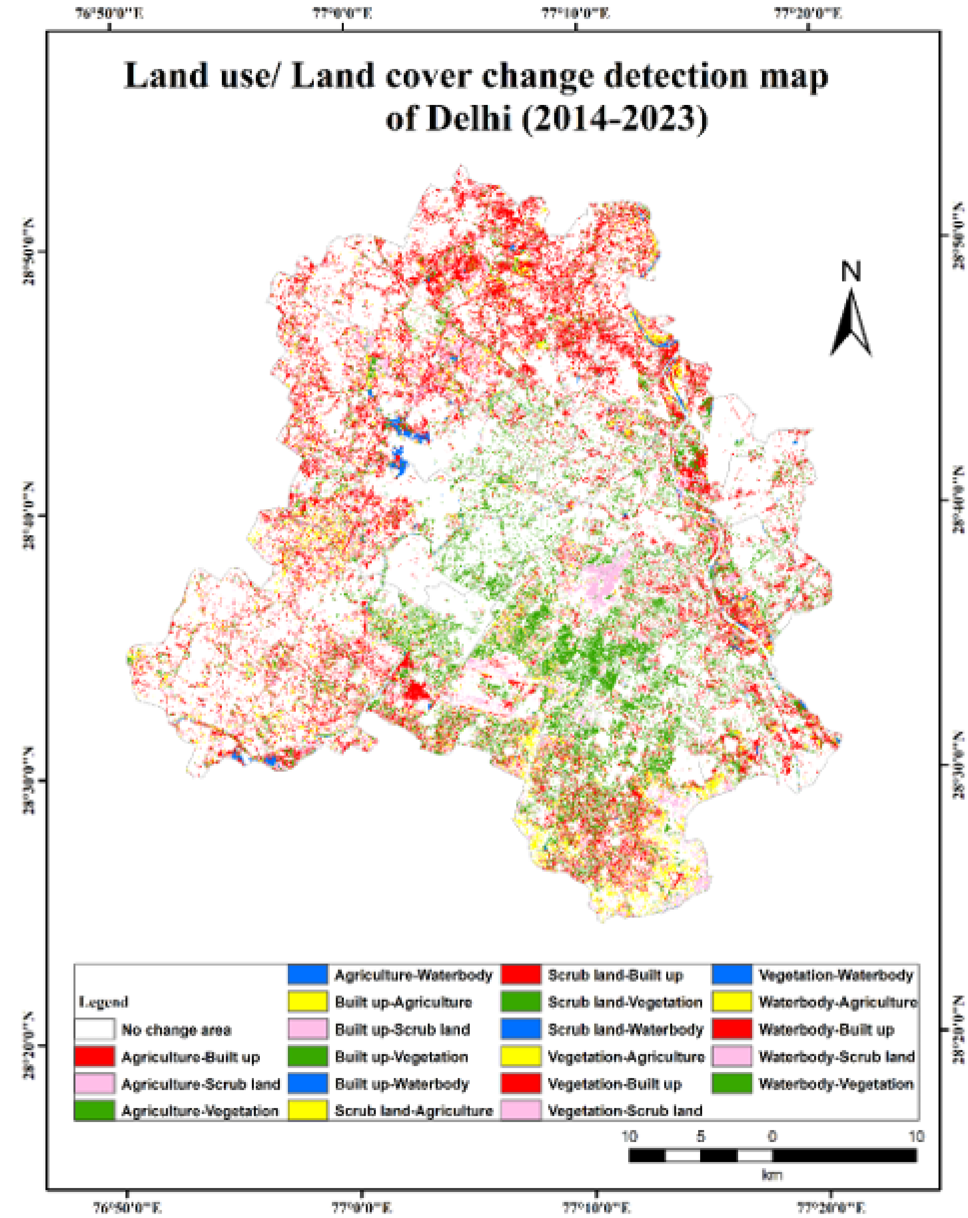

Figure 6

Change detection map of Delhi (2014-2023)