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Prediction of future land use land cover changes in Valsad District, Gujarat using remote sensing

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ABSTRACT

The main objective of the present article is to attempt to predict future land use land cover patterns based on current land use land cover. Remote sensed Landsat images of Valsad district were studied over 20 years (1998 - 2018) to predict the future in 2028. We used Arc GIS, ENVI, and IDRISI Selva software for our study. Preprocessing, classification, and post-classification processing of Landsat images in the years 1998, 2008, and 2018 were done in ENVI, administrative boundary shapefile, and post-classification corrections were done using Arc GIS, the prediction was done using Markov Chain Modeling of IDRISI Selva. The result showed that in the year from 1998 to 2018, there has been an increase in the built-up area, plantation, cultivated land, and dry deciduous forested area. A decrease in water and aquaculture, mudflat and saltpan, scrublands, barren land, Casuarina plantation, and mangrove areas. This study will act as a database for sustainable ecological management of the Valsad district in the future. This study will help in determining the ecological sustainability of the district in the future.

Key words : *Land use land cover, Classification, Markov Chain Modeling, Arc GIS, ENVI, IDRISI Selva*

Introduction

Land use and land cover changes help to understand the dynamics of land and its associated diversity. According to Verburg land-use change is a modification of change in land use not necessarily changing the land cover. But when the intensity of land use increases, land cover change takes place. Alteration of land use and land cover pattern on spatial and temporal scales is an indicator of environmental change, rate of loss of floristic diversity, and change in floristic diversity. Mostly agricultural land, forest, and wetland are converted into the urban landscape (Yuan *et al*., 2005). LULC changes in India is mainly due to increasing population pressure and rapid unplanned urbanization (Prakasham, 2010). In a joint study between the International Geosphere-Biosphere Program and International Human Dimension Program, it was observed that LULC patterns monitoring is important for the management and planning of ecological resources of the area (Irwin and Geoghegan, 2001). Monitoring LULC changes spatiotemporally becomes accurate and cost-effective using remotely sensed data. LULC monitoring is essential for sustainable development. Accuracy assessment and change detection act as modeling tools for prediction (Yuan *et al*., 2005). Prediction is mostly done based on the past trend of land use and land cover, using Markov Cellular Automata Modeling (Islam and Ahmed, 2011). Our study area faces several environmental and human-induced changes such as low availability of fresh surface water, unplanned industrialization and urbanization.

Materials and Methods

Study area

Research was carried out in the Valsad district of south Gujarat on the bank of the Arabian Sea, located in 20.61^0 N and 72.92^0 E, covering an area of 3,035km^2. The district is bounded by the state of Maharashtra on the east and south. Valsad district,lying in the Gulf of Khambat has five taluks namely Valsad, Pardi, Dharampur, Khaprada, and Umbergaon. Valsad belongs to the zone III seismic zones. The topography is composed of flat-topped hills, both narrow and wide river valleys, coastal plains with an abundance of lakes and ponds, seashores (Rao, 2015). The district has high relief undulating terrain in the east, flat coastal plain in the central part and shore, and beaches in the west. The district was drained by nine rivers. The shallow water levels of less than 5 mg were observed along the coast, and in parts of the Hilly region (Bhatt *et*

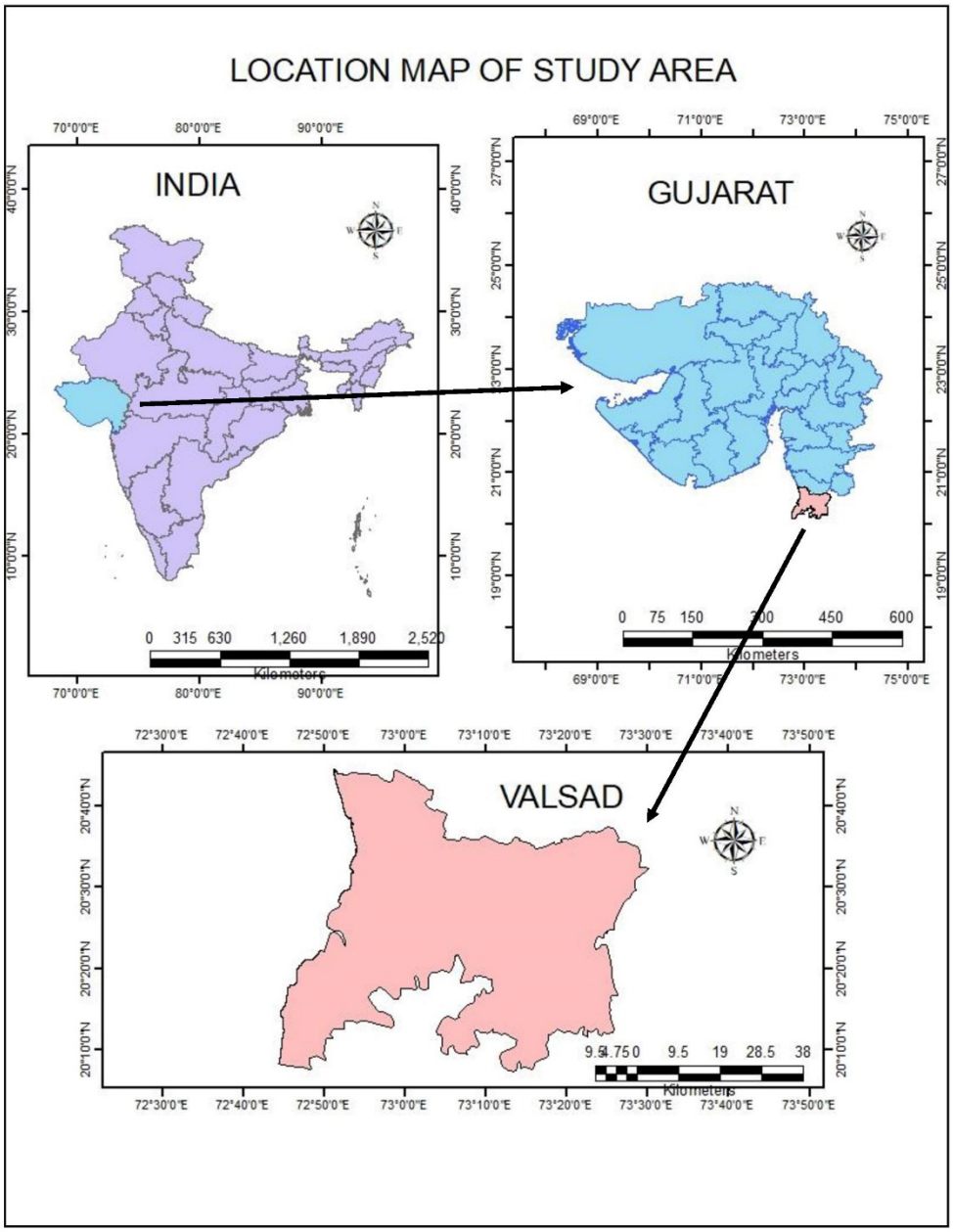

Fig. 1. Location of the study area

al., 2013). Several consecutive months of heavy rainfall experienced during the monsoons in south Gujarat because of which severe drought period not experienced here. The rainy season sets in mid-June and lasts up to October. The average annual precipitation varies from about 1963 mm to 2338 mm in Valsad (Groundwater yearbook 2016-17). Little difference was observed between summer (41 ^{0}C) and winter temperature (22 ^{0}C). This area never faces floods as the rivers have low water volume. The mean annual temperature ranges from 25 to 28 ^{0}C. Temperature minimum coincides with heavy rainfall seasons. Geology and soil condition affect the floral diversity by influencing the moisture regime, texture, and drainage pattern. Rock formations in Valsad are sandstone, gravel, pebbles, conglomerates (of the quaternary period), and basalt (Mesozoic period). Major soil type is black soil. Modified soil surrounds the villages due to agriculture and practices. Coastal areas have saline soil due to the ingression of salty water. The study area is shown in Figure 1.

Remote sensing Data Analysis

Primary Data

Land use and land cover mapping, change detection of lands at images were done for the last 20 years, and prediction of 10 years. Images of the study area collected from the USGS site for a gap of 10 years for the last twenty years from Landsat 4 - 5 (bands used were 1, 2, and 3) and Landsat 8 images (bands 2, 3, and 4). Each band has its collection optics. Datum used WGS 84; zone 43 of UTM projection. Landsat 4-5 (MSS-TM) image has sensors called Multispectral Scanner (MSS) and Thematic Mapper (TM). Landsat 8 (OLI-TIRS) image sensors are called Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Post rainy season satellite data used according to availability and cloud cover of less than 10 % for better identification of objects in the images. Satellite images were selected for a gap of every 10 years for the last 20 years. All the satellite images have the same spectral resolution of 30 m, which is needed to determine the temporal changes in the land use and land cover changes (LULC) over 20 years. The details of the Landsat satellite images selected for the present work are given in Table 1.

Field Survey

Field surveying or Ground truthing was conducted to survey the study area and acquire data that will assist the supervisedclassification of the satellite images into different land use land cover types for a period of one year from 2017 to 2018. We surveyed the study area, characterized the major vegetation, and photographs were taken for reference as it helps to identify different features observed in satellite images for classification and accuracy assessment (reference secondary data). An optimum number of sites were selected for maximum representation. We have used 571 training points in the satellite image of the entire study area in which unidentified land use land cover types. We compared training points on the Google Earth map to exactly locate on the ground. Using GPS the pre-identified points on Google earth map were located on the ground and observations were made regarding land use and land cover (ancillary data).

Ancillary data

The ancillary data helped in the classification process. The Survey of India (SOI) topo sheets were used for landscape analysis modeling. Satellite images were clipped to the district administrative boundary. This clipping reduced the runtime of various software processes by reducing the amount of data to be processed. Topo sheets collected from Survey of India of 1:50,000 scale for the corresponding region with No 46D/11, 46D/12, 46D/14, 46D/15, 46D/16, 46H/2, 46H/3, 46H/4, 46H/6, 46H/7 and 46H/8.

Software used

Arc GIS (version 10.6) is used for creating, editing, and mapping of image. It is used to map the ground truth points, add attributes to images, and perform

Table 1. Details of satellite data acquisition

Sl No	Satellite	Sensor	Path	Row	Zone	Date of Image
1	Landsat 4-5	MSS-TM	148	WGS 46	43	26th November 1998
2	Landsat 4-5	MSS-TM	148	WGS 46	43	21st November 2008
3	Landsat 8	OLI-TIRS	148	WGS 46	43	17th November 2018

image overlay.

ENVI (version 5.3) is raster-based software used for Preprocessing, Classification, and Post classification to analyze the trends in multi-temporal images. Preprocessing is the radiometric calibration and atmospheric correction process of image for data extraction. Classification of images is done to identify the degree of LULC changes. Sieving of the pixel, smoothing of class boundaries, clumping of classified output, and correction of the class is done in post-classification image processing. Estimation of statistical accuracy of producers and users are also done.

IDRISI Selva (version 17.0) is used for prediction and identifies the degree of LULC changes.

Methodology

The entire process of image processing of LULC is divided into four stages namely pre-processing of the image, image classification, post-classification image processing, and editing, and change detection. LULC of Landsat images were procured for 20 years and predictions made for the next 10 years and compared.

Pre classification Image Processing

Pre classification processing included the radiometric correction of orthorectified Landsat satellite images at a gap of 10 years. The radiometric resolution of Landsat satellite data is 16-bit data has a spatial resolution of 30 m. The radiometric correction process is done to improve the interpretability of remotely sensed data. It includes atmospheric correction and sensor calibrations. Here DN values were converted to TOA radiance at sensor level which is further atmospherically corrected to get surface reflectance. Atmospheric correction model was used for radiometric correction. Data needed for radiometric calibration provided in the metadata of Landsat images. Different layers of images are stacked and used. Band 1, 2, and 3 for Landsat 4-5; Band 4, 3, and 2 of Landsat 8 images were combined to acquire False Color Composite (FCC). Atmospheric correction was done using the Flash technique in ENVI. Band math has been done before visual interpretation and classification. The selected area was clipped from the whole scene called subset.

Supervised classification

Classification of the images using supervised classification with a maximum likelihood algorithm to produce land use land cover images. For classification masking done and false-color composite used for visual interpretation and delineation of classes using image processing software called ENVIS. The first step was to mask the study area. The second step was the addition of training data points obtained during ground-truthing where the LULC at various points were identified and interpreted for classification. Training data was saved and the resultant classified image was saved as vector format. Our training point (571 training point) were taken based on the field study information. In mapping 10 LULC classes were Water bodies and Aquaculture, Mudflat and Salt pan, Barren land, Casuarina, Mangrove Area, Scrublands, cultivated land, Settlement, Plantation, and Dry Deciduous. Rivers, ponds, and aquaculture ponds have shown together as a single class since it includes some water. Mudflat and salt pan took as a class as mudflat was converted to salt pans.

Post classification Image Processing

Sieve filtering; smoothing is done using a 3x3 pixel medium filter and clumping done by ENVIS. Editing at certain spots for which raster files were converted into asci and then spot edited using Arc GIS. Editing is done with the help of fieldwork data, topo sheets, and the use of google images. After the post-classification comparison was made of data of the last 20 years.

Accuracy assessment

An accuracy assessment is done to determine the accuracy of classification by the confusion matrix using ENVI. The confusion matrix or error matrix compares the reference data from field visits with the classified image pixel by pixel. Classification accuracy is of two types, Producer's and User's accuracy. The producer's accuracy corresponds to the error of commission (inclusion). It shows how often real class on the ground is correctly shown on the classified map from the perspective of the map maker. The user's accuracy corresponds to the error of omission (exclusion). It points out the probability that a pixel is classified as a species class accurately representing the class on the ground from the perspective of the map user.

$$\text{Overall accuracy} = \frac{\text{Total number of correct samples}}{\text{Total number of samples}} \times 100$$

$$\text{Producers Accuracy} = \frac{\text{Number of the correctly classified pixel in each LULC class}}{\text{Total number of pixels computed in reference data}} \times 100$$

$$\text{Users Accuracy} = \frac{\text{Number of the correctly classified pixel in each LULC class}}{\text{Total number of pixels classified in the class}} \times 100$$

$$\text{Kappa coefficient} = \frac{(\text{Observed accuracy} - \text{Chance agreement})}{(1 - \text{Chance agreement})}$$

Prediction

The output land use land cover images are used to predict the future land use land cover image by the Markov chain modeler of IDRISI Selva software (Sheik and Ekkirala, 2014). Using Landsat image of 2008 and 2018, land use land cover image of 2028 was predicted first, then compared with actual land use land cover image of 2018. The change detection analysis was carried and presented. The methodology adopted in this workis shown in the Figure 2.

Results and Discussion

The land use land cover images for the years 1988, 2008 and 2018 and the output images were processed along with the future predicted land use land cover image of the year 2028, presented in Figure 3. Table 2 shows the area wise statistical change analysis of land use land cover between the years 1998, 2008, 2018 land use land cover prediction for the year 2028. In the years between 1998 and 2008, an increase in dry deciduous, cultivated, plantation, and settlement. The decrease in the areas of scrublands, mangroves, casuarina, barren land, and water. This altered land cover is indicative of anthropogenically driven land use in the first ten years of studies. It was observed that between 2008 and 2018, there is an increase in the settlement area, plantation, scrublands, and cultivated land. The decrease in Casuarina and dry deciduous, mangroves, barren land, mudflat, and water.This indicates the same trend in land use in the next ten years of our study, which caused the same land cover change. The predicted land use land cover in 2028 was an increase in area in plantation and settlement. Predicted land use and land cover of 2028 showed decreased water and aquaculture, mudflat and saltpan, barren land, casuarina, mangroves, scrublands, cultivated and dry deciduous.

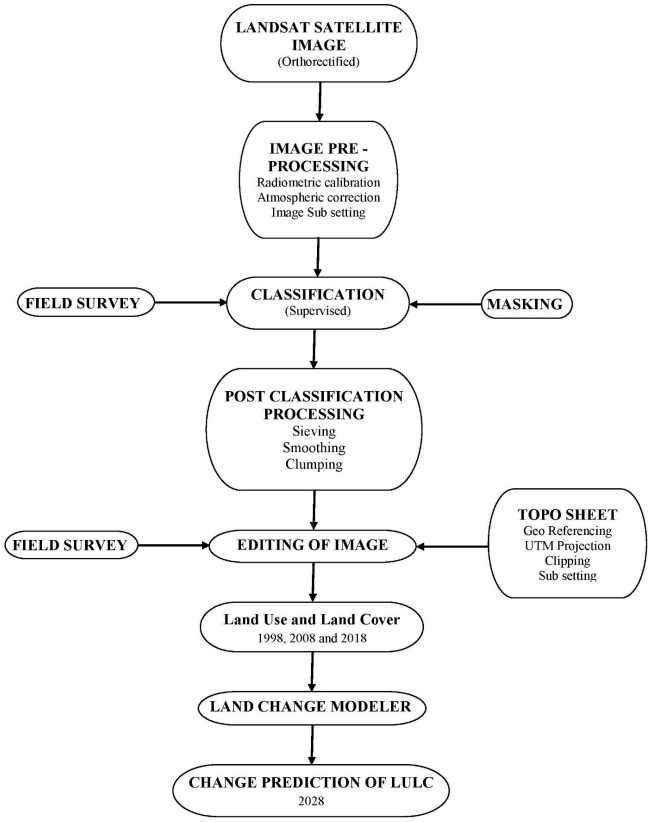

Fig. 2. Flow chart of Methodology

Table 2. Change analysis of land use land cover area

Sl. No.	Land Use Type	Area, Km²				Change, %		
		1998	2008	2018	2028 P*	1998 -2008	2008 -2018	2018 -2028
1	Water and Aquaculture	89	84	81	76	-6.4	-3.7	-5.9
2	Mudflat and Saltpan	54	63	49	41	15.8	-21.6	-16.4
3	Barren land	282	116	51	46	-59.0	-56.0	-10.2
4	Casuarina	203	116	0.2	0.1	-43.0	-99.9	-38.7
5	Mangroves	20	12	12	11	-40.8	4.3	-6.7
6	Plantation	674	685	790	830	1.6	15.3	5.0
7	Scrubland	35	17	21	19	-53.1	23.5	-8.2
8	Cultivated land	355	398	436	407	12.0	9.4	-6.5
9	Settlement	88	105	171	202	18.7	63.2	18.0
10	Dry Deciduous	1255	1462	1447	1425	16.5	-1.1	-1.5

P* - Prediction

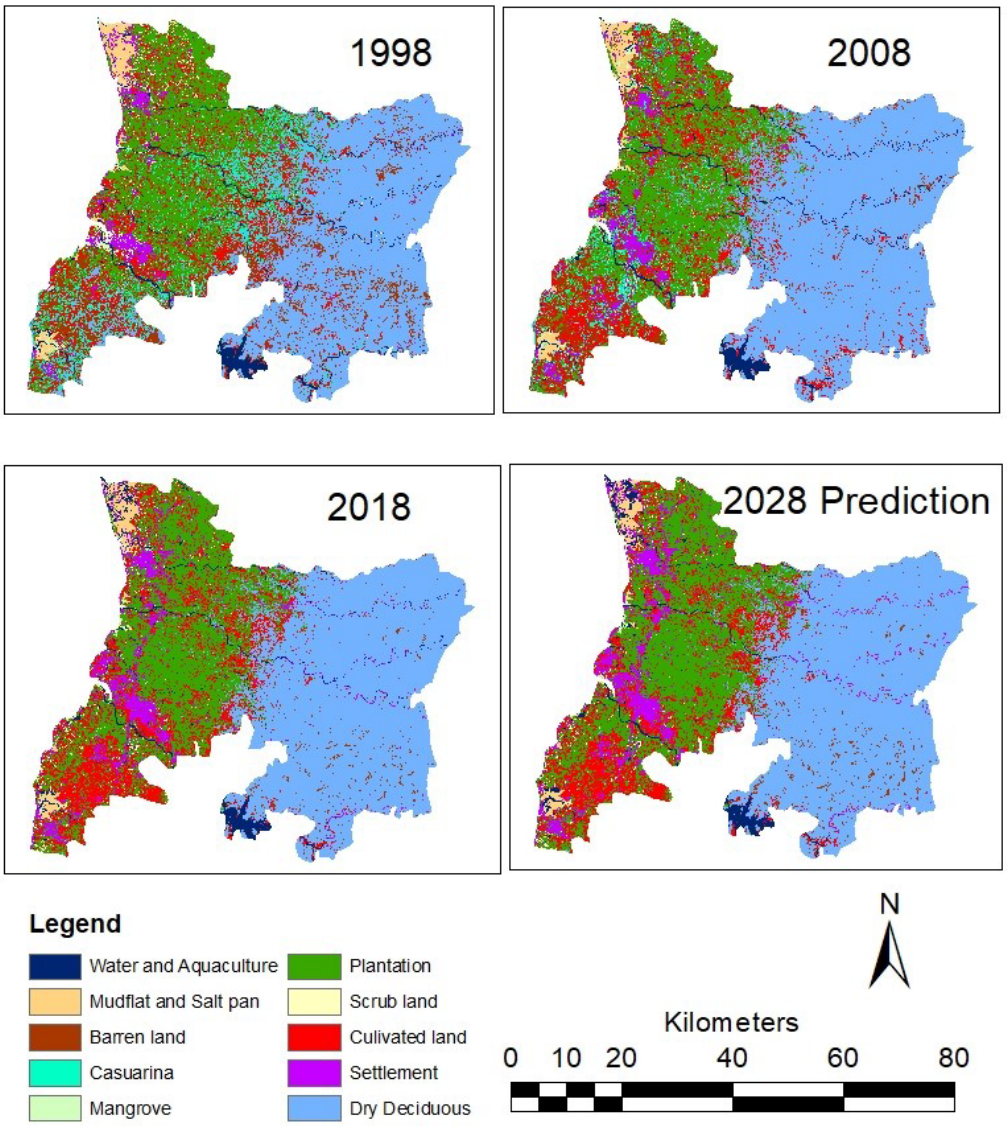

Fig. 3. Land use land cover (LULC) images of different years

A significant change occurred between 1998 and 2008, the same pattern continued till 2018. From the change analysis of land use land cover, we observed that there is an increase in the Settlement area and a decrease in scrublands, mangrove area, Casuarina, Mudflat, and salt pan. Here the main significant change that occurred in land use the land cover of twenty years (between 1998 and 2018) is that barren area in the plain land got converted to cultivated land, plantation, and settlement area. The settlement included both industrial and urban areas. This is mainly due to population pressure for food and employment that leads to infrastructure development.

There was also a decrease in water as rivers were dammed multiple times and used for irrigating cultivated land, plantation areas in the plains. Open dry deciduous forest land was found to increase for the first ten years and then decrease for the last ten years of our study. A large area in the eastern portion of this district has an undulating terrace and faces drought in summer, not many LULC changes observed here. Though anthropogenic pressure has been responsible for whatever LULC changes but most changes are concentrated in the central coastal plain and coastal areas. Thus we observe that these changes are predominantly limited by topography and climate. These changes have adverse impacts on environmental and management plans. A balance in floral diversity has to be maintained as horticultural practices lead to monoculture and reduced floral diversity. It is necessary to mitigate these effects by studying and analyzing the pattern of LULC changes.

The classification of LULC of Valsad district has an overall accuracy is 88.2 % and Kappa Coefficient is 0.86. The kappa coefficient measures the agreement between classification and truth values. According to Cohen's original article, values ≤ 0 as indicating no agreement, 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement. So the classification and prediction done had a high accuracy rate and almost perfect agreement between classification and truth values

Table 3. Producer's and User's Accuracy of LULC classes

Sl. No.	Class	Accuracy, %	
		Producer's	User's
1	Water and Aquaculture	88	90
2	Mudflat and Saltpan	94	92
3	Barren land	77	87
4	Casuarina	78	100
5	Mangroves	79	83
6	Plantation	87	64
7	Scrubland	71	93
8	Cultivated land	86	64
9	Settlement	100	94
10	Dry Deciduous	93	100

The major contribution of the LULC of transformation is the increasing rural population that wants more and more arable land resulting in more barren land brought under cultivation. An increase in the urban population that wants to invest in more industries resulted in urban expansion. Valsad has been passing through the hasty process of the creation of artificial forest in the form of plantation mainly for horticultural trees along with minor timber plantation in previous barren lands. This process makes the area act as a carbon sink, but plantation leads to monoculture and loss of native or endemic trees of the Western Ghats that may not be so economically viable. Due to population increase, there has been tremendous pressure for the employment of both rural and urban folk. This has in turn put enormous pressure on land use and land cover of the district. Infrastructural development was observed more in the plains than in the hilly area of the district. Loss of eco-sensitive mangrove area observed is mainly due to loss of availability of freshwater from the rivers due to their use in irrigation by repeated damming of major and even minor rivers. This repeated damming on the other hand is responsible for converting the barren land into agricultural and horticultural lands. Intense loss of the Casuarina area is mainly their plantation in the riverine ecotone, which becomes seasonally flooded during the rainy season and Casuarina is a shallow-rooted plant that gets logged during and after rains. As most of the economic activities are centered in the industrial and urban areas, an increase in settlement area is very much clumped and is mostly as an addition of the pre-existing settlements.

Conclusion

In the present work, there has been an increase in the vegetation (from 1998 to 2018) and the prediction of future expansion in the vegetation in the year 2028. The results show that barren land of the Valsad area has been decreased from 1998 to 2008

and finally in 2018. The major land cover change has been from barren land to settlement area, cultivated land, and plantation forest. There has been an increase in vegetation cover but monoculture of economically important horticultural trees will create an ecological imbalance. The slow loss of mangrove areas will have serious ecological impacts unless environmental management plans were implemented for the district. Our work will act as an information database for problem identification and initiation of appropriate plans for ecology friendly land management.

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