Chapter 14
The Magnitude of Transformation in Land Use Land Cover of Kalyan-Dombivli, Smart City

Astha Smarth Kapur, Pankaj Kumar, G. Areendran, and Krishna Raj

Abstract Kalyan-Dombivli is a twin city in a municipal corporation, with its headquarters located in Kalyan in Thane district in the Indian state of Maharashtra. Besides carrying the impression of a rich cultural heritage and societal vibrance, the historic significance of the city which dates back to the British era is particularly enthralling. Due to its highly educated population (91% literacy rate), it is often called the second cultural capital of Maharashtra after Pune and boasts of a pioneering status in providing E-governance solutions to its residents. A time period of approximately three decades has been considered in order to determine the level of current physical and economic development in the city, an attempt has also been made to substantiate the same, providing sufficient amount of evidence, in the backdrop of GIS and Remote Sensing. To estimate the extent and pattern of change in the land-use and cover of the area, two satellite imageries of the years 1990 and 2017 are selected, over which, hybrid pixel classification is run, and ten classes of varying land-use/cover are created. On its basis, LULC maps have been generated. The subsequent results are pretty much in line with the ongoing increase in population and the developmental activities indicating maximum growth in built-up from 12.7% in 1990 to 31.8% in 2017 and corresponding shrinkage in fallow lands and wastelands from 34% in 1990 to 8% in 2017 and 17% in 1990 to 6% in 2017, respectively. This, to a large extent implies that, the area in a few years may be optimally developed so as to be successfully delineated as a smart city.

Keywords Kalyan-Dombivli · Hybrid pixel classification · Land-use land cover · Normalized difference vegetation index

A. S. Kapur (✉) · P. Kumar
Department of Geography, Delhi School of Economics, University of Delhi, Maurice Nagar, New Delhi, India

G. Areendran · K. Raj
Indira Gandhi Conservation and Monitoring Centre (IGCMC), WWF-India, Lodi Estate, New Delhi, India
e-mail: gareendran@wwfindia.net

K. Raj
e-mail: kraj@wwfindia.net

R. B. Singh et al. (eds.), *Remote Sensing and Geographic Information Systems for Policy Decision Support*, Advances in Geographical and Environmental Sciences,
https://doi.org/10.1007/978-981-16-7731-1_14

14.1 Introduction

Portions of land on the surface of the earth, may be termed as territories belonging to a country, state, district, tehsil or a village and can be occupied by natural components or can be attributed to umpteen number of uses which are of significance to mankind, but essentially all these portions collectively form the land resource. The resource that is a home to almost all types of activities those are associated with humans and other living creatures alike. Land cover fundamentally links and influences the human and physical environment. Any change in herein, can simply be designated as a primary cause affecting the global ecological system that influences the world climate (Vitousek 1994). Due to its widespread availability, humans since times immemorial have always utilized the land resource in manners that make their lives comfortable, be it the era of gathering foods from the forests or cultivation of crops, or the era of construction of offices, industries or residences by clearing the vegetation which even created room for primary, secondary and tertiary activities. Now this land, due to its capability of being able to support both natural covers and myriad land-uses, possesses indescribable amount of vitality for us, and we on our part need to tend it and plan our daily activities judiciously on it. This is known as land-use planning, for which purpose, humans, using their intelligence and wit have devised several usable, comprehensive and authentic methods of successfully carrying out their enterprises, within the boundaries of their territories and in the limited spaces made available to them by their respective governments, without disturbing the delicate balance of the surrounding ecology.

One among these methods involves the use of Remote Sensing and Geographical Information System (GIS) technology. This art, a few calibrated experts have been able to master and it has been trickling down to the common man ever since. The result is satellite-based and computer-aided assessment of land, its existing land covers and uses as well as designing of measures that create scope for enhancement, advancement and optimum expansion, particularly in areas which are designated as cityscapes which are essentially recognized for having a predominance of land-use, over land cover. As in this case, where the current study revolves around the city of Kalyan and Dombivli falling under the jurisdiction of Kalyan-Dombivli Municipal Corporation (KDMC) that has been categorized as a 'Smart City' by the Government of India. This paper deals with the utilization of the Remote Sensing and GIS techniques for providing a suitable analysis of the area with all its land usages and covers. It is most appropriate to commence from the very beginning of this study and thus the paper shall progress through all the steps undertaken, in a chronological fashion, covering the minute details for attempting a logical analysis of the prevalent land-use land cover patterns and the transformations that have occurred over a period of, a little less than three decades, from 1990 to 2017.

14.2 Scope and Objectives

The maps of land-use and cover thus generated shall prove to be highly beneficial in order to come up with lucrative land-use planning ideas and with accountable conclusions to promote a healthy balance between the components of a smart city to reach a situation wherein there is a proportionate allocation of the facilities to the residents. Moreover, urban expansion brings about phenomenal modification in the existing forested tracts, agricultural areas and scrublands, hence, these maps shall pave the way for sustainable land-use planning with minimum threat to the natural environment. The key objective of the study is to generate maps showcasing the land-use and cover of the area under KDMC, with special emphasis on Kalyan and Dombivli City, for two years namely 1990 and 2017, using satellite images, so as to be in a position to be able to assess the magnitude of change that has taken place therein during this time span of 27 years through the method of change detection. And also to calculate the NDVI for the study area, to assess the extent of change in vegetation.

14.3 Study Area

The present study revolves around Kalyan-Dombivli Municipal Corporation Area, situated in Thane District of Maharashtra. Its areal extent is 113.22 km^2. Its latitudinal and longitudinal boundaries span an area of 19°4′–19°14′ N and 72°9′–73°17′ E, respectively. Its northern boundary is flanked by Ulhās Creek and Ulhās and Kalu Rivers. KDMC, prominently covers 8 major township settlements, namely—Kopar, Dombivli, Thakurli, Kalyan, Vithalwadi, Shhard, Ambivli and Titwala. Out of these, Kalyan and Dombivli have seen maximum development and provide residences to a huge number of people who have their offices in Greater Mumbai and Mumbai Suburban. Kalyan-Dombivli contributes approximately 40% to the GDP of the entire state and is regarded as a part of the Mumbai Metropolitan Region (MMR) (KDMC-CDP 2012).

14.4 Materials and Data Used for Land-Use/Land Cover Mapping

For gaining a successful understanding of the land cover, the dynamics and patterns of land utilization, it is imperative to first understand the importance of having and protecting land cover. Only then will the efforts of predicting the impacts of land cover change become meaningful. Since land cover is highly dynamic in nature, thus, it can be understood only with the help of accurate data. This purpose is well served by Remote Sensing, since it is an attractive source of thematic images that

Table 14.1 Details of landsat 5 TM and landsat 8 OLI/TIRS images

S. No	Satellite	Path and row	Date of pass	Characteristics
1	Landsat 5 TM	148 and 047	9th March 1990	Spatial resolution = 30 m No. of bands = 7
2	Landsat 8 OLI/TIRS	148 and 047	30th January 2017	Spatial resolution = 30 m No. of bands = 11

demonstrate the Earth's surface as it actually is (Foody 2002). Hence, for appropriate use in the current study, good quality, cloud-free data, in the form of two satellite images i.e. Landsat 5 with Thematic Mapper (TM) Sensor on board, Path-148 and Row-047 and Landsat 8 with both Operational Land Imager and Thermal Infra-Red Sensors (OLI-TIRS) on board Path-148 and Row-047 for the dates 9th March 1990 and 30th January 2017, respectively, both having a spatial resolution of 30 m each, were downloaded from the USGS Earth Explorer website of NASA (National Aeronautics and Administration) and projected in the Universal Transverse Mercator (UTM) projection (Zone 43 N) in the World Geodetic System (WGS) 1984 datum. Although images of the winter and the spring season i.e. January and March have been chosen but since the area is primarily urban and the process of urbanization per se continues, thus the images of different seasons i.e. winter and spring are not of much consequence. Besides, the areal extent of the green cover for both the seasons has been productively measured. The details of satellite data are shown in Table 14.1.

14.4.1 Software Used

ERDAS IMAGINE 2014 software is an essential and user-friendly application for carrying out various techniques of Remote Sensing. Software ARCMAP VERSION 10.2.1 is a user-friendly application, primarily used to create maps, perform spatial analysis and manage geographic data in an automated scenario. GOOGLE EARTH PRO is a software that readily assists the user in GIS data-related operations like digitization for map creation, visualization, manipulation and exporting of data.

14.5 Methodology

First of all, the shapefile of the study area, acquired from the Kalyan-Dombivli Municipal Corporation office was projected in UTM projection Zone 43 N, WGS 1984 and was geo-referenced. The cloud-free satellite images of the years 1990 (Fig. 14.1) and 2017 (Fig. 14.2), containing the study area were downloaded and layer stacked.

Fig. 14.1 Image 9th March 1990 (downloaded from USGS Website)

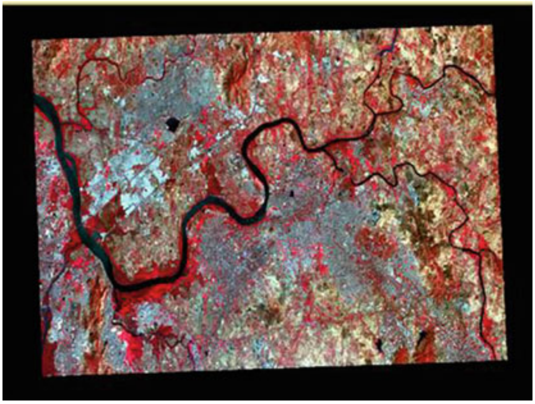

Fig. 14.2 Image 30th January 2017 (downloaded USGS Website)

14.5.1 Method and Procedure

Hybrid Pixel Land-use/Land Cover Classification (using Unsupervised Classification Technique).

This type of classification is attempted by grouping together those pixels that possess spectral similarity, and the resultant classified image is then regarded as a thematic map that highlights the land-use and land cover of the region (Foody 2002). To reach this stage, a number of steps were followed that is the subset of the study area/Area of Interest (AOI) was extracted from the imagery and finally *Unsupervised Image Classification* was run for the multiband imageries. The *ISODATA (Iterative Self-Organizing Data Analysis Technique) Algorithm* is used by Erdas to perform the Unsupervised Classification. It is named as iterative since it repeatedly performs the entire classification and recalculates the statistics. Thus, the output is in the form of a thematic raster layer. It self organizes the pixels present in the image, such that, it locates the clusters inherent in the dataset. This approach is followed in those cases wherein the user wishes to separate those classes that are liable to be confused with some other class. For instance, shadow, water and dark vegetation are quite often mistaken for each other. It also helps in the identification of detailed subclasses in the final classified image. The minimum spectral distance formula is made use of, in the *ISODATA* clustering method, to form clusters. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set, and each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration. Clustering of the image is repeated till the time the execution of maximum number of iterations has taken place or maximum percentage of unchanged pixels has been reached. To ease out the interpretation of the image subset, so that corresponding colours can be assigned to the respective pixels, the colour scheme is selected as False Color Composite (FCC), and the band combination is selected as 4, 3 and 2 for both Landsat Image subsets. By selecting the Unsupervised Classification option, the software allocates the necessary statistics to the image, for classification into various physical features on the basis of different colours. By clicking and selecting various pixels in the image and manually assigning discreet colours to the features present therein, optimum recognition of the land-use land cover classes becomes possible. As a pixel is selected, simultaneously its corresponding class gets highlighted in the attribute table. Thus, a befitting name is entered in the table for the given pixel. On completion of the classification for all the classes, the process of *'Recoding and cleaning'* of the image subset is initiated. This is done so as to limit the classes to a number that is convenient to handle and easily relatable, and furthermore, the image is cleaned in a manner that excess colour is removed or merged into the existing classes to provide a discreet and understandable view of the surface of the study area after the final categorization. For those land-use and cover classes, that are difficult to differentiate from each other, AOIs are carved out through digitization for those specific features and these are then recoded into the requisite class for both the Landsat Image subsets. Then the geo-referenced shapefile of the study area is clipped from the image subset. This clipped portion is then used for preparation of LULC maps for the two given years (Figs. 14.3 and 14.4). Table 14.2 denotes the LULC classes used for identifying the changes that occurred in a time span of 27 years from 1990 to 2017. A total of ten classes were used in the classification.

14.5.2 Change Detection

It is pretty obvious that readily perceptible changes in LULC have occurred in the study area within a considerable time gap of 27 years. Hence, the change detection technique comes in quite handy in this situation. The change though is evident from the satellite image itself, but in order to arrive at accurate conclusions, it became requisite to proceed through the above procedures and finally prepare a matrix to appropriately and sufficiently showcase the magnitude and extent of occurrence of

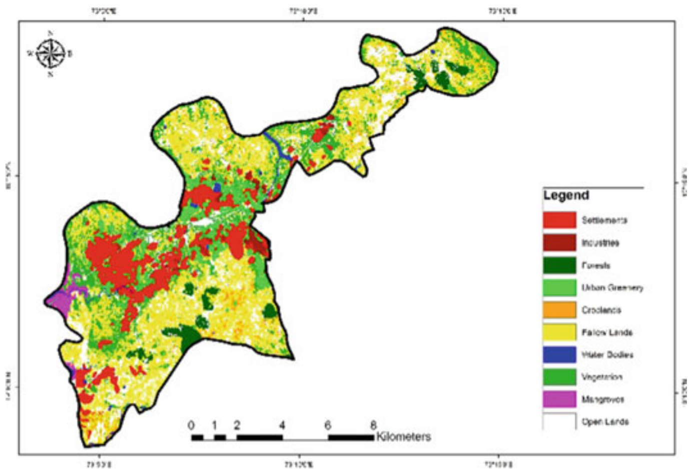

Fig. 14.3 Land-use/cover map of KDMC, 1990

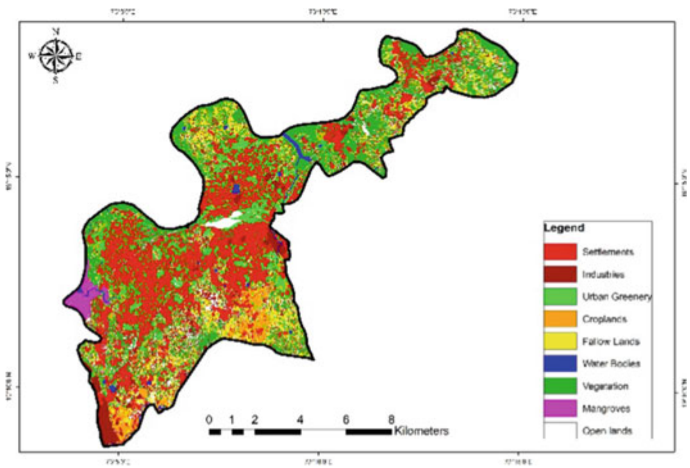

Fig. 14.4 Land-use/cover Map of KDMC, 2017

the change to provide a better understanding of the same. For correctly detecting the change in LULC, a change detection matrix has been created.

14.5.3 Accuracy Assessment

There may arise disagreements between the two data sets i.e. the remotely sensed data and the LULC map derived from it. These are collectively termed as errors (Congalton

Table 14.2 LULC classes for 1990 and 2017

Land-use land cover class	General description
Settlements	Buildings used for residential purposes
Industries	Buildings used for commercial purposes
Forests	An area at the fringe of settlements, and crown density of less than 10% of the canopy cover
Urban greenery	Land dedicated to parks, gardens or green areas between habitations
Cropped-land	Land used for current cultivation, with crops
Fallow land	The lands used for cultivation but left uncropped for one or more seasons
Water bodies	An area covered with water, in the form of lakes, ponds, canals and rivers
Vegetation	Landscape dominated by scrubs, having a tendency of intermixing with cropped areas
Mangroves	An evergreen vegetation type that grows along tidal creeks in coastal areas in the tropics
Open lands	Lands left vacant or used for commercial purpose like roads, railways etc.

1991; Smedes 1975). Thus, accuracy assessments are essentially vital for any user of the LULC classification techniques so as to judge the level of precision and to arrive at satisfying outcomes. It also provides scope for further rectification. Till the time the accuracy of any classification is assessed, it is not considered complete (Lillesand and Kiefer 2000). There are several options available for accuracy assessment, but Cohen's KAPPA Analysis is preferred in this case for checking the accuracy of the Unsupervised LULC classification. It is a discreet multivariate measure of agreement, used in several classifications. The overall classification accuracy came out to be 82.00%.

14.5.4 NDVI Calculation

With the completion of the LULC classification, began the segment of the Normalized Difference Vegetation Index (NDVI) calculation. The Normalized Difference Vegetation Index (NDVI) is a numerical indicator which is widely applicable in vegetation studies, as it optimally indicates the extent of pasturelands, crop yields, healthy and unhealthy vegetation, carrying capacities of range lands and the like. It is highly advantageous for analysing the remotely sensed vegetation measurements and to identify the presence of live green vegetation in the observed target. It is computed using the visible red and the near-infrared bands of the electromagnetic spectrum. Healthy vegetation absorbs most of the visible light that falls on it and reflects majority of the near-infrared light. Contrary to this, unhealthy or sparse vegetation reflects most of the visible light and absorbs the near-infrared light. (Holme et. al, 1987). A larger difference between the near-infrared and the red reflectance points to the fact that there is a higher incidence of vegetation in that particular region. Thus for the present study, NDVI for both the images Landsat 5 TM and Landsat 8 OLI/TIRS is calculated with the help of the formula:

NDVI = (NIR - RED) / (NIR + RED) or
NDVI = (Band 4 – Band 3) / (Band 4 + Band 3) in case of Landsat 5 TM

For Landsat 8 OLI/TIRS the following formula was used:

NDVI = (NIR - RED) / (NIR + RED) or
NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)

Finally, the study area being clipped from the resultant image is reclassified to restrict the number of classes to 5 for 1990 image and 4 for 2017 image and bring out precise depiction of NDVI. The colour scheme of the obtained areas is then changed to the most befitting one for the appropriate demarcation and precise understanding of the vegetation for the specified area (Figs. 14.5 and 14.6). The values for NDVI range between −1 and + 1. The area covered by vegetation, after calculation came out to be 18.68 sq. km. for 1990 and 12.68 sq. km for 2017. This emphatically indicates that the green cover has systematically declined over the area especially in the Kalyan-Dombivali twin city, so as to make room for construction activities and facilities that are a prerequisite in a smart city. Albeit, the practices of environmental conservation have not been totally compromised, and the importance of green cover in such an upcoming urban area has not been undermined.

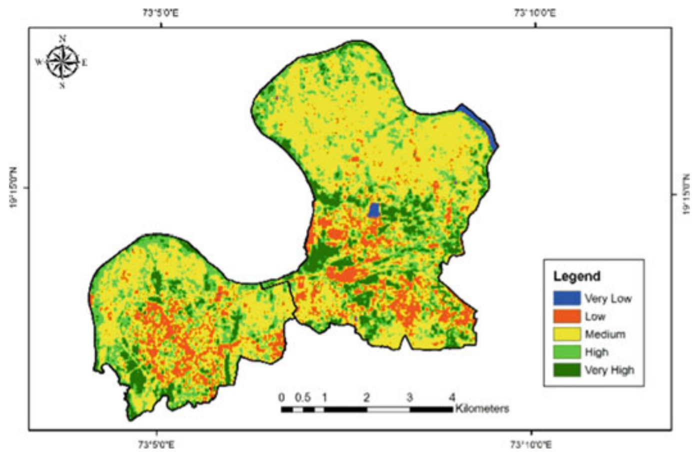

Fig. 14.5 Kalyan-Dombivli NDVI, 1990

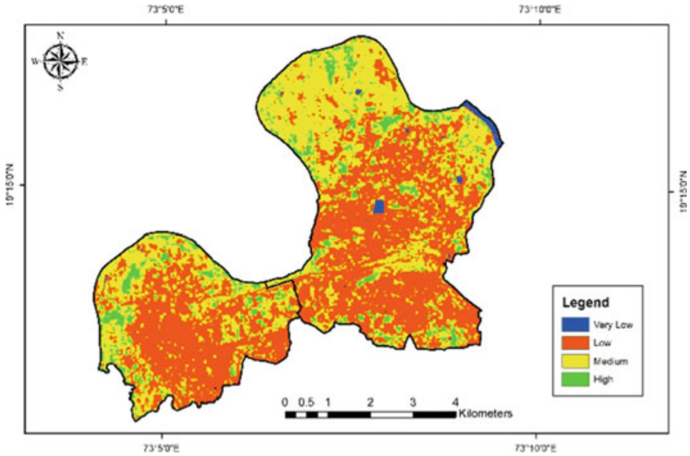

Fig. 14.6 Kalyan-Dombivli NDVI, 2017

14.6 Results and Discussion

As is quite evident from Figs. 14.1 and 14.2, the subsets for the years 1990 and 2017 have been carved out from Landsat 5 TM and Landsat 8 OLI/TIRS, respectively. Land-use/cover maps have been generated, as can be seen in Figs. 14.3 and 14.4. These maps clearly indicate changes in LULC that have taken place over the last 27 years, but in order to be precise with the changes, a table of change detection has been created, showcasing the 10 classes (Tables 14.3 and 14.4).

The Tables 14.3 and 14.4 indicate likely changes in the LULC of the region. The most conspicuous ones stand highlighted in the tables. These include the categories

Table 14.3 Land-use/cover KDMC, 1990

Class name	Area in Sq. Kms	Area in %
Settlements	14.37	12.70
Industries	1.26	1.11
Forests	3.96	3.50
Urban greenery	5.20	4.59
Croplands	5.65	4.99
Fallow lands	38.42	33.93
Water bodies	1.30	1.15
Vegetation	22.39	19.77
Mangroves	1.56	1.38
Open lands	19.33	17.08
Total	113.22	100.00

Source: *Land-use Map of KDMC, 1990*

Table 14.4 Land-use/cover KDMC, 2017

Class name	Area in Sq. Kms	Area in %
Settlements	35.99	31.79
Industries	6.23	5.51
Forests	0.00	0.00
Urban greenery	12.61	11.14
Croplands	9.13	8.07
Fallow lands	9.04	7.98
Water bodies	1.32	1.17
Vegetation	30.36	26.81
Mangroves	1.34	1.19
Open lands	6.97	6.15
Total	113.22	100.00

Source Land-use Map of KDMC, 2017

of settlements plus industries which can collectively be termed as the built-up in the region. This category points to the maximum swell, owing to in-migration of population from the heavily congested parts of Mumbai in search of bigger, better and cost-effective houses, plus employment opportunities in the industries, as the cities of Kalyan and Dombivli lie in close proximity. The built-up class has witnessed a rise of 23.5% in 2017 from 1990. There is a complete loss of forests, which had a crown density of less than 10% of the canopy cover. But this may be attributed to the expansion of the cityscape and conversion of the forested tracts into croplands or lands with light vegetation in the form of scrub. Furthermore, the 26% decline in fallow lands in 2017 and 11% fall in open or vacant lands clearly point to the fact that there is rapid urbanization in the area and in order to cater to the food requirement and demand of space for settlements of the growing population, the fallow and vacant areas have been consumed majorly by the builders for establishing residences, and entrepreneurs for establishing service industries or shopping complexes, partially by the cropped lands to meet the food requirements, and also by the vegetation and urban greenery for beautification of the area. The open/ vacant lands, fallow lands and forests can be seen prominently diminishing, for this is the price required to be paid for rising urbanization! From the two maps of Kalyan and Dombivli (Figs. 14.7 and 14.8), a remarkable expansion in the built-up area can be perceived.

These point to the fact that there has been a considerable increase in the construction activity in 27 years, which is attributable to the influx of population from the crowded parts of Mumbai and suburbs due to provision of affordable housing, basic amenities, inviting infrastructure and peaceful ambience. Majority of the population residing here belongs to the literate middle-income group.

The graph in Fig. 14.9 represents the amount of area occupied by the different types of land-uses and covers in KDMC. Out of the total area of 113.22 km^2, maximum area 38.42 km^2 was occupied by fallow land, indicating that in the year 1990, the area was primarily agrarian and the population was predominantly engaged in primary

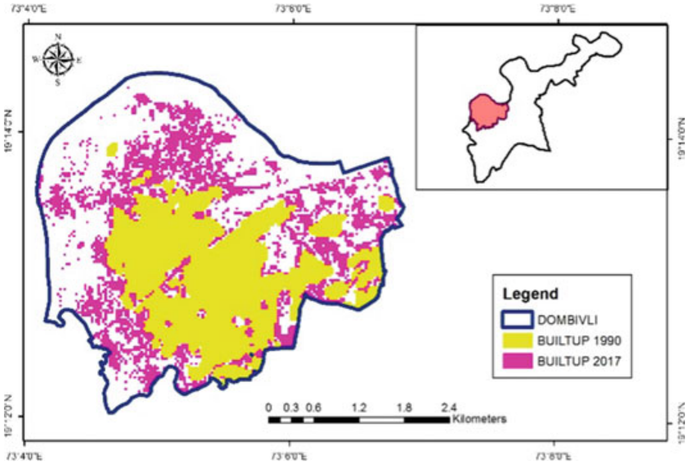

Fig. 14.7 Built-up increase, Dombivli, Since-1990

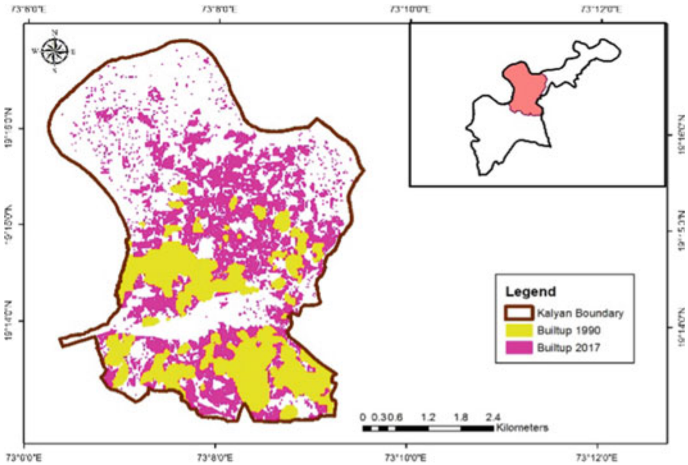

Fig. 14.8 Built-up Increase, Kalyan, Since-1990

activities, and the second highest area was under scrubland vegetation which also points to the presence of primary sector activities and the least area was occupied by industries suggesting minimal engagement in secondary and tertiary activities. The 14.37 sq. km area under settlements housed this agrarian population along with some immigrant population from the neighbouring areas. On the other hand, the graph of LULC of KDMC in 2017 brings to light an overwhelming rise in the area under settlements, as the subregion in a time span of a little less than three decades has acted as a magnet for attracting a tremendous population towards itself, especially those people who came looking for better opportunities in terms of residences,

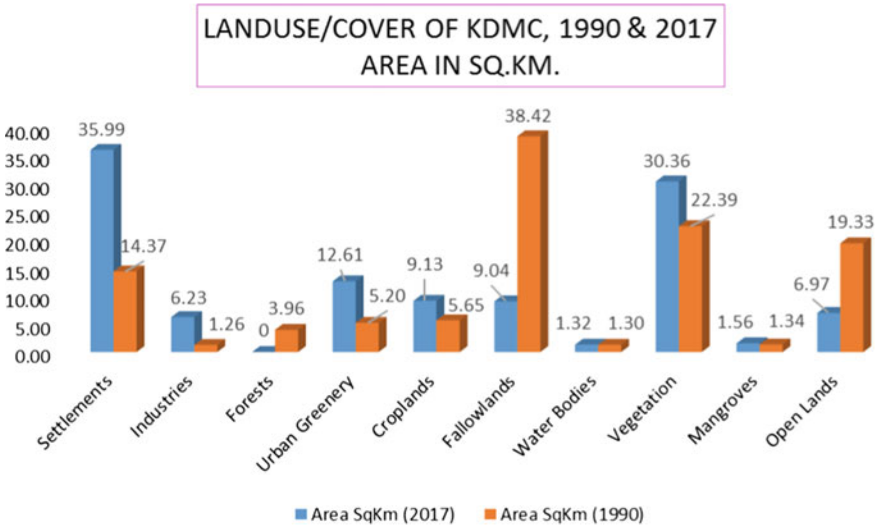

Fig. 14.9 Land-use/cover of KDMC, 1990 and 2017

infrastructure and economy. Moreover, there has been a significant rise in the area under industries i.e. 6.23 sq. km from 1.26 sq. km, this is sufficient to showcase the level of involvement of the people in the secondary sector and also points to a shift in the pattern of employment and their sources of livelihood. The forests have been depleted to make room for construction activities, agriculture and at places these have been replaced by plain vegetation. On comparing the two years, it becomes evident that though there has been a drastic increase in land uses, but it has not been so at the expense of land cover to a superior degree thus keeping the environmental aspect in view and giving it due importance. The urban greenery has duly swelled to prevent KDMC from turning into a concrete jungle.

Maps of Dombivli for 1990 and 2017 (Figs. 14.10 and 14.12) and their corresponding pie charts (Figs. 14.11 and 14.13) of the same years (1990 and 2017) reveal the reality of the ongoing change in the LULC in Dombivli in the last 27 years. There has been a remarkable rise in the settlements from 34% in 1990 to 49% in 2017. The industries have also grown by 1% to synergize the employment scenario. The improvement in urban greenery has perfectly blended with the built up, offering spaces for healthy living. The agricultural lands have been pushed away to the peripheral areas, and the open lands that were lying vacant have been judiciously used as lands of financial worth.

An attentive look into the scenario of LULC in Kalyan unfurls a similar pattern as can be seen in the case of Dombivli (Figs. 14.14 and 14.16). Herein, the rise in residences has been brisk and greater in comparison to its twin city, marking a 21% rise from 1990, and there has been a corresponding increment in the urban greenery as well. The industries have grown by 2% which primarily include service industries, municipal workshops, bus depots and treatment plants. The open and

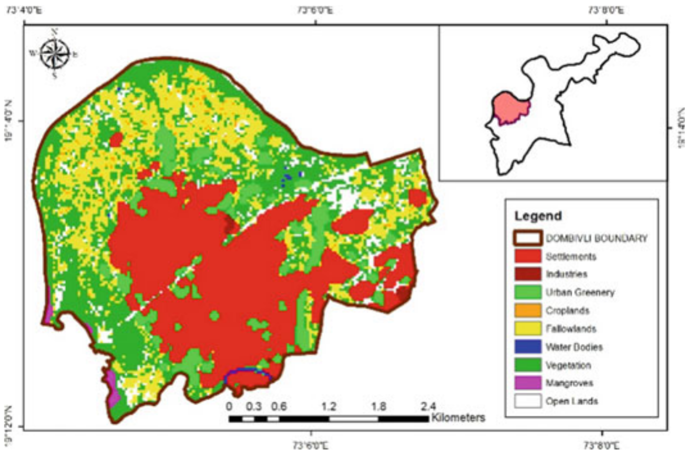

Fig. 14.10 Land-use/cover of Dombivli in 1990

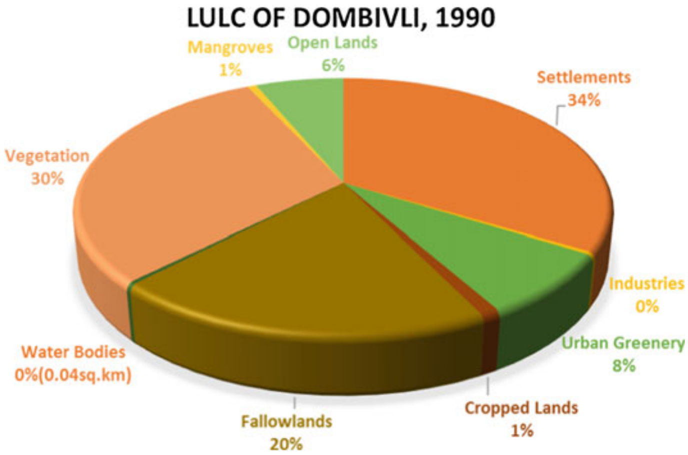

Fig. 14.11 Pie chart showing LULC of Dombivli, 1990

vacant lying lands which in 1990 were sporadic but plentiful in Kalyan, now support plush greenery, residential buildings and structures of public utility (Figs. 14.15 and 14.17). Worth mentioning is the fact that the water bodies in the form of ponds and lakes have been given their due importance and even practices of beautifying them are underway to convert them into spots of recreation and tourist attraction.

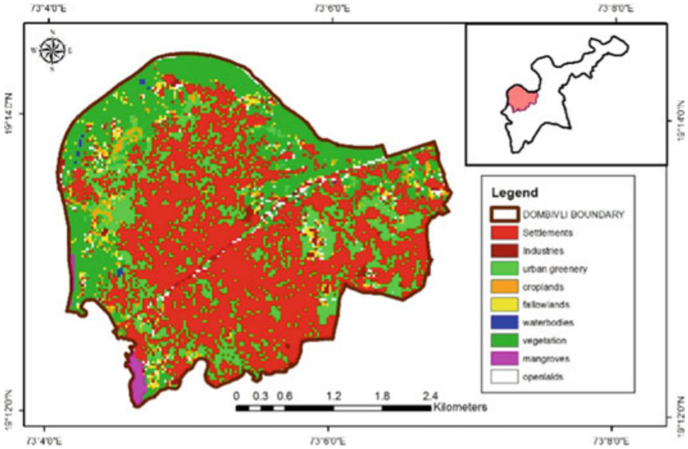

Fig. 14.12 Land-use/cover of Dombivli in 2017

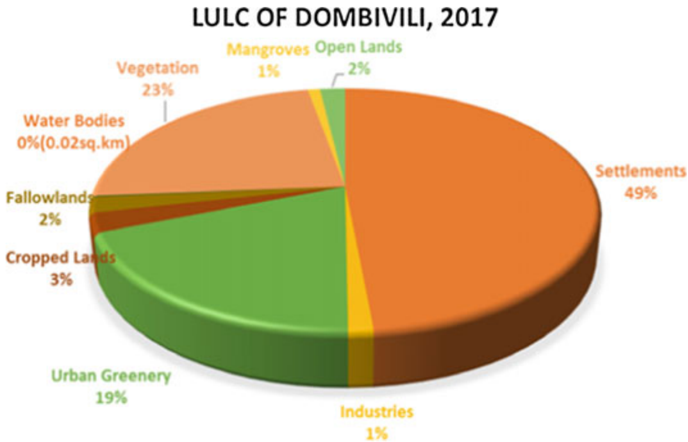

Fig. 14.13 Pie chart showing LULC of Dombivli, 2017

14.7 Conclusion

From the above data, observations and discussions, it can logistically be concluded that the land-use and cover of the area in question have drastically changed, wherein land-use, in comparison to land cover has overwhelmingly expanded, converting it from an area of predominantly agrarian nature to one with organized urbanization. This change owes its existence to improvements in technology, in incomes and occupations which in turn has significantly altered the standard of living of the existing residents and those who moved in from other parts of Maharashtra in search of better accommodation. The area also supports several rented settlements and hotels suitable

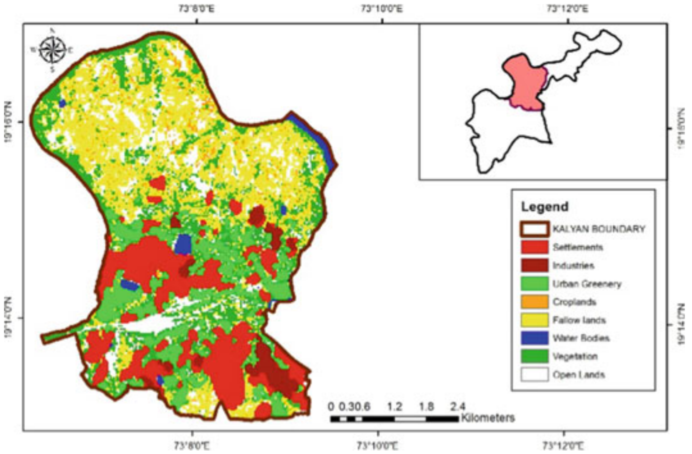

Fig. 14.14 Land-use/cover of Kalyan in 1990

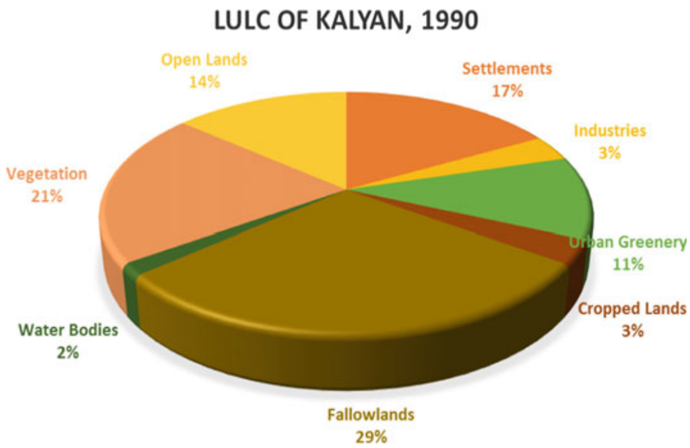

Fig. 14.15 Pie chart showing LULC of Kalyan, 1990

for the low, middle and high income bearers. Besides this, the presence of the municipal corporation headquarters and regional office makes the area administratively sound. There has been a welcome expansion of the cityscape which is inclusive of the facilities of comfortable as well as luxurious living. The marketplace is flooded with all types of commodities ranging from those of daily needs like grocery, to clothes of international brands. Not excluding repair shops, warehouses, even multiplexes and malls. The most striking feature about the population is that 91% of it is educated and a majority of the people belongs to the middle-income category who are extremely aware about their surroundings and government policies. As far as the Normalized Difference Vegetation Index (NDVI) is concerned, a net decrease of

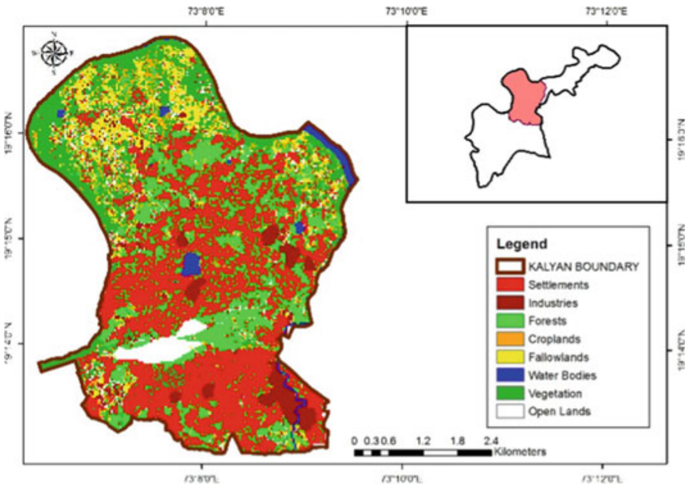

Fig. 14.16 Land-use/cover of Kalyan in 2017

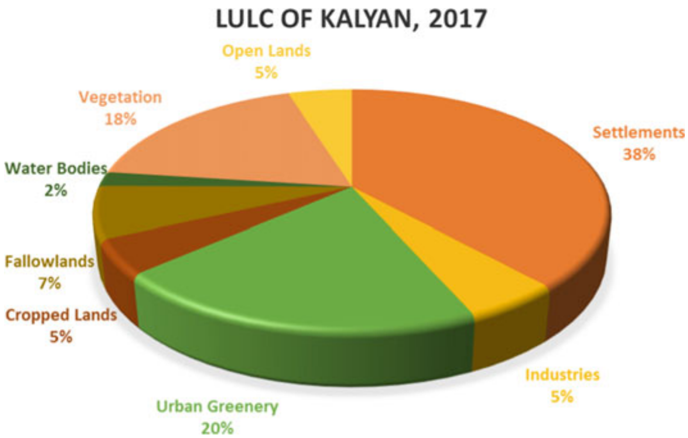

Fig. 14.17 Pie chart showing LULC of Kalyan, 2017

6 sq. km from 1990 to 2017 has been recorded. But nevertheless, there has been a visible upgradation of the greening activities around the buildings in the region. Thus in a nutshell, it can be concluded that with further investment, proper funding and improved citizen participation, the area shall see speedy returns in terms of becoming a smart city as projected by the central government and urban local bodies.

Acknowledgements For any research procedure to reach a successful conclusion, several factors and resource persons play a vital role. Similarly, this paper is an articulation and embodiment of the consistent and efficacious efforts and timely inputs in the form of guidance which was genuinely and abundantly provided by my mentor and guide Dr. Pankaj Kumar (Assistant Professor, Delhi

School of Economics, University of Delhi) as well as Dr. G. Areendran (Dr. G. Areendran, Director and Head of IGCMC division, WWF-India) and Dr. Krishna Raj (Senior Program Officer IGCMC division, WWF-India) who paved the way for me to learn the necessary software in WWF and made accessible several data (apart from whatever I collected during field surveys) required to produce the desired outcomes. Their contribution in this paper is undeniable and profound.

References

Anonymous. https://www2.le.ac.uk/departments/physics/research/eos/format-eo/2014-example-outputs/land-classification-tutorial.

Census of India (2011) Village and town directory, series-28, part XII-A, district census handbook. Census of India, Thane, Maharashtra

Congalton RG (1991) A review of assessing the accuracy of classifications of remotely sensed data. Rem Sens Environ 37:35–46

Foody GM (2002) Status of land cover classification accuracy assessment. Rem Sens Environ 80:185–201

George J et al (2016) Land use/land cover mapping with change detection analysis of Aluva taluk using remote sensing and GIS. Int J Sci Eng Technol 4(2):383–389

Holme A et al (1987) The development of a system for monitoring trend in range condition in the arid shrub-lands of Western Australia. Aust Rangeland J 9:14–20

Kafi KM et al (2014) An analysis of LULC change detection using remotely sensed data: a Case study of Bauchi City. IOP Conf Series: Earth Environ Sci 20:1–9. https://doi.org/10.1088/1755-1315/20/1/01205

KDMC (2012) Revised city development plan. Kalyan-Dombivli Municipal Corporation, Thane, Maharashtra

Lillesand TM, Kiefer RW (2000) Remote sensing and image interpretation, 4th edn. Wiley, New York

Mallupattu PK et al (2013) Analysis of land use/land cover changes using remote sensing data and GIS at an urban area, Tirupati, India. Sci World J 2013:6

NRSC. http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0405.pdf

Roderick M et al (1996) Calibrating long term AVHRR derived NDVI imagery. Rem Sen Environ 58:1–12

Smedes HW (1975) The truth about ground truth. In Proceedings 10th international symposium on remote sensing of environment, pp 821–823.

USGS. https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

USGS. https://earthexplorer.usgs.gov/

Vitousek PM (1994) Beyond global warming: ecology and global change. Ecology 75:1861–1876