

REVIEW ARTICLE

Remote Sensing and GIS in Urban Land Use Change Studies: A Review of Methods and Indian Applications

Dr. Mohan Kalidas Kale*

*Assistant Professor, Department of Geography, Sangameshwar Ratra Mahavidyalaya, Solapur, Maharashtra, India*** Corresponding author***OPEN ACCESS**

This article is licensed under CC BY-NC 4.0.

**ARTICLE HISTORY**

Received: 21 Sep 2026

Accepted: 04 Oct 2026

Published: 14 Oct 2026

CORRESPONDING AUTHOR

Dr. Mohan Kalidas Kale, Department of Geography, Sangameshwar Ratra Mahavidyalaya, Solapur, Maharashtra, India.

HOW TO CITE

Kale, M. K. (2026). Remote Sensing and GIS in Urban Land Use Change Studies: A Review of Methods and Indian Applications. *Global Journal of Advanced Science and Technology*, 1(1), 12–16.

© 2026 The Author(s).

ABSTRACT

Indian cities have expanded rapidly over the last four decades, often faster than planning records can follow. Satellite remote sensing, combined with geographic information systems (GIS), offers a consistent way to map how land is used and how it changes over time. This review examines the methods used in urban land use and land cover (LULC) change studies and the way they have been applied in India. It covers the main sources of free satellite imagery, image pre-processing, classification methods from maximum likelihood to random forests, spectral indices for built-up areas, vegetation and water, accuracy assessment, change detection, and measures of urban sprawl such as Shannon's entropy. Indian studies have shown the value of these methods for cities such as Kolkata and Mangaluru, but many published studies share avoidable weaknesses: small or unreported validation samples, overall accuracy reported without area-adjusted estimates, and classification schemes that are not comparable between studies. The review recommends that urban LULC studies adopt current good-practice guidance on accuracy assessment, use cloud platforms such as Google Earth Engine to analyse long image series, and give more attention to the medium-sized cities, including Solapur, where most of India's future urban growth is expected.

Keywords: Remote sensing; GIS; Land use and land cover; Change detection; Urban sprawl; Landsat; Sentinel-2

1. Introduction

The growth of an Indian city is easy to see from its edges. Agricultural land on the outskirts is subdivided into plots, roads appear before houses, and villages that were once separate become part of the urban area. Tracking this change on the ground is slow and expensive. Census figures arrive once a decade, and municipal records rarely cover the fringe where most new building happens.

Satellite remote sensing changed this. Since the first Landsat satellite in 1972, the same areas of the earth have been imaged repeatedly, and since 2008 the entire Landsat archive has been free to use. With a GIS to combine images with maps, census data and field observations, a geographer can now reconstruct

how a city has grown over several decades. This review describes the methods involved and examines how they have been used in India.

2. Land use, land cover and classification systems

Land cover describes the physical material on the surface, such as buildings, vegetation, water or bare soil; land use describes what people do with it, such as housing, industry or agriculture. Satellite images record land cover directly, and land use must be inferred. Anderson et al. (1976) proposed the classification system that most later studies adapt, with broad first-level classes such as urban or built-up land, agricultural land, forest, water and barren land. Using a standard scheme matters: studies that define their own classes cannot easily be compared.

3. Data sources

Most urban LULC studies in India rely on free medium-resolution imagery (Table 1). The Landsat series offers the longest record at 30 m resolution (Roy et al., 2014), while Sentinel-2, launched by the European Space Agency in 2015, provides 10 m resolution and more frequent coverage (Drusch et al., 2012). Indian Remote Sensing satellites, available through ISRO's Bhuvan portal, are a useful national alternative.

Table 1. Free satellite data commonly used in urban LULC studies.

Sensor	Period of record	Resolution	Revisit	Remark
Landsat 5 TM	1984–2013	30 m	16 days	Basis for historical change
Landsat 7 ETM+	1999 onwards	30 m (15 m pan)	16 days	Data gaps after 2003 sensor fault
Landsat 8 OLI / Landsat 9	2013 / 2021 onwards	30 m (15 m pan)	16 days (8 combined)	Improved radiometry
Sentinel-2 MSI	2015 onwards	10, 20, 60 m	5 days (two satellites)	Best free detail for cities
IRS Resourcesat LISS-III	2003 onwards	23.5 m	24 days	Indian source via Bhuvan

Source: compiled by the author from Roy et al. (2014), Drusch et al. (2012) and agency documentation.

4. Methods

A typical urban LULC change study follows the sequence shown in Figure 1. Each step involves choices that affect the final result.

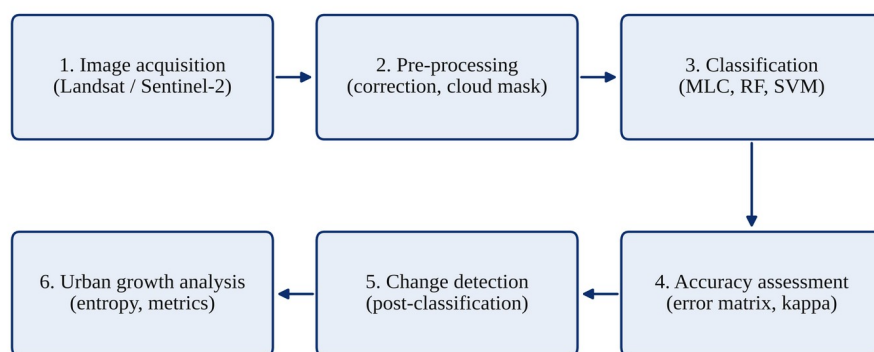


Figure 1. Typical workflow of an urban land use and land cover change study.

4.1 Pre-processing

Images from different dates must be comparable. This requires geometric registration so that the same pixel covers the same ground, atmospheric correction so that differences in haze do not appear as land change, and masking of clouds and their shadows. Analysis-ready surface reflectance products from Landsat and Sentinel-2 now carry out much of this work, which reduces errors that were common in older studies.

4.2 Classification

Supervised classification assigns each pixel to a class using training samples identified by the analyst. Maximum likelihood classification, which assumes that each class follows a normal distribution, was standard for decades and still appears in many Indian studies. Machine learning classifiers have largely replaced it in international work. Belgiu and Drăguț (2016) reviewed the use of random forests in remote sensing and found that they gave high accuracy, handled many input variables and were relatively insensitive to their settings. Support vector machines perform similarly. In fast-growing cities, the main source of error is often the mixed pixel at the urban edge, where a 30 m pixel contains buildings, soil and vegetation together.

4.3 Spectral indices

Spectral indices combine bands to enhance particular surfaces (Table 2). The normalised difference vegetation index (Tucker, 1979) highlights vegetation, the normalised difference built-up index (Zha et al., 2003) highlights built-up land, and the modified normalised difference water index (Xu, 2006) separates water from built-up surfaces. Indices can be used on their own for quick mapping or added as extra inputs to a classifier.

Table 2. Spectral indices commonly used in urban LULC mapping.

Index	Formula	Use in urban studies
NDVI	$(\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$	Separates vegetation from built-up and bare land
NDBI	$(\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$	Highlights built-up surfaces
MNDWI	$(\text{Green} - \text{SWIR}) / (\text{Green} + \text{SWIR})$	Maps water bodies; reduces confusion with buildings

NIR = near-infrared; SWIR = shortwave infrared. Sources: Tucker (1979); Zha et al. (2003); Xu (2006).

4.4 Accuracy assessment

A land cover map is only as useful as its accuracy is known. The standard tool is the error matrix, which compares mapped classes with reference data at sample locations (Congalton, 1991). From it come overall accuracy, user's and producer's accuracy for each class, and, in many studies, the kappa coefficient. Foody (2002) and later Olofsson et al. (2014) argued that kappa adds little and that studies should instead report class-wise accuracies, use a proper probability sample of reference points, and estimate the area of each class and of change with confidence intervals. These recommendations are still rarely followed in Indian urban studies.

4.5 Change detection

Lu et al. (2004) reviewed more than thirty change detection techniques, from simple image differencing to model-based methods. Most urban studies use post-classification comparison: each date is classified separately and the maps are overlaid to produce a matrix of changes, for example from agriculture to built-up land. The approach is easy to interpret, but errors in each map multiply in the change map, which is another reason for careful accuracy assessment.

4.6 Measuring urban sprawl

Change in built-up area says how much a city has grown but not how. Yeh and Li (2001) used Shannon's entropy, calculated from the share of built-up land in zones around the city centre or along roads, to measure whether growth is compact or dispersed: values near zero indicate concentration, values near one indicate sprawl. Landscape metrics, such as the number of built-up patches and their mean size, add detail on fragmentation.

5. Indian applications

Indian studies have used these methods to document both the speed and the form of urban growth. Sudhira et al. (2004) combined remote sensing and GIS to study sprawl along the Mangaluru–Udupi region, using Shannon's entropy and landscape metrics to show dispersed growth along highways. Bhatta (2009) used multi-date satellite images and GIS to analyse the pattern of Kolkata's growth and to measure the degree of sprawl. Many later studies of Indian cities follow the same pattern: two to four Landsat images a decade apart, maximum likelihood or random forest classification, post-classification change detection and an entropy measure of sprawl.

Three weaknesses recur in this literature. Validation samples are often small or not described. Overall accuracy and kappa are reported without class-wise accuracies or area-adjusted estimates. And the classes differ from one study to the next, so results from different cities cannot be compared. Most published studies also concern metropolitan cities, while the medium-sized cities where growth is now fastest, such as Solapur, have received comparatively little attention.

6. New directions

Two developments make better studies easier. Google Earth Engine provides the full Landsat and Sentinel archives and the computing power to process them in the cloud, so that an analyst can classify every year of a thirty-year record rather than two or three dates (Gorelick et al., 2017). And the arrival of Sentinel-2 at 10 m resolution has reduced the mixed-pixel problem at the urban fringe. Combining annual image series with good-practice accuracy assessment would make Indian urban LULC studies both more detailed and more comparable.

7. Conclusion

Remote sensing and GIS give geographers a consistent, repeatable record of how Indian cities grow. The methods are mature, the data are free, and cloud platforms have removed most computing barriers. What the field now needs is rigour rather than new tools: standard classification schemes, proper reference samples, class-wise and area-adjusted accuracy estimates, and attention to the medium-sized cities that will shape India's urban future. Studies of this kind would be of direct use to the town planners and municipal bodies that must manage that growth.

Conflict of interest: The author is the Editor-in-Chief of the Global Journal of Advanced Science and Technology. This manuscript was handled independently by another member of the editorial board, and the author took no part in its review or in the editorial decision.

Funding: This research received no external funding.

Declaration of generative AI use: During the preparation of this work the author used an AI writing assistant (Claude, Anthropic) to help structure and draft the text. The author reviewed, edited and verified the content and takes full responsibility for this article.

References

- Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976). A land use and land cover classification system for use with remote sensor data (Geological Survey Professional Paper 964). U.S. Government Printing Office. <https://doi.org/10.3133/pp964>
- Belgiu, M., & Drăguț, L. (2016). Random forest in remote sensing: A review of applications and future directions. *ISPRS Journal of Photogrammetry and Remote Sensing*, 114, 24–31. <https://doi.org/10.1016/j.isprsjprs.2016.01.011>
- Bhatta, B. (2009). Analysis of urban growth pattern using remote sensing and GIS: A case study of Kolkata, India. *International Journal of Remote Sensing*, 30(18), 4733–4746. <https://doi.org/10.1080/01431160802651967>
- Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37(1), 35–46. [https://doi.org/10.1016/0034-4257\(91\)90048-B](https://doi.org/10.1016/0034-4257(91)90048-B)
- Drusch, M., Del Bello, U., Carlier, S., Colin, O., Fernandez, V., Gascon, F., Hoersch, B., Isola, C., Laberinti, P., Martimort, P., Meygret, A., Spoto, F., Sy, O., Marchese, F., & Bargellini, P. (2012). Sentinel-2: ESA's optical high-resolution mission for GMES operational services. *Remote Sensing of Environment*, 120, 25–36. <https://doi.org/10.1016/j.rse.2011.11.026>
- Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, 80(1), 185–201. [https://doi.org/10.1016/S0034-4257\(01\)00295-4](https://doi.org/10.1016/S0034-4257(01)00295-4)
- Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment*, 202, 18–27. <https://doi.org/10.1016/j.rse.2017.06.031>
- Lu, D., Mausel, P., Brondizio, E., & Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, 25(12), 2365–2401. <https://doi.org/10.1080/0143116031000139863>
- Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., & Wulder, M. A. (2014). Good practices for estimating area and assessing accuracy of land change. *Remote Sensing of Environment*, 148, 42–57. <https://doi.org/10.1016/j.rse.2014.02.015>
- Roy, D. P., Wulder, M. A., Loveland, T. R., Woodcock, C. E., Allen, R. G., Anderson, M. C., et al. (2014). Landsat-8: Science and product vision for terrestrial global change research. *Remote Sensing of Environment*, 145, 154–172. <https://doi.org/10.1016/j.rse.2014.02.001>
- Sudhira, H. S., Ramachandra, T. V., & Jagadish, K. S. (2004). Urban sprawl: Metrics, dynamics and modelling using GIS. *International Journal of Applied Earth Observation and Geoinformation*, 5(1), 29–39. <https://doi.org/10.1016/j.jag.2003.08.002>
- Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8(2), 127–150. [https://doi.org/10.1016/0034-4257\(79\)90013-0](https://doi.org/10.1016/0034-4257(79)90013-0)
- Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International Journal of Remote Sensing*, 27(14), 3025–3033. <https://doi.org/10.1080/01431160600589179>
- Yeh, A. G.-O., & Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. *Photogrammetric Engineering & Remote Sensing*, 67(1), 83–90.
- Zha, Y., Gao, J., & Ni, S. (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. *International Journal of Remote Sensing*, 24(3), 583–594. <https://doi.org/10.1080/01431160304987>