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Research Article

IMPACT OF PREDICTED SEA LEVEL RISE ON LAND USE & LAND COVER OF DAHEJ COAST, BHARUCH DISTRICT, GUJARAT, INDIA

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ABSTRACT
Increasing rates of sea level rise caused by global warming are expected to lead to permanent inundation in low-lying coastal areas. Sea level rise is a significant and growing threat to the coastal region of the world. In the present study coastal land use & land cover of Dahej coast which are susceptible to predicted sea level rise are identified. The merged image of Resourcesat-1 LISS-IV and Cartosat-1 PAN data of period 2006 has been draped over high resolution (0.5 meter contour interval) Digital Elevation Model (DEM) and inundation modeling has been done over the land use land cover map. The study found that 13.79 % of Dahej's land area will be affected by inundation. The major land use/land cover classes which may be inundated due to predicted Sea level Rise are observed to be the agricultural land 5.80 sq km, forest(non-tidal)/plantation area 2.43 sq km, scrub land 6.18 sq km. It is observed that the area is likely to be inundated widely through Ghaguria Khadi creek in the north western part of the study area and connecting the Narmada estuary through small inlet west of Ambheta.

Key Words: *Sea Level Rise, Coastal Zone, Land Use & Land Cove, DEM*

INTRODUCTION
There is large anxiety among the people about our immediate future because of global warming and the resulting climate change and sea level rise. It is supposed that the global warming is rapid because of human activities. Human activities such as industrial activities, agricultural practices and destruction of forest and development of transport system are major causes of increasing emission of greenhouse gasses like co2, methane and CFCS into the atmosphere. The intergovernmental Panel on Climate Change IPCC (2001) estimated that the atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have grown by about 31%, 151% and 17%, respectively, between 1750 and 2000. The global averaged temperature near the Earth's surface rose by 0.74 ± 0.18 °C over the period 1906–2005 (IPCC 4th assessment report). According to Allen and Komar 2006, most commonly recognized impact of global warming is the eustatic rise in sea level due to thermal expansion of seawater and addition of ice-melt water. IPCC has predicted in the 2007 that the global sea level will rise by about 18 to 59 cm by the 2100 (IPCC, 2007). The most direct impact of the sea-level rise is on the coastal zones around the world because these narrow zones are low-lying. The sea-level rise would lead to accelerated erosion and shoreline retreat, besides leading to saltwater intrusion into coastal groundwater aquifers, inundation of wetlands and estuaries, and threatening historic and cultural resources as well as infrastructure (Pendleton *et al.,* 2004). It is estimated that 1.2 billion people, or approximately 23 % of the world's population, live within 100 m of sea level and 100 km from the coast (Nicholls and Small, 2002; Nicholls, 2003). The population densities in coastal regions occur at approximately three times the global average with maximum densities occurring below 20 m in elevation (Nicholls, 2003). These impacts are scale-dependent however, in that they will be unevenly distributed among and within nations, regions, communities and individuals as a result of differential exposures and vulnerabilities (Clark *et al.*, 1998). In Indian, Unnikrishnan *et al.,* 2006, based on the analysis of long-term tide-gauge data from various stations along the Indian coastal regions reported that the sea level is rising. Protection of life, property and coastal environment along the coast are major causes of concern. This paper presents a comprehensive assessment of the potential impacts on of sea level rise on land use & land cover of Dahej

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coast. Sea level rise is projected for Dahej coast and applied to digital elevation models to illustrate the extent to which coastal areas are susceptible to permanent inundation.

Study Area

The study area is located on the northern bank of the Narmada estuary in the Bharuch district of Gujarat state, India. The geographic location of the study area (figure1) is 72^{0}30’ E to 72^{0}37’30” E and 21^{0}37’30” N to 21^{0}45’00”N covering Survey Of India (SOI) topographical map no. 46 C/10 NW at 1:25, 000 scale. The area is surrounded by the Gulf of Khambhat towards its west, Narmada estuary towards its south, Ghugaria Khadi creek and gently sloping coastal plain towards its north and gently sloping coastal plain towards its east. The coastal configuration of the Dahej coast is structurally controlled due to the Cambay rift trending NNW-SSE as well the Narmada – Son rift trending ENE-WSW. Tide dominated coastal processes cover the entire region. Major geomorphological features observed are estuary, shoals, Mud flats, Creeks, beach ridge complex and coastal plain. The entire coastal region is rapidly developing as a major industrial region in the Gujarat state. The major industries established and developing are Reliance, GACL, Birla Copper Chemical Port Terminal Company Limited and IPCL. Reliance, I.P.C.L. and Birla have LNG/LPG terminals developed in the region.

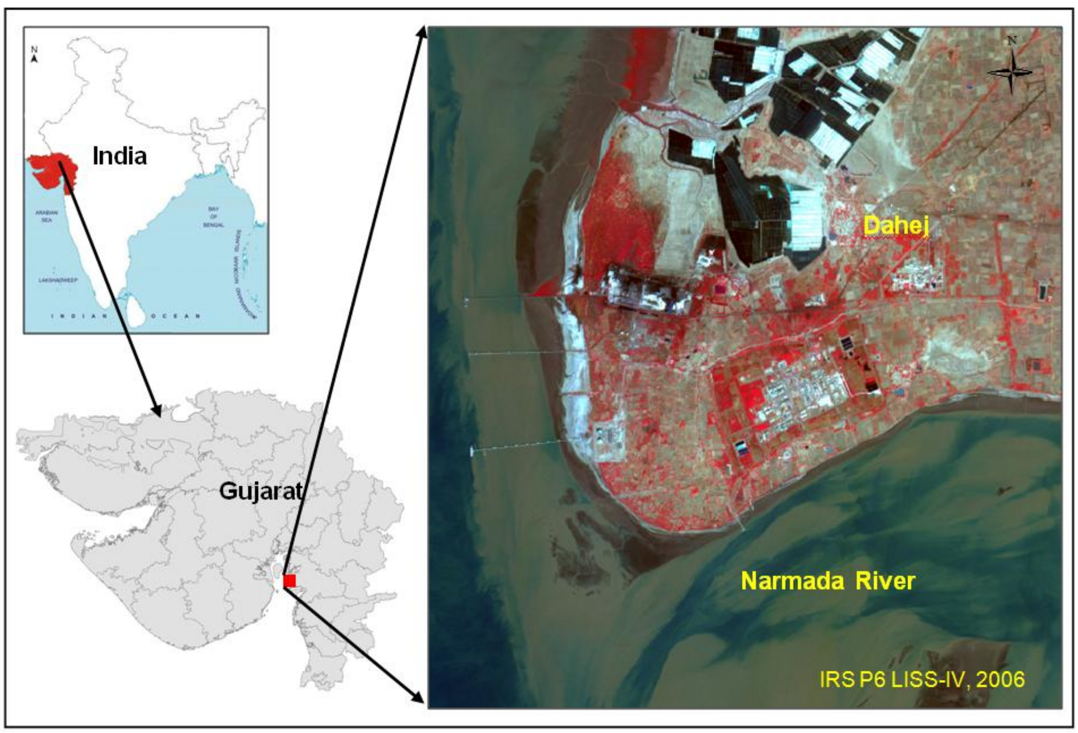

Figure 1: Study area

MATERIALS AND METHODS

Image registration of Resourcesat-1(P6) LISS-IV of 16th February 2006 with spatial resolution of 5.8 m and Cartosat-1 PAN data of 28 February 2006 with 1 m spatial resolution was carried out. Both images were merged using principle component analysis approach in ERDAS IMAGINE software. A high resolution Digital elevation Model (DEM) has been prepared from contour map having 0.5m contour interval, provided by survey of India. Land use and land cover map (figure 3) of the study area has been prepared from the satellite image of IRS P6 LISS IV 2006, by visual image interpretation. High Tide Line (HTL) has been considered as shoreline. HTL has been delineated from the satellite image Resourcesat-1(P6) LISS-IV of 16th February 2006. HTL of 1990 was prepared from satellite image Landsat TM.

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Temporal changes in the shoreline indicating the zones of erosion and accretion. By overlaying technique in GIS, the shift in shoreline during the 16-year period from 1990 to 2006 is carried out. The tide data was taken from the Indian Tide Tables, 1979 to 2006 and the highest tidal height was noted from the daily heights given in the tide table. These data was reduced to Mean Sea Level (MSL) from the datum levels provided in the tables. The Highest High Water height with respect to MSL for the Dahej coast is 5.61m. Intergovernmental Panel on Climate Change's IPCC (2007) predicted that the global sea level will rise by at most 59 cm by the end of the 21st century. IPCC, 2001 has given projections for the period up to 2100 also (Figure 2). It is seen from the figure that on an average 49 cm of sea level rise can be expected on a global level for the period 2000-2100. Sea level change is only 10-20 cm in a century for the Indian coast (Unnikrishnan *et al.*, 2006). Since our coasts fall in the average/below average category (of the global) the maximum sea level rise that can be expected along our coasts shall be well within the 49 cm rise in 100 years. Coastal Inundation due to predicted Sea level rise for the period of 2100, was computed by adding Highest High Water Level (m) and predicted sea level rise, i.e. (5.61+0.49) = 6.10m. A contour of 6.10m was generated from DEM in ARC GIS software. The Land use land cover categories which are below 6.10m contour, are supposed to be inundated are identified.

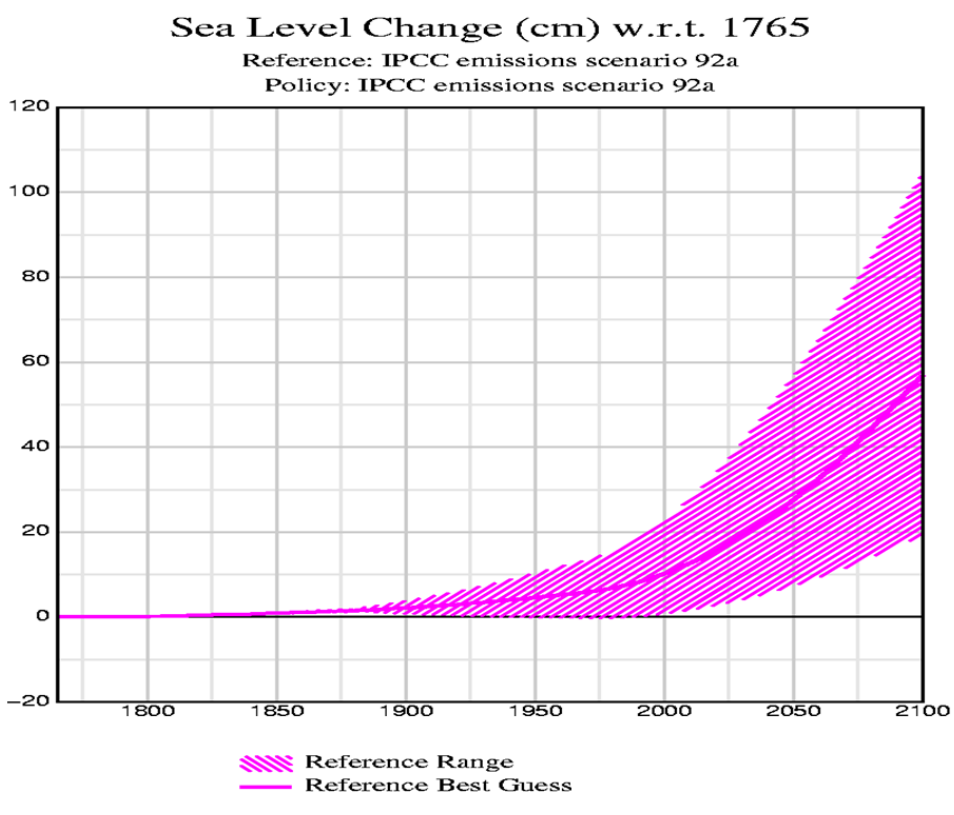

Figure 2: Shows IPCC 2001, prediction of sea level rise

RESULTS AND DISCUSSION

Temporal changes in the shoreline indicating the zones of erosion and accretion. The total land gained by accretion is about 3.70 km^2 and total land lost by erosion was about 2.49 km^2. The high erosional areas were found in the north bank of Narmada estuary (figure 4) and North West portion of the study area. It is supposed that if the sea level rises the wave and tidal energy are supposed to increase which lead to more coastal erosion. All coastal areas below 6.10m elevations are assumed to be inundated if sea level rises by 0.49 m. It is estimated that a 0.49 m rise would inundate approximately 18.8km² of the study area.

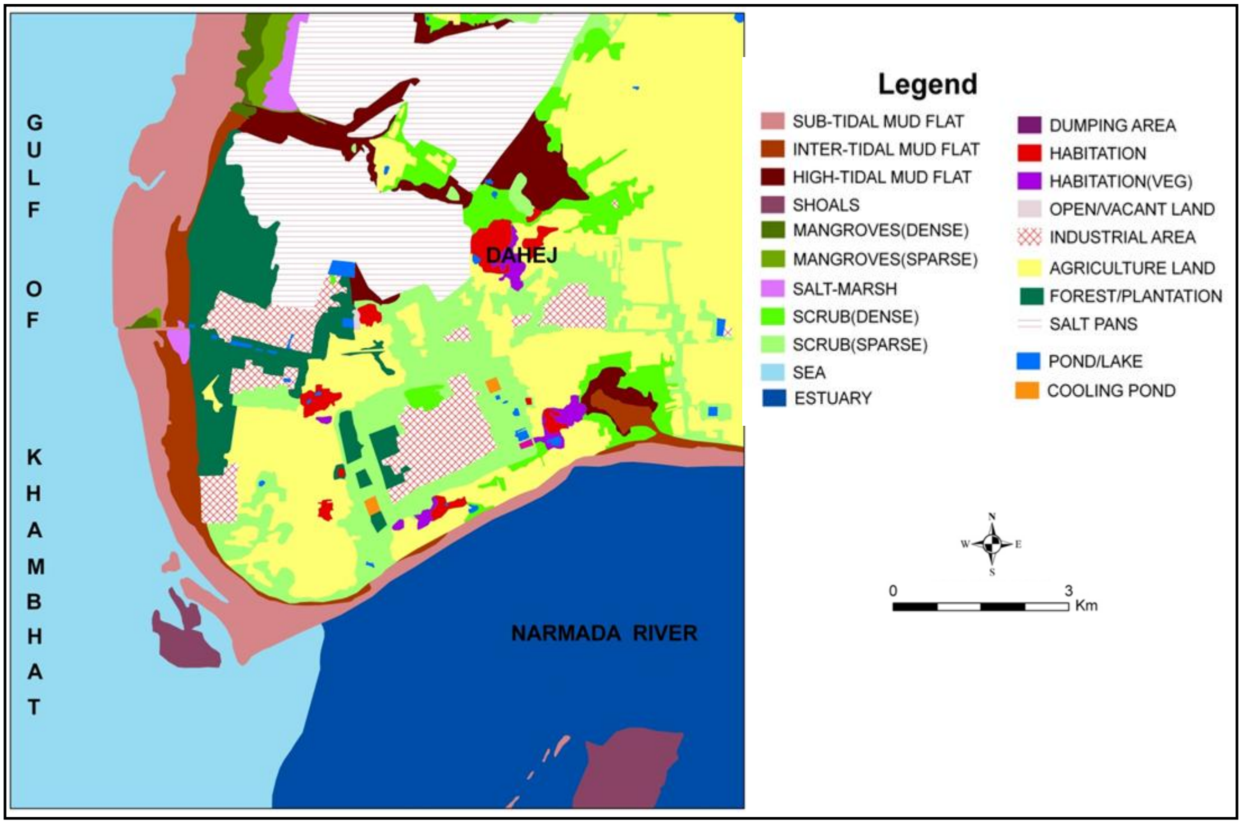

Figure 3: Land use & land cover map of study area

The land use & land cover a class (figure 5) which are inundated, is shown in table1. The inundated area of agriculture land would be 5.80 km^2 i.e., 19.97 % of the study area. The area of scrub land would be inundated 6.18 km^2. The forest cover would be inundated about 2.43 km^2 areas. About 1.73 km^2 area of industrial area would be flooded. It is observed that the area is inundated widely through Ghaguria Khadi creek in the north western part of the study area and connects the Narmada estuary through small inlet west of Ambheta.

Several factors make the Dahej coast highly susceptible to inundation. It is characterized by a flat coastal plain, gently sloping shoreline, sandy beaches and salt marshes, which produce extensive shoreline displacement with relatively small rises in sea level. Further, the construction of Sardar Sarovar dam upstream has reduced the Narmada river discharge to a large extent, resulting in large changes at the Narmada. Undercutting of the steep cliff, coastal road being breached by advancing sea, collapse of the sea wall, show the severity of the coastal erosion in northern bank of the Narmada River. The increasing rates of sea level rise increase the likelihood of coastal inundation of Dahej.

Applying projected sea level rise to simple digital elevation models has limitations. The models characterize a fixed representation based on land elevation and are not able to represent future shorelines. The model does not consider land subsidence, erosion, accretion and other natural adaptations. Accelerating sea level trends could seriously exacerbate erosion, inundation and salinization hazards, with increased risk to human life and property along low-lying coastal areas. The most obvious outcome of sea level rise is the permanent inundation of coastal areas

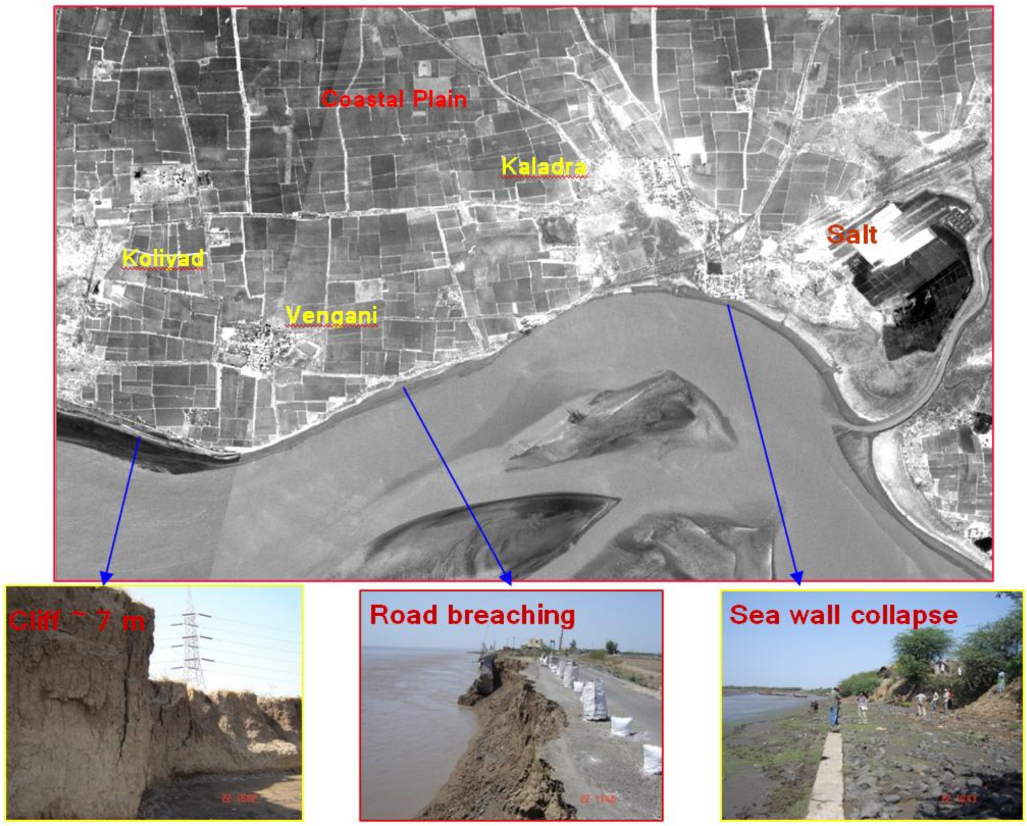

Figure 4: Shows the coastal erosion along the northern bank of Narmada river

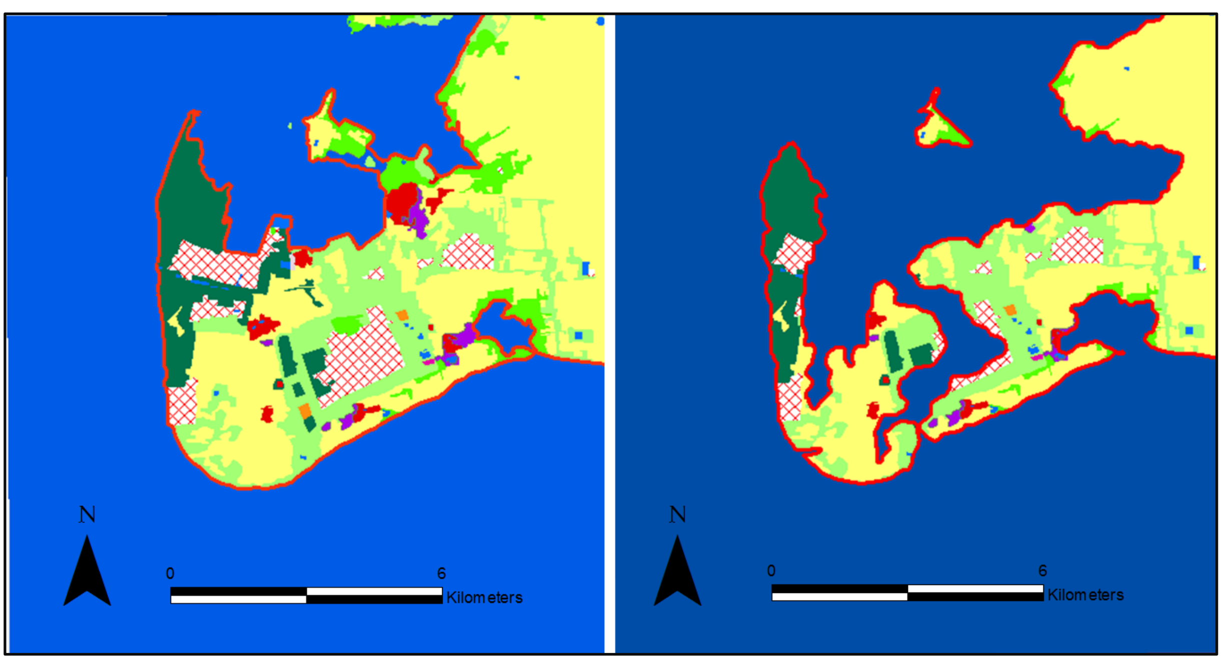

Figure 5: Shows the inundation of Dahej area, (a) due to the high tide (5.61m), (b) due to Sea level rise (0.49m)

Table1: Shows the coastal land use & land cover classes which are getting inundated due 0.49m sea level rise

Land use &land cover category	**Total area (km^2)**	**Area (km^2) of inundation if SLR 6.10m**	**% of inundation**
Agriculture land	29.04	5.80	19.97
Cooling pond	0.11	0.06	54.55
Dumping area	0.03	0.00	0.00
Estuary	37.22	37.22	100.00
Forest	6.37	2.43	38.15
Habitation	1.27	0.88	69.29
Habitation(veg)	0.66	0.36	54.55
Industrial area	1.73	0.42	24.28
Industry	3.57	2.39	66.95
Inter-tidal(m.flat)	3.36	3.36	100.00
Mangroves(dense)	0.62	0.62	100.00
Mangroves(sparse)	0.66	0.66	100.00
Open/vacant land	0.04	0.04	100.00
Pond/lake	0.49	0.25	51.02
Saline area	4.02	4.02	100.00
Salt pans	16.85	16.85	100.00
Salt-marsh	0.72	0.72	100.00
Scrub(dense)	4.32	3.23	74.77
Scrub(sparse)	11.14	2.95	26.48
Sea	42.69	42.68	100.00
Shoals	2.84	2.84	100.00
Sub-tidal (m.flat)	11.27	11.27	100.00

Over time the inundation changes the position of the coastline and drowns natural habitats and human structures. Inundation can also enhance coastal erosion by transporting submerged sediment offshore, and extending the effects of coastal flooding by allowing storm waves to act further inland. Inundation is determined by a host of factors including the rate of sea level rise, sediment availability and the slope and geomorphology of the shoreline.

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