Change Detection Mapping of Land Use Land Cover Using Multidate Satellite Data

(A case study of Pichavaram Mangrove)

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***Abstract*- This paper examines the use of GIS and Remote Sensing for change detection mapping of Land Use Land Cover of mangrove area by using multidate satellite data. The area of study was selected as Pichavaram mangrove area at Cuddalore district, India. This paper deals the impact of Land Use Land Cover on Mangrove between August 1991 and October 2000 and January 2009. Subsequently, an attempt has been made for projecting the observed land use land cover and total exceeded Mangrove area change in the next 9 years in 2018. It has been found that there is increase by 1780.00 [ha.] and decrease by 174.12 [ha.] of mangrove area between 1991-2000 and 2000-2009 respectively followed by other land use land cover changes. In achieving this the other indicator parameter for mangrove area is Land Consumption Rate [LCR], Land Absorption Coefficient [LAC] of Mangrove area and total population of Mangrove area of Pichavaram has been estimated and introduced to aid in the quantitative assessment of the change. Which shows significant change in their value at both spatial and temporal scale, LCR value changes from 0.098 to 0.756, 0.756 to 1.120, and 1.120 to 1.976 in between 1991-2000, 2000-2009 and 2009-2018 respectively. Whereas LAC is [-0.888], [0.154], and [-0.521] of 1991/2000, 2000/2009 and 2018 respectively. The result of the work shows a rapid growth in aquaculture pond, degraded mangrove, agriculture area, mangrove, sea water/sea and very rapid decrease in fallow land, forest plantation, mudflat, sand/ beach area, swamp, waterlogged area, between 1991 and 2000. While the periods between 2000 and 2009 witnessed a growth in agriculture area, aquaculture pond, fallow land, swamp, water logged area & decrease in degraded mangrove, forest /forest plantation, mangrove, mudflat, sand/beach area and sea water/sea.**

***Key words*- Land Use Land Cover; Mangrove; LAC; LCR; Pichavaram.**

I. INTRODUCTION

Most of the human settlement along the Indian coast is located along the estuaries and deltas. In India, mangrove forest are traditionally been used for a variety of purposes like, boat-building, tannin extraction, firewood, stakes for fishing, fodder etc. In south east Asia, there is a severe drive for the conversion of mangrove lands for agricultural, industrial, aquaculture, settlement forest plantation purposes, The factors that severely affect mangrove ecosystems are diminishing fresh water inflow, increasing salinity and & nutrient supply [MOEF., 1987]. Prawn culture in the mangroves of Chorao Island [Goa], Chilka lagoon [Orissa] and Pichavaram (Tamilnadu) is of great concern to different environmental groups in India. In general, the Indian mangroves are considered as degraded [Krishnamoorthy., 1995]. The land use/land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change. Remote Sensing [RS] and Geographic Information System [GIS] are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analysis of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity [Wilkie and Finn., 1996]. Therefore, an attempt has been made in this study to map out the status of land use land cover of Pichavaram mangrove between 1991, 2000 and 2009 with a view to detecting the land consumption rate and the changes that has taken place in this status particularly in the mangrove area, so as to predict possible changes that might take place in the next 9 years using both Geographic Information System and Remote Sensing data.

The study site, the Pichavaram mangrove [**Lat 11° 20'** to **11° 30' north** of and **Long 79° 45'** to **79° 55' east**], is located between the Vellar and Coleroon estuaries and has direct opening to the Bay of Bengal at Chinnavaikkal. It is 51 km north east of Chidambaram, Cuddalore district, Tamil Nadu. It is estuarine type of mangrove situated at the confluence of Uppanar, a tributary of the Coleroon River. Villages, agriculture, cropland, fishing area, Aquaculture pond and beach surrounds the area. This mangrove environment is attracting large number of tourists. The Pichavaram mangrove wetland has 51 islets and the total area of the Vellar-Pichavaram-Coleroon estuarine complex is 2335.5 [ha.] of which only 241 [ha.] is occupied by dense mangrove vegetation. Nearly 593 [ha.] of this wetland is occupied by halophytic vegetation like Suaeda, 262.5 [ha] barren mud flats and 1238.5 [ha.] barren high saline soil [Krishnamoorthy, et al.,1994] out of 2335.5 [ha.] of this mangrove wetland only 1100 [ha.] comprising the entire mangrove vegetation located in the middle portion of the Vellar-Pichavaram-Coleroon wetland has been declared a reserved forest. Department of Forest, Govt. of Tamil Nadu. Since the Pichavaram mangrove ecosystem is lying between the rivers Vellar and Coleroon, therefore alluvium is dominant in the western part. And fluvial marine, beach sand cover eastern part of the mangrove. Geomorphology of the area is major area covered by floodplain, sedimentary plain and beach sand. Major part of the area falls under nearly level sloping category. The soil group of the area is Hydrological soil group C [USDA] low infiltration and moderate runoff potential found 50% area.

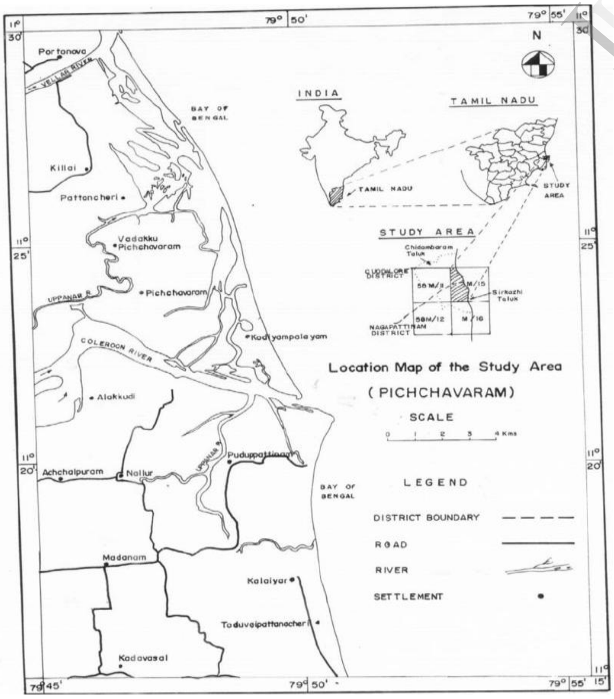

Fig. 1 Study Area, Pichavaram Tamil Nadu, India

II. STUDY AREA

The soil group `B' with moderate runoff is covering about 45% areas. The remaining 5% area is occupied by soil group `A' with high infiltration low runoff potential [Ranjan, et al.,]. In Tamilnadu, mangrove is well developed in Pichavaram & Muthupet. The Pichavaram mangrove is a typical swamp, extending between Vellar and Coleroon estuaries. In Pichavaram sixteen species Angiosperm were recorded, fourteen of them are exclusively mangrove species [Krishnamoorthy, et al., 1981].

III. MATERIAL & METHODS

A. Data & Image Analysis

For the study, Landsat satellite images of Pichavaram were acquired for three different times; 25 august 1991, 28 October 2000, 30 January 2009 from the website of landsat organization. The data used in this study were LANDSAT TM and ETM band, having 142 path and 52 rows & 30 m resolution. The [**fig. 2]**. Shows the methodology adopted for the study. Here the Image classification applied Delta or post classification comparisons digital change detection techniques for Pichavaram mangrove. And Image classification performed using unsupervised classification approach. In unsupervised classification an algorithm is chosen that will take remotely sensed image data set & find a pre-specified number of statistical clusters in measurement space [Schowengerdt 1997]. This method can be used without having prior knowledge of ground cover of the study area. The acquired images of different time period were classified in ERDAS 9.1. Unsupervised classifiers do not utilize training sets as the basis for classification it rather involves algorithms called clustering algorithms, in order to obtain the maximum information from satellite images used for image processing for LULC study. The Landsat images of different times having different bands & which is radiometrically & geometrically corrected were first stacked followed by unsupervised classification. The first approach for unsupervised classification is based on the aggregation of the classes depending on the spectral reflectance. The Iterative Self Organising Data Analysis Technique [ISODATA] was employed as a clustering algorithm. After this we recoded those pixels in their respective feature classes who assigned the other different features during unsupervised classification. After the recoding we performed clumping operation because in the process of recoding all pixels do not recode, some of the pixels remain scattered. So we performed clumping operation in which the scattered pixels merges with in the nearest clusters/spectral reflectance by nearest nebhourhood method. After clumping we performed elimination operation. In which the remaining pixels which do not clumps that get eliminated. Then we obtained Raster map. The spectral classes were identified by comparing the Raster map to ground truth points & validation, the accuracy assessment was greater than >86% & out put classified map obtained. The next step is to combine and label the spectral clusters in to information classes.

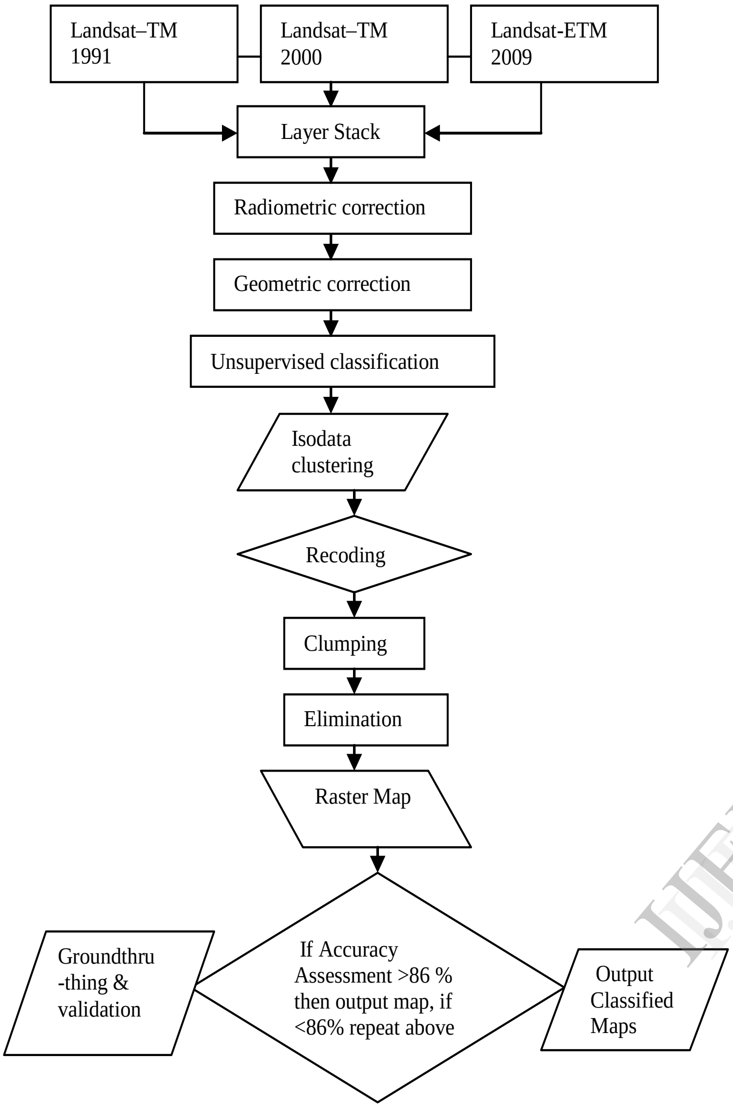

Fig. 2 Showing detail process for LULC classification

Four main methods of data analysis were adopted in this study.

(i) Calculation of the Area in hectares of the resulting land use/land cover types.

(ii) Accuracy assessment

(iii) Land Consumption Rate and Absorption Coefficient

The fist method used for identifying change in the land use types. Therefore, it has been combined in this study.

(iv) The comparison of the land use land cover statistics assisted in identifying the percentage change [trend] and rate of change between 1991 and 2000 and 2009 of Pichavaram area. In achieving this, the first task was to develop a table showing the area in hectares and the percentage change for

In this study the multidate satellite images were classified in to eleven classes, the image is classified in to following classes: 1-sea water/sea, 2- degraded mangrove, 3-mud flat, 4-

each year [1991, 2000 and 2009] measured against each land use land cover type. Percentage change to determine the trend of change in Pichavaram can then be calculated by dividing observed change by sum of changes multiplied by 100.

Percentage change [Trend]

= Observed change/ Sum of change ×100

The annual rate of change of mangrove can be obtained by; dividing the land consumption rate (LCR) of mangrove of each year and adding to the new values and again divided by 3, that is the land consumption rate per year of mangrove.

The Land consumption rate & absorption coefficient formula are given below;

$$\mathbf{L.C.R = A/P}$$

A = aerial extent of the city in hectares.

P = population

$$\mathbf{L.A.C = A_2 - A_1 / P_2 - P_1}$$

A_1 and A_2 are the aerial extents [in hectares] for the early and later years, and P_1 and P_2 are population figure of Pichavaram for the early and later years respectively (as 1991 and 2000.).

L.C.R = A measure of compactness which indicates a progressive spatial expansion of the area.

L.A.C = A measure of change in consumption of new land by each unit increase in population.

Both the 2009 and 2018 population figures were estimated from the 1991 and 2000 population figures of Pichavaram respectively using population estimation formula

$$\mathbf{Pn} = Po + [n \times t]$$

Where-

$$\mathbf{n} = r/100 \times Po \qquad [1]$$

$$\mathbf{Pn} = Po + [n \times t] \qquad [2]$$

Pn = estimated population [2009, 2018], **Po** = base year population [1991 & 2000 population figure].

r = growth rate, **n** = annual population growth

t = number of years projecting for.

Note-The formula given for the population estimate was developed by the researcher.

IV. RESULTS & DISCUSSION

A. Land Use Land Cover

mangrove, 5-waterlogged area, 6-aquaculture pond, 7-swamp, 8-beach/sand, 9-fallow land, 10-forest/forest plantation, 11-agriculture area. The classes so created and the proportion of total area of the image covered by them, provide an insight into the composition of total area. The different feature is represented by above mention classes. On account of analysis of these classified images, we are able to infer to a certain extent, that the changes that occurred in spatial composition of different physiographic features. To know the changes that occurred in the spatial composition of different geographic features. First we compared the classified image 1991 **[fig. 3]** with the classified image of 2000 **[fig. 4]**. We find that there is increase of 3273.46 [ha.] in agriculture area; it is due to decrease in fallow land, which had been used for agriculture purposes. The increase in 367.98 [ha.] of aquaculture pond is due to commercial and business purposes to maintain and increase the local economy of the area, and for the fulfillment of livelihood of local farmers. The increment of 1372.02 [ha.] in degraded mangrove reveals the degradation of mangrove has occurred for the construction purpose of aquaculture pond along the bordered of mangrove as well as in the middle of mangrove in patches. An **increase of 1780.00 [ha.] in mangrove vegetation** is due to utilization of few fallow land, mudflats for mangrove restoration. And the increase of 573.97 [ha.] areas in sea water/sea due to inflow of water from Bay of Bengal through river coleroon and vellar. It is a physiological phenomenon. Whilst there is decrease of 1217.53 [ha.] area of fallow land is due to land utilization for the agriculture practices and mangrove restoration. While decrease in 1523.44 [ha.] area of forest/forest plantation because of excessive utilization for fuel, fodder, firewood and for agriculture, construction of aquaculture pond. 902.37 [ha.] decrease in mudflat area is due to restoration activities of mangrove and for aquaculture activities. And the decrease of land about 1160.54 [ha.] in sand/beach is due to coverage of sea water/sea, construction of aquaculture pond and restoration of mangrove. About 2210.26 [ha.] area decrease in swamp because of conversion of swamp area in to agriculture crop, aquaculture pond. And some swamp area along the rivers gets converted in to sea water/sea or river water. And decrease of 353.26 [ha.] area of waterlogged also follows the conversion process as in case of swamp area.

In the similar way a comparison of classified images of 2000 **[fig. 4]** and 2009 **[fig. 5]** gives detail changes that had occurred in land use land cover of Pichavaram. We encountered changes that, there is increase in 6248.66 [ha.] areas in agriculture cover is due to decrease in degraded mangrove, forest cover/ forest plantation, mangrove vegetation cover, mud flat, sand/beach, seawater/sea. This has been used for agriculture purposes. An increase of 150.07 [ha.] in aquaculture pond is due to decrease in area of degraded mangrove, forest cover/forest plantation, mangrove vegetation, mudflat and sand/beach. It is also found that there is increase in fallow land of 1713.06 [ha.] is due to decrease in forest cover/plantation, mangrove vegetation, and sand/beach. There is increase in 161.08 [ha.] of swamp area because of decrease in mangrove vegetation, forest cover/forest plantation and sea water/sea along the rivers. The increase of 96.65 [ha.] in waterlogged area is also due to decrease in sea water/sea along the rivers. Whereas there is decrease found of 954.77 [ha.] in degraded mangrove is due to conversion of degraded mangrove land in to agriculture cover, aquaculture pond, fallow land and swamp. The decrease of about 578.20 [ha.] area in forest cover/forest plantation is because of land utilization for agriculture cover, aquaculture pond and some pieces of land conversion in to fallow land, swamp and waterlogged area. A **decrease of 174.12 [ha.] in mangrove vegetation** indicates that, the mangrove degradation has occurred and that land has been used for agriculture, few piece of land used for aquaculture and conversion in to fallow land swamp and waterlogged area. There is decrease in mudflat area of about 66.78 [ha.] is because of its conversion in to agriculture, fallow land, swamp and few land in to aquaculture pond. A decrease in 3865.18 [ha.] of sand/beach and 2730.44 [ha.] of seawater/sea is because of conversion of lands in to aquaculture pond, swamp, fallow land, waterlogged area and agriculture cover.

When we compared the classified image of 2009 **[fig. 5]** with 1991 **[fig.3]** then we come to know that, there is increase in 9522.12 [ha] in agriculture area which is for the reason of decrease in forest cover, utilization of mud flat, swamp area for agriculture practices and due to decrease of sand/beach, sea water/sea. An increase in 518.05 [ha.] in aquaculture pond is because of conversion of some land of forest cover in to aquaculture pond, mud flat, sand/beach, sea water/sea. The increment of 417.24 [ha.] area of degraded mangrove is because of decrease in forest cover, mud flat, and conversion of some area of swamp, sand/beach, sea water/sea in to degraded mangrove. An increase in 495.52 [ha.] in fallow land is for the reason of decrease in forest cover/forest plantation, mud flat, sea water/sea, sand/beach swamp. It was also found interestingly that an **increase of 1605.87 [ha.] of mangrove vegetation** is because of utilization of few mudflat, forest cover, sand/beach, sea water/sea area, and swamp for mangrove restoration purposes. Whereas there was decrease found of 2101.65 [ha.] in forest cover/forest plantation because of excessive utilization for fuel, fodder, fire wood, aquaculture activity, agriculture cover, and fallow land and mangrove restoration purposes. About 969.16 [ha.] decrease in mudflat area is due to fallow land, degraded mangrove & use of mud flats for agriculture, restoration activities of mangrove and for construction of aquaculture ponds. Decrease of 5025.73 [ha.] in sand/beach is because of coverage by agriculture, aquaculture and restoration of mangrove & fallow land. In between 1991-2009 the decrease of 2156.47 [ha.] area of sea water/sea is due to construction of aquaculture pond, and conversion of sea water /sea area in to fallow land, waterlogged area and agriculture cover. And it was found that there is decrease in about 2049.18 [ha.] area of swamp it is because of conversion of swamp area in to agriculture cover, aquaculture pond, and fallow land. And decrease of 256.61 [ha.] waterlogged area is due to increase in agriculture cover, construction of aquaculture pond, mangrove vegetation and some waterlogged area along the rivers get converted in to sea water/sea or river water.

V. CONCLUSION

Optical Remote sensing data such as Landsat -TM is complimentary to coastal and marine information extraction at a particular time, and for monitoring changes over a given period. It provides better information about coastal wetland and land use such as mangroves, degraded mangrove aquaculture areas, tidal and mudflats, marsh, vegetations, lagoonal system and shoreline changes. There is no substitute of development but there is great need to reduce the negative impacts of change in land use land cover. The increase in agriculture in Pichavaram area has irreversible loss on mangrove vegetation. Aquaculture activities and degradation of mangrove are the important factor for degradation of unique mangrove vegetation; these activities are performed for increase in local economy, boat-building, tannin extraction, firewood, stacks, fishing, fodder and fulfillment of livelihood. Increase in fallow land have also impact on land use land cover, and play significant role in degradation of mangrove vegetation by changing the physical biological, geochemical and hydrological factor of the soil. And forest covers also changes the entire ecology and land use land cover of the mangrove area, and make it unfit for growth & flurishment of mangrove vegetation by decreasing in cover. Swamp area also affects the land use land cover pattern of Pichavaram & mangrove vegetation. Mudflat sand/beach, seawater/sea, and waterlogged area fluctuate due to environmental condition of atmosphere and tide of Bay of Bengal and changes the entire ecology & land use land cover pattern of the Pichavaram. The study revealed that the regular monitoring of Pichavaram mangrove is very essential with the help of remote sensing and geographical information system. Which serve very essential technique to assess the magnitude, rate, location, trend of land use land cover as well as local environmental changes. And to quantify interaction among local land use land cover changes. The prospects of the study is the reduction of environmental degradation of unique species of mangrove and restoring damage of Pichavaram mangrove vegetation and ecosystem for sustaining ecological goods and services.

VI. FIGURES &TABLES

Table 1. Land Use Land Cover Classification Area Distribution of Pichavaram Mangrove (1991, 2000, 2009)

LULC Class Names	**1991 Area (Ha.)**	**1991 Area (%)**	**2000 Area (Ha.)**	**2000 Area (%)**	**2009 Area (Ha.)**	**2009 Area (%)**
Mangrove	472.4046	0.86473756	2252.409	4.123039157	2078.28	3.804295676

Table 2. Percentage Change, (-) sign & (+) sign denotes decrease & increase in the relevant area respectively

LULC Class Names	**2000-1991**		**2009-2000**		**2009-1991**	
	Area (Ha.)	**Percentage Change**	**Area (Ha.)**	**Percentage Change**	**Area (Ha.)**	**Percentage Change**
Mangrove	1780.0044	12.08021276	-174.129	-1.0402550	1605.8754	6.393411164

Table 3. Land Absorption coefficient of Mangrove

LULC Class Names	LAC OF 1991/2000	LAC OF 2000/2009	MEAN OF L.A.C (LAC OF 2018)
Mangrove	-0.88820542	0.154919039	-0.52156223

Table 4. Land Consumption Rate

YEAR	**LAND CONSUMPTION RATE RATE (Mangrove Area)**	**Average LCR of Mangrove area/year**	**LULC Class Names**	**2018 Area (Ha.)**
1991	0.098705516	0.073186146	Mangrove	2078.28
2000	0.756349563	**Year**	**Population Difference**	
2009	1.120970874	2009-2000	-1124	
2018	1.976025953	2018-2009	-1123	
		2009-1991	-2932	

Table 5. Population figure of Pichavaram in years 1991, 2000, 2009 & 2018

YEAR	**POPULATION FIGURE**	**SOURCE**
1991	4786	Directorate of census department Tamil Nadu
2000	2978	Directorate of census department Tamil Nadu
2009	1854	Estimated
2018	731	Projected

Table 6. Research Estimate of year 2018

Year	**Total Population**	**LCR(Mangrove)**	**LAC(Mangrove)**	**Total Mangrove Area (exceeded)**
2018	731	1.976025953	-0.52156223	3900.675232

Fig. 3 Landsat image of the year 1991 and its unsupervised classification

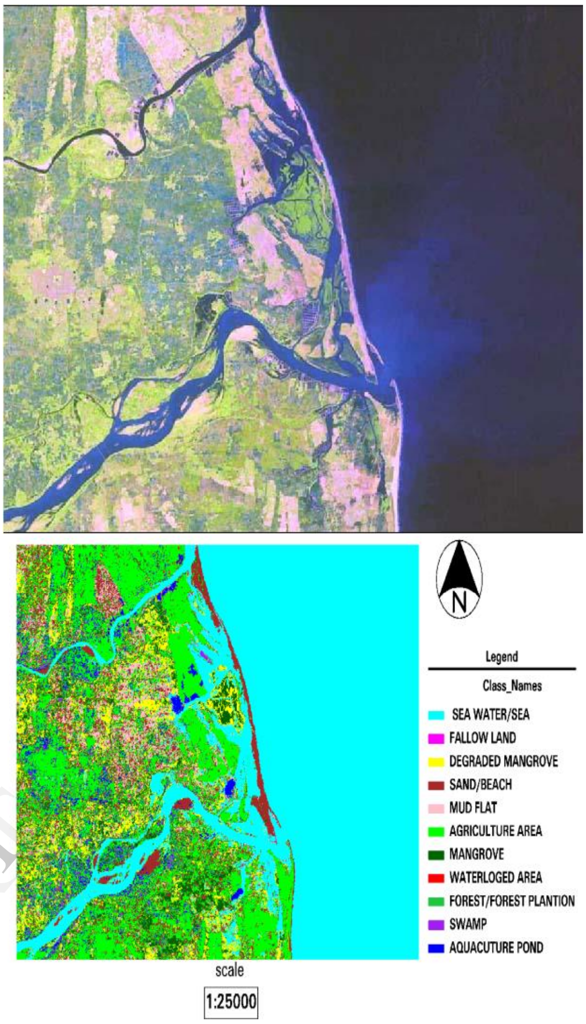

Fig. 4 Landsat image of the year 2000 and its unsupervised classification

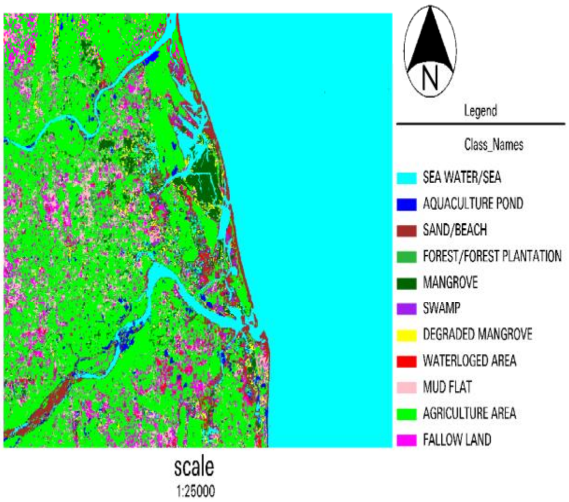

Fig. 5 Landsat image of the year 2009 and its unsupervised classification

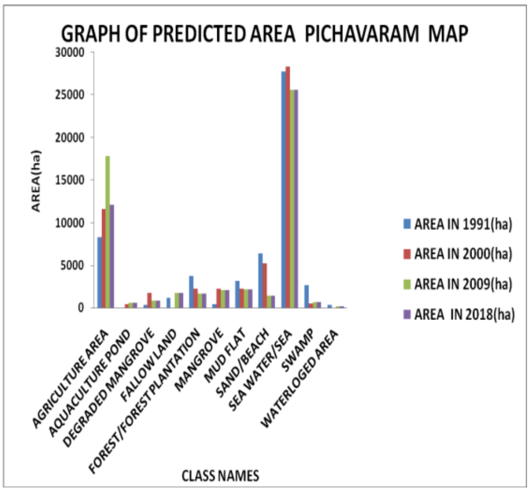

Fig. 6 Bar diagram indicates the land use/land cover change in the study region during the year from 1991 to 2009 & predicted land use/land cover for year 2018

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REFERENCES

[1] 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 No. 964, U.S. Government Printing Office, Washington, D.C. p. 28.
[2] Alexander R.H., & Milazzo V.A. (1973). Urban and regional land use analysis and census cities experiment package, MO, Progress Report E 74-1 0252, NASA-CR 1365661.
[3] Benarchid, O., Raissouni, N. (2013). Potential of semi-automatic object-based land cover classifications using very high resolution satellite images: Tetuan-city comparison case study, Research & Reviews: Journal of Space Science & Technology, ISSN: 2321-2837.
[4] IGBP., (1993) Report No.24. 'Relating landuse and global land cover change', a proposal for an IGDB-HDP core project, 65pp.
[5] Kuenzer, C., Bluemel, A., Gebhardt, S., Quoc, T.V., & Dech, S. (2011). Remote sensing of mangrove ecosystems: A review, Remote Sensing, ISSN 2072-4292, Remote Sens. 2011, 3, 878-928; doi:10.3390/rs3050878.
[6] Krishnamoorthy, L. Selvam, V.Ramasubramaniam, R Mishra. P.K., & Bharathan S.K. (1994). Application of remote sensing and GIS to study the impact of coastal hydrology and geomorphology on mangroves'. Proceedings of the 10 Thematic Conference on Geologic Remote Sensing Vol.II pp 12- 26.
[7] Kirishnamoorthy R. (1997). Managing mangroves in India' GIS Asia Pacific June/July issue pp 26- 29.
[8] Lillysand, T.M., & Keifer, R.W. (1987). Remote sensing and image interpretation, John Wiley and Sons New York.
[9] MOEF. (1987). Mangrove in India –status report Ministry of Environment and Forest Government of India, New Delhi, 150pp.
[10] Mukherjee S. (1998). Change in groundwater environment with land use pattern in a part of south Delhi. A remote sensing approach, journal of Asia- pacific Remote Sensing and GIS 9 (2): 9-14.
[11] Mukherjee S. (2004). A text book of environmental remote sensing, Macmillan, India Ltd.
[12] Nayak S.G., S.RM.C. , & Chawan H.B. (1986). Wetland and shoreline mapping of the part of Gujarat coast using satellite data, scientific note (IRS-UP-SAC-MCE/SN06/85) Space Application Centre, Ahmedabad, 24pp.
[13] Seteo K.C., Woodcock C.E., Song C., Huang X., Lu J., & Kaufmann R.K. (2002). Monitoring land use change in the Pearl River delta using using landsat TM, Intenational Journal of Remote Sensing 23 (10):1985-2004.
[14] Schowengerdt R.A. (1997). Remote sensing: models and methods for image processing, Second ed, Academic Press, San Diego, CA.
[15] Wilkie, D.S., & Finn, J.T. (1996). Remote sensing imagery for natural resources.
[16] Weng Q. (2002). Land use change analysis in the zhujiang delta of China using satellite remote sensing, GIS and stochastic modeling, Journal of Environmental Management 64: 273-284.
[17] Wali M.k., Evrendilek F., West T., Watts S., Pant D., Gibbs H., & McClead B. (1999). Assessing terrestrial ecosystem sustainability: usefulness of regional carbon and nitrogen models, Nature & Resources 35(4): 20-33.
[18] XiaoMei Y., & Rong Qing L.Q.Y. (1999). Change detection Based on remote sensing information model and its application on coastal line of Yellow River delta, Earth Observation Centre, NASDA, China.