International Journal of Geography, Geology and Environment

P-ISSN: 2706-7483
E-ISSN: 2706-7491
www.geojournal.net
IJGGE 2024; 6(1): 26-31
Received: 08-11-2023
Accepted: 13-12-2023

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Spatio-temporal analysis of land use and land cover in the national capital region of India

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DOI: https://doi.org/10.22271/27067483.2024.v6.i1a.198

Abstract
One of the most important methods for managing and monitoring the progress of natural resources is the examination of changes in land use and land cover. Urbanization is the main cause of these modifications. Cities with a dense population are more likely to see these kinds of shifts. The national capital of India, Delhi, was chosen as the study region for the current investigation. This article used Landsat 8 data for 2014 and Landsat 9 data for 2023 to map the changes. For both datasets, five classes were selected: vegetation, built-up, scrubland, water body, and agriculture. For the classification purpose maximum likelihood algorithm was used, and the outcome was reported to be 86% (kappa 0.82) for 2014 and 90% (kappa 0.87) for 2023 in terms of accuracy. The change detection indicated that there is a rise in built-up land cover (+3.80) as well as in natural vegetation (+5.49), while a decline in scrubland (-1.51) and agricultural areas (-7.91) was detected. In summation, information on urban growth, land use, and land cover change studies is crucial for local government and urban planners to construct long-term strategies for the city's sustainable growth.

Keywords: Land cover, Landsat, Delhi, change detection, accuracy, change matrix

1. Introduction

Urbanization [7] is an irreversible phenomenon that permanently changes the land cover of an area. It is one of the primary factors in a region's Land Use [22] Land Cover (LULC) transition. The majority of the landscapes on the surface of the Earth have undergone some level of change as a result of growing environmental involvement by expanding population. The upshot is that the terrestrial ecosystem and all of its components are under tremendous stress. Land cover, which indicates how a parcel of land is used for purposes like agriculture, habitation, or industrial uses, refers [15] to the features that are present on the land such as flora, rocks, or settlements. LULC [11, 12, 13] studies have become crucial tools for managing natural resources [1] and understanding many impacts that human activity has impacted on the environment. One of the key factors in the evolution of LULC is the pace of urbanization. What permits the urban-to-rural ratio to alter is the conversion of the rural area into an urban region as a result of economic growth and development, as well as people shifting from rural to urban environments. From 224 million to 2.9 billion people lived in cities between 1900 and 1999, a more than 10-fold rise. The percentage of people living in urban areas topped 50% in 2006 and will approach 60% in 2020, according to data from the United Nations. Although it is predicted that urban [2] populations would increase by approximately 2 billion over the next 30 years, rural populations will decline slightly, from 3.3 billion in 2003 to 3.2 billion in 2030 [14]. Metropolitan areas are therefore expected to accommodate all planned population growth shortly. If not totally, then mostly, this increase is taking place in poor countries. The nation's capital [8, 14] has experienced exponential population growth. The population of Delhi, one of the cities with the greatest population growth worldwide, increased dramatically from a meager 405,800 in 1901 to 16,753,200 in 2011 [3]. The population density in Delhi increased from 6352 per square kilometre in 1991 to 11,297 per square kilometre in 2011. Rural-urban migration, the regional extension of urban zones through colonial expansion, and the transformation and reorganization of rural regions into micro-urban towns are the main causes of the current trend of urbanization in emerging economies. Data show that between 1991 and 2001, 2.22 million immigrants travelled to Delhi, a significant rise from the 1.64 million who did so between 1981 and 1991 [9].

The primary forces behind the expansion of the metropolitan periphery are the influx of new immigrants as well as the suburbanization of the working class outside of the center metropolis. There are differences in the relative weight attributed to each of these various urbanization and suburbanization drivers within and across regions and countries. India was affected by urbanization and LULC shifts in the same ways as the rest of the world. The country's independence served as an additional impetus for urbanization in Indian metropolises like Mumbai, Delhi, Kolkata, and Chennai [10]. The growth of the service sector is driving economic success in Indian cities, in contrast to Western urbanization, which was a gradual transition in the economic basis from farming to industrialization and then to tertiary sector-driven economic progress. The economic [18] liberalization plan of 1991 increased the Indian economy's exposure to the world market leading to a considerable influx of foreign direct investment (FDI) in metro cities. Delhi received the largest percentage of FDI when compared to other parts of the country. Due to the Indian government's support of 100% FDI in infrastructure and real estate, the city is susceptible to rapid urban growth [10]. As a result, the primary sector's contribution to Delhi's economy has dropped due to reductions in agriculture and related activities [18].

People looking for work from many states are drawn to job opportunities provided by this significant shift from agriculture to services. The premium cultural model is yet another factor that attracts people to the city. Knowledge of land use and land cover, as well as options for their optimal use, is critical for determining, planning, and implementing land use plans to meet the growing need for basic human demands and well-being. Remote sensing technologies are also used to follow the dynamics of land usage as a result of changing needs caused by population growth. Traditional approaches for detecting changes in land cover rely on comparing sequential remote sensing-derived land-cover maps, but ground surveys are frequently used to monitor land use and urban growth [16]. Because of organizational challenges and time restrictions, ground surveys cannot be conducted in quick succession, and hence cannot create the required time series data. This issue can be easily resolved using remote sensing data. As a result, techniques [19] like aerial photography, remote sensing, and image processing [15] become essential. Using remote sensing [21, 22] and image processing, urban dynamics and growth have been studied in various [4, 5, 6] locations all over the world over the past few decades.

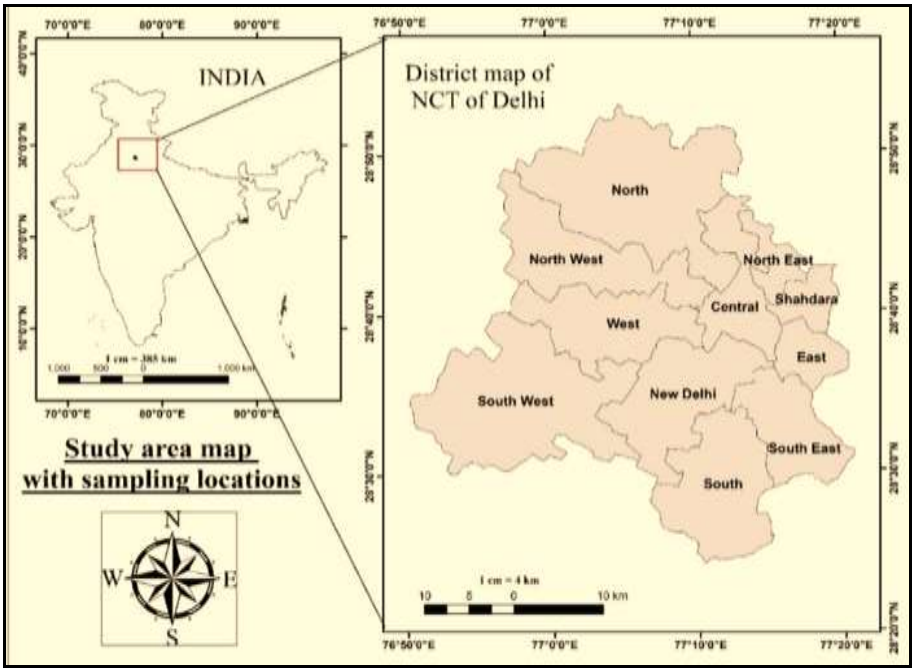


Fig 1: Study area location map of Delhi

Every developmental strategy must include planning, implementing, and creating policies and programs, as well as having up-to-date and correct data on the distribution and development of the LULC pattern. Satellite imaging appears as the most credible solution when there aren't many trustworthy data sources available and government data frequently turns out to be insufficient or out of current trend. The study's goals include analyzing change detection in the NCT of Delhi from 2014 to 2023 using data from Landsat 8 and 9.

Table 1: Details of the images 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

2. Methodology

Toposheets, satellite data, and image processing software were utilized in further processing and interpretation. The acquired data set (supervised images from both years) underwent individual class analysis. The following information provides more details:

2.1 Study area

Delhi, India's national capital territory, has a total area of 1483 km^2 and is located (Figure 1) between the coordinates 28024′17″ and 28053′00″ N and 76050′24″ and 77020′37″ E. New Delhi, Central Delhi, West Delhi, North Delhi, North West Delhi, South Delhi, South East Delhi, East Delhi, North East Delhi, and Shahdara are the eleven districts.

Gurgaon, Noida, Faridabad, and Ghaziabad are a few of the nearby satellite cities that finally sprang up around Delhi [20]. From a larger geographical context, the research region is situated between the Himalayas in the north, the Aravalli mountains in the south, and the Yamuna River in the east having mean sea elevation of approximately 213 and 290 meters. Due to the aforementioned geographic expanse, there are dry, chilly winters (1-3 °C) and summers with extremely high peak temperatures (45-47 °C). Monsoons are the main climatic component on which much of agriculture depends, with an average rainfall of roughly 790 mm observed. The prominent soil type includes the sodic and alkaline types for most of the region.

2.2 Satellite data used

Data for the years 2014 and 2023 were downloaded from the USGS Earth Explorer as mentioned earlier. The images were chosen with the least amount of cloud cover possible. For easier comparison, the downloaded dataset was from the same season for the temporal analysis (Table 1). By using city plan maps at a scale of 1:50000 obtained from the Delhi Municipal Corporation and Survey of India Toposheets, the study area was defined. The generated base layer is used to sub-set the satellite image.

2.3 Classification

Stacking is carried out on bands 1-7 to get the composite image. The images were categorized using both supervised and unsupervised classification approaches. According to the required number of classes and the available digital pixels, the ISODATA clustering algorithm was applied in ERDAS Imagine. The image will be classified using the maximum-likelihood algorithm and user-provided training sites (Signatures) from the supervised classification [19] technique. The software is trained to select the pixels to choose for different types of land cover by the user-provided training data. Since it is based on spectral data, the unsupervised image has been utilized as a reference to spot any anomalies in the classification. For this study, the following categories were identified: vegetation, built-up areas, scrubland, waterbodies, and agricultural areas. For each LULC [23, 24, 25] category, 50 training regions (belonging to homogenous pixels) were selected. A new class of spectral signatures was created by grouping similar kinds of signatures, and this process is repeated for each class. The variations in LULC categories for both years were also obtained using this categorization method.

2.4 Accuracy assessment

The post-classification accuracy assessment step of the LULC classification and mapping process is used to assess the accuracy of the categorized images. The accuracy of developed LULC maps has already been assessed by studies using techniques [19] including the Kappa coefficient, error matrices, and index-based procedures [20]. In this study, the Kappa coefficient technique is applied to 500 randomly selected points (100 for each class) by stratified random sampling to evaluate the accuracy of the maps produced. The points were determined to fairly represent each LULC class and all research region areas. The Google Earth Pro domain and Bhuvan ISRO were utilized as reference data. Both reference datasets provide a higher resolution for estimating land cover. The projected overall accuracy for 2014 and 2023 was 86% and 90%, respectively, with kappa statistics of 0.825 and 0.875 (Table 2).

2.5 Change detection analysis

Change detection analyses and measures differences between satellite datasets compared at various periods and locations. When it comes to recognizing different changes in land use classes, such as increases or declines in any group of classes that may be measured simultaneously, this approach is quite helpful (Table 3). These studies are highly beneficial for environmental modeling, monitoring, disaster management, agriculture and forestry, urban planning and infrastructure development, climate change studies, and infrastructure monitoring.

3. Results and Discussion

The section further explains the LULC analysis and accuracy assessment for the study period. The changes were described in terms of net percent change and area change.

3.1 Land Use/Land Cover

The LULC maps were displayed in Figure 3, and a total of 5 classes were represented: vegetation, built-up areas, scrubland, water bodies, and agricultural areas. The study area has experienced considerable changes in each class of land cover during a brief time. Numerous studies have shown that over an extended period, land use has changed by significant percentages [21, 22, 23, 24]. The research area's north-eastern, western, and central regions have reached build-up cover saturation. Rohini and Dwarka, two of the northern areas, were still in the development stage but showed signs of continued growth. Table 3 lists the modifications to the land use classes. Using FCC images, LULC maps for both years were created and are displayed in Figure 3. The main reason for producing the FCC is that it is very helpful for identifying the land use classes in the research area. The differences between the LULC maps can be observed as an incursion of built-up areas into the rural parts of the study area's northern and southern regions. Although the overall green cover is seen to be improving, the central ridge shows less vegetation cover than earlier. Scrub lands have generally decreased to some extent due to certain plantation [17] drives in Delhi recently. Through the relative change (Figure 2), all of this can be observed.

3.2 Accuracy Assessment

The accuracy assessment approach compares producer and user accuracy and computes the overall accuracy. The overall accuracy of the image is based on the number of correctly categorized points. Table 2 represents the findings of the method used. This technique is frequently used to calculate the kappa coefficient and overall accuracy of classified images.

3.3 Change Detection Analysis

The data obtained from the study area's five LULC classes served as the foundation for the analysis of the land cover transition. In terms of land cover area, agriculture experienced the largest relative changes (-7.9%) while scrubland as the lowest (-1.5%), whereas an increase in vegetation and built-up was reported (Table 3).

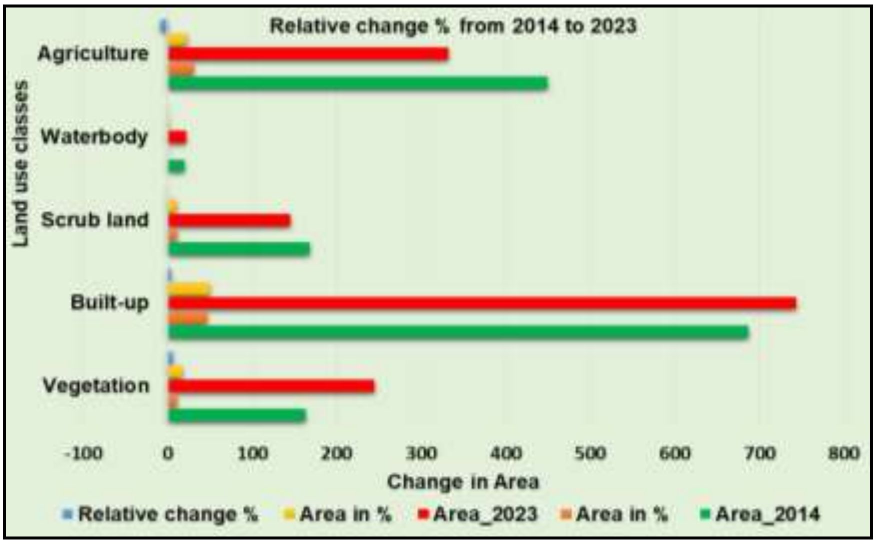


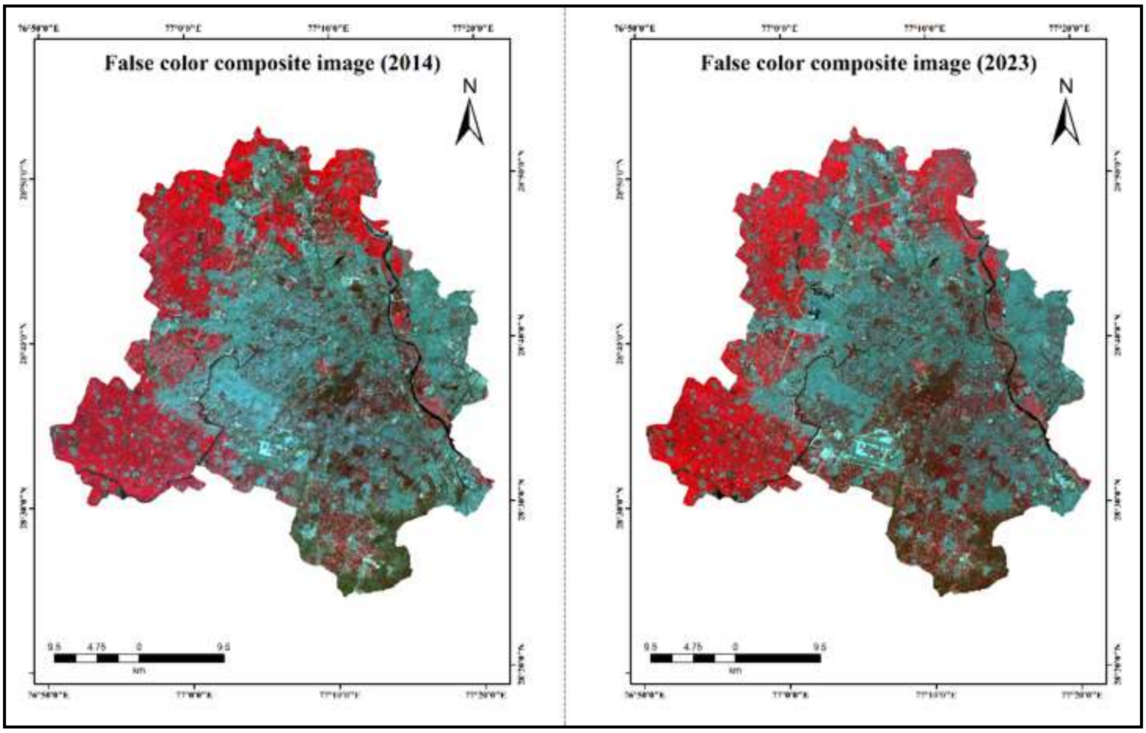
Fig 2: Relative Change Percentage from 2014 to 2023.

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
Water body	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	

Table 3: Change detection matrix for LULC (2014-2023)

Year	2023					
2014	Vegetation	Built-up	Scrub land	Water-body	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
Water body	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



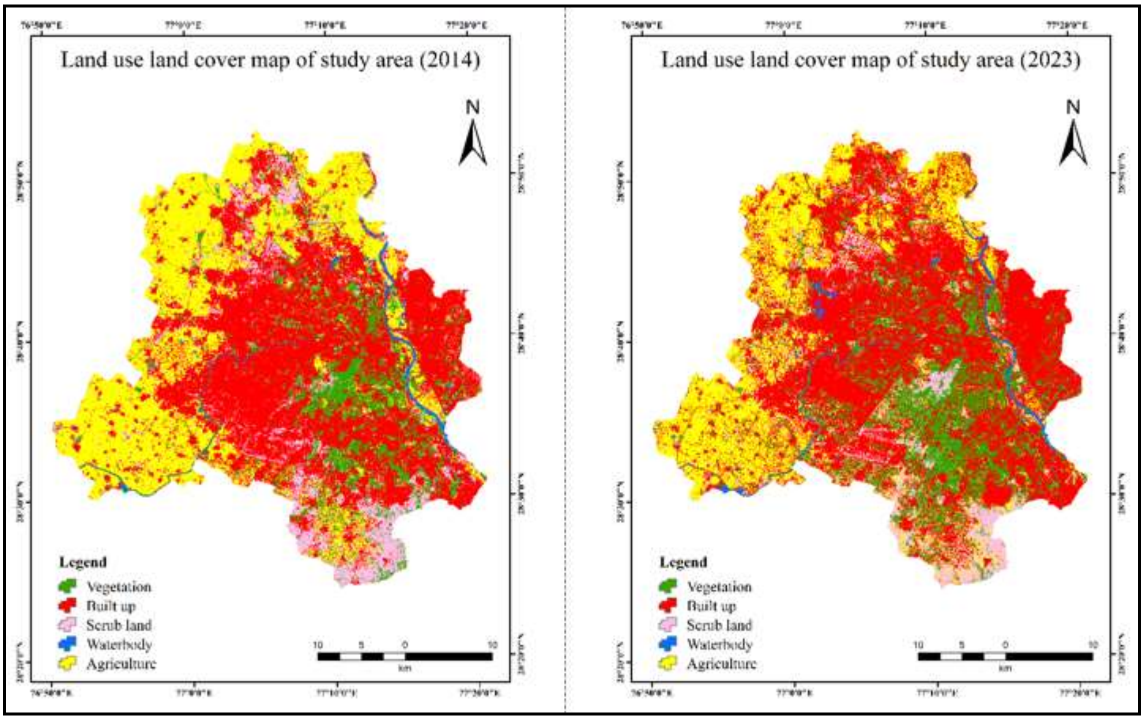


Fig 3: False color composite and LULC map for the years 2014 and 2023

With the To-and-From algorithm, the change detection was apparent (Table 4). The "To and from" method [15], calculates the shortest path between each pair of pixels, used to spot change areas in remote sensing data from two different periods. The method can be used to compare the spectral features of a single pixel position across two different images. A distance matrix that includes the spectral value differences between each pair of pixels in the two images is created using this technique. The spectral value difference between the pertinent pixels in the two images is initially used to populate the matrix. The software (ERDAS) then considers intermediate pixels to assess if there is a shorter path between each pair of pixels. If a shorter path is found, the distance matrix is updated. The distance matrix produced can be used to identify the regions that underwent major changes between the two time periods. High-valued pixels in the distance matrix represent areas where there have been significant spectral value shifts. The "To and From" method is useful for change detection in remote sensing applications because it can accurately identify the difference in spectral values between all pairs of pixels in two images.

4. Conclusion

With the availability of satellite data, information can now be extracted to monitor developments in a completely new way. The study was performed to map the LULC changes from 2014 to 2023 in the NCT of Delhi. These studies are important to map the present shift or implement any mitigating measures directly at the source of creation. Although assessing changes across a vast area is a difficult undertaking, it is now possible because of remote sensing. For the distinct temporal periods, Landsat 8 and 9 data were used. The LULC maps were created using supervised classification and five different classes: vegetation, built-up, scrubland, water body, and agriculture. The overall accuracy was found to be 86% in 2014 and 90% in 2023. According to the change detection analysis, there was an increase in vegetation cover (+5.4%), followed by build-up (+3.8%), and a drop-in scrubland area (-1.5%) and agricultural areas (-7.9) along with a minor variation in water body (+0.12). Although the time period is quite short in terms of change detection studies still the changes can be observed and mapped accordingly. Even the slightest changes can be monitored with the help of remote sensing techniques.

5. Acknowledgment

The authors would like to thank USGS Earth Explorer for providing the satellite data and UGC for providing financial assistance to the first author. The detailed study was carried out due to the facilities provided by the Department of Environment Management, Guru Gobind Singh Indraprastha University.

6. Conflict of interest: None.

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