Spatial and Temporal Analysis of LULC Dynamics of Mahi and Dhadhar River Estuaries at Gulf of Cambay, Gujarat Using RS-GIS Techniques

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Abstract* —The Gulf of Cambay (GoC), also known as the Gulf of Khambhat, is a vital extension of the Arabian Sea along Gujarat's coastline. The coastal belt plays a significant role in the state's economic development, particularly through its estuarine systems like those of the Mahi and Dhadhar rivers and others too. However, these regions are facing a multitude of environmental challenges due to both natural processes and human activities. For the Spatial and Temporal Analysis of Land Use Land Cove (LULC) Dynamics of Mahi and Dhadhar River Estuaries at Gulf of Cambay, decadal landform changes for the 1978-2017 time frame and Level I & II Classification System for Coastal Land Use Mapping for the geology and geomorphological features were considered. Satellite data were used in ArcGIS environment to construct the geo-data sets and produce LULC classified thematic maps and geo-statistics. Statistical analysis generated were materialised to reveal the outcomes. Industries, mangroves, settlements, depict a growth from 1978 to 2017. Sandbars have negative and mudflats have positive but fluctuating trend. Further association of classified and predictable features on image were established with Ground Control Points (GCP). The spatial extent of mud flats, salt encrusted land and sand bars have transformed indicating the natural parameters are under pressure over this region. The trend of fluvial water and rejuvenation through sediment flux in gulf in the recent time is declining compare to previous and in contradictory, the spatial extent of mud of marine nature and its deposition and change in its quality is striking and evident.

***Key Words*— Spatial and Temporal analysis, Gulf of Cambay, Landform features, LULC dynamics, River estuaries, RS & GIS**

I. INTRODUCTION

The coastal zone comprises a suite of unique ecosystems adapted to high concentrations of energy, sediments and nutrients that stimulate both high biological productivity and a diversity of habitats and species [1]. The coastal zone includes river basins and catchments, estuaries and coastal seas and extends to the continental shelf. It is a broad transitional area in which terrestrial environments influence direct marine environments and vice-versa [2]. The Pilot Analysis of Global Ecosystem (PAGE) study defines coastal regions to be the intertidal and sub-tidal area on and above the continental shelf (to a depth of 200 meters) area routinely inundated by saltwater and immediately adjacent lands [3]. Over the last century, humans with their technological capabilities have accelerated the rate of change, increasing their influence on the dynamics of already highly variable ecosystems [4]. Sixty percent of the world's major cities are located in coastal zones, and 40% of the all the people on the planet live within 100 km of a coastal zone [6]. Total coast line of the world is 35, 6000 km and the coastal area covers more than 10% of the earth surface. In India, 500 m distance from the high tide line towards landward is taken for demarcating the coastal zone [5]. The estuary is a transitional zone where freshwater from the River mixes with saltwater from the sea water, creating unique ecological conditions. The estuary plays a crucial role in the ecosystem of the region, providing habitats for diverse species and supporting local communities. The estuarine area is vulnerable to pollution from industrial effluents, waste disposal, and fishing activities. Because of the economic benefits that accrue from access to ocean navigation, coastal fisheries, tourism, recreation and industrialization, human settlements are often more concentrated in the coastal zone than elsewhere. About 40% of the world's population lives within 100 km of the coast. About 10% of the world's population resides in low elevation coastal zone (<10 m) making their lives highly vulnerable to coastal disasters. About 35% of Indians live within 100 km of the country's coast line measuring 7517 km [7]. Here is the statistics summarised in TABLE: 1 stating the share of Indian cost to the world.

	Coastal Length (km)	Area of Continental Shelf (up to 200 m depth)	Territorial Sea (Up to 12 nm)	Claimed Exclusive Economic Zone	Exclusive Fishing Zone	Total Potential Maritime Area	Population within 100 km from the coast
	a	000 km2	000 km2	000 km2	000 km2	000 km2	Percent
World	1634701	24287.1	18816.9	102108.4	12885.2	X	39.0
India	17181	372.4	193.8	2103.4	X	2297	26.3

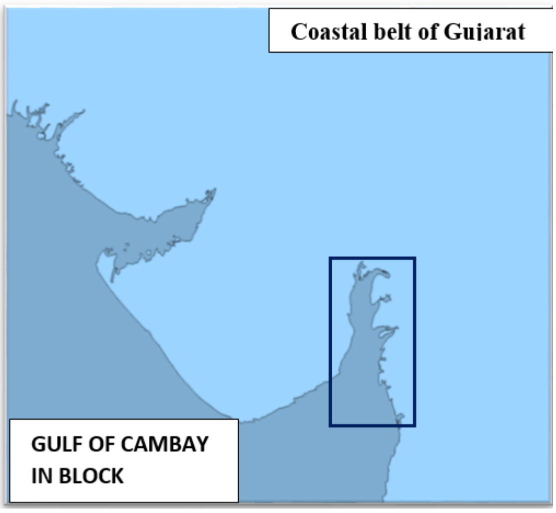
Table 1 Share of coastal area of India to the world: (Courtesy: PAGE: WRI, 2000)

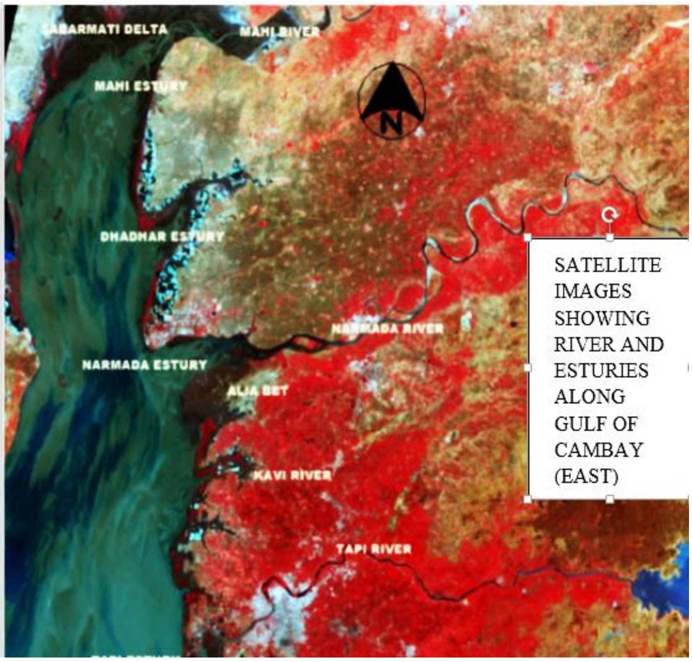
The Pilot Analysis of Global Ecosystems (PAGE) highlights that human activities have significantly altered coastal ecosystems worldwide. Approximately 30% of the land area in these ecosystems has been extensively modified or destroyed due to increasing demands for housing, industry, and recreation. This degradation is further exacerbated by the growing coastal population [3]. Gulf of Cambay part of Gujarat coastal belt, Western coast of India too, facing the environmental challenges like human encroachment, transforming land use land cover pattern, landform dynamics, wet land loss, and shore line erosion. Along the Gujarat coastal belt, the population in coastal talukas of Gujarat Coast has increased by nearly 18.3 percent from 2001 [8]. The urban Population increased by about 34 percent in the six major coastal districts of Gujarat [9]. Over the last century, humans with their improving technological capabilities have accelerated the rate of change, increasing their influence on the dynamics of already highly variable ecosystems [1]. The RS tool provides a valuable source of multi-temporal data at spatial and temporal scale. The GIS is useful for mapping and assessing the associated patterns. These tools provide a unique opportunity to develop information sources and support decision-making activities in a plethora of coastal zone applications [5]. This paper is an effort to study the Mahi River and Dhadhar River Estuaries at Gulf of Cambay.

II. OVER VIEW OF THE STUDY AREA

2.1 General

The Gulf of Cambay (GoC) also referred as Gulf of Khambhat, is geographically located between latitude 20° 30' and 22° 20' N and longitude 71° 30' and 73° 10' E. (Fig.1). The Gulf of Cambay (Khambhat) in the state of Gujarat, is an inverted funnel shaped highly indenting, constituting western Continental shelf of India. The trumpet shaped gulf has separated Saurastra peninsular to the Main land Gujarat crafting western flank of Gulf i.e. Saurastra and eastern flank of Gulf i.e. Main land Gujarat. The mouth of this Gulf opening to Arabian Sea is having width of 70-75 kms and attaining length of 130-135 kms [24]. As a part of research work of GoC, it is found that the width drastically reduces to 25 km at Bhavnagar and then approximately 15 km [24] or even less up to ~ 6 km [9] towards the tail of the Gulf while towards the mouth width attains almost 200 km [7]. Geographically the limits of the GoC is covered by Survey of India Toposheet No.46 B/8 and 46C /6, C/9, 10, 11, 12 and 14 at scale of 50,000 of 1968 to 1974 years and the Naval Hydrographic Chart No.208 (Hydrographic Chart of Gulf of Khambhat at scale 1:50,000, Original published in 31.07.2006 by National Hydrographic Office-Dehradun, GOI. [24].





Several rivers join the gulf, including the Sabarmati, Mahi, Dhadhar, Narmada, Tapti, and Shetrunji, Bhadar, and Kalubhar and hence, the GoC is characterized by a number of estuaries, islands, mudflats, cliffs, and mangroves. Among all these rivers Sabarmati, Mahi, Narmada, Tapi are perennial rivers and the rest are seasonal or drain with negligible water flow. Shetrunji, Kalubhar and Bhadar meets Gulf from the western flank while Sabarmati empty its water from north of GoC and the remaining rivers Mahi, Dhadhar, Narmada, and Tapi debouch their water from eastern flank. Mahi river estuary spans approximately 50 kilometres and passes through districts like Anand, Vadodara, and Bharuch along with the Dhadhar River, but Dhadhar Estuary span is less comparatively.

III. METHODOLOGY

3.1 Data Used

While selecting the data, it was preferred to have a data of same season/period and tidal height at specific interval of temporal resolution to estimate the spatial and temporal variations in the LULC pattern over the past few decades. In order to ensure consistency in comparison studies, it is imperative to select imageries with similar characteristics (season, tidal conditions, etc.). Landsat TM; Landsat ETM, and Landsat OLI_TRS datasets with universal transverse Mercator (UTM) zone 43 north Projection – WGS ‘84 projection system have been used for this study region. Data used are shown in TABLE: 2

Satellite	Date	Sensor	Resolution (mts)	Band (Nos.)	Time Pass	Path	Row	Zone/ projection
Landsat 3	16.10.1978	MSS	60	04	04:38:00	159	45	Datum: WGS 84 Map Projection: UTM Zone 43
Landsat 5	19.10.1990	TM	30	07	04:38:00 .	148	45	
Landsat 7	22.10.2000	ETM+	30	08	05.23.26	148	45	
Landsat 5	14.11.2011	TM	60	07	5.20.41	148	45	
Landsat 8	29.10.2017	OLI-TIRS	30	11	5.33.30	148	45	
IRS-R2	11.03.14	LISS 4 (NRSC)	5.8	03	5.20	093	057	
Additional support of Google earth Pro (2018); Bhuvan-NRSC, High resolution satellite images (new-2018) and open street map during process and analysis of work.								

Table: 2 Satellite data used for the study

3.2 Methodology

Satellite Imageries is affected by the solar incidence angle, solar azimuth, earth-sun distance, viewing angle, atmospheric effects, bidirectional reflectance distribution function (BRDF) of the surface sensed, and sensor band spectral response functions, thus these factors in combination produce significant band radiometric differences [29]. To correct this the most essential step is conversion of digital number to reflectance of each dataset, used for interpretation. It is desirable to implement these steps to bring in consistency of the time-series data set. After radiometric correction geocoded Landsat digital data series (1978-2017) were then analysed using onscreen visual interpretation techniques using major key elements along with ancillary information through topo maps, hydrographic charts, published thematic maps to interpret landforms and LULC of North of GoC, Gujarat. LULC maps were prepared on 1:50,000 scale in Geographical Information System (GIS) environment. Geo-data base was created in GIS using ARC GIS10.3. Software package based on Nation Spatial Framework on 1:250000 with LCC projection and WGS 84 datum. An exclusive landform features classification was evolved due to spatio-temporal data set to facilitate an appropriate assessment of all the land use/land cover categories and landform features over the study area. This outcome is the part of research work of whole Gulf of Cambay to understand the natural dynamics and anthropogenic influence. The selected area is based on the uniqueness of geology, geomorphology and physiography of the region with consideration of presence of estuarine delta treated here is a cell. Here the dimensions, size and shape of the cell and district boundaries are not taken into consideration. Attributes of the cell for chosen area is given in TABLE: 3. Adaptation of Level I & II - Classification System for Coastal Land Use Mapping [30], [31] for each cell could help to recognise some of the eight landforms for Mahi – Sabarmati confluence at Gulf, North of GoC while extracting the information from the available satellite data sets which are considered for the Land Use/ Land Cover change as well forming the landform features partly (Landform dynamics). The different landforms features used here are having essence of geomorphology as well as ecology as referred into various papers, not defined here.

S.N.	Cell Name		latitude	longitude	Area	L (Max)	W (Max)
					(Sq.Km)	kms	kms
1	Mahi	LT	22 15N	72 29E	850.52	20	41.3
		RT	22 32N	72 87E			
		RB	22 14N	72 85E			
		LB	22 17N	72 45E			
2	Dhadhar	LT	22 17N	72 49E	1326.84	28.5	49
		RT	22 15N	72 76E			
		RB	21 74N	72 70E			
		LB	21 76N	72 13E			
LT: Left Top LB: Left Bottom			NOTE: The dimensions of each cell are Non Uniform and having variable Length (L) and Width (W) even for individual cell.				
RT: Right Top RB: Right Bottom							
Max: Maximum							

Table: 3 Attributes of the selected area

IV. RESULTS AND DISCUSSION

4.1 Landform cover change: General overview of the region

The Mainland Gujarat coast facing the Gulf is made up of fluvial sediments of considerable thickness; nowhere hard rocks are encountered on the surface along the coast. The Mainland Gujarat coast is alluvial dissected by rivers Narmada, Mahi, Dhadhar, Tapi etc. and with cliffy river mouth banks. The rivers carry a lot of water and also bring vast quantities of sediments every year. The waters of Gulf heavily loaded with the fluvial sediments brought from the Mainland side as well as the Gulf sediments, constantly churned up by the tidal currents of the Gulf. The extreme muddiness of the Gulf waters and the complex interplay between the tides and river water flow has resulted into an interesting assemblage of depositional land forms in and around the Gulf. Mudflats represent the most dominant landform stretching Mahi river mouth to as far as

Khambhat. Being under the constant influence of tides, these mudflats are criss-crossed by a network of tidal channels. The rivers entering the Gulf do not carry too much of water, mainly after the constructions of various small, medium civil structure. The river Mahi entering from NE. In case of Mahi river entering GoC from NE direction, out of 134 dam structure and 4 weir structures almost 65% (counted) are functional after the year of 1985 [33]. One study is based on suspended sediment concentration, flow structure, geomorphic features and hydrodynamics reveals that the fine grained sediments are transported to the inner Gulf and sandy sediments are transported south words as the tides here are largest in the Indian coast [34]. This is how organic activities are highest in Sabarmati followed by Mahi. This is surely due to release of sewage water as well as industrial waste [35]. At many places the flats are seen supporting growth of mangroves. Here is the geostatistical analysis TABLE: 4 carried out for the years of 1978, 1990, 2000, 2011, 2017.

Land use Land cover in %										
	Mahi River Cell					Dhadhar River Cell				
Category	1978	1990	2000	2011	2017	1978	1990	2000	2011	2017
Agriculture Land	37	40	40	42	42	47	50	50	51	51
Industrialisation	0	1	1	3	3	0	4	6	9	9
Mangrove	0	0	0	0	0	0	1	3	1	0
Mud Flats	13	15	11	10	19	14	14	3	4	2
Salt encrusted land/ salt pan	13	16	15	10	13	18	11	9	7	7
Sandbar	0	0	0	3	0	0	0	0	0	0
Scrubland	9	1	2	0	1	1	0	0	3	2
Settlement	0	1	1	1	1	0	0	0	0	0
Waterbody	27	26	30	30	21	20	20	28	25	28
Grand Total	100	100	100	100	100	100	100	100	100	100

Table 4: geostatistical analysis of different land features identified (Area covered by feature of total in %)

Mahi and Dhadhar Estuary: The estuarine river mouths of Mahi and Dhadhar are broad, muddy and N-S extended and westerly expanded for several kilometres. During high tides , the sea water enters through the river mouths to fairly long distances (landward to 40-50 kms) on account of gradient less slope, as a result of which extensive accumulations of tidal muds (characterised by intertidal mudflats) are encountered along the estuaries of the two rivers. The mouths of the river Mahi during low tides exposes vast stretches of muddy shoals across which the river flows through a network of braided channels. The Dhadhar river mouth provides a good example of the choking of the river due to increasing mud accumulation that the river meanders, bifurcates and then joins again while flowing within the muddy deposits. Mud banks of variable dimensions and shapes occur in abundance between the mouths of Mahi and Dhadhar River. Most of the mud banks near the Mahi river mouth are sandy and silty while those of Dhadhar are silty and clayey based on visual inspections. Most of them get submerged during high tide. Interestingly, the configuration of these features keep on changing frequently in course of time or even seasonally. Another factors governed for erosion and deposition in the region is the flow, intensity and quantity of discharged water of river. Older mudflats, alluvial islands or 'bets' occurring between channels or mudflats, salt encrusted land, waste land and salt pans are other features reported here. The islands of irregular shape, dimensions, vegetated cover may rise few meters are conspicuous. Here is the statistical analysis carried out for the years of 1978, 1990, 2000, 2011, 2017, cell wise. For Mahi and Dhadhar river Different 9 features have been recognised and the area covered by individual feature, referred here as category was calculated in % of the total area of the cell.

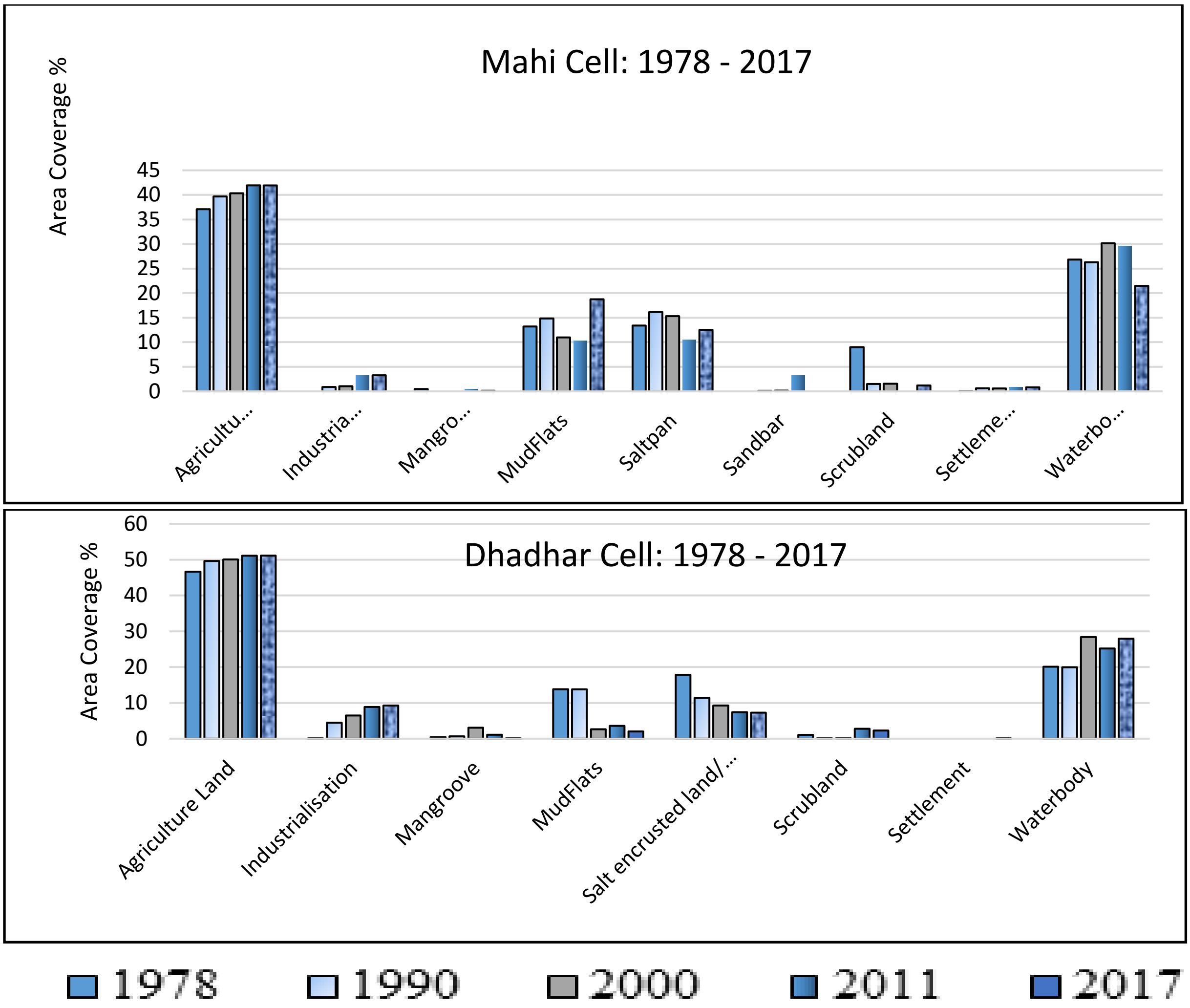


Fig: 2 Geostatistical graphs

Geostatistical graphs are presented for the area in figure: 2 for the timeframe 1978-2017 and spatio-temporal mapping of the same timeframe for selected area has been presented in Fig.3 for understanding the change in landforms.

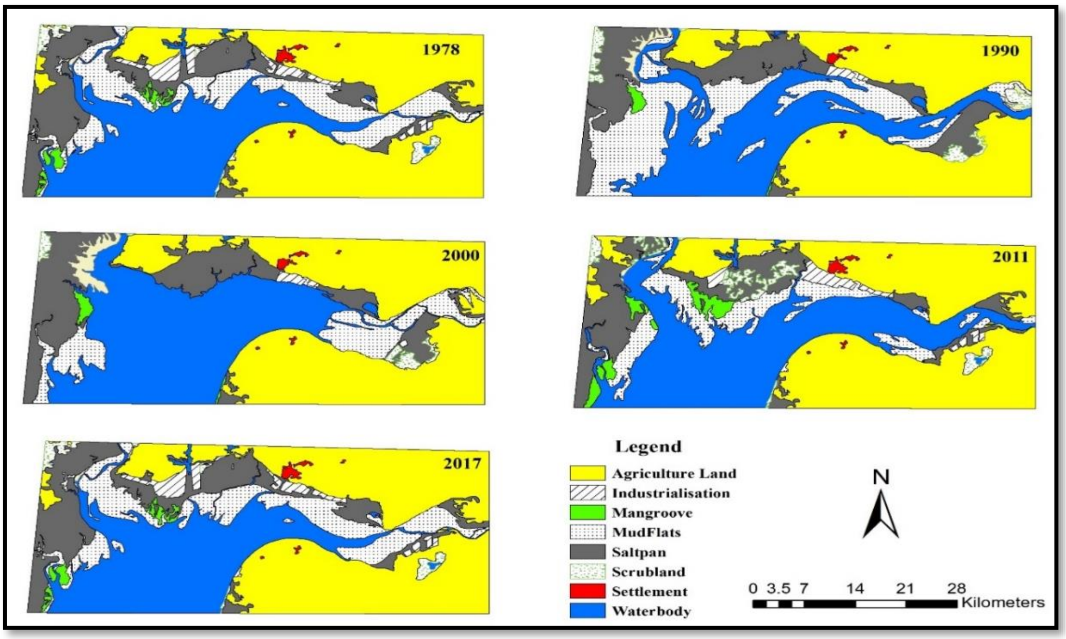


Fig: 3 Spatio-temporal landform feature change for the Mahi River (1978-2017)-Digital processed Landsat Images

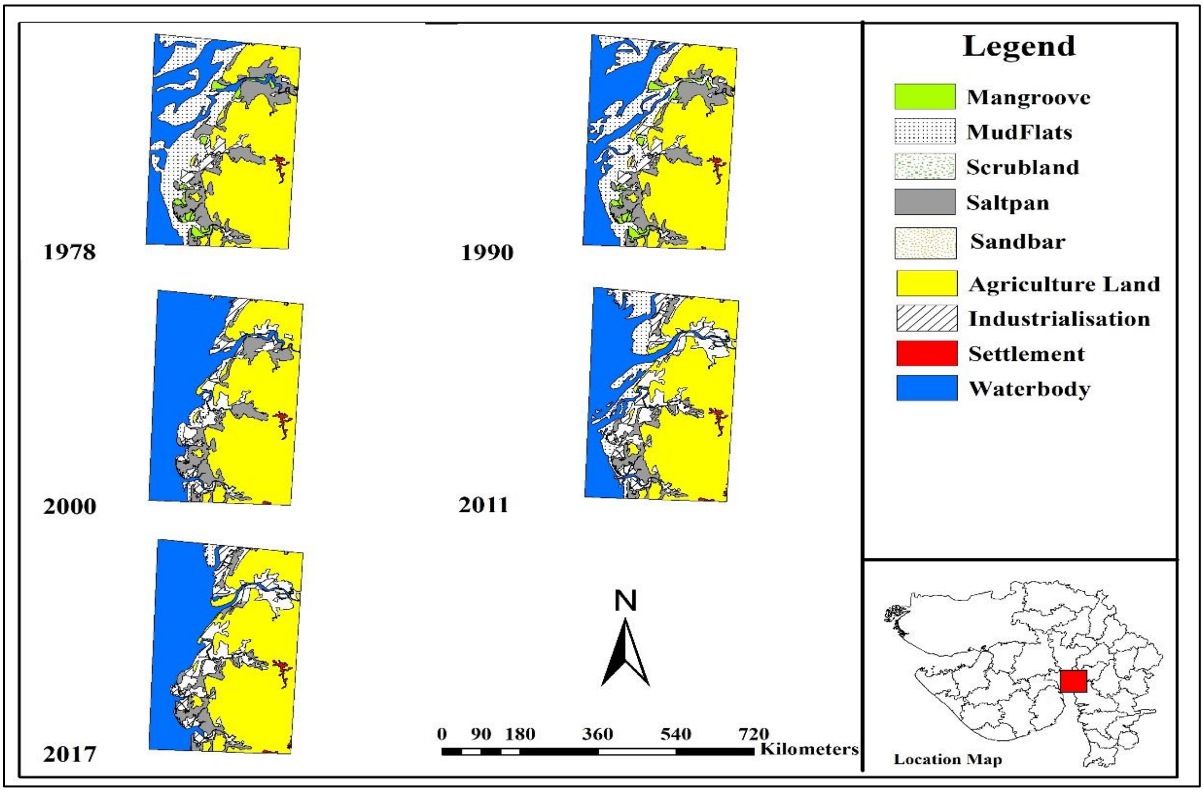


Fig: 4 Spatio-temporal landform feature change for the Dhadhar River (1978-2017)-Digital processed Landsat Images

V. OBSERVATIONS

The cell wise LULC classes are represented here for the different time series satellite image of 1978, 1990, 2000, 2011, 2017 along with the statistics and graphical bar charts on decadal scale.

In general the followings are the observations based on the available statistics for the given cells.

1. Agricultural /vegetation cover shows increasing trend, 7-10 % rise in Mahi and Dhadhar near the coastal belt
2. Industrialisation and human population or settlement categories shows drastic increasing trend .
3. For Dhadhar cell industries have increased from the year of 2010 (Almost nil to 10% of the area) while it is 3% in Mahi cell region. These both the events of industrialisation and settlements can be correlated with the economic growth in this regions. The influence of these category is evidently noticeable for the salt pan and mud flat features.
4. Dhadhar cell shows less growth in settlement due to maintaining the agriculture activity compare to other regions. No doubt the trend of decrease in mudflats and increase in salt farming activities are clearly apparent and revealed.
5. The presence of Mangrove the particularly in tidal zone is illustrate increasing trend (from 0 to 4% of the total cell area), but at the end it is also slightly declining. More careful study is needed on seasonal bases as well as on less time span scale to understand the actual cause. This is in accordance with the need of intervention of the people to increase the mangrove cultivation.
6. Validation : Photograph description in favour of ground truth (figure 4) as given below

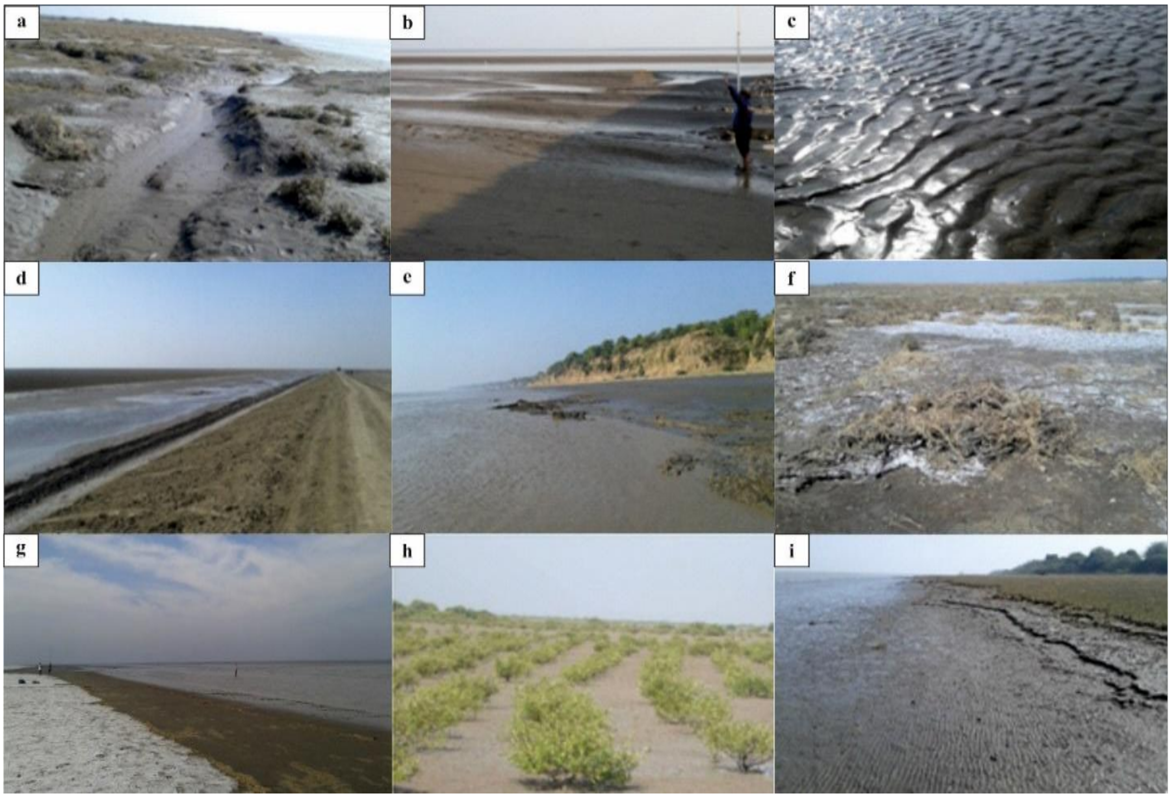


Fig .4 field photographs ground truth validation

Fig 4: (a).Mahi estuary with numbers of dissected mud flats traversed by tide water, channels flooded with tide water (b) Foreshore mudflats and offshore mud banks. Due to heavy tide currents, regularly changing recent features. Creating large depressions and elevated grounds without notice. (c) Reflecting water flow trend, showing ripple features in the flow direction at Dhuvaran (d) Reclamation activity for encouraging saltpan activity or aquaculture activity Wasteland inundation during high tide leaving behind salt encrusted land and supporting shrub at Tip of Mahi, Khambhat town (e) Recession of tide water in front of raised alluvial vertical cliffs at Mahi-Badalpur site (f) Salt affected land with dried scrub and other vegetation (g) At Tip of Mahi, near Khambhat, showing raised firm alluvial older platform, tide water inundation portion and recession of tide water (h) Mangroves planted (i) Estuary along Dhadhar river.

VI. CONCLUSION

Different spatial classes are represented here in image for temporal resolution of 1978, 1990, 2000, 2011, 2017 along with the statistics and graphical bar charts on decadal scale. The climate, socio-economic condition has more influence on agriculture and settlements which has remained unchanged or marginally changed. Mangroves are taken care of by the nature. The contribution of water and sediments flux from river side is comparatively (based on referred research work) compare to mud flat expansion through tides within the gulf and along estuaries, encouraging more marine deposition and saline in nature. The quality degradation and quantity of mud flats in this region at the tail of Gulf and towards Mahi and Dhadhar esturies are eye catching. The region is under fluvial marine deposition, but fluctuating contribution from river side, need more study on chemical analysis for refined work.

VII. ACKNOWLEDGMENT

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REFERENCES

[1] Crossland Christopher J, Baird Dan, Ducrotoy Jean Paul A, Lindeboom H J: *the domain of global interactions chapter-march 2006* https://www.researchgate.net/publication/226867603

[2] Carter R. W. G. 1988, *coastal environments an introduction to the physical, ecological and*

cultural systems of coastlines' academic press limited london.

[3] WRI: World Resources Institute (2000): Revenga, C., Brunner, J., Henninger, N., Kassem, K., & Payne, R. *freshwater systems. washington, dc.page,2000 world resources institute coastal ecosystem pilot anaysis of global ecosystem published by washington dc* http://www.wri.org/wr2000

[4] Crossland, C.J., Kremer, H.H., Lindeboom, H.J., Marshall Crossland, J.I., Le Tissier, M.D.A. (Eds.), 2005. *coastal fluxes in the antropocene: the land–ocean interactions in the coastal zone, igbp series. springer-verlag, berlin, 232 pp.*

[5] SAC: Space Applications Centre (ISRO), Ahmedabad (2012): *coastal zones of india. isbn no. 978-81-90997b-9-b*

[6] Niholls R J, Wong P.P., Burkett V, Codignotto,J. Hay, R. and others: *coastal system and low lying area climate change 2007 4th assessment report of the ipcc uk cambridge university press 2007, 315-356*

[7] CZI: 2012, *coastal zone of india space applications centre (isro) ahmedabad isbn no. 978-81-90997b9b*

[8] Census of India, 2011, http://www.censusindia.gov.in/2011census/population_enumeration.html

[9] GEC-2011 : Gujarat Ecology Commission Ecological : *profile of coastal talukas around gulf of khambhat gandhinagar, 2011*

[10] Shaikh M G; Nayak S ; Shah, P.N.; Jamusaria, B B. "Coastal Landform Mapping around the Gulf of Khambahat using Landsat TM data, *Photonirvachak, Journal of the Indian Society of Remote sensing, Vol.17, No:1, 1989*

[11] Turner R K and Adger W N (Lead Authors): *coastal zone resources assessment guidelines, land-ocean interactions in the coastal zone (loicz), (igbp), (icsu) (cserge) research centre of the uk economic and social research council (esrc).1995*

[12] Mahapatra, Manik *Vulnerability of Gujarat coast due to sea level rise – an investigation based on remote sensing & GIS techniques* , PhD Thesis, Nirma Univerity, Ahmedabad, Feb 2015.

[13] Nina Siu-Ngan Lam, S. Liang (ed.), Methodologies for Mapping Land Cover/Land Use and its Change, *Advances in Land Remote Sensing, 341–367. 341 c Springer Science + Business Media B.V.,* 2008

[14] Nayak, S. R and Sahai, B. (1985); Coastal morphology: a case study of the gulf of Khambhat (Cambay). *Int. J. Remote Sensing, 1985, 6, 559–567*

[15] Nayak Shailesh (2017) Coastal zone management in India – present status and future needs, *Geo-spatial Information Science, 20:2, 174-183, ISSN: 1009-5020 (Print) 1993-5153 (Online)*

[16] Desai P S, Narain A. Nayak S R. : IRS 1A: Applications for Coastal and Maine Resource, *Current Science, Vol. 61, 3 & 4, 25 Aug' 1991, Special Issue on: Remote sensing for National Development*

[17] Joshi, M D.; Sahai, Baldev: Mapping of salt-affected land in Saurastra coast using Landsat Satellite data, *International Journal of Remote sensing, Vol:14, 1993, Issue: 10*

[18] Nayak, S. & Bahuguna, A. Application of Remote sensing data to monitor mangroves and other coastal vegetation of India, *Indian Journal of Marine Sciences, Vol 34, December 2001*

[19] Chauhan, H. B., & Nayak, S. (2005). Land use/land cover changes near Hazira Region, Gujarat using remote sensing satellite data. *Journal of the Indian society of Remote Sensing, 33(3), 413-420*.

[20] Misra, A. & Balaji, R. "Decadal changes in the land use/land cover and shoreline along the coastal districts of southern Gujarat, *India, Environ Monit Assess (2015), Springer International Publishing Switzerland 2015*

[21] Merh: S.S. *Geology of Gujarat Geological Society of Gujarat Bangalore 1995*

[22] Sourav saha, Anupam ghosh, Santanu Banerjee, Pratul k Saraswatiand Stuart D Burley. Characteristics of an Open Coast Tidal Flat: Example from Daman, West Coast of India, *Journal geological society of India,2011*

[23] Sourav Saha, Stuart D. Burley, Santanu Banerjee, Anupam Ghosh, Pratul K.Saraswati,; *The morphology and evolution of tidal sand bodies in the macro tidal Gulf of Khambhat, Western India, 2015*

[24] Modi D, Subhash Bhandari, 2018: Landscape change detection of Aliabet, Mouth of Narmada river, Gujart using geospatial tchniques, *Journal of Emerging Technology and*

Innovative Research, Vol:5, Issue 7, ISSN: 2349-5162.

[25] Merh S.S,(1995): *Geology of Gujarat, Geological Society of India, Bangalore, 1995*

[26] Patel M.P., Patel S.G. and Merh S.S.: Geomorphic studies on the Coastline between Mahi and Tapi river mouth paper published in Geology and Geomorphology of Quaternary Terrains of Gujarat with special reference to Coastline evolution: A report work of Dept. of Geology, M.S.University, December 1982

[27] Patel M.P., Patel S.G. and Merh S.S.: Geomorphic Evidences of Quaternary Sea-level changes in Mahi-Tapi coastal segment of Gujarat published in proceedings of the All-India Symposium, Geology Dept, M.S.University of Baroda, February 6-8, 1983

[28] Badrul Islam,Md *Geological set up of the gulf of Khambhat Cambay A critical appraisal of the relevant onshore and offshore geo environmental parameters. Ph.D Thesis, Maharaja Sayajirao University of Baroda, 1986, Shodhganga. Web 16 December 2015.*

[29] Royer, A., Vincent, P., & Bonn, F. (1985). Evaluation and correction of viewing angle effects on satellite measurements of bidirectional reflectance. *Photogrammetric Engineering and Remote Sensing, 51(12), 1899-1914.the process at regular time intervals.*

[30] Nayak S, Pandeya Anjali, Shaikh M G, Coastal Zone classification System: A Remote zone Classification system, proceeding of the Seminar, National seminar on Quaternary Landscape of Indian Sub-Continent (1-3 December, 1988), M S University, Baroda, Gujarat (Proceeding 1991)

[31] Shaikh M G; Shailesh Nayak; P.N.Shah, B B Jamusaria “Coastal Landform Mapping around the Gulf of Khambahat using Landsat TM data, *Photonirvachak, Journal of the Indian Society of Remote sensing, Vol.17, No:1, 1989*

[32] Ganpathi S, the Shoreline Morphology of the Gujarat Coast: An Appraisal, Status of Coastal zone studies and future trends: Special reference to western India, 24-25, Feb 2006, Dept. of Geology and SAC

[33] WRIS, NRSC, 2014: *River basins of India GOI Ministry of water Resources CWC,NRSC, Sabarmati rive basin & Mahi river basin*

[34] Kunte, P. D. (2008). Sediment concentration and bed form structures of Gulf of Cambay from remote sensing. *International Journal of Remote Sensing, 29(8), 2169-2182.*

[35] Deshkar S, Jayendra Lakhmapurkar: State of three estuaries of Gulf of Khambhat, *Indian Journal of Geo-marine sciences, 2012 , 41(1): 70-75*

[36] http://www.earthexplorer.usgs.gov/