Integrated coastal zone management plan for Udupi coast using remote sensing, geographical information system and global position system

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Abstract: Coastal areas are under great pressure due to increase in human population and industrialization/commercialization and hence these areas are vulnerable to environmental degradation, resource reduction and user conflicts. In the present study an Integrated Coastal Zone Management Plan (ICZMP) has been developed for Udupi Coast in Karnataka, along West Coast of India. The various data products used in the present study includes IRS-1C LISS-III + PAN and IRS-P6 LISS III remotely sensed data, Naval Hydrographic Charts and Survey of India (SOI) toposheets, in addition to ground truth data. Thematic maps such as land use/ land cover map, bathymetry map, shoreline configuration map, transportation and drainage network maps, GPS survey map, CRZ map, contour map, DEM, inundation map, critical erosion area map were prepared. A Coastal Vulnerability Index has also been calculated for the study area to know the resistance of study area to sea level rise and is demarcated into four categories; Very high, High, Moderate and Low vulnerability, and a vulnerability map has been prepared. The results of the present study are encouraging. Some of the specific conclusions of the study are; about 50% study area is prone to erosion, river mouths along study area show shifting tendency towards south, and the beaches along the Udupi Coast are maintaining dynamic equilibrium. Coastal Zone Information System (CZIS) has been developed through V.B.6.0 using results of various data analysis.

Keywords: Shoreline configuration, naval hydrographic charts, coastal vulnerability index, digital elevation model, coastal regulation zone.

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1 INTRODUCTION

The coastal zone of the world is under increasing stress due to development of industries, trade and commerce, tourism and increasing population growth. The region is of very high biological productivity and thus an important component of the global life system. The coastal areas are vulnerable to environmental degradation, resource reduction, and user conflicts. The development of industries along the coast has resulted in degradation of coastal ecosystems and diminishing the living resources of Exclusive Economic Zone (EEZ). Episodic events, such as cyclones, floods and tsunami pose serious threat to human life and property in the coastal zone. In the country like India, where a large number of people are dependent on coastal natural resources for their survival, social dimensions of livelihood and ecological security have been incorporated. Around 75% of the total human population is expected to be living in the coastal zone by 2025. A Coastal Zone Information System (CZIS) has been designed and developed in GIS and V.B 6.0 environment to prepare an effective Coastal Zone Management Plan (CZMP). This will not only guide for development of various activities such as industries, tourism, setting up of harbor and jetties along the coast and also will help in proper utilization of coastal resources to avoid any adverse effect or damage to the entire coastal eco-system. Similar CZIS has been developed by various researchers [1-2].

2 OBJECTIVES

The objectives of the present study are

1. Development of Coastal Vulnerability Index (CVI) for Udupi coast
2. Identification of Critical Erosion Areas
3. To develop comprehensive ICZMP for Udupi Coast
4. To develop CZIS

3 STUDY AREA

The coastal stretch starting from Surathkal in south to Navunda in the North, along Dakshina Kannada Coast, Karnataka, West Coast of India is the study area. It lies between 13°00'00"-13°45'00"North Latitude and 74°47'30"-74°38'00"East Longitude. The length of the coastline is about 90 km and is oriented along the NNW – SSE direction [Fig. 1]. The study area has a tropical climate. March to May constitute the hot season, average daily temperature is 36° C. The study area receives a very heavy downpour between June and September due to southwest monsoon. The average annual rainfall is 3954 mm of which 87% is received during the monsoon season. Maximum wave height recorded so far is 5.4 m with zero crossing periods of 8.9 seconds. The tides along this coast are semi-diurnal in nature, with approximate tidal range of 1.6 m. laterites are abundant in the region. The exposed laterites develop a hard crust and are devoid of vegetation as they do not retain any moisture. The area between the shoreline and Western Ghats can be broadly divided in to three regions namely the low land, the mid and high land [3].

4 DATA PRODUCTS

While carrying out the present work, both conventional and remotely sensed data were used and the details about the same are furnished in Table-1

Software Used

- ERDAS Imagine 8.7
- Arc Map
- Visual Basic 6.0

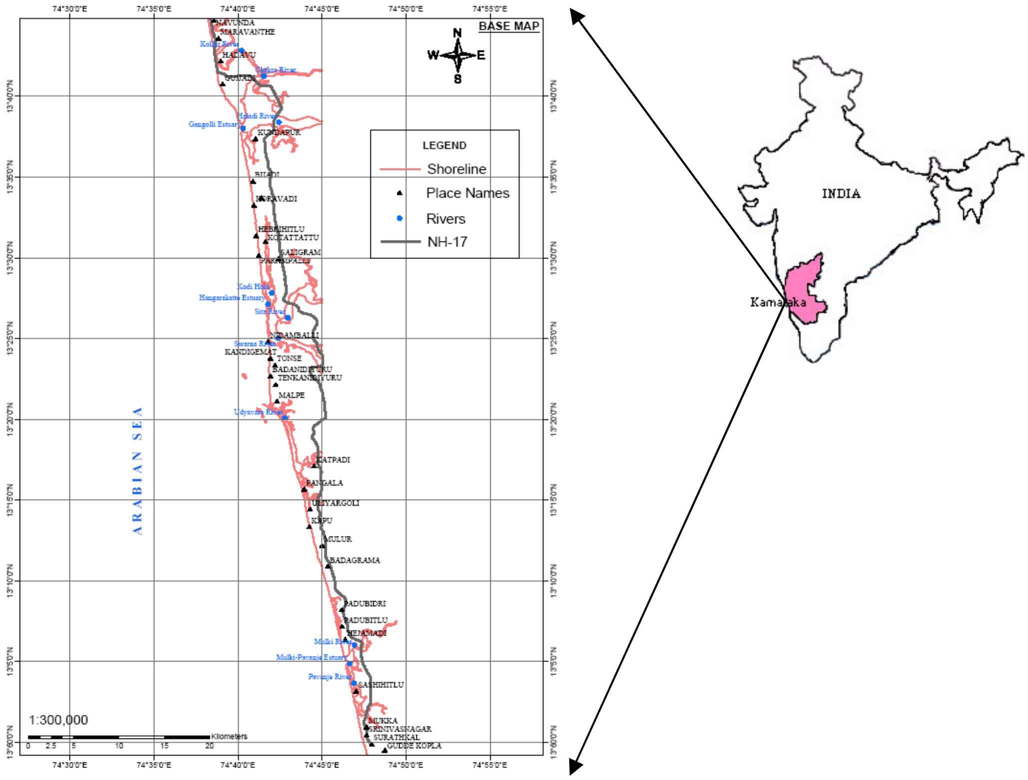

Fig. 1. Map showing study area.

5 METHODOLOGY

The methodology adopted in the present study while developing the Coastal Zone Information System through V.B.6.0 using the remote sensing and conventional data, analyzed in GIS environment. An Integrated Coastal Zone Management Plan (ICZMP) is then developed by analyzing the various maps prepared. The database can be viewed, upgraded, or modified.

Table 1. Database for the present study.

Sl No	Type Of Data	Source	Purpose
1. CONVENTIONAL DATA			
A.	Toposheet	Survey of India (SOI)	To prepare Base map, Shoreline Change map and Delineate the HTL and LTL, Drainage map, CRZ map.
B.	Naval Hydrographic Charts	NMPT	To Develop Bathymetry map
C.	GPS Survey Data	Field Visit	To finalize LU/LC map
2. REMOTE SENSING DATA			
A.	IRS-1C LISS III +PAN Merged Data (2004)	NRSA	To prepare LU/LC map, Shoreline change map, Inundation map.
B.	IRS-P6 LISS III (2006)		

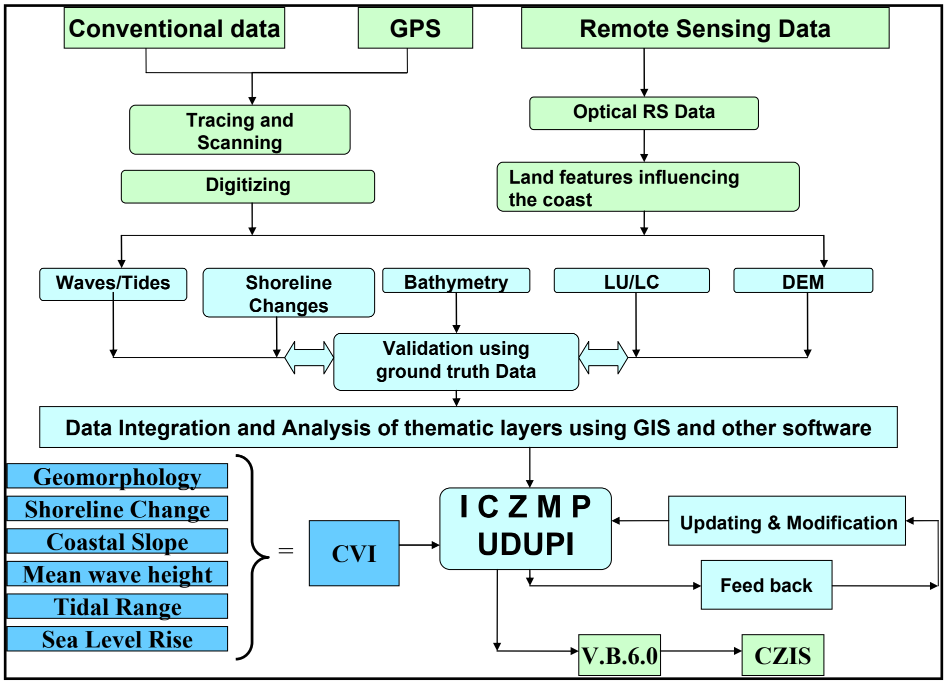

Fig. 2. Flowchart showing the methodology.

6 RESULTS AND DISCUSSION

Various thematic maps prepared in the present study includes shoreline change detection maps, LU/LC maps, contour maps, inundation map, in addition to the base map. The results of analyses of these maps and the derived maps are discussed in the following sections.

The base map was prepared using SOI toposheet, digitized using Arc Map a GIS software and converted to image format before importing to ERDAS imagine 8.7, a DIP software for further analysis. In the present paper only required maps are provided due to restriction on number of pages.

6. 1 Shoreline Change Analysis

Throughout the world many areas are being eroded which threaten life and property of local population. The economic and human costs of the coastal erosion are growing as more people migrate towards coast [4, 5, 6, 7]. Shoreline change detection has been studied with three sets of data starting from 1967-87, 1987 – 2000 and 2000-2006 using IRS 1C LISS III + PAN-2000 and IRS P6 LISS III- 2006 data and toposheets of 1967 and 1987. A part of the study area (due to space constraints) illustrating the shoreline change detection for the three period datasets is shown in Figs. 3-5.

The area of erosion/accretion has been calculated and tabulated in Table 2.

Table 2. Summary of total of erosion/accretion over 39 years.

1967-1987		
	Area (km^2)	Rate of change (km^2/yr)
Erosion	*4.4241*	*0.2212*
Accretion	*1.5501*	*0.0775*

1987-2000		
	Area (km^2)	Rate of change (km^2/yr)
Erosion	0.7458	0.0573
Accretion	13.0039	1.0003
2000-2006		
	Area (km^2)	Rate of change (km^2/yr)
Erosion	*3.6109*	*0.6018*
Accretion	*2.0119*	*0.3353*

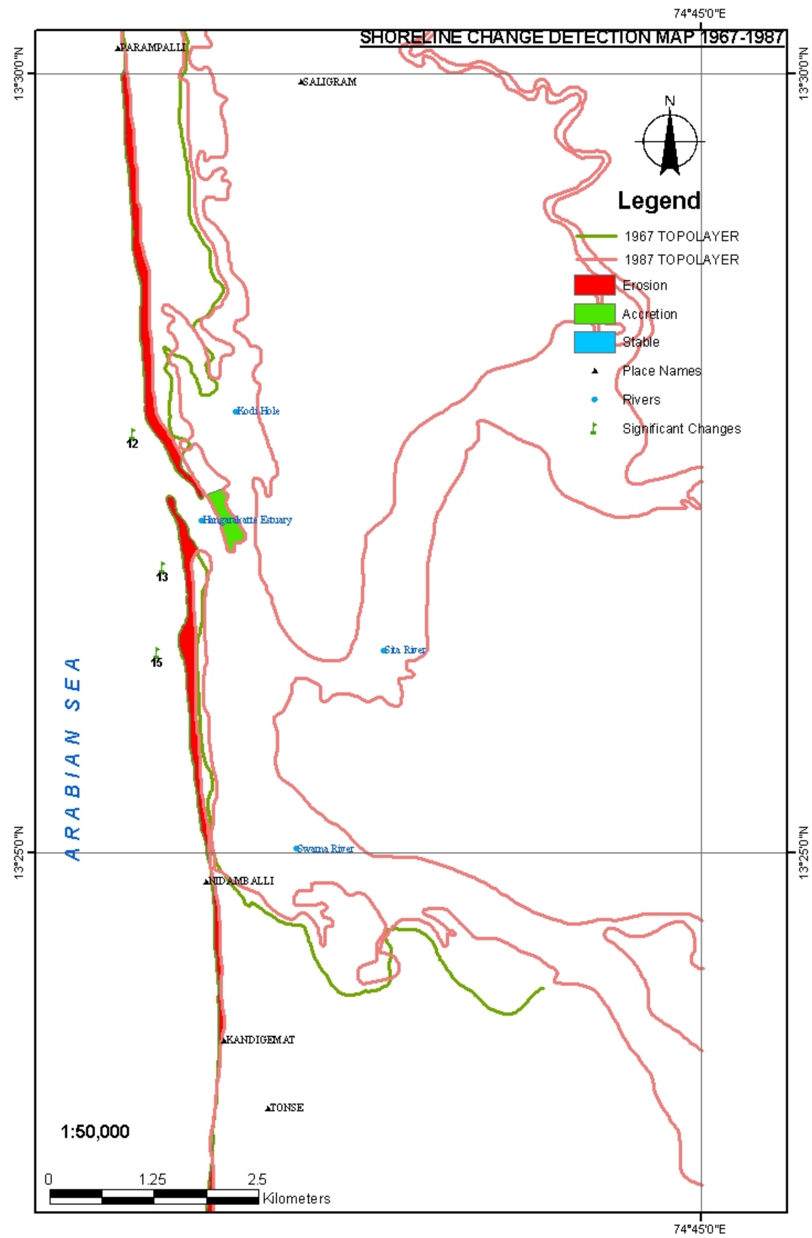

Fig. 3. Shoreline change detection map (1967-1987).

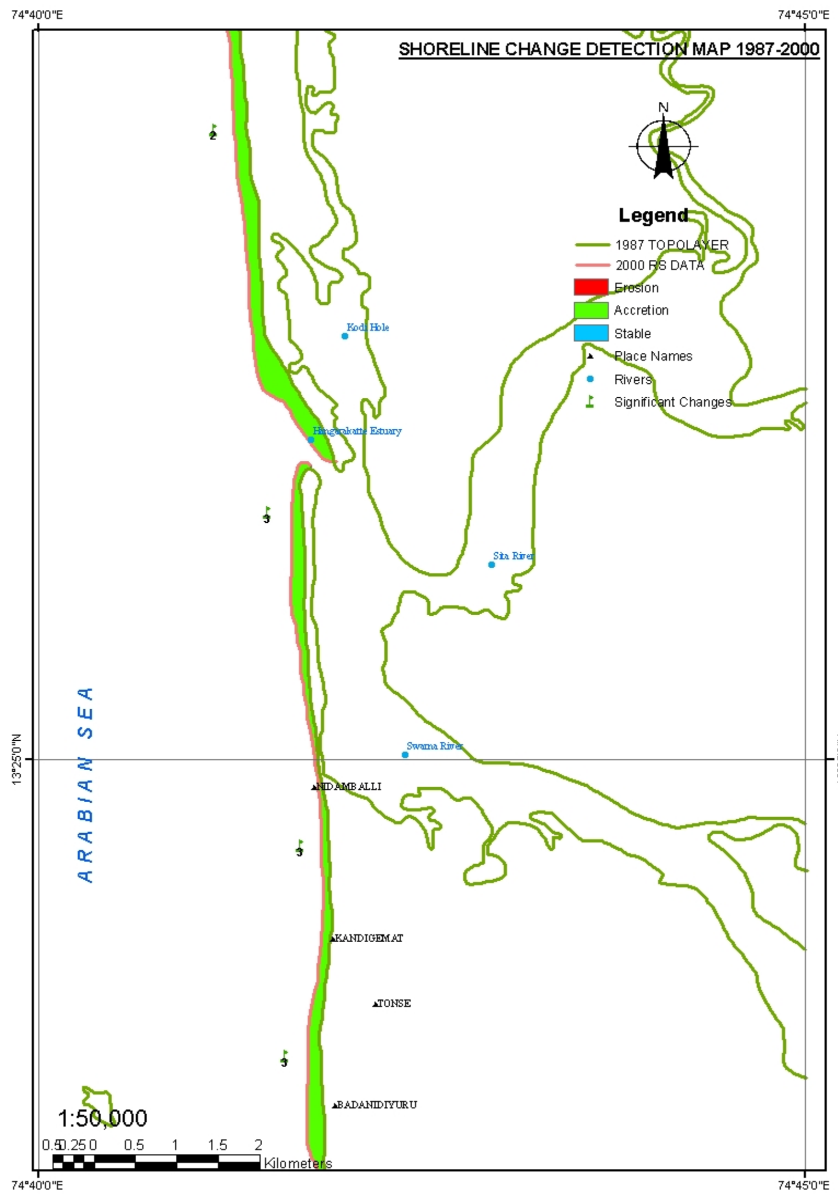

Fig. 4. Shoreline change detection map (1987-2000).

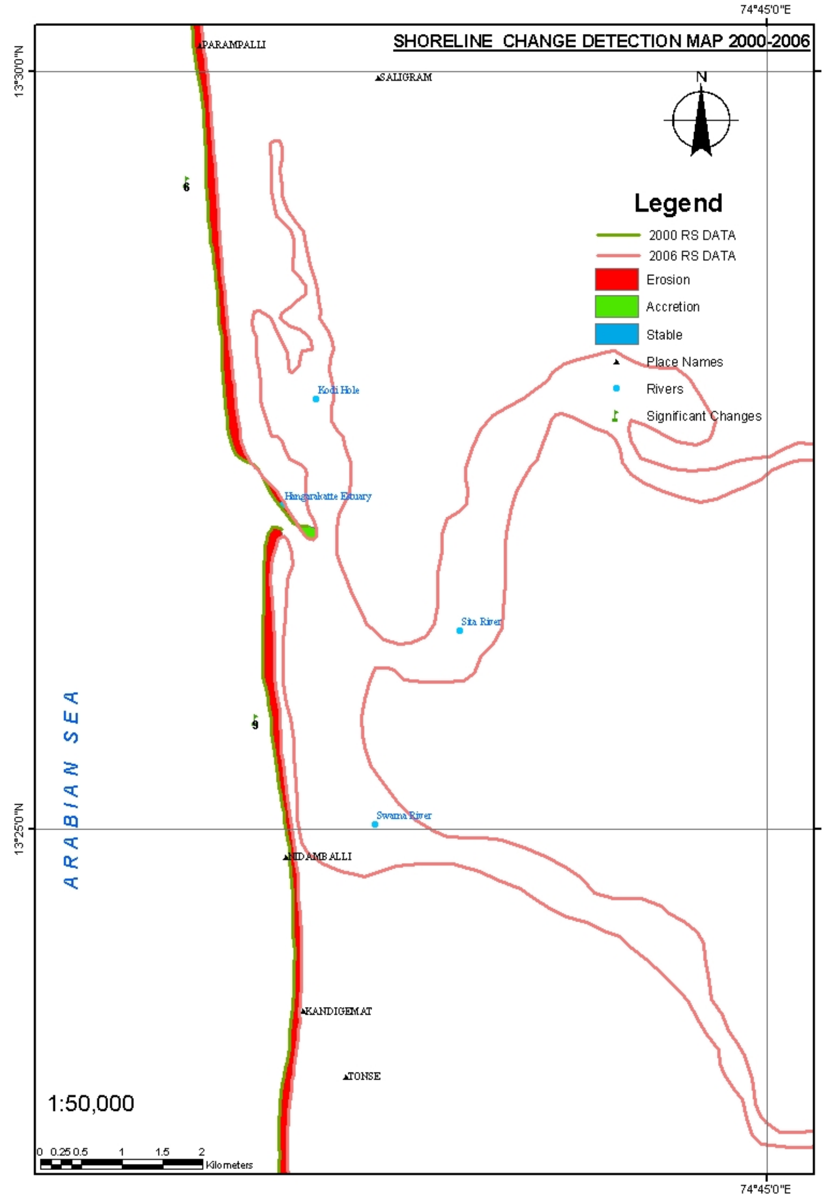

Fig. 5. Shoreline change detection map (2000-2006).

During 1967-87, the total area of erosion was 4.421 km^2 and total area of accretion was 1.5501 km^2. The average rate of erosion is 0.2212 km^2/yr and average rate of deposition is 0.0775 km^2/yr. This shows that there is no large scale erosion/deposition in the study area during 1967-87. During 1987-2000, the total area of erosion is 0.7458 km^2 where as accretion is 13.0039 km^2. The average rate of erosion which is 0.0573km^2/yr is very small when compared to a high rate of accretion which is 1.0003km^2/yr. The probable reason for this high rate of accretion during this period are:

- High rate of sediment movement from the rivers
- Reduction in sand mining activities

During 2000-2006, the total area of erosion is 3.6109 km^2 and accretion accounts for 2.0119 km^2. The average rate of erosion is 0.6018 km^2/yr and accretion is 0.33531 km^2/yr. From these values it is clear that the erosion rate (0.6018 km^2/yr) during 2000-2006 is much higher than the erosion rate (0.2212 km^2/yr) during 1967-1987. This high rate of erosion shows that some of the locations are undergoing erosion at a faster rate.

With these three sets of data it can be observed that the shoreline change is under cyclic process with alternate variation in erosion and accretion. A few of the locations with tendency of cyclic processes are given in Table 3.

Table 3. Cyclic process of erosion (-)/accretion (+) for selected sites.

LOCATION	**1967-1987 [Area (km^2)]**	**1987-2000 [Area (km^2)]**	**2000-2006 [Area (km^2)]**
KUMBHASHI	- (0.0858)	+ (3.7395)	- (0.8352)
HANGARAKATTE (SOUTHERN SPIT)	- (0.0756)	+ (1.2054)	- (0.1247)
BADANIDIYURU, MALPE	- (0.3159)	+ (1.2054)	- (0.0021)
UDYAVARA (SOUTHERN SPIT)	- (0.1672)	+ (1.5905)	- (0.0351)
KATPADI, ULLIYAGOLI	- (0.9854)	+ (1.5925)	- (0.0606)
PADUBITLU, HEJAMADI	- (0.0346)	+ (0.0183)	- (0.0017)

The dynamic changes that have been observed at the river mouths of the study area are tabulated in Table 4. Comparing all the three data sets, the critical erosion areas were identified and a Critical erosion area map [Fig. 6a] was prepared. This map was validated using field data/ground truth data [Fig. 6b].

Table 4. Shifting of river mouths in the study area over 39 years.

LOCATION	**Shifting of river mouth**		
	1967-1987	**1987-2000**	**2000-2006**
GANGOLLI ESTUARY	Northern Spit Shifted Towards North and Southern Spit Shifted Towards South	Northern Spit Shifted Towards South and Southern Spit Shifted Towards North	Shifted Towards South
HANGARAKATTE ESTUARY	Shifted Towards South	Shifted Towards North	Shifted Towards South
UDYAVARA RIVER MOUTH	Shifted Towards North	Growth of Southern Spit	Small Shift Towards South
MULKI-PAVANJE RIVER MOUTH	Shifted Towards North	Shifted Towards South	Shifted Towards South

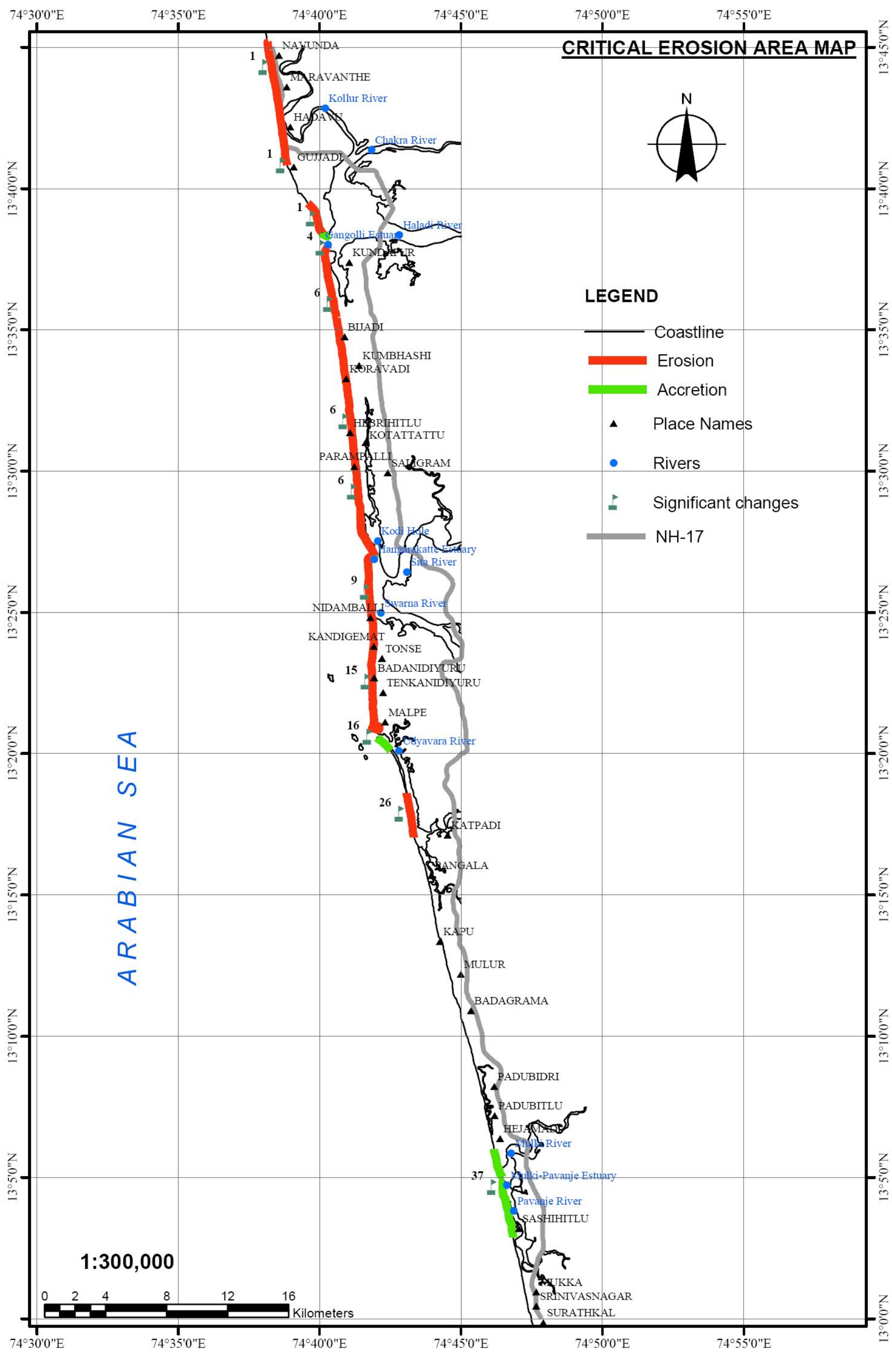

Fig. 6a. Critical Erosion Area from analysis.

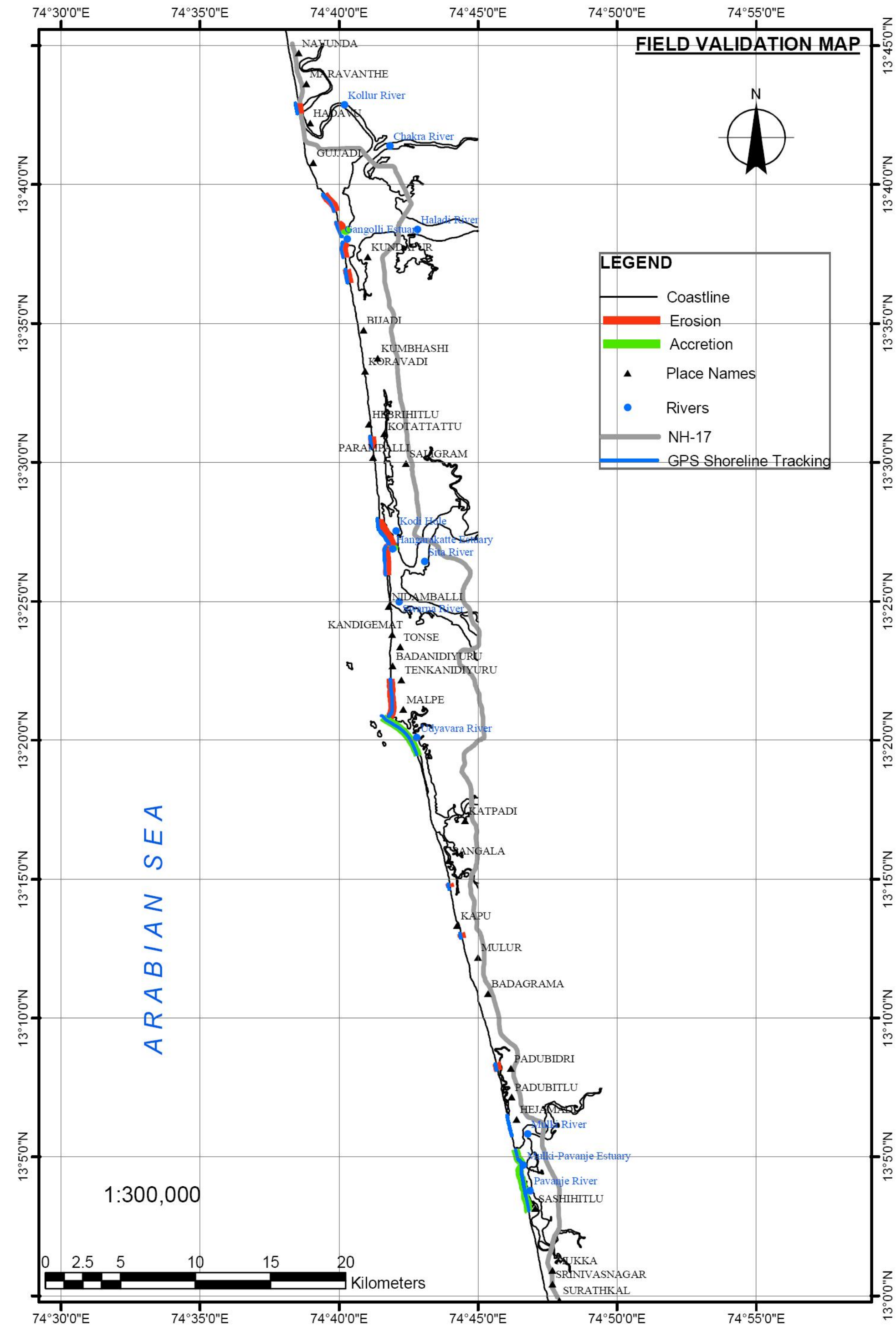

Fig. 6b. Field validation.

6.2 Digital Elevation Model

Contour map of 20m interval was extracted from the toposheet. The contours of 5m interval were also derived from Shuttle Radar Topography Mission (SRTM) data which is available online. The maximum horizontal distance that is reached by a tsunami is referred to as inundation [8]. By keeping sea level rise and tsunami in mind, an inundation map was prepared for the study area using Virtual GIS module of ERDAS Imagine software. In the present study, inundation map was prepared for six run-up values i.e., 1m, 2m, 3m, 4m, 5m and 10m with reference to mean sea level. Digital Elevation Model of the study area has been created using contour map extracted from SOI toposheet. Also SRTM DEM data available as 5º by 5º grid size has been downloaded and elevation map was generated. The area of submergence for 1m and 5m rise in sea level is shown in Figs. 7a and 7b respectively.

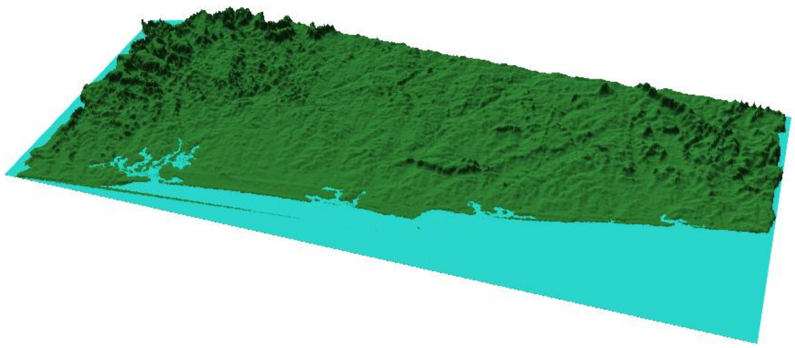

Fig. 7a. Inundation for 1m rise in sea level.

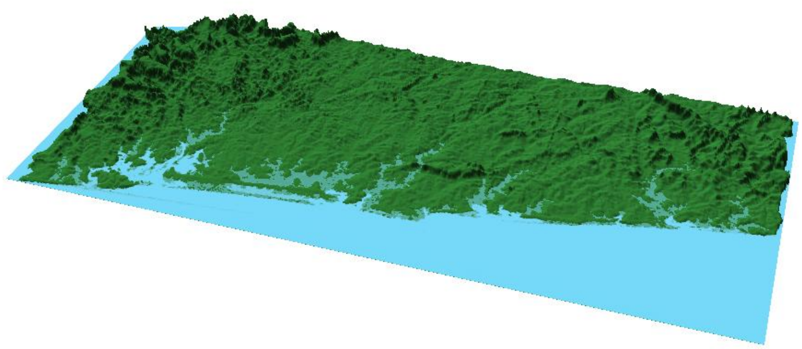

Fig. 7b. Inundation for 5m rise in sea level.

The area of submergence for 1m rise in water level is up to 42.19 km^2 and subsequently for 2m, 3m, 4m 5m and 10m rise in water level are 56.34 km^2, 75.04 km^2, 89.58 km^2, 150.67 km^2 and 372.08 km^2 respectively. The low lying areas of the study area are highly vulnerable for submergence in case of a tsunami or a rise in sea level. The inundation maps can be overlaid on land use/land cover maps to find out the extent of submergence of different LU/LC areas. It is necessary to incorporate the elevation levels for new/expanded settlement areas under the town planning acts so that human life and property are saved from natural hazards/vulnerabilities. The run-up levels can be used as guidance to determine the safe locations of settlements from shoreline.

6.3 Coastal Regulation Zone maps

As per the coastal regulation zone (CRZ) notification by the government, some of the sites which come under CRZ III which is within 500 m from the shoreline have been identified and has been incorporated in the database. The location which comes under CRZ I which is within

100m from shoreline has also been identified and this should be very helpful for the regulatory authorities in the planning process of any area. By over laying CRZ maps on inundation maps, it is possible to find out the extent of submergence in different zones during extreme events like tsunami. All these information will be very much essential for development of Integrated Coastal Zone Management Plan. A few CRZ maps along with the table giving CRZ details are shown in Figs. 8a, 8b and Table 5 respectively.

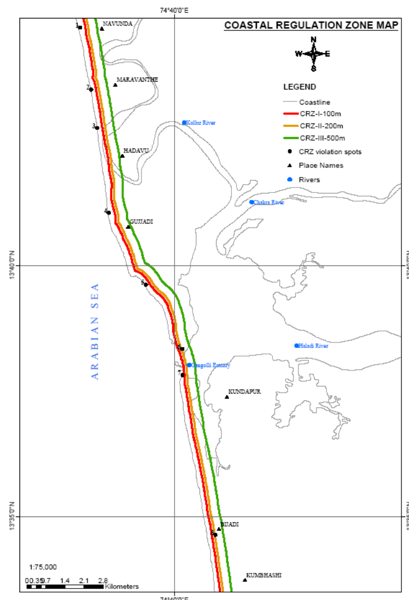

Fig. 8a. CRZ map.

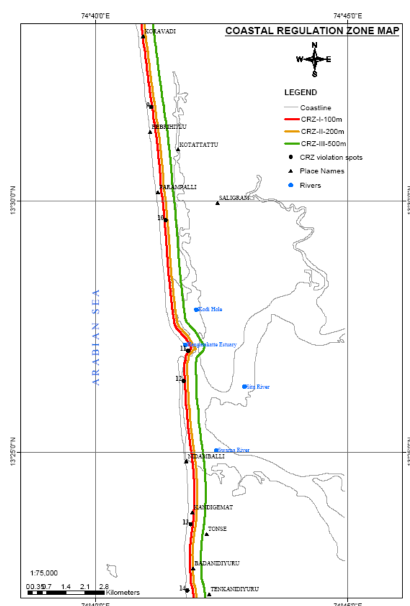

Fig. 8b. CRZ map.

Table 5. LU/LC details in CRZ Areas.

Sl. No	Lat/Long	Place Names	LU/LC in CRZ I	LU in CRZ II	LU in CRZ III
1	13º 44' 44" / 74º 38' 08"	Navunda	Coconut plantation dense settlements	-----	Govt. PU College Road NH 17 Settlements with plantation
2	13º 43' 30" / 74º 38' 21"	Maravanthe	Dense coconut plantation with settlements	Sparse coconut plantation with school Road NH 17	Maravanthe city with school Road NH 17
3	13º 42' 44" / 74º 38' 28"	Maravanthe beach	Long seawall, hotel, sea view temple, NH 17, road	Part of Kollur river with plantation with coconut and Casuarina plantation	Part of Kollur river mixed plantation with settlement Road NH 17
4	13º 41' 03" / 74º 38' 42"	Trasi	Trasi beach resort mixed coconut and casuarina plantation with settlement	Habitation with mixed vegetation	Habitation with mixed vegetation
5	13º 39' 37" / 74º 39' 26"	Gangolli	Gangolli lighthouse seawall, settlement	Crop land with mixed vegetation	PV college, habitation with vegetation
6	13º 38' 50" / 74º 40' 05"	Gangolli river mouth	Settlement with mixed vegetation, coconut and casuarina plantation	Coconut plantation with settlement, temple	Settlement with mixed vegetation coconut, Mangroves, and aquaculture pond
7	13º 37' 50" / 74º 40' 08"	Gangolli kodi	Seawall casuarina plantation, coconut plantation, Baeary's school, sea view hotel	Coconut plantation with settlement, temple	Settlement with mixed vegetation coconut and Mangroves aquaculture pond
8	13º 34' 38" / 74º 40' 49"	Bijadi, Gopadi , Korvadi, Koma	Seawall, settlements with mixed vegetation	Settlement with mixed plantation	Bijadi school and temple settlement with mixed vegetation and glass industries Koravadi school

6.4 Land use/ Land cover Analysis

Land is the most important natural resources, which embodies soil, water and associated flora and fauna involving the total ecosystem [9, 10]. The satellite image of 2006 in conjunction with Google Earth high resolution images and ground truth data has been classified into 6 major classes (Level I) namely built-up area, agricultural area, forest, water bodies, wasteland and others. The classes are further divided into sub-classes up to level III classification. The LU/LC classification details have been generated for 4 major river mouths along the stretch of the study area since these are the areas more sensitive to development and dynamic changes occur mostly in these areas. The four river mouths are:

1. Kollur-Chakra-Haladi 2. Sita-Swarna 3. Udyavara 4.Mulki-Pavanje

The inundation map can be overlaid on the land use/land cover map and the details of submergence can be obtained. A minimum length of 3 km and maximum of 14 km on either side of the river mouths and more than 2 km from shoreline towards ocean side and more than 5km towards landward side has been considered for classification since dynamic changes occur mostly around the estuaries. The features have been identified and assigned classes based on visual interpretation and ground truth data and the details of the final LU/LC map along with areal extent are shown in Figs. 9a, 9b and Table 6. Similar maps and tables have been prepared for other three river mouths in the study area.

6.4.1 Built-up Land: The built-up area is seen around the Udyavara river estuary with area coverage of 1932 hectares including beach resorts, settlements and port facilities. Whereas, built-up area around Sita-Swarna is the least covering an area of 14.59 hectares. Settlements and port facilities are also seen around Kollur-Chakra-Haladi and Mulki-pavanje river estuary covering an area of 100.94 and 126.36 hectares respectively.

6.4.2 Agricultural Land: Agricultural land to a large extent is seen around Kollur-Chakra-Haladi river estuary with area coverage of 4776.30 hectares. Agricultural activities are also observed around Sita-Swarna and Udyavara river estuary covering an area of 3120.59 and 3575.17 hectares respectively. An agricultural activity around Mulki-Pavanje is comparatively less with an area of 1187.17 hectares.

6.4.3 Forest: Forest cover is mainly seen around Mulki-Pavanje river estuary with an area of 1206.42 hectares, whereas no forest area has been observed around Sita-Swarna and Udyavara river estuary. Forest area of 9.41 hectares could be identified around Kollur-Chakra-Haladi river estuary.

6.4.4 Wasteland: A large extent of wasteland cover is seen around Kollur-Chakra-Haladi with an area of 1135.96 hectares. Wasteland which is mostly sandy beach and marine rocky island around Sita-Swarna, Udyavara and Mulki-Pavanje has an area of 117.10, 154.47 and 109.77 hectares respectively.

6.4.5 Water bodies: The extent of area coverage by water bodies at Kollur-Chakra-Haladi is comparatively high with an area of 5226.86 hectares since there is a confluence of three rivers and also the presence of many tanks/ponds. The area of water bodies at Sita-Swarna, Udyavara and Mulki-Pavanje are about 3537.40, 3243.14 and 1819.68 hectares respectively.

6.4.6 Others: The land cover details classified as others include habitation with vegetation, mixed vegetation and aquaculture ponds. These areas could be identified around all river mouths. Habitation with vegetation is seen to a large extent around Udyavara river mouth with an area of 2220.78 hectares. Large areas of mixed vegetation are seen around Sita-Swarna and Mulki-Pavanje with an area of 2189.80 and 2136.83 heactres respectively. Aquaculture activities to a large extent are seen near Kundapur region, around Kollur-Chakra-Haladi estuary with an area covering 230.91 hectares.

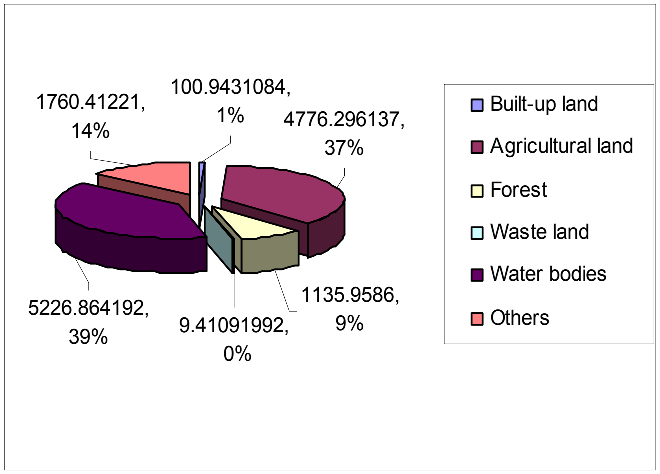

Fig. 9a. Pie chart showing land use/land cover percentage.

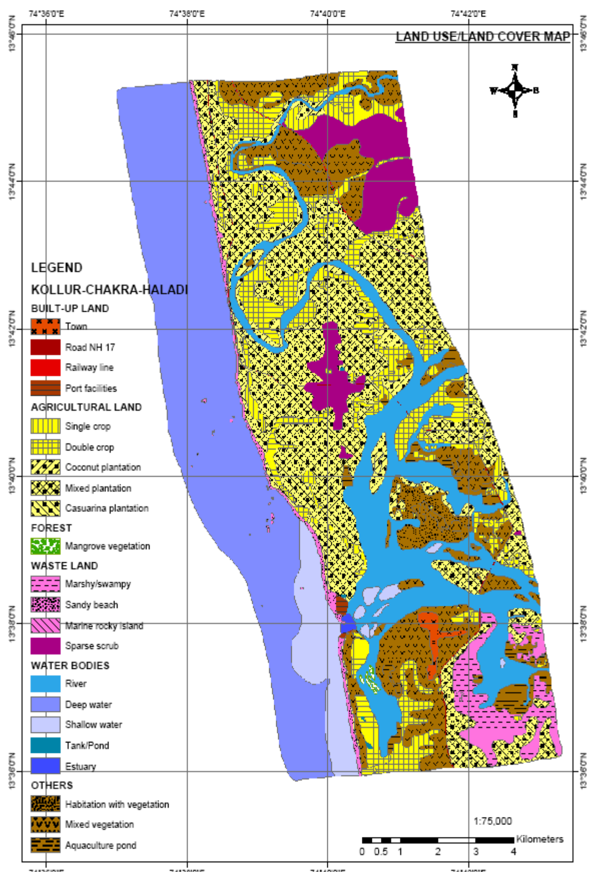

Fig. 9b. Land use/land cover map in the vicinity of river mouth.

Table 6. Land Use / Land Cover details in the vicinity of river mouth.

Land Use/ Land Cover Classification		**Area (m^2)**
Built-up land	Town	543574
	Road NH 17	222183.96
	Railway line	100179.62
	Port facilities	143493.5
	Total	**1009431.08**
Agricultural land	Single crop	2426077.111
	Double crop	12429659.61
	Coconut plantation	2962876.18
	Mixed plantation	29681433.66
	Casuarina plantation	262914.80
	Total	**47762961.37**
Forest	Mangrove vegetation	94109.19
Waste lands	Marshy/swampy	3796454.30
	Sandy beach	1452555.19
	Marine rocky island	59357.54
	Land with scrub	6051219.79
	Total	**11359586.84**
Water bodies	River	16770330.4
	Deep water	30117400
	Tank/Pond	37469.72
	Shallow water	5199084.79
	Estuary	144357
	Total	**52268641.92**
Others	Habitation with vegetation	1695530
	Mixed vegetation	13599476.8
	Aquaculture pond	2309115.30
	Total	**17604122.1**

6.5 Coastal Vulnerability Index (CVI)

The CVI allows the six variables viz., Geomorphology, Shoreline change, Coastal Slope, Mean Tidal Range, Mean Significant Wave Height, Sea Level Rise [11] to be related in a quantifiable manner that expresses the relative vulnerability of the coast to physical changes due to future sea-level rise. This method yields numerical data that cannot be equated directly with particular physical effects [12,13]. It does, however, highlight areas where the various effects of sea-level rise may be the greatest. Once each section of coastline is assigned a vulnerability value for each specific data variable, the coastal vulnerability index (CVI) is calculated as the square root of the product of the ranked variables divided by the total number of variables. The CVI can be used by scientists and engineers to evaluate the likelihood that physical change may occur along a shoreline as sea-level rises and take necessary actions. The CVI may also be used to judge the suitable sites of industrialization, development of ports and harbours, urbanization or tourism. The CVI is calculated using the formula

$$\sqrt{\frac{a \times b \times c \times d \times e \times f}{6}} \qquad (1)$$

where,
a = Geomorphology
b = Shoreline change detection
c = Coastal Slope
d = Mean Tidal Range
e = Mean Significant Wave Height
f = Sea Level Rise

The ranking of variables for different parameters and coastal vulnerability map and related pie chart is shown in Table 7, Figs. 10a and 10b respectively.

Table 7 Ranking of variables for different parameters.

Sl No	Ranking	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
2	**Geomorphology**	Rocky cliffed coasts	Meduim cliffs, Indented coasts	Low cliffs, lateritic palin	River deposits, alluvial plain	Coastal plain , Beach, Mud flats
1	**Shoreline Erosion/Accretion (m/yr)**	>+15	+5 to +15	-5 to +5	-15 to -5	< -15
3	**Coastal Slope (%)**	> 0.6	0.5 to 0.6	0.4 to 0.5	0.3 to 0.4	< 0.3
4	**Mean Tide Range (m)**	> 4.0	3.0 to 4.0	2.0 to 3.0	1.0 to 2.0	< 1.0
5	**Mean Significant wave Height (m)**	< 0.7	0.7 to 1.4	1.4 to 2.1	2.1 to 2.8	> 2.8
6	**Mean sea level rise (mm/yr)**	< 1.8	1.8 to 2.5	2.5 to 3.0	3.0 to 3.4	> 3.4

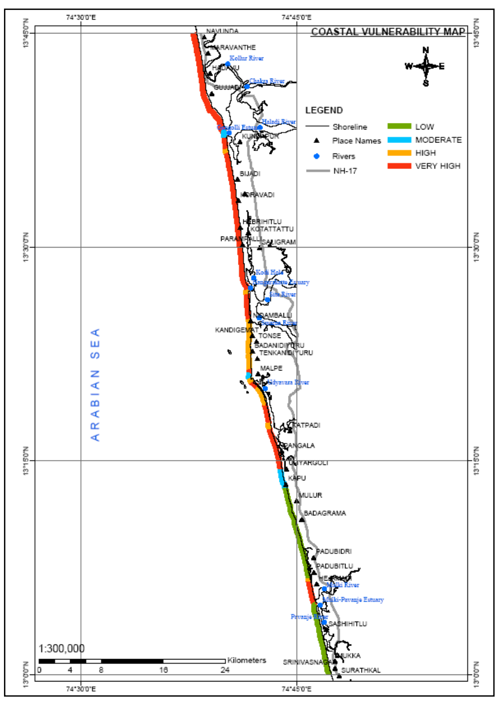

Fig. 10a. Costal vulnerability map.

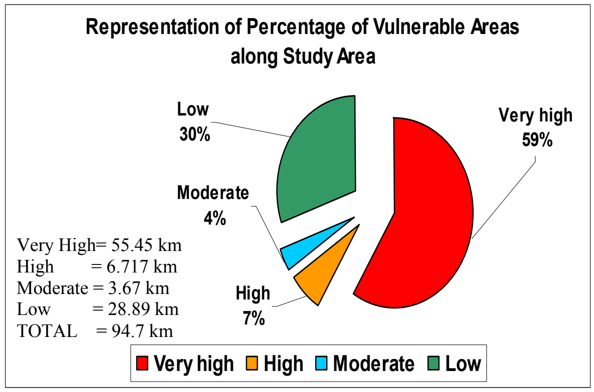

Fig. 10b. Pie chart showing percentage of vulnerable areas along the study area.

The calculated CVI values for the coastal stretch ranges from 7.5 to 17.89. The mean value is 14.33 and standard deviation is 1.95. The 25th, 50th and 75th percentiles are 10.29, 12.82 and 15.36 respectively. The CVI scores are divided into low, moderate, high, and very high vulnerability categories based on quartile ranges and visual inspection of the data. CVI values below 10.29 are assigned low vulnerability. Values from 10.29 to 12.2 are assigned moderate vulnerability, high vulnerability lies between 12.82 and 15.36. CVI values more than 15.36 are assigned very high vulnerability.

6.6 Integrated Coastal Zone Management Plan

Most of the coastal management issues originate from resource conflict. In addition to over exploitation of the coastal zone resources and degradation of coastal zone environment, there are two major coastal zone management problems [14]. Dealing with these two cross-sector problems appropriately is a vital issue of ICZM.

1. Conflict on Multi-demand for and multi-use of coastal zone resources
2. Imbalance between development/utilization of coastal resources and conversion/ protection of coastal zone environment.

6.6.1 Action Plan Map

The various thematic maps prepared in the present study are integrated to generate an action plan map which consists of all the information such as critical erosion areas, existing seawall, coastal regulation zone information, tourism spots, and port facilities etc. By over laying CRZ maps on inundation maps (which is prepared using DEM), one can easily find out the possible extent of submergence in different zones during extreme events like tsunami. And hence suitable decisions can be taken. The action plan shown in Fig. 11 includes all the necessary information required to develop a coastal zone management plan. The planning map consists of both spatial and non-spatial information to be available at the click of a button in Coastal Zone Information System.

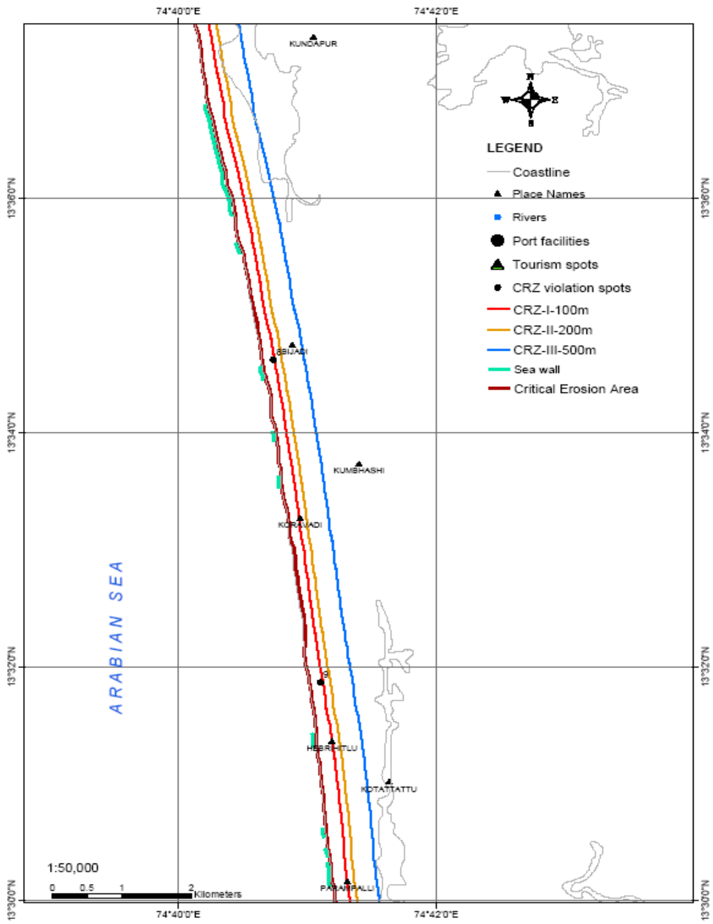

Fig. 11. Action plan map

6.7 Development of CZIS

The Coastal Zone Information System [CZIS] incorporates data in the form of several layers those could be overlaid on each other for analysis thus aiding decision making [15]. Based on the requirements of a CZIS and to develop an integrated coastal zone management plan, the input data required for query and analysis needs to be ascertained. Accurately developed CZIS could help re-categorization of existing categories of coastal regulation zones. For this the latest information required such as ecological sensitivity, existing development status, census information, occupational profile, regional development plans, information on infrastructural facilities, could be updated to be picked up from the system for planning.

The output of various analyses carried out using Remote Sensing, GIS and GPS are used as an input to develop CZIS using V.B.6.0 as front end and MS-Access as the back end. In this CZIS, all the information is available in the form of GIS database in which the user can get the information regarding the particular feature by clicking on the map. The main pages of CZIS interface are shown in Figs. 12a and 12b.

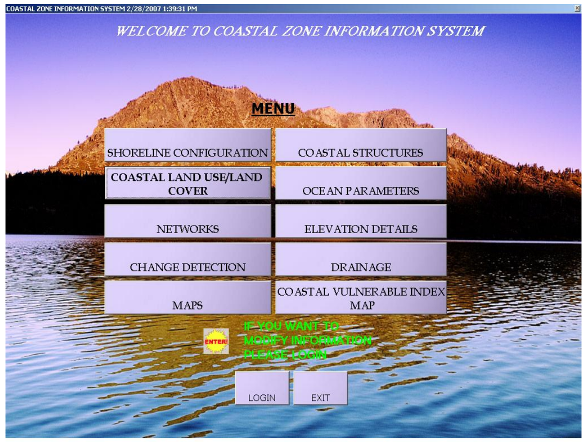

Fig. 12a. CZIS module front page

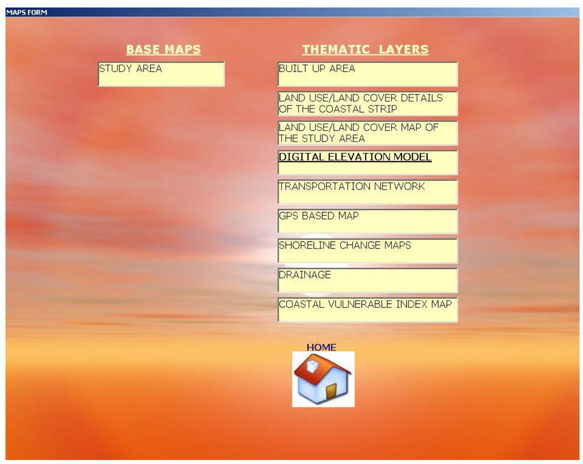

Fig. 12b. CZIS module details page.

7 CONCLUSIONS

Based on the present study the following conclusions can be drawn:

- Around 46 km of the total 90 km stretch of the study area is under critical erosion.
- Kollur-Chakra-Haladi river estuary is having 4776.30 hectares of agricultural land and 1135.96 hectares of wasteland, whereas Udyavara river estuary is having 1932 hectares of built-up land.
- Around 42.19 km^2 will be submerged for a 1m rise in sea level. About 59% of the study area is under very high vulnerability category and 30% is under low vulnerability to sea level rise as be determined by the coastal vulnerability indices.
- The CVI provides insight into the relative potential of coastal damage due to future water level rise. The maps presented here can be viewed in at least two ways:
    - To identify areas where physical changes are most likely to occur as sea-level rises; and
    - As a planning tool for managing and protecting resources in the study area.

- Identification of CEA will assist in monitoring the developmental activities along the coast and also provide necessary safety measures for the existing settlements.
- Various thematic and derived maps can be integrated to acquire necessary information in order to make suitable decision for the sustainable development of the area.
- The CZIS module provides a dynamic interface so as to view only selected parameters of interest and facilitates easy access to different information such as Coastal Land Use/Land Cover, Ocean Parameters, Shoreline Change etc. and thus help in sustainable development of the coastal region.

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