# Mangroves' Susceptibility to shifting Coastal Regulation Zones: An analysis of Goa's Chapora and Sal Estuaries

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***Abstract***

*Goa is a coastal State located on the west coast of India, known for its pristine sandy beaches and environment. Ministry of Environment and Forest implemented Coastal Regulation Zone Notification in 1991 for monitoring the coastal zones for unplanned developmental activities. The regulation has been changed in recent years, thereby making the coastal and the riverine ecosystem more vulnerable to human interference. In the name of development, various hazardous, unplanned activities have taken place which are degrading the coastal and riverine environment, especially mangroves. Mangroves are halophytes that are usually found in the inter-tidal regions in tropical and sub-tropical regions.*

*The vulnerability of mangroves to the changing regulations with respect to 1991 and the 2018 CRZ notifications has been studied considering the land use land cover changes within the regulated zones of Chapora and Sal estuaries in North and South Goa district respectively. Both the estuaries have sparse to dense fringing mangrove vegetation. In Chapora and Sal estuaries, fisheries and tourism related activities are prominent in nature. Hence, increase in human induced activities in the regulated zones can impose threat to the estuarine ecosystem. Spatial analysis techniques and software such as ArcGIS 10.3 and ERDAS IMAGINE 2014 have been used for analysis and results. The findings from the study can be effectively implemented in monitoring the regulated zones and protecting mangroves efficiently.*

**Keywords:** CRZ, mangroves, Goa, LANDSAT.

## Introduction

**Coastal Regulation Zone:** India adopted Coastal Regulation Zone Legislations in the year 1991, the first specialized step to control the unsustainable activities around the coastal zones[1]. Seas, bays, estuaries, creeks, rivers and backwaters influenced by tides within 500 m of high tide line fall under CRZ category[9].

However, there have been frequent amendments in the notifications. As per 2011 CRZ Notification, the coastal areas from High Tide Line to 500 m on the landward side and the land area between High Tide Line to 100 m along the tidal influenced water bodies connected to the sea, are declared as protected under Coastal Regulation Zone[4].

As per the recent implementation of CRZ Notification of 2018, the CRZ shall apply to the land area between High Tide Line to 50 m of coast or width of the creek, influenced by tidal action[6]. With these CRZ revisions, a number of unplanned developmental activities will arise, thereby resulting in the loss of natural resources and functioning of ecosystem[5].

**Mangroves:** Mangrove forests are found in the intertidal zones along the tropical and subtropical coastlines[3,17]. Mangroves are among the world's productive ecosystem[8]. Mangroves act as wildlife reserve which protects a large number of flora and fauna by proving habitats, spawning grounds and nutrients[12]. Economically, mangroves are popular for eco-tourism and recreation activities[7]. The mangrove covers in Goa in approximately 0.5% to the total mangrove covers of India[10].

**LULC:** Remote sensing and Geographical Information System (GIS) are widely used for mapping the land use land cover (LULC) for different spatio-temporal scales[16]. Land use is the output of the relation between natural and manmade processes. Hence, analysis of land-use and land-cover distribution is the most essential means to execute planning and management in sensitive areas/zones[13]. The spatio-temporal changes of land use and land cover studies are helpful in a variety of environmental applications such as management of natural resources, planning or policy making as they help in utilization, conservation and management[2].

Monitoring the land use land cover change along the Coastal Regulation Zone (CRZ) areas is essential for understanding the existing status of ecologically sensitive areas to protect the ecosystems from damaging activities[14]. The present study aims to understand the vulnerability of mangroves to changing CRZ limits. The objective is to study the changes in land use land cover along the regulated zones of Chapora and Sal estuaries using remote sensing data and geospatial techniques.

## Study Area

Goa is a coastal State on the Western Coast of India with lat-long extent of 14°55' N to 15°45' N and 73°40' E to 74°10' E[11]. Chapora river is located in Bardez and Pernem taluka of North Goa district and has an estuarine length of 30 km[15] whereas Sal river flows North to South in Salcete taluka of

South Goa district and has an estuarine length of 10 km[15]. Both rivers drain in the Arabian Sea. Chapora and Sal estuaries have dense to sparse distribution of mangroves which are fringing in nature. Study area is represented in figure 1.

## Material and Methods

The study is based on both primary and secondary data. The primary data includes field based observations. Nevertheless, a major part of the study is based on secondary data source which includes satellite imageries of 1991 and 2018, resembling to the time periods of the amended notifications. Satellite images of 2011 were not selected due to presence of scan line errors on the images. LANDSAT images with no cloud cover are downloaded from the United States Geological Survey (USGS) website. For analysis purpose, geospatial software such as ArcGIS 10.3 and ERDAS IMAGINE 2014 software have been used. LANDSAT satellite images are used to classify and map the land use land cover changes within the CRZ using ArcGIS 10.3 software. LANDSAT 4-5 TM and LANDSAT 8 OLI images of the years 1991 and 2018 of 30 m resolution each and Survey of India (SOI) topographic maps of 1:50,000 scale were used to derive necessary data for analysis. Both the estuaries-Chapora and Sal are demarcated up to the tidal influence using the toposheets (Figure 1).

The selected satellite images corresponding to low tide conditions were preferred to get maximum exposure to the land features and to yield accurate results. Table 1 displays the data used and derived for the analysis. The pre-processing of the images (atmospheric and radiometric corrections), layer stacking and mosaic were carried out using the image processing software ERDAS IMAGINE 2014. Stacking of Green, Red and Near Infra-Red (NIR) generated False Colour Composite (FCC) images for both satellite data. ArcGIS 10.3 software was used for georeferencing and projecting the Survey of India toposheets (WGS84 UTM Zone 43 N). Survey of India (SOI) toposheets were used for reference and to demarcate the high tide line. The high tide line was demarcated up to the tidal influx in the estuaries.

Upon demarcation of the high tide line, the Buffer Analysis tool was used to extract 100 m and 50 m zone along the high tide line of Chapora and Sal estuaries. The extracted zones of 100 m and 50 m for the years 1991 and 2018 were used for studying land use land cover changes and the vulnerability of mangroves to the changing CRZ. The land use land cover classes were categorized into 5 classes namely, barren land, built-up, mangroves, vegetation and water. The classes were demarcated using the onscreen digitization method. Mangrove patches were identified from other land use on the basis of visual interpretation techniques and were verified using high-resolution Google Earth platform. Change detection of LULC classes for 100 m zone between the period 1991 and 2018 was performed in ArcGIS 10.3 software. Figure 2 displays the methodology chart.

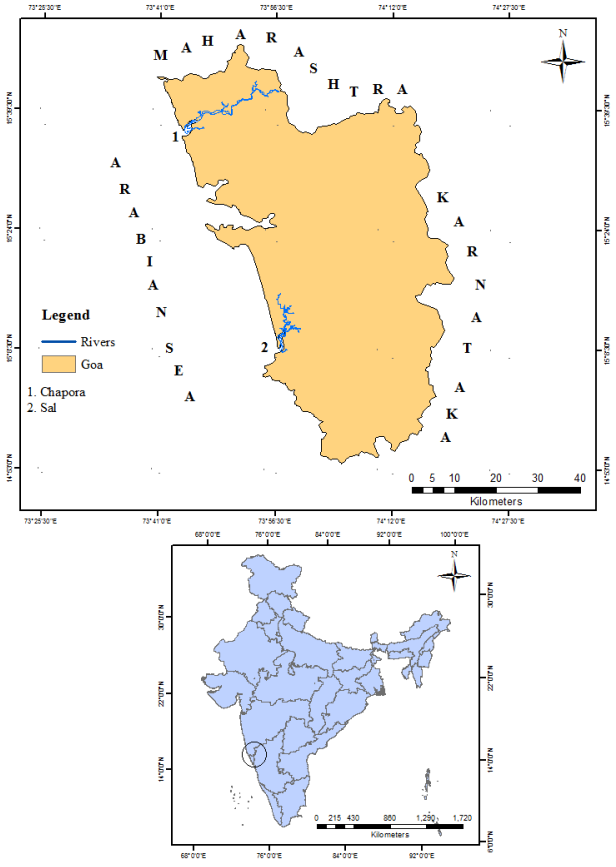


**Figure 1: Map of study area**

## Results and Discussion

The long-term monitoring of changes in land use and land cover is crucial as it provides necessary information about the past, to understand the current situation and future change of land cover[16]. Through the land use land cover change study within the 100 m and 50 m of CRZ, it has been observed that tremendous changes have taken within the regulated zones along the Chapora and Sal estuaries. Furthermore, in 2018 the changes in the CRZ notification have reduced the CRZ from 100 m to 50 m along the creeks and estuaries to increase changes in the land use pattern.

As inferred in table 2, in the year 1991 (in 100 m zone), the area under barren land, built-up, mangroves, vegetation and water in Chapora estuary was 2.1 $km^2$, 0.38 $km^2$, 0.63 $km^2$, 4.67 $km^2$ and 1.38 $km^2$ respectively. Whereas, in the year 2018 (in 100 m zone), the area under barren land, built-up, mangroves, vegetation and water in Chapora estuary was 1.3 $km^2$, 0.6 $km^2$, 1.17 $km^2$, 4.66 $km^2$ and 1.43 $km^2$ respectively.

In case of Chapora estuary, over the period of 27 years, area under built-up, mangroves and water has increased by 0.22 $km^2$, 0.54 $km^2$ and 0.05 $km^2$ respectively. On the other hand, areas under barren land and vegetation have decreased by 0.8 $km^2$ and 0.01 $km^2$ respectively. The reason for increase in mangrove cover can be attributed to natural increase in mangrove vegetation. The estuary has sediment deposition along its banks providing suitable area for the mangrove propagules to germinate. The increase in built-up is a result of influence of tourism in this region. The area under vegetation and barren land has decreased due to developmental activities. Figures 3, 4, 5 and 6 represent LULC changes within 100 m and 50 m zones of the Chapora estuary. Figure 7 depicts the conversion of the LULC classes in the Chapora estuary from 1991 to 2018.

For Sal estuary, in the year 1991 (in 100 m zone), the area under barren land, built-up, mangroves, vegetation and water in Sal estuary was 3.76 $km^2$, 0.26 $km^2$, 0.75 $km^2$, 3.17 $km^2$ and 0.66 $km^2$ respectively. Whereas, in the year 2018 (in 100 m zone), the area under barren land, built-up, mangroves, vegetation and water in Sal estuary was 1.47 $km^2$, 0.73 $km^2$, 2.13 $km^2$, 3.62 $km^2$ and 0.65 $km^2$ respectively as inferred in table 3. In case of Sal estuary, over the period of 27 years, area under built-up, mangroves and vegetation has increased by 0.47 $km^2$, 1.38 $km^2$ and 0.45 $km^2$ respectively. But, the area under barren land and water is found to have decreased by 2.29 $km^2$ and 0.01 $km^2$ respectively. The reason for increase in mangrove cover can be attributed to natural increase in mangrove.

**Table 1**
**Data source and data derived**

| Data Used | Source | Data Derived |
|---|---|---|
| Survey of India (SOI) toposheets of 1:50,000 scale | Survey of India | High Tide Line (HTL) |
| LANDSAT 8OLI images (19/01/2018)<br>LANDSAT 4-5 TM images (10/02/1991)<br>30 m spatial resolution each | United States Geological Survey (USGS) website | Land use land cover (LULC) |
| Google Earth and Field Visit | - | Ground truthing |

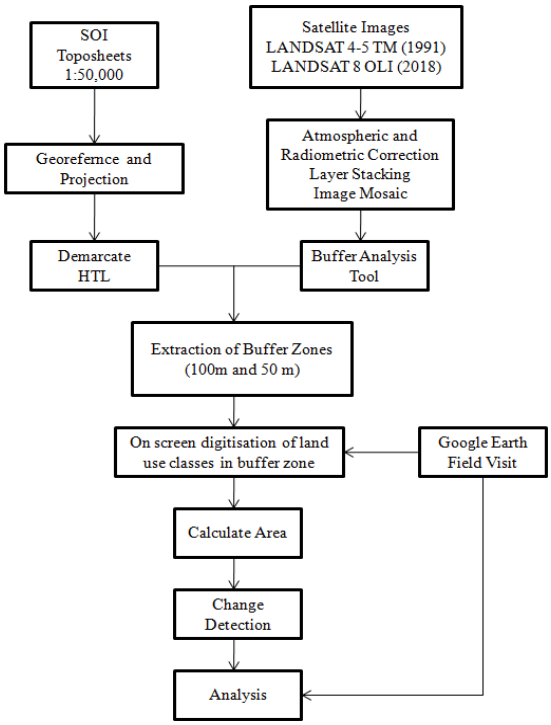


**Figure 2: Methodology Chart**

**Table 2**
**LULC changes within the 100 m and 50 m CRZ of Chapora estuary (1991 and 2018)**

| Land use/ Year | Chapora estuary (Area in km$^2$) | | | |
|---|---|---|---|---|
| | 1991 (100 m) | 2018 (100 m) | 2018 (50 m) | 2018-1991 Overall Loss |
| Barren land | 2.1 | 1.3 | 0.49 | -0.8 |
| Built-up | 0.38 | 0.6 | 0.33 | 0.22 |
| Mangroves | 0.63 | 1.17 | 0.55 | 0.54 |
| Vegetation | 4.67 | 4.66 | 2.22 | -0.01 |
| Water | 1.38 | 1.43 | 1.02 | 0.05 |
| Total | 9.16 | 9.16 | 4.61 | - |

Source: Image Classification

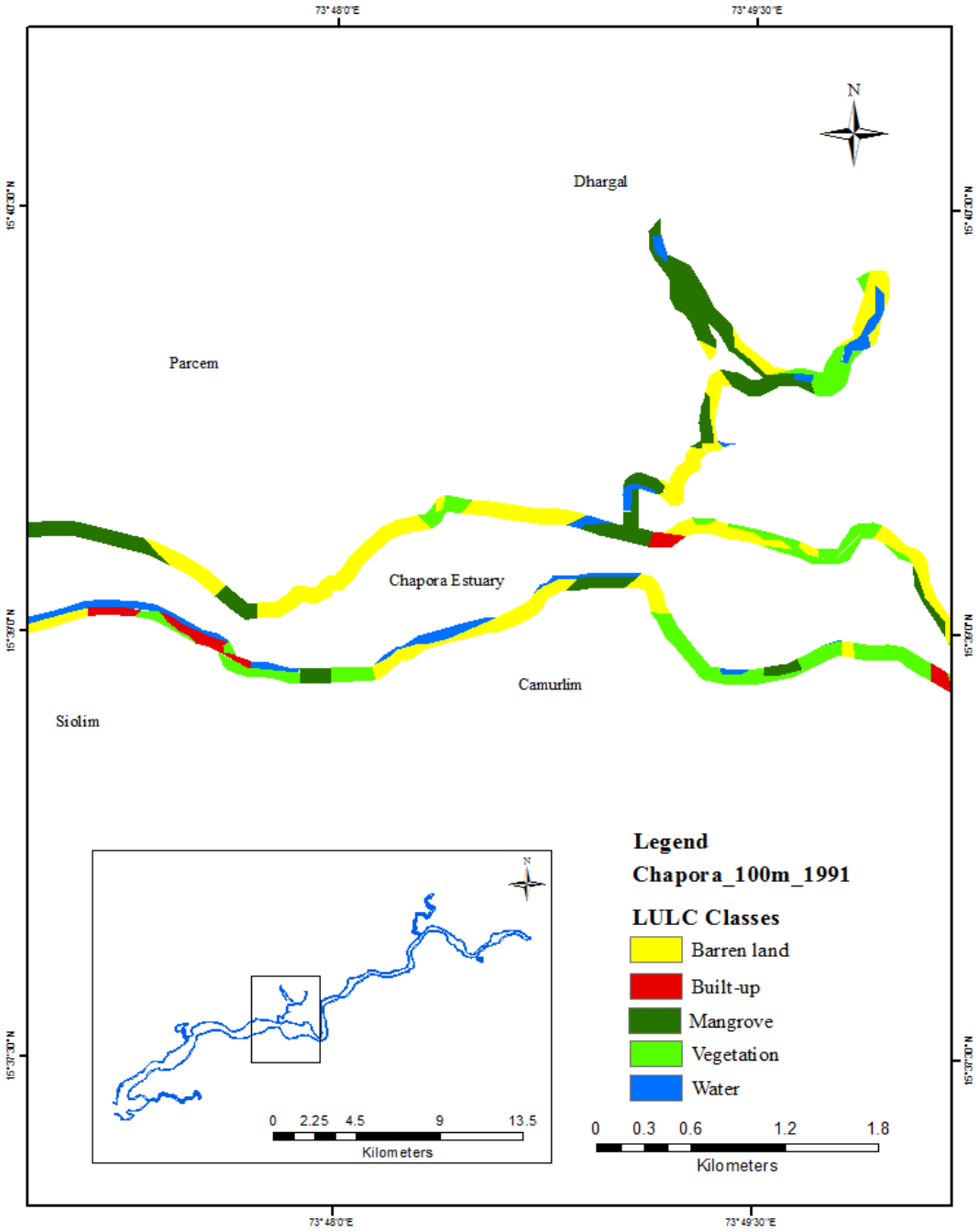


**Figure 3: LULC changes within 100 m zone of Chapora estuary (1991)**
Source: Image Classification

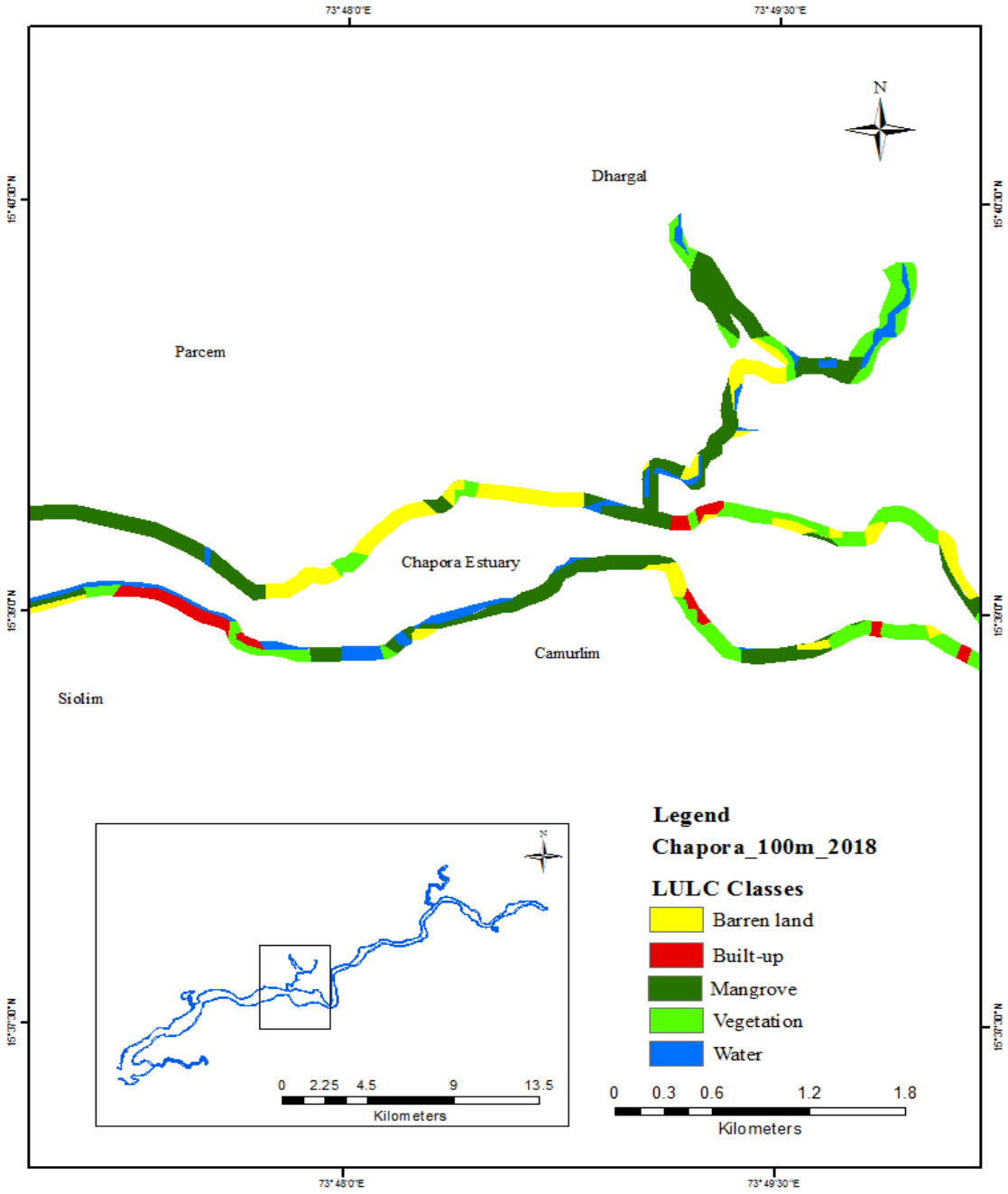


**Figure 4: LULC changes within 100 m zone of Chapora estuary (2018)**
Source: Image Classification

**Table 3**
**LULC changes within the 100 m and 50 m CRZ of Sal estuary (1991 and 2018)**

| Land use/ Year | Sal estuary (Area in km$^2$) | | | |
|---|---|---|---|---|
| | 1991 (100 m) | 2018 (100 m) | 2018 (50 m) | 2018-1991 Overall Loss |
| Barren land | 3.76 | 1.47 | 0.64 | -2.29 |
| Built-up | 0.26 | 0.73 | 0.37 | 0.47 |
| Mangroves | 0.75 | 2.13 | 1.27 | 1.38 |
| Vegetation | 3.17 | 3.62 | 1.84 | 0.45 |
| Water | 0.66 | 0.65 | 0.34 | -0.01 |
| Total | 8.6 | 8.6 | 4.46 | - |

Source: Image Classification

Mangroves have ability to regenerate in areas where land is vacant. The propagules of mangroves get dispersed and can germinate in suitable conditions. Sal area is well known for fishing, aquaculture, prawn farming and tourism. Due to tourism activities, built-up has also increased. Barren land and water areas have reduced due to reclamation of land for activities related to fishing, tourism infrastructure etc. Figures 8, 9, 10 and 11 represent LULC changes within 100 m and 50 m zones of the Sal estuary. Figure 12 depicts the conversion of the LULC classes in the Sal estuary from 1991 to 2018.

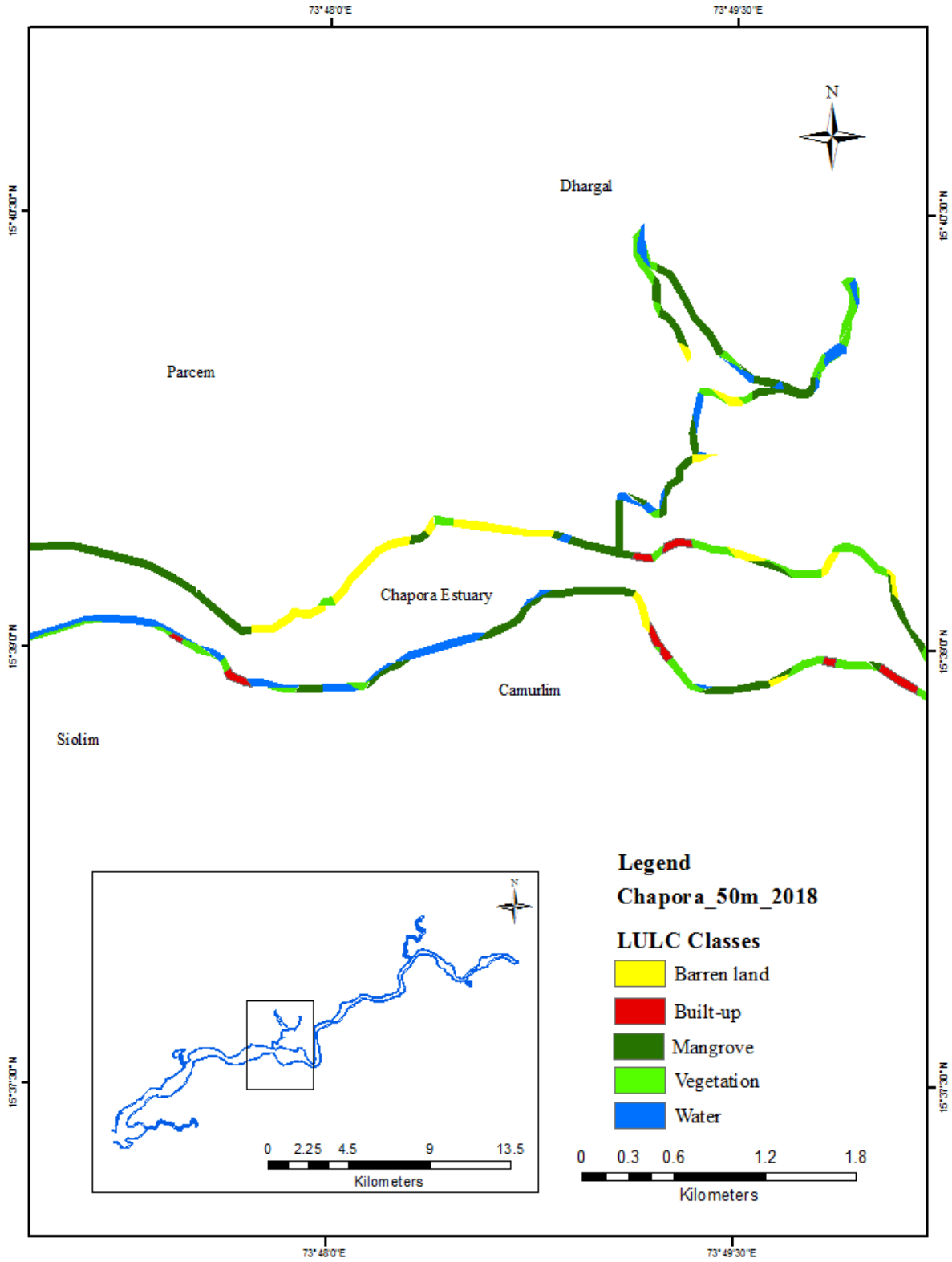


**Figure 5: LULC changes within 50 m zone of Chapora estuary (2018)**
Source: Image Classification

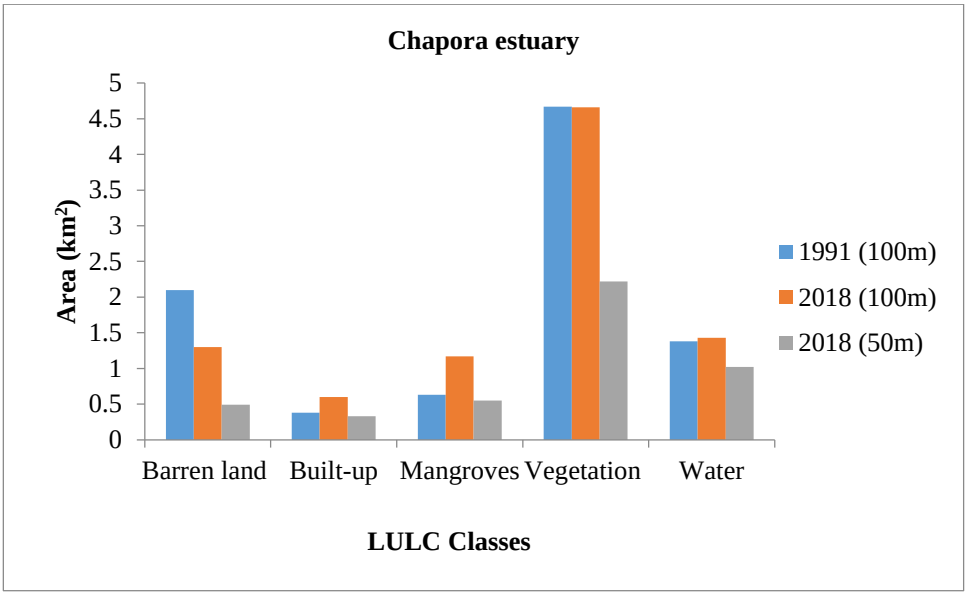


**Figure 6: LULC changes in 100 m and 50 m zones of Chapora estuary**
Source: Image Classification

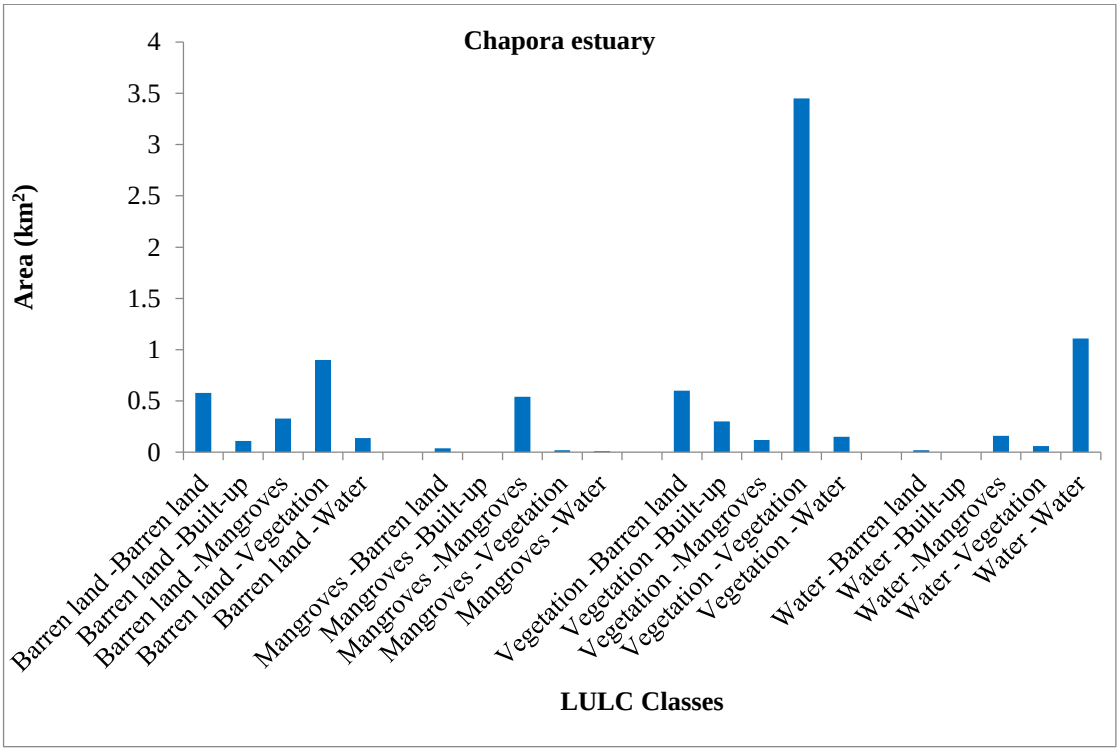


**Figure 7: Change detection in 100 m zone of Chapora estuary (1991-2018)**
Source: Image Classification

Though mangroves have shown an increasing trend, but as per the CRZ Notification of 2018, the regulated zone has been reduced to 50 m. With the decline in the demarcation of the regulation zone, human interference is likely to increase leading to more harmful and unplanned development within the zone which may increase the vulnerability mangroves to degradation. Since mangroves are fringing in nature along the Chapora and Sal estuaries, depletion is likely to occur with changes in regulated zone. Both estuaries-Chapora and Sal are located in tourism dominated talukas i.e. Salcete and Bardez talukas are the most prime tourist locations.

Currently, with the increasing tourism and tourist activities not just in coastal areas, but also along the estuarine regions of Chapora and Sal can put sensitive coastal and estuarine ecosystem at risk. The risks are imposed from various anthropogenic activities such as development of hotels and resorts along the river banks, water sports activities, aquaculture and fishing, dumping of waste etc.

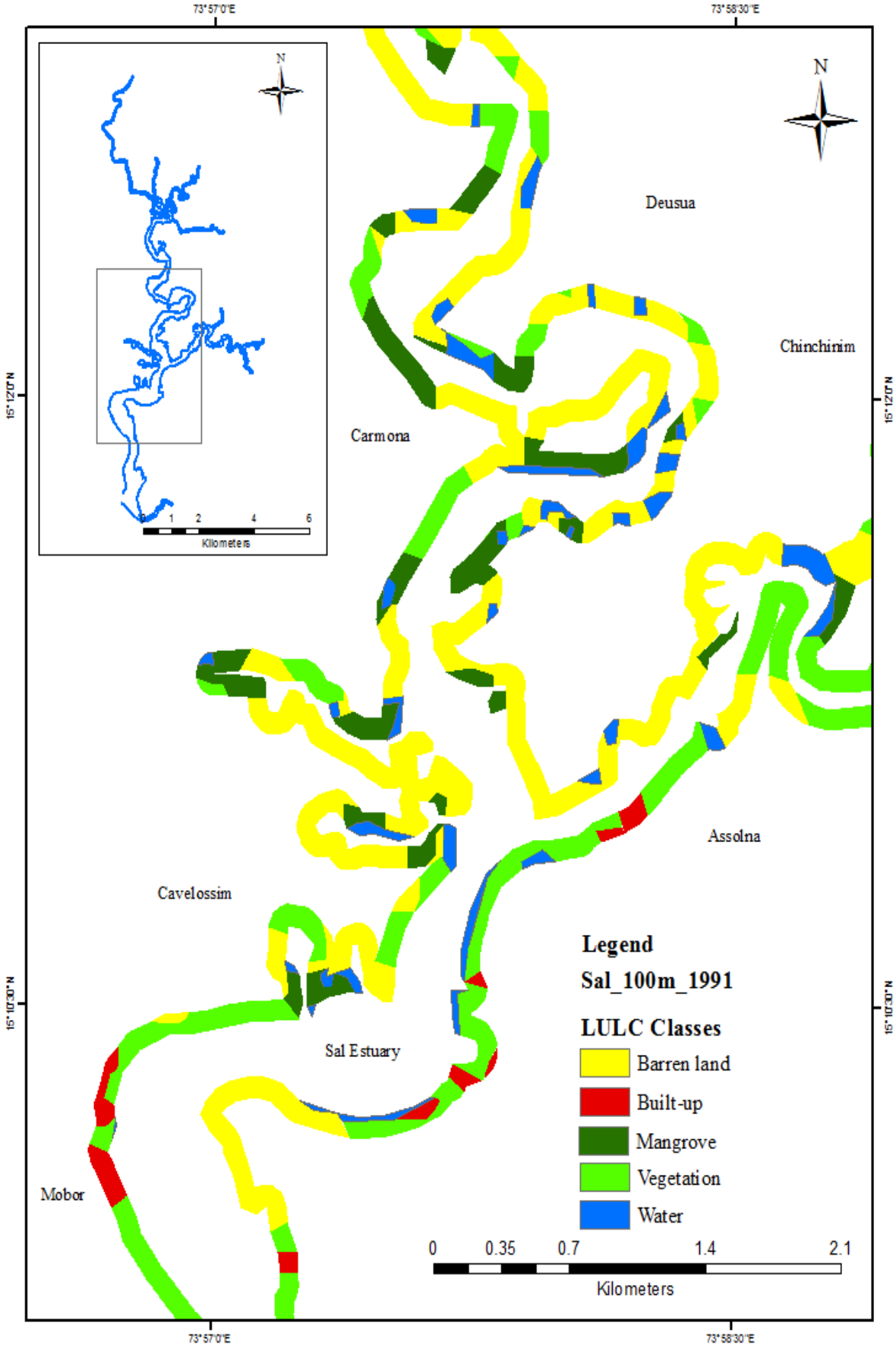


**Figure 8: LULC changes within 100 m zone of Sal estuary (1991)**
Source: Image Classification

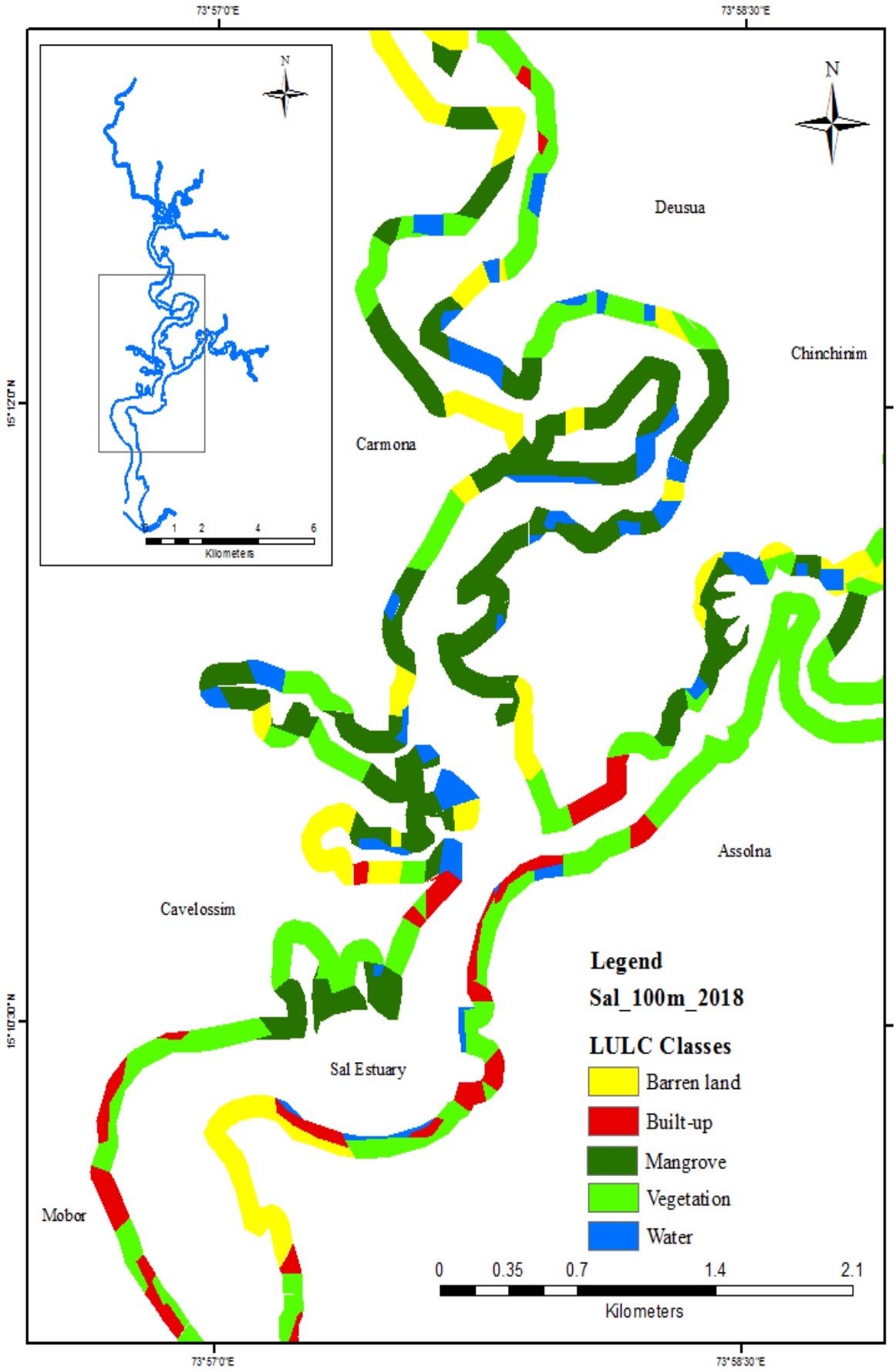


**Figure 9: LULC changes within 100 m zone of Sal estuary (2018)**
Source: Image Classification

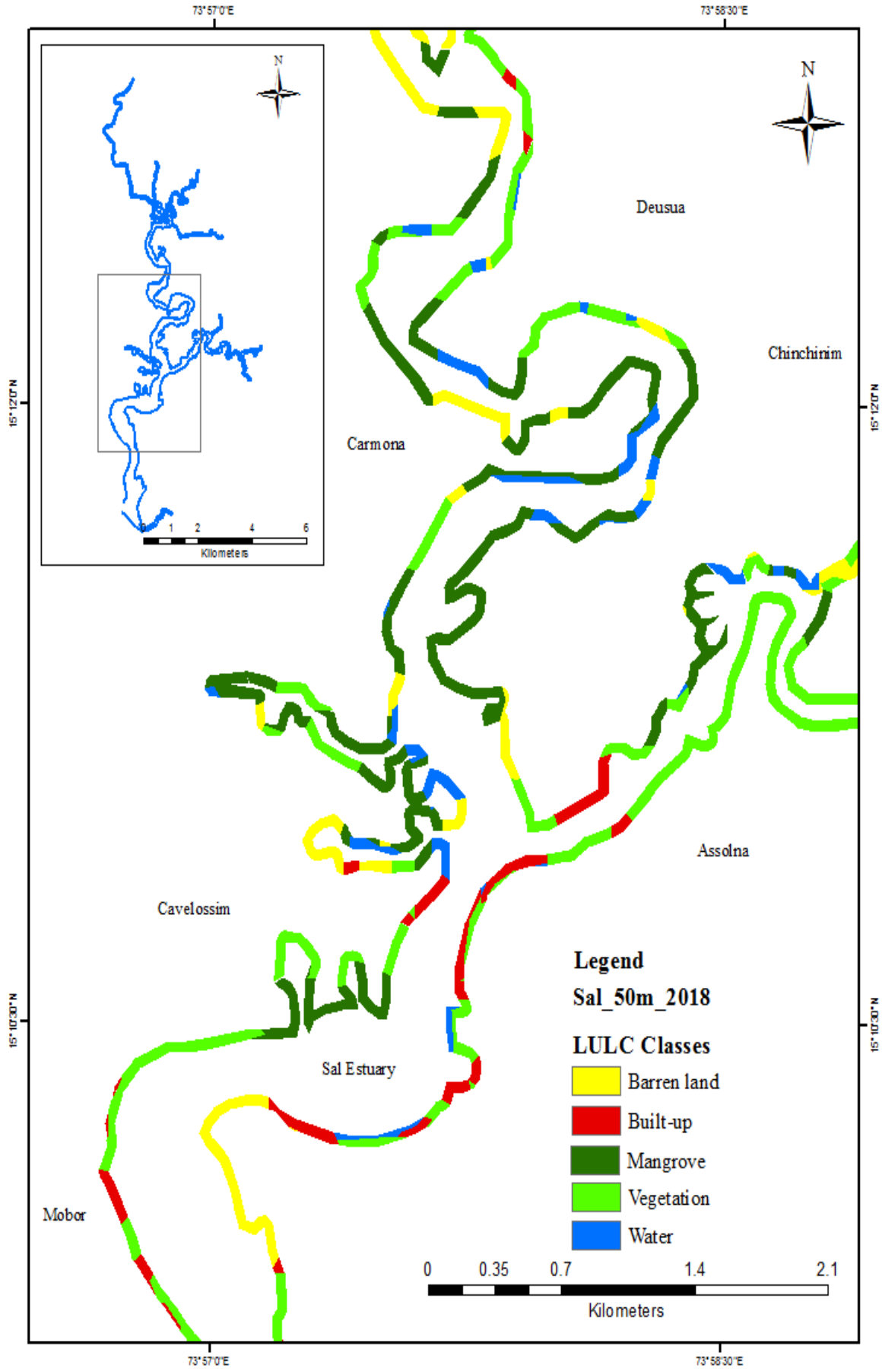


**Figure 10: LULC changes within 50 m zone of Sal estuary (2018)**
Source: Image Classification

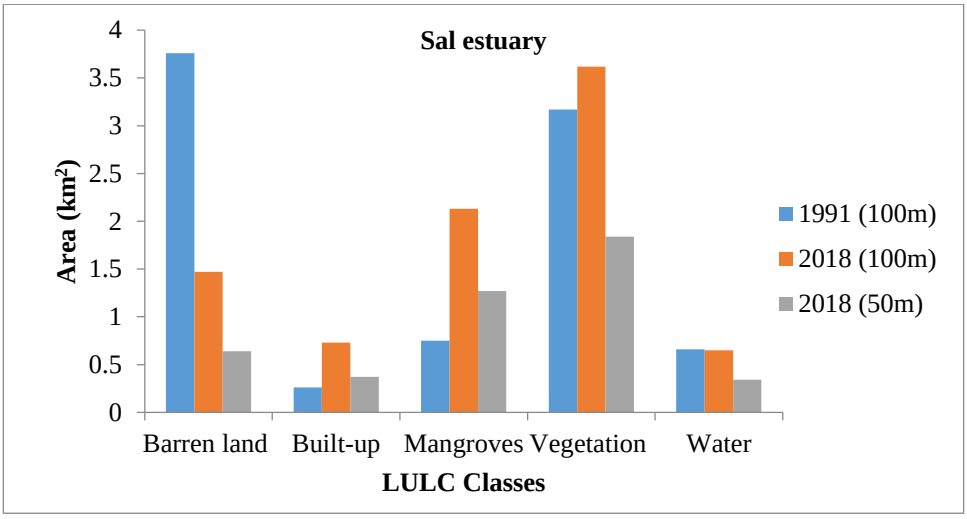


**Figure 11: LULC changes in 100 m and 50 m zones of Sal estuary**
Source: Image Classification

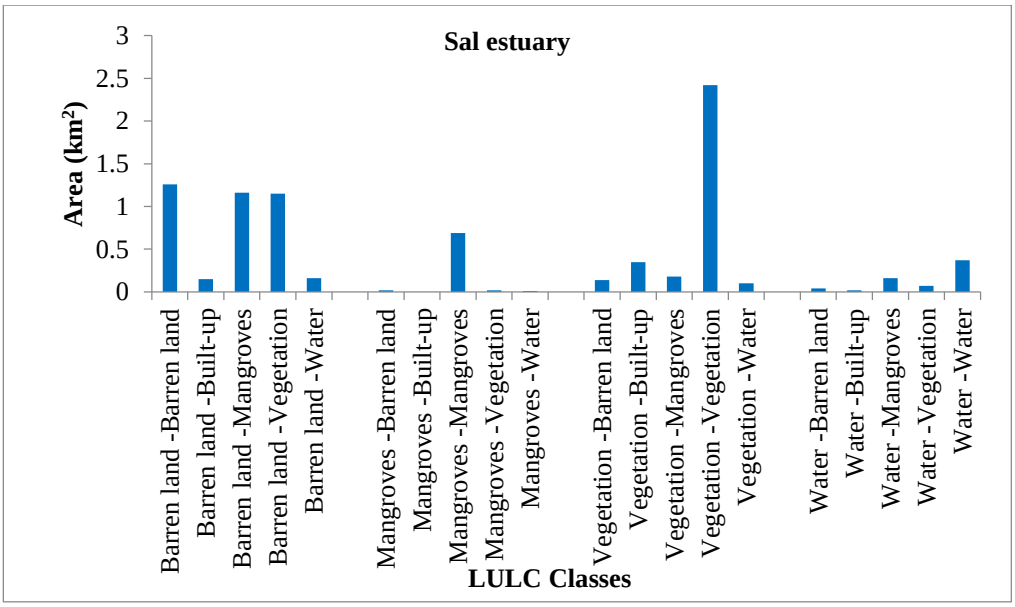


**Figure 12: Change detection in 100 m zone of Sal estuary (1991-2018)**
Source: Image Classification

## Conclusion

There is urgent need to promote the eco-friendly and sustainable development in sensitive zones. Government may also collaborate with the local NGOs or private partners or locals to revive mangroves areas and work towards their conservation. Plantation drives and encouraging people's participation can lead to first hand measure towards mangrove conservation and in saving the fragile ecosystem for posterity. Such phenomenal task requires proper surveys, documentation and mapping. Moreover, sustainable tourism needs to be promoted in mangrove areas so as to create awareness about the mangrove ecosystem amongst the people.

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