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LAND-USE CHANGE DETECTION AND ASSESSMENT FOR SUSTAINABLE DEVELOPMENT OF PERI-URBAN AREAS USING REMOTE SENSING AND GIS: A CASE STUDY OF COIMBATORE CITY, TAMIL NADU, INDIA

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Abstract. Aimed at urban planning as well as environmental management of quickly growing cities, the detection of future urban growth is extremely helpful today. This paper endeavours to detect and assess the present as well as future growth of peri-urban regions of Coimbatore city of Tamil Nadu in India by evaluating the Land Use Land Cover (LULC) changes with the aid of the satellite images. The present research work estimates the LULC changes over '3' decades of 1997, 2009 and 2017 with the aid of Remote Sensing (RS) as well as Geographic Information System (GIS) approaches to effectively predict the urban growth specifically in the years 2030 along with 2040 by employing the Artificial Neural Networks (ANN) centred GIS land-use change modeller analysis tool. The outcomes of the study implied that the built-up (BU) land augmented by 12.18% between 1997 and 2009 and 41.03% between 2009 and 2017 in the PU regions. The predicted LULC outcomes specify that those lands would augment between the years 2017 and 2030 by 69.53% and between the years 2030 and 2040 by 29.85%. This rapid augmentation in the BU land calls for the attention of the urban planners and administrators towards the proper planning of the Study Area (SA) to ensure sustainable development.

Keywords: Peri-urban (PU), Geographical Information System (GIS), Artificial Neural Network (ANN), built-up land.

AIMS AND BACKGROUND

Because of the recent swift peri-urbanisation process, a substantial urban extension is happened in India[1]. PU areas are fringe regions of cities or adjacent rural areas that intrinsically relate the city's financial system, undergo a constant transformation, and have a blend of rural with urban activities[2]. Already these core urban and sub-urban regions are being saturated with zero opportunity for additional developments, thus, a demand for settling the fast-growing populace in the PU regions is urging. Regarding the 2011 Census done in India, urbanisation has

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augmented quicker than anticipated. India has a higher urban populace of 31.16% (Ref. 3) with Tamil Nadu being one of the foremost urbanised states since 1971, with above 40% of the urban populace. In which Coimbatore is a major city of Tamil Nadu has a populace of 29.17 lakhs (2001) as well as 34.58 lakhs (2011) encompassing 1.6% t populace growth rate. This urbanisation model challenges the conception of sustainability. It carries a negative effect on environmental and also socio-economic systems[4]. The rapid increase of urban agglomerations has escalated alarms for effectively mapping and observing the urban and PU areas in the perspectives of scientific land utilisation planning, environmental, along with developmental programmes[5]. The development can well be monitored by means of estimating the LULC (Ref. 6) change patterns over the PU regions. In the last 2 decades, RS techniques are chiefly utilised for LULC change detection that permits for the precise characterisation of LULC change, comprising urban expansion[7]. The chief contributions of this work are to ascertain the spatial scope of urban LULC changes in Coimbatore city utilising RS and GIS, and to scrutinise the effect of urban changes on the spatial constitution of urban landscapes of the study field.

Jinrong Hu and Yuanzhi Zhang[8] recommended the seasonal changes utilising multiple-temporal images attained from MODIS during LULC classes in a quick urbanising area. The approach of maximum probability was effectuated to extract the '5' classes of LULC. A post-classification-type change detection (CD) was then employed to effectively ascertain the changed sorts. The Image Classification (IC) accuracy was satisfactorily contrasted with other studies. Nevertheless, there was an issue of the spatial dispersion of errors and this could limit and also influence the classification accuracy. Firoz Ahmad et al.[9] developed multiple LULC maps specifically for the urban regions of Ranchi in India. It estimated LULC changes utilising geospatial tools namely GIS and RS. Several datasets like LANDSAT TM and 8 OLI, and ETM of years 2015, 1989, and 2002 bearing satellite imageries were deployed for analysing urban LULC changes, which was then employed for predicting changes in 2015 and also 2028 utilising Markov transition matrix (MTM) and was as well cross-verified with real LULC of 2015. The data gathered as of coarse resolution-type temporal satellite could effectively be harnessed to evaluate LULC change but a prediction could be made with 89.02% accuracy grounded on MTM. Alemayehu Shawul and Sumedha Chakma[10] put forward a Supervised Image Classification (SIC) approach for determining the past LULC changes grounded on 1984-LANDSAT 5 TM, 1972-LANDSAT 1 MSS, 2014-LANDSAT 8 OLITIRS together with LANDSAT 7 ETM+2000. The LULC change in future was as well estimated utilising the machine-learning methodologies of Land Change Modeller. The LULC-CD revealed significant increment in the cropland and urban regions, and decrement trending in the pasture, shrub land coverage, and forests. Outcomes corroborated that excellent Kappa coefficient (KC) and accuracy was acquired for LULC 2014 on considering LULC 1972.

EXPERIMENTAL

Study area. The SA encompasses the PU regions, i.e. 10 km buffered area as of Coimbatore Municipal Corporation (CMC) limits. The entire area of CMC is 257.07 km^2 in which 1052.29 km^2 are taken. The total populace of the Coimbatore district on the 2011 population census was about 34.58 lakhs, in which around 75.73% of the populaces live in an urban region[3].

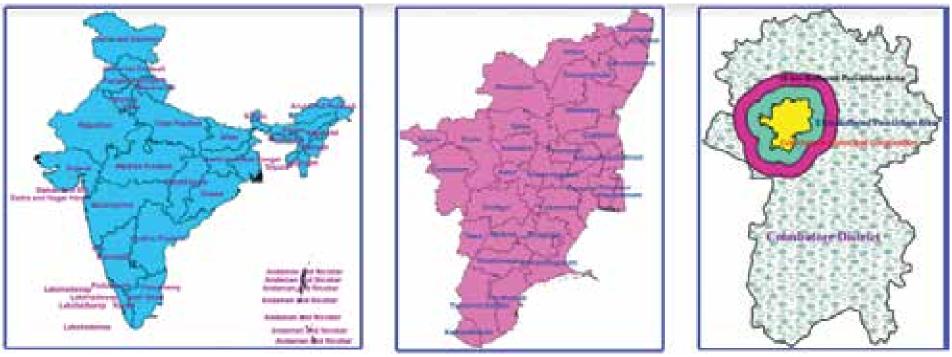


Fig. 1. Key map of SA

Amongst the Indian cities, Coimbatore urban populace has given the rank of 16. Large-scale agriculture along with livestock is being widely practiced in this district that composes the commonest land use activity. Figure 1 clearly displays SA. The SA is located in the latitudes 76°46′44.814″E – 77°9′28.572″E as well as longitudes 10°49′16.859″N – 11°11′37.622″N. The SA is included in the Survey of India (SoI) toposheets 58A/16, 58B/13, 58E/4 as well as 58F/1 in the scale of 1:50 000. CD of LULC–centric study was executed for the urban as well as PU region of Coimbatore city. The CMC limit, constituting the urban along with sub-urban areas was regarded as Zone 1. The SA encompassed Zone 2 and Zone 3, wherein, Zone 2 alludes to the 5 km buffered area as of the CMC boundary. Zone 3 comprises the 5 km buffered area as of the boundary of the Zone 2 (10 km buffered area as of the CMC boundary). The research method has the below workflow (Fig. 2).

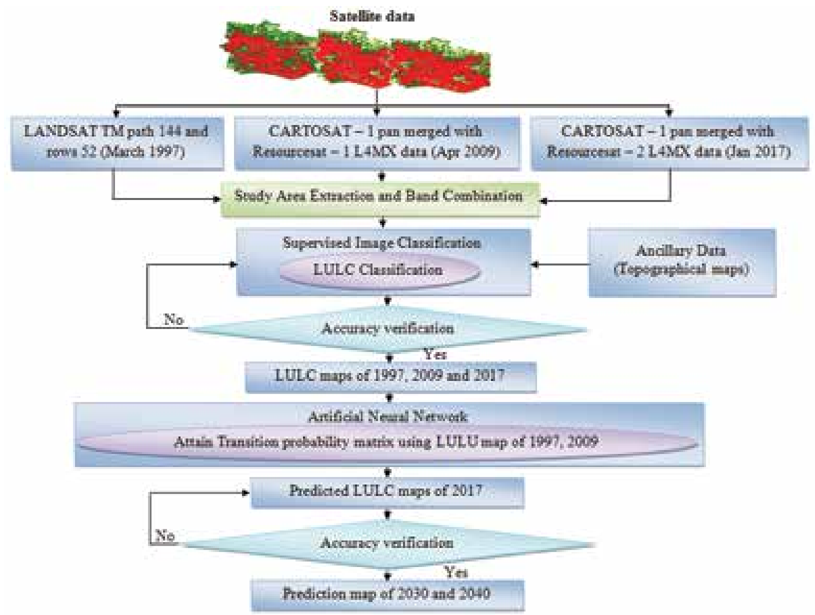


Fig. 2. Research methodology flowchart

Data collection. The toposheets for inputted dataset comprises topographical map numbers 58A/16, 58B/13, 58E/4, together with 58F/1 that are attained as of the SoI.

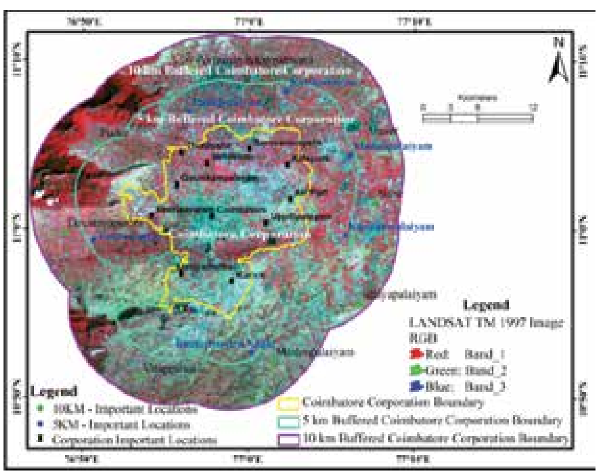


Fig. 3. LANDSAT TM 1997 satellite image

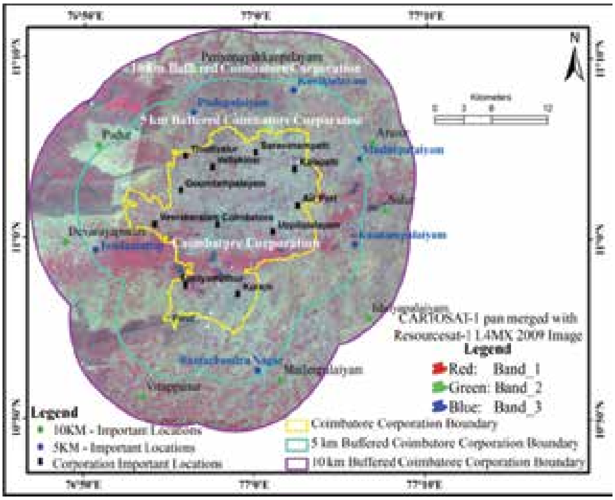


Fig. 4. CARTOSAT-1 Pan merged with Resourcesat-1 L4MX 2009 satellite image

The inputted satellite images were purchased from National Remote Sensing Centre, Hyderabad. The downloaded digital data of LANDSAT TM path 144 as well as row 52 (March 1997) is exhibited in Fig. 3. Resourcesat-1 (16-Feb-2009) L4MX data of Spatial Resolution (SR) 5.8 m fused with CARTOSAT-1 (Apr 2009) PAN data of 2.5 m SR encompassing path 0545 and also row 0344 was utilised. The CARTOSAT-1 pan fused with Resourcesat-1 L4MX data is exhibited in Fig. 4. Resourcesat-2 (05-Jan-2017) IRS-R2A L4FX data of SR 5.8 m fused with CARTOSAT-1 (Apr 2017) PAN_AFT data of SR 2.5 m encompassing path 0543 as well as row 0344 was also employed. The CARTOSAT-1 pan fused with Resourcesat-2 L4FX data is exhibited in Fig. 5. In the research of LULC classification and its accuracy evaluation, the topographic maps along with GPS points were considered. Topographic maps at the level of 1:50 000 were attained as of the Geological SoI Mapping, and were scanned to digital form and anticipated to WGS1984, TM zone 44N. When the GPS points were amassed, the land cover type and the point location description was recorded. For countering the inaccessible points on the SA, the data were amassed on the main roads, the roads' intersection, together with famous locations.

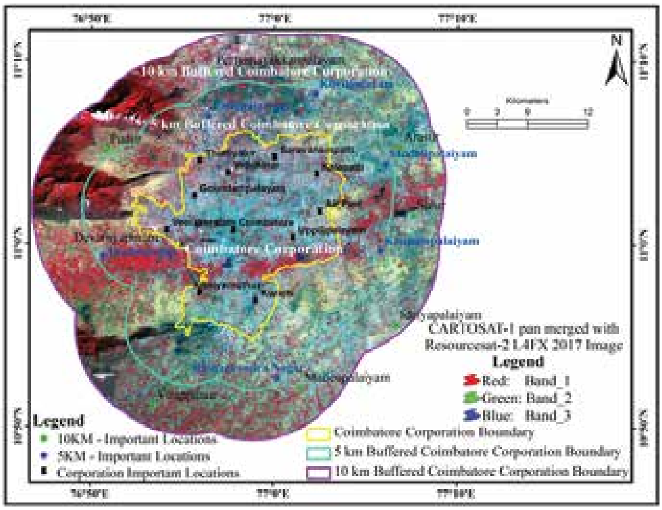


Fig. 5. CARTOSAT-1 pan merged with Resourcesat-2 L4FX 2017 satellite image

LULC classification using supervised image classification. IC procedure is utilised for the automated classification of all pixels in a terrain image into LULC classes. The proposed work utilises a SIC approach. The SIC approach is grounded on the notion that a user could choose sample pixels in an image that are representative of specified classes, and subsequently, the Image Processing software is directed to ground truth (GT), that is, area or training sites (TS) as references for the classification of all other image-pixels. This work utilises GT information-2017 as TS for LULC classification. The captured LULC images are examined and future CD is executed.

LULC change detection. CD implies a 'process of discovering differences in the states of an object by perceiving it many times'. The output attained from the LULC images is sent to the ANN for finding the future LULC image. ANN encompasses an input, hidden, along with output layer[11]. ANN algorithm utilises back propagation, which is the utmost commonly utilised sort of neural computing in RS. In ANN, train the neurons with the LULC of the year 1997 and 2009, and then, evaluate the transitions' potential, for which the year 1997 is concerned as a base layer and land use of 2009 was a transition year, utilising which the LULC for 2017 was developed. Split the sample dataset as a training set as well as a test set centred on the user setting. During iterations, update the ANN to fit the training set, and verify the outcome in the validation set[12], which means the predicted 2017 image is analogised with the original LULC image of 2017. Now, the LULC images of 2030, as well as 2040, are predicted utilising 1997, 2009, and 2017 images. Accuracy assessment for the predicted LULC-2017 map was done grounded on GPS data for validating the proposed LULC CD system's effectiveness.

RESULTS AND DISCUSSION

During LULC classification, the SA (Coimbatore) is classified and plotted utilising 3 satellite images, namely LANDSAT TM multispectral image (1997), Cartosat-1 Pan merged with Resourcesat-1 L4MX satellite image (2009) as well as Cartosat-1 Pan merged with Resourcesat-2 L4FX satellite image (2017) into 11 LULC classes: (a) Built-up (BU) land; (b) Crop land; (c) Fallow land; (d) Hill and forest; (e) Land with scrubs; (f) Land without scrub; (g) Mining process; (h) Plantations; (i) Water bodies; (j) Water bodies with vegetation, and (k) Water channel area[13,14]. These LULC classified images contain both past and current valuable information about the LULC pattern. This SA is separated as 3 Zones: Zone 1 representing the Coimbatore Corporation Boundary, Zone 2 signifying 5 km Buffered Coimbatore Corporation Boundary, and Zone 3 indicating 10 km Buffered Coimbatore Corporation Boundary.

LULC classification analysis. The LANDSAT TM Multi-spectral image (1997) undergoes a SIC process, and the resultant LULC spatial map (Fig. 6) evinced that the urban development in respect of BU land was mainly from the central part to outer regions of the CMC.

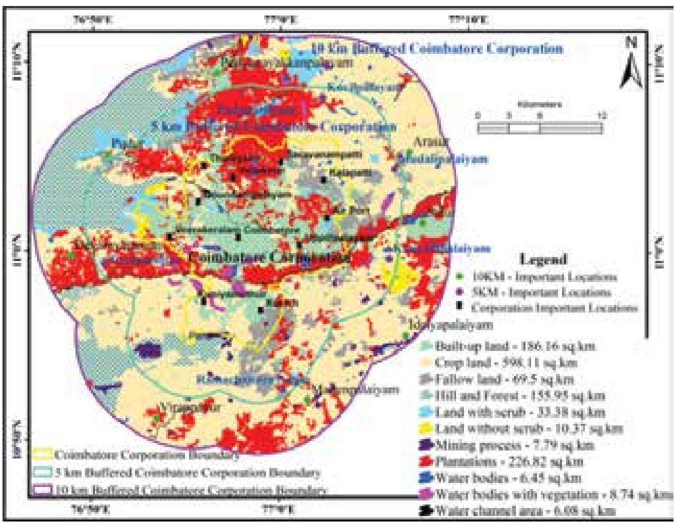


Fig. 6. LULC 1997 spatial map

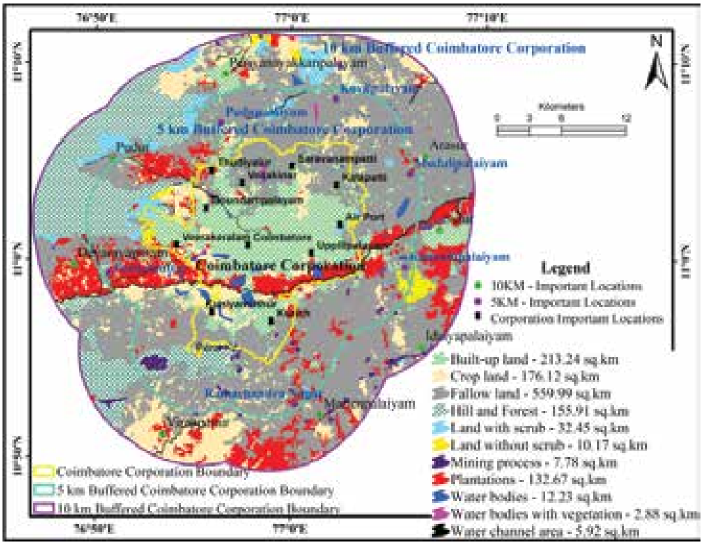


Fig. 7. LULC 2009 spatial map

In analysing Fig. 6, the SA in 1997 was mostly covered by the agricultural lands of the crop. The cropland covered about 598.11 km^2, which is 45.67% of the total SA, whereas, other agricultural lands like fallow and plantation cover 69.5 km^2 (5%) and 226.82 km^2 (17%) of area, respectively. The plantation area is the 2nd dominant class, whereas, the BU land stands as the 3rd dominant one with 186.16 km^2 area. Next, the hill and forest area cover was 155.95 km^2 and the other classes cover area less than 50 km^2. Figure 7 clearly evinces the LULC spatial map 2009 of the considered SA (Coimbatore). This map is acquired by employing SIC to the Cartosat-1 Pan merged with Resourcesat-1 L4MX satellite image (2009). In 2009, the area of fallow land has expanded at a fast rate, that is, the total fallow land was increased by 37% amid the period of 1997–2009. Contrarily, amid that same period, the cropland was decreased by 32%. The total cover area of fallow land is 559.99 km^2, whereas the cover area of cropland is 176.12 km^2. In 2009, the 2nd dominant class is BU land, which covered an area of 213.24 km^2. The area covered by water bodies with vegetation was very low, which is only 2.88 km^2, but, in 1997, it was 8.74 km^2. Other than this, no big changes have occurred in the covered area of other classes. The Cartosat-1 Pan merged with Resourcesat-2 L4FX satellite image (2017) was classified utilising the SIC process. Figure 8 clearly evinces the proportions of LULC of the considered SA in 2017. In 2017, the maximal area was fallow land, that is, 39% (510.20 km^2), but it was decreased by 3% when contrasted to 2009. The other agricultural lands namely, crop and plantations land covered an area of 185.29 and 102.49 km^2, respectively. In 2017, water bodies covered very less area of about 4.02 km^2, and water channel covered 5.67 km^2 which was the 2nd last covered area. In analysing Fig. 8, the cover area of water body lands, namely water bodies, water bodies with vegetation, and water channel area was low when contrasted to the other 8 classes. The area of mining process was 7–8 km^2, and it has no changes in 3 decades.

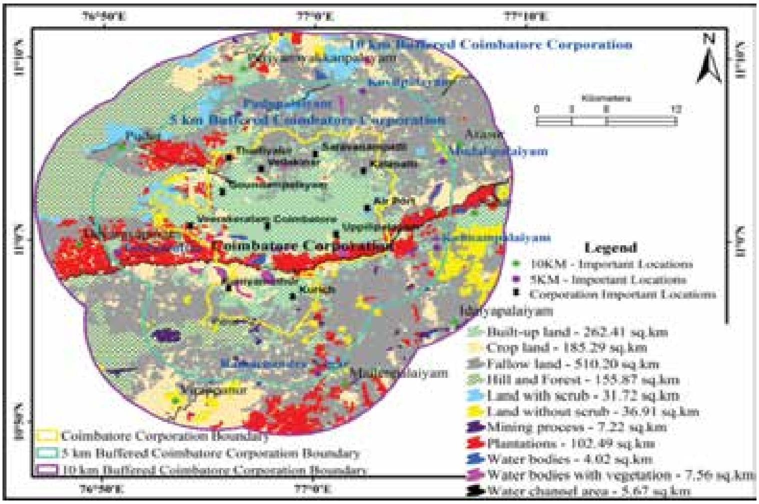


Fig. 8. LULC 2017 spatial map

Accuracy assessment. It is utilised to cross-check the quality of classified LULC maps. It is a vital process and is performed by forming an error matrix. The outcomes were assessed grounded on user's accuracy, overall accuracy, producer's accuracy, along with KC (Refs 15 and 16), which are derived as of the error matrix. For the LULC 1997 map, the producer accuracy was 100% in BU, fallow, and hill and forest lands, and the user accuracy was 97% in BU and crop lands. The LULC 1997 map had 0.92 KC and 93.54% overall accuracy. From this accuracy assessment test, it is cleared that the SIC is effective and accurate for LULC detection. The LULC 2017 map had 96.43% overall accuracy of classification and 0.95 KC. The BU, fallow, and hill and forest lands were classified exactly with 100% accuracy rate. All the 11 classes had a producer and user accuracy of above 70% in both the maps.

Change analysis of LULC. From 1997 to 2009 (Fig. 9), tremendous growth in fallow land was found in Zones 1, 2, and 3. In 2009, the fallow land covered area of 63.77 km^2 in Zone 1, whereas, 261.23 km^2 and 235.01 km^2 in Zone 2 and Zone 3 with the increment of 17 and 16.5%, respectively. Most agricultural lands, namely crops and plantations were transmogrified into fallow lands; therefore, the maximal loss occurred in plantation and vegetation lands. In 2009, the vegetation land covered only 1.09, 0.99 and 0.80 km^2 in Zone 1, Zone 2, and Zone 3, respectively. From 1997 to 2009, about 68% of the vegetation lands were transmogrified into BU land, water bodies as well as fallow land. In Zone 3, the plantation land reduced from 80.40 to 64.73 km^2, whereas, the BU land expanded as of 33.02 to 36.49 km^2 over that period, and this clearly specifies the big development of urbanisation.

a

b

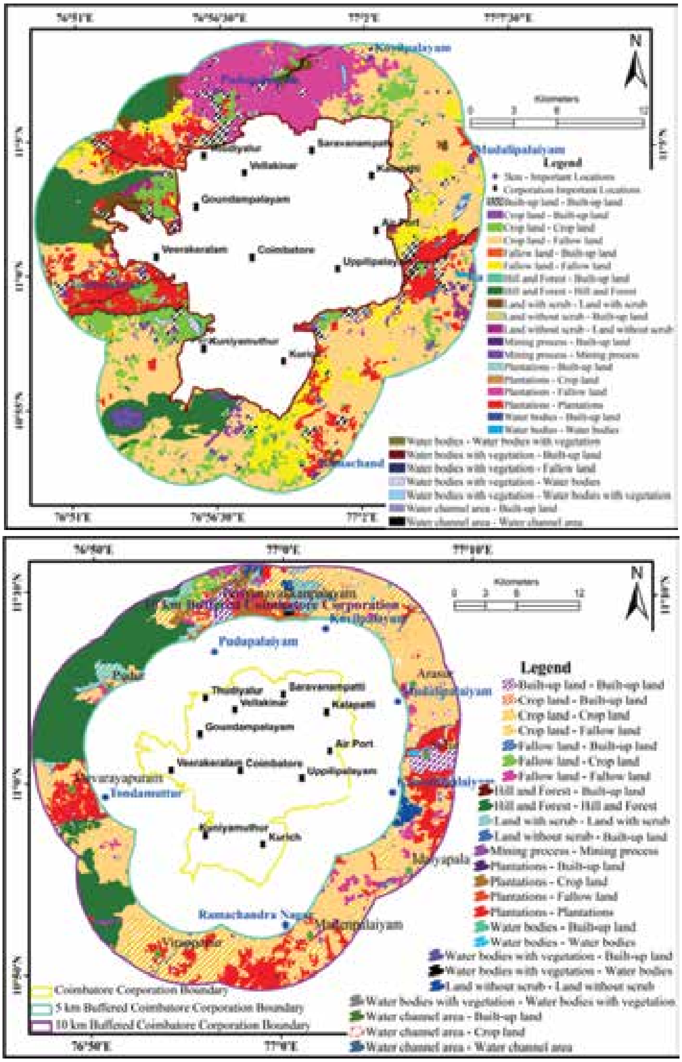
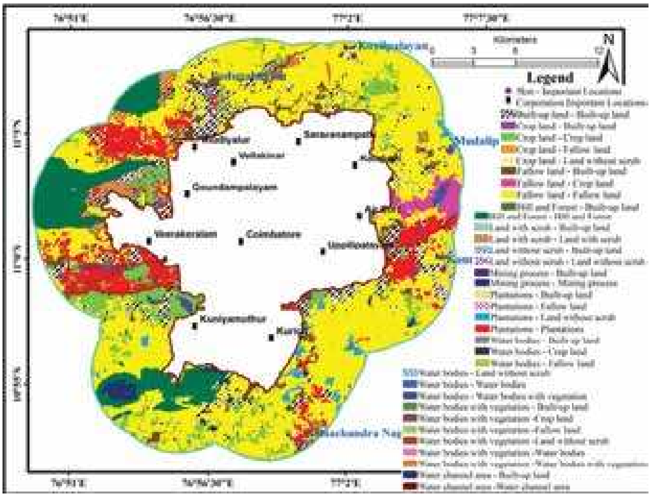


Fig. 9. LULC change detection 1997–2009 map: *a* – Zone 2; *b* – Zone 3

Furthermore, cropland, fallow land, hill and forest, lands-without scrub, plantations, water bodies, water bodies with vegetation and water channel area were urbanised mostly in the northern side of Zone 2 and Zone 3 around Pudupalayam, eastern side near Kannampalayam, southern side near Ramachandra Nagar, Periyanayakkanpalayam and eastern side around Sulur, where the emergence of PU region was perceived. Those areas have witnessed major development with river and water bodies that occupied most BU lands for the study period. The land with scrub, without scrub and mining land area, was relatively not changed between the 2 periods. On analysing the CD for 2009–2017 LULC (Fig. 10) in Zone 1, the areas of fallow land, plantation, and water bodies were reduced by 11.9 km^2 (0.90%), 1.48 km^2 (0.11%), and 24.62 km^2 (0.35%), respectively, but the vegetation land was expanded by 3.55 km^2 (0.27%). No other significant changes are found in Zone 1. Moreover, the land covers-change matrix between the 2 maps indicates that 24.07 km^2 regions had been urbanised in Zone 2. In Zone 3, the BU area had been expanded by 8.63 km^2. When contrasted to Zone 3, the BU lands had been increased more in Zone 1 and Zone 2. Specifically, the plantation was highly changed onto BU lands in the southern regions of Zone 2 on account of the high industrial development. The outcomes also signified the reduction of fallow land in the northern part of Zone 2 and Zone 3 where the major development of the PU area has occurred. The development of these regions can well be attributed to the fact that Coimbatore district being a highly agricultural and industrial potential area, experienced high and rapid migration amid this period mainly from the surrounding districts, like Erode, Namakkal, Salem, and Dharmapuri. For the years between 2030 and 2040, the predicted (future) land cover images acquired as of the Land-use change modeller are shown in Figs 11 and 12.

The predicted LULC change analysis for 2017–2030 clearly showed that the BU land increased by 31.52, 46.17, and 31.92 km^2 in Zones 1, 2, and 3, respectively. But, the cropland is decreased by 8.70, 6.73, and 6.77 km^2 for Zones 1, 2, and 3, respectively. In those zones, a reduction in fallow land by 16.45, 30.93, and 19.33 km^2 is also perceived. The BU land is increased to a great extent in the northern regions of the SA along Periyanayakkanpalayam and Pudupalayam. The regions near Sulur on the eastern side of the SA observed significant expansion in the PU areas. As the aforesaid areas already have many manufacturing and textile industries, the increase in the BU land can well be attributed to the higher potential for industrial development. The predicted LULC change analysis for 2030–2040 showed that the BU land extended by 16.41, 31.11, and 25.72 km^2 in Zones 1, 2, and 3, respectively. But, the cropland is reduced by 4.14, 4.33, and 5.72 km^2 for Zones 1, 2, and 3, respectively. In those zones, a reduction in fallow land by 8.33, 20.51, and 15.33 km^2 is also perceived. In the year 2040, the predicted change in LULC signified an increase in the BU land when contrasted to 2030 mainly along Pudupalayam and Periyanayakkanpalayam on the northern side, Sulur and Arasur on the eastern side, Devarayapuram on the eastern side, and also Deverayapuram on the southern part of the SA. As those areas are the utmost potential areas for further industrial and social development, it is natural that these areas experience maximisation in the BU land.

a



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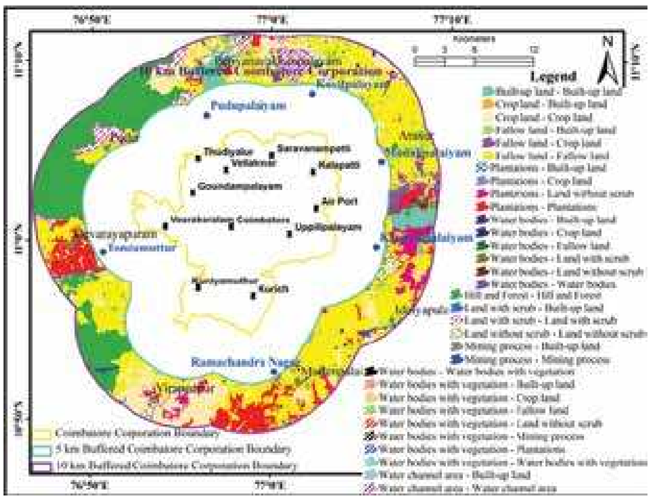


Fig. 10. LULC change detection 2009–2017 map: *a* – Zone 2, *b* – Zone 3

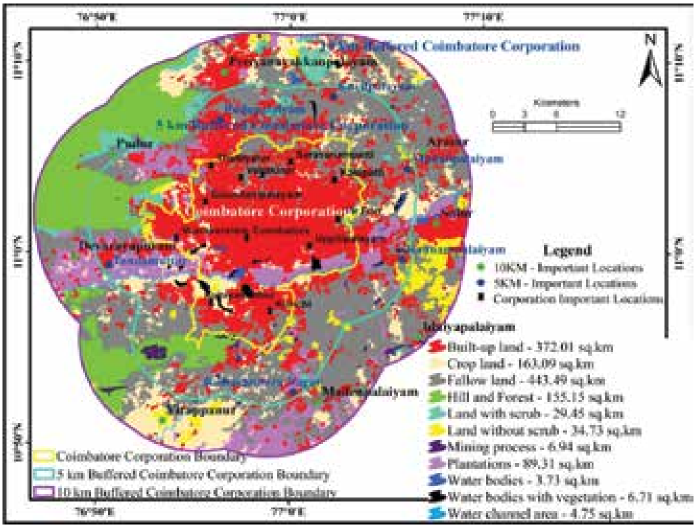


Fig. 11. Predicted LULC-2030 map

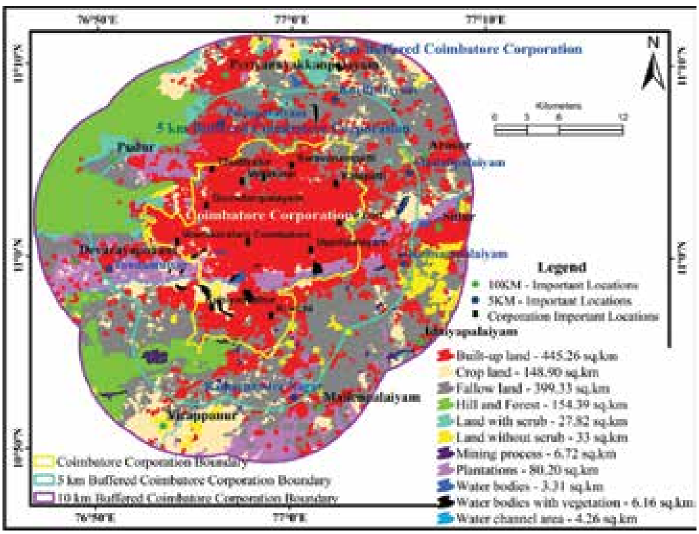
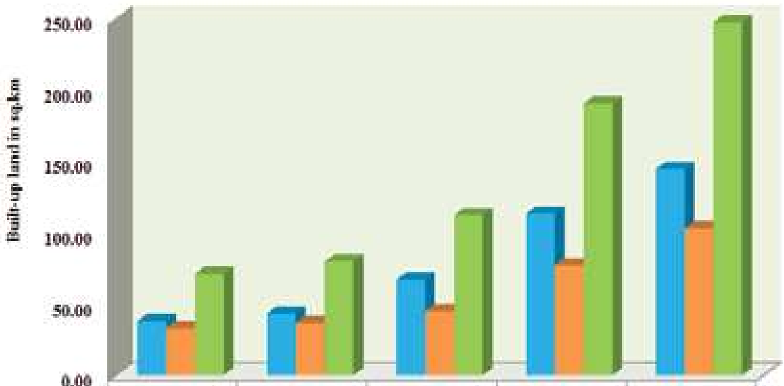


Fig. 12. Predicted LULC-2040 map

Figure 13 signifies the area change in BU land in the PU areas over the study period. It is perceived that the BU land in the total PU area encompassing the zones 2 and 3 increased as of 70.98 km^2 in 1997 to 247.22 km^2 in 2040. This increased area of BU land could be correlated to the population growth, social growth, and industrial growth of Coimbatore over the study period.



	1997	2009	2017	2030	2040
Zone 2	37.97	43.15	67.21	113.37	144.49
Zone 3	33.01	36.48	45.09	77.01	102.73
Total peri-urban	70.98	79.63	112.30	190.39	247.22

Fig. 13. Built-up land area change in sq.km for peri-urban area

Coimbatore being the fast-growing city in India, a natural inclination is perceived for migration of people from nearby villages and towns to the Coimbatore on account of the presence of higher employment, social, and education opportunities. Figure 14 signifies the percentage change in BU land in the PU areas over the considered study periods. The statistical outcomes specify that the BU land in the total PU area increased by 12.18% between 1997 and 2009, 41.03% between 2009 and 2017 for both Zones 2 and 3. The study projected that the BU land would increase by 69.53% in the total PU area encompassing Zones 2 and 3 between the years 2017 and 2030. It is also projected that the BU land would increase by 29.85% in the total PU area encompassing the Zones 2 and 3 between the years 2030 and 2040. There is a possibility of the PU areas getting saturated for further developments on account of the decrease in the growth percentage of BU land between 2030 and 2040 when contrasted to the years 2017 as well as 2030.

This, thereby, reduces the possibility of further growth of the areas because of insufficient or lack of proper facilities to make sure sustainable development of the PU areas. As perceived in the case of major cities all through the world, when the further growth and development opportunities cease, the developments start shifting to neighbouring satellite towns. This phenomenon attributes to the reduction in the BU land between 2030 and 2040 in the PU areas of Coimbatore. After the year 2040, the emergence of the neighbouring satellite town would lessen the growth potential of Coimbatore.

	1997-2009	2009-2017	2017-2030	2030-2040
Zone 2	13.63	55.76	68.69	27.44
Zone 3	10.51	23.62	70.79	33.39
Total peri-urban	12.18	41.03	69.53	29.85

Fig. 14. Built-up land percentage change for peri-urban area

CONCLUSIONS

This work studied the PU growth of Coimbatore city in Tamil Nadu over three decades (1997, 2009, and 2017) utilising CD of LULC and predicted the future PU-LULC for the years 2030 and 2040 via the ANN-centric prediction approach to comprehend the future growth of PU areas. The LULC maps prepared for the years 1997, 2009, and 2017 utilising the gathered satellite images and certain ancillary data are employed for preparing the predicted LULC maps for 2030 and also 2040 with the aid of ANN-centric prediction approaches. The major outcomes of this research study specified that the BU land in the PU area of Coimbatore increased as of 70.98 km^2 in 1997 to 112.30 km^2 in 2017 and it is projected to increase up to 190.39 km^2 in 2030 and 247.22 km^2 in 2040. The BU land is predicted to be increased by 134.92 km^2 in 2040 when contrasted to 2017 amounting to an elevation of 120.14%. This rapid extension in the BU land in the PU areas is mainly owing to the observed pattern of high migration of people as of the neighbouring districts of Erode, Salem, Tiruppur, and Namakkal seeking better economic, employment, social, and education opportunities existent in Coimbatore city. The BU land area-increase and the overall decline of other land classes, has led to an overall deterioration of the environment and the quality of life in urban regions. This stresses the requirement for the planning and implementation of more stringent development control regulations in the PU areas for checking this sort of rapid and enormous conversion of vegetation and cropland onto the BU lands. The present research recommended that the stringent development control regulations may be framed and effectuated by the local planning authorities grounded on the future LULC prediction outcomes for ensuring a regulated and orderly growth of the PU areas, thereby leading to the sustainable development of the SA.

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