Integrating Remote Sensing and GIS For Spatio-Temporal Landform Change Analysis" For Tapi River Estuary at Gulf of Cambay, Gujarat.

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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 Narmada and the Tapi rivers and others too. However, these regions are facing a multitude of environmental challenges due to both natural processes and human activities for evaluation of Landform Feature change analysis through Spatio-Temporal Change Detection Methods of Tapi River Estuary 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.**

***Index Terms*—Gulf of Cambay, Landform features, Spatial and Temporal analysis, River estuaries, RS & GIS**

1. 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 coast to the world

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	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 taluka 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 Tapi River Estuary at Gulf of Cambay.

2. 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].

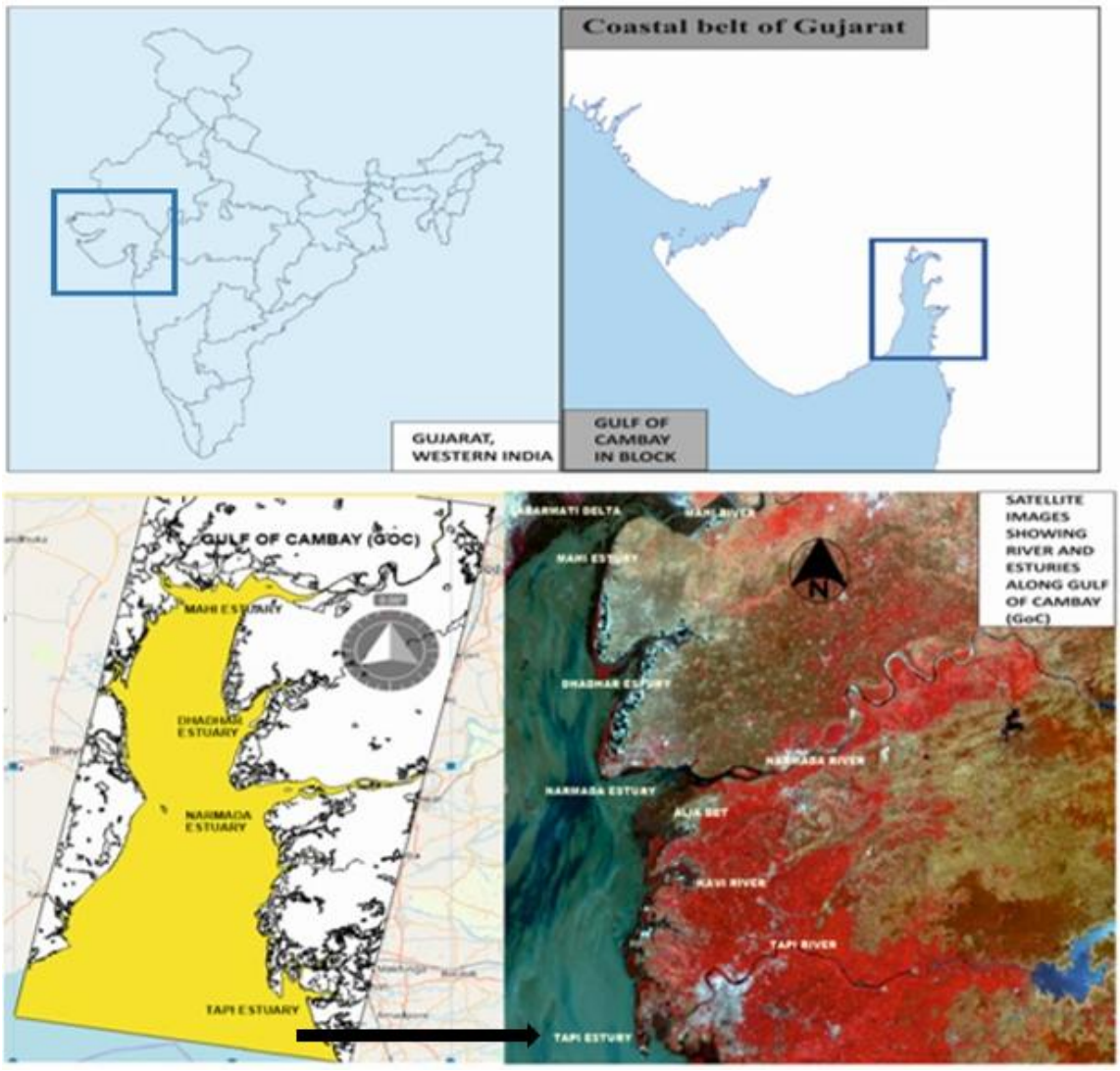


Figure: 1 Study Area

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.

3. 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 has 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 Meffects, 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] 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)
1	Tapi	LT	21 22N	72 34E	799	18	50
		RT	21 22N	72 44E			
		RB	20 58N	72 45E			
		LB	20 58N	72 35E			
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

4. 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, and Tapi etc. and with cliffy river mouth banks. 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 assemblage of depositional land forms in and around the Gulf. 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. 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]. At many places the flats are seen supporting growth of mangroves. Here is the geo-statistical analysis TABLE: 4 carried out for the years of 1978, 1990, 2000, 2011, 2017.

Land use Land cover in %					
Tapi River Cell					
Category	1978	1990	2000	2011	2017
Agriculture Land	34	35	34	34	35
Industrialisation	2	4	5	10	10
Mangrove	4	4	4	4	4
Mud Flats	14	12	2	4	0
Salt encrusted land/ salt pan	13	10	9	8	9
Sandbar	2	2	2	0	0
Scrubland	0	0	0	1	1
Settlement	0	0	1	1	1
Water body	30	32	42	37	41
Grand Total	100	100	100	100	100

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

4.2 Cell: Tapi Estuary

The region between Hansot- Hazira segments, is mainly drained by major rivers like Narmada and Tapi. This segment carries very less or no cliffs, enormous quantity of water compare to earlier segment and geological variability.

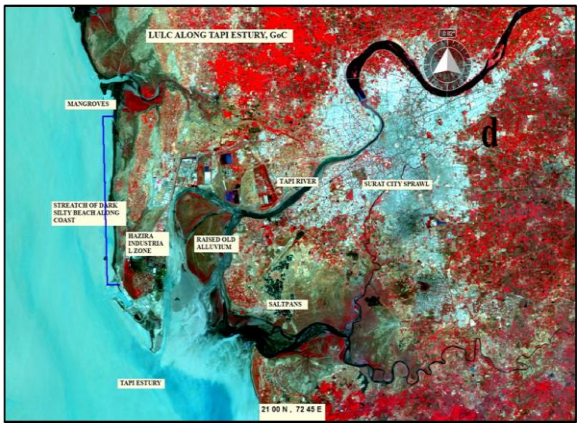


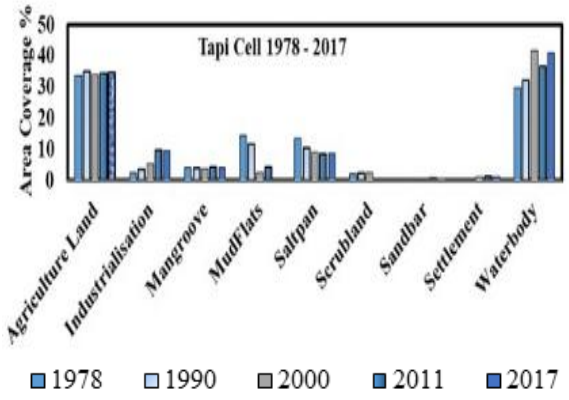
Fig: 2 Satellite Image representing Tapi cell: Tapi River (d)

(Tapi River opens up into Gulf of Cambay eastwardly, showing estuary, salt encrusted and salt affected land, salt pans, mud flats, vegetation, mangroves, sandy beach, waste land or scrub, industrialisation and urbanisation etc.)

The Tapi estuarine mouth is comparatively smaller than the Narmada and shows considerable complexity and heterogeneity of coastline depositional and erosional processes. The beach is having grey toned silty sand and quite different than the earlier rivers. Here is the statistical analysis carried out for the years of 1978, 1990, 2000, 2011, 2017, cell wise. For Narmada and Tapi river cells, 9 different 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. Table 4: shows geo-statistical analysis of different land use land cover classes.

Geo-statistical graphs are presented for the Tapi cell separately in figure: 3 for the timeframe 1978-2017 and spatio-temporal mapping of the same temporal timeframe for each selected cells have been presented in Figure 4 for understanding the change in landforms.

(Geo-statistical graphs are presented for the area in figure: 3 for the timeframe 1978-2017 and Spatio-temporal mapping of the same timeframe for selected area has been presented in Fig.4 for understanding the change in landforms.)



Features calculated in % of the total area of the cell in Tapi.

Fig: 3 Geo-statistical graphs

5. OBSERVATIONS

For Tapi cell (one of the cells) 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 cell.

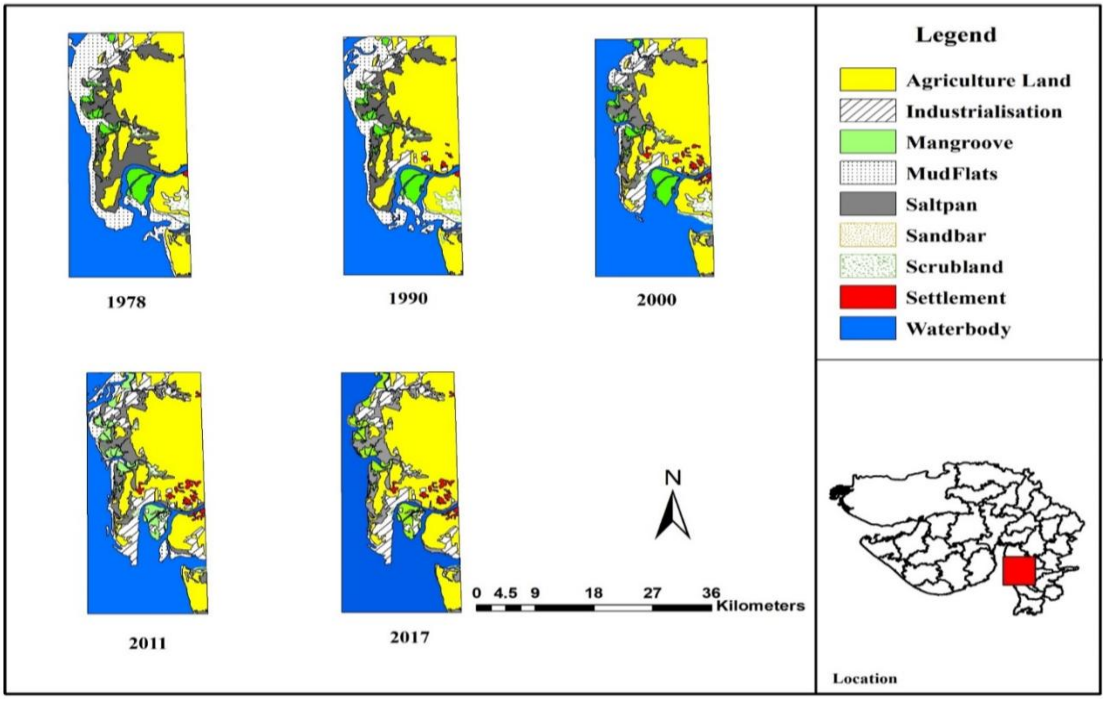


Fig: 4 Spatio-temporal landform feature change for the Tapi River (1978-2017)-Digital processed Landsat Images

The conclusions are based on the available statistics for the given cell and the dimensions under consideration.

1. Well-developed Agricultural /vegetation cover shows declining trend for the Tapi region.
2. Industrialisation and human settlement categories show drastic increasing trend in this region. For Tapi cell the industrialisation is up to 10% rise. This can be matched with the expansion of the region (ports) Dahej and Hazira. There has been a considerable upsurge and spatial expansion in the urban built-up class. That is from negligible to 2% rise. These both the events of industrialisation and settlements can be correlated with the economic growth in this region. The influence of these category is evidently noticeable for the salt pan and mud flat features.
3. Mangrove, that illustrate increasing trend (from 0 to 4% of the total cell area), but at the end it is also slightly declining for Tapi cell. Reducing trend in the area of Hazira Island can be seen along with decrease in the extent of mudflats (10 -15%), scrubs (2-3%), sandbars (1-2%) and salt encrusted land. The fluctuation in water body on spatial extent is due to high tide levels that is conspicuous in this Tapi cell.
4. Increment in human settlements, industrialisation and expansion of saltpans along Tapi River, displays networks of landmass with nearer towns. The connectivity has increased, resultantly disappearance of channels, tributaries are very noticeable. Brings the change in land form features along this major river. Consequently, may have impact on shore line change too.

5. CONCLUSION

The present study is an effort towards continuous observing the changes along coastal belt of Cambay. Periodic studies and monitoring can provide information about the previous to current situations. The amplified industrialization and urbanization in the last few decades have stressed on coastal area of Gujarat state. 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. 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 of estuary is eye catching. It could be inferred that the incremental rise can transform the scenario of the region. For the refined outcome, using satellite data of higher resolution at specific smaller interval and at micro level is essential.

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