A Spatio-Temporal Landform Feature Change Detection And Assessment By Means Of RS-GIS Techniques: Case Study Of Mahi – Sabarmati River Confluence, Gulf Of Cambay, Gujarat

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Abstract: The Gulf of Cambay (GoC), the extension of the Arabian Sea, is the valuable asset and is prime concerned of economic progress for the state. Easy to access but complex in system nature has also, invited intricacies due to encroachment, LULC transformations, geomorphological alterations consequently shore line changes. Present case study is thrusted on estuaries along Northern entrance of GoC, to detect and assess the decadal landform changes for the 1978-2017 time frame. Level I & II Classification System for Coastal Land Use Mapping using the geology and geomorphological features were deliberated. Satellite data were used in ArcGIS environment to construct the geo-data sets and produce LULC classified thematic maps and geostatistics. Statistical analysis generated were materialised to divulge the outcomes. Industries (7%), mangroves (>1%), settlements (>1%) 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 GCP. The spatial extent of mudflats, salt encrusted land and sand bars have transformed indicating the natural parameters are under pressure over this region. Presumably, the outcome of this study may help the planner and policy makers for planning the region judiciously.

Key Words: Geomorphological changes, Gulf of Cambay, Landform features, LULC changes, 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]. It is a broad transitional area in which terrestrial environments influence direct marine environments and vice-versa [2]. There is no single definition of the coastal zone. Some have referred to it as “that part of the land most affected by its proximity to the sea and that part of the ocean most affected by its proximity to the land”. The PAGE study defines coastal regions to be the intertidal and subtidal area on and above the continental shelf (to a depth of 200 meters) area routinely inundated by saltwater and immediately adjacent lands [3]. According to Carter [2] the coastal zone includes river basins and catchments, estuaries and coastal seas and extends to the continental shelf. Crosland [4] treats coastal zones as the narrow transition areas that connect terrestrial and marine environments, earths most productive and valued ecosystems. In other arguments coastal zones are the area of interaction between land and sea which is located between terrestrial and marine environments [5]. 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. [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. 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. The results from the Pilot Analysis of Global Ecosystem (PAGE) show that human activities have extensively altered coastal ecosystem worldwide. Nearly 30% of the land area in the world’s coastal ecosystems had already been extensively altered or destroyed by growing demand for housing, industry and recreation [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 and geomorphological changes, 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]. The understanding of coastal process helps to manage coastal zone and that is possible through the mapping and study the coastal landforms that are changing due to tides, waves and currents [10]. Monitoring of land-use/land-cover changes is needed for
understanding of change mechanism and modelling the impact of change on the environment and related ecosystems at different scales [11]. 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, and the GIS is useful for mapping and assessing the associated patterns. Thus, these tools provide a unique opportunity to develop information sources and support decision-making activities in a plethora of coastal zone applications [5]. In order to evaluate and predict the extent of geomorphic and ecological changes taking place, coastal zones require an enormous amount of site-specific research, by virtue of the complexities associated with them at the regional level [12]. Mapping land cover/land use accurately and efficiently via remote sensing requires good image classification methods [13]. Pioneering the work focusing on Coastal zones and Remote sensing technology, Nayak & Sahai [14] on the basis of Landsat Imagery has described the tidal as well as seasonal sea level changes, current patterns and sediment transport and the relationship of these phenomena with some erosional and depositional-coastal geomorphic features, coastal Mapping [10][15]: IRS 1A: Application for Coastal and Marine Resources, mapping of the tidal wetlands, coastal landforms, suspended sediments, understanding the process of estuary dynamics, shoreline changes, degradation of coral reefs etc. [16]; mapping of salt affected land in parts of Gujarat [17], monitoring mangroves and other coastal vegetation [18] are worth to be recognised here. Availability of repetitive, synoptic and multi-spectral data from various satellite platforms, viz. IRS, LANDSAT, SPOT, have helped to generate information on varied aspects of the coastal and marine environment [18]. Chauhan and Nayak [19], carried out a study to assess the LULC for the Hazira region of Surat District and reported an increase in the anthropogenic pressure due to industrial activities. Misra and. Balaji [20], studied the LULC changes that have taken place in the districts of Surat, Navsari and Valsad located in southern Gujarat. The off shore work of Sourav Saha, and others, on characteristics of open coast tidal flats of Daman [22] and another effort on “morphology and evolution of tidal sand bodies in the macro tidal Gulf of Kambhat, Western India” [23] has remarkable attainment in this area for the Gulf of Kambhat. This paper is an effort to study the North of Gulf of Cambay (GoC), part of Gujarat coastal belt, focusing mainly on estuaries and or deltaic estuary formed by rivers Bhadar, Bhogavo meeting Sabarmati and Mahi at North of GoC with some additional approach and dataset, to reach out the close trend of change of landform features, intending to apprehend geomorphological changes and shoreline changes in this region and other parts of Gulf.

2.0 Over View of The Study Area:

2.1 General

Gujarat, one of the longest maritime states of India prides of taking up two gulfs, Gulf of Kachchh and Gulf of Kambhat respectively within its boundaries. Both the gulfs owe their own peculiarities in terms of physiography, hydrography, biodiversity and the surrounding confluences [9]. The Gulf of Cambay (GoC)/ Gulf of Kambhat (GoK), also referred as 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 (Kambhat) in the state of Gujarat, is an inverted funnel shaped highly indenting, constituting western Continental shelf of India. The trumpet shaped gulf has literally separated Saurashtra peninsular to the Main land Gujarat crafting western flank of Gulf i.e. Saurashtra 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 [12],[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], so monitoring this region would be scientifically interesting. In India, 500 m distance from the high tide line towards landward is taken for demarcating the coastal zone [5]. This feature makes the Gulf second in the world in terms of tidal amplitude [9]. Geographically the limits of the GoC is covered by Survey of India Toposheets No.46 B/8 and 46C /6, C/9, 10, 11, 12 and 14 at scale of 50,000 of the varying years 1968 to 1974 and the Naval Hydrographic Chart No.208 (Hydrographic Chart of Gulf of Kambhat at scale 1:50,000, Original published in 31.07.2006 by National Hydrographic Office-Dehradun, GOI. [24].

Figure: 1 Study Area

2.2 Physiography and Coastal Geomorphology aspect of the region:

The Gujarat coast provides a wide range of coastal features due to varied physiography, geomorphology, coastal processes and river discharge into the sea [25]. Based on shore line
configuration, energy condition, tidal current, littoral configuration, substrate, drainage, climatic condition, salinity and turbidity, Gujarat coast precisely divided in to Kutch, Saurashtra, Main land Gujarat segments. [26] [27] [25]. The GoC forms a very small portion of the West Coast but upholds an instrumental geo environmental collection hence the geological, geomorphological reflections are due to past geotectonic process and climatic condition. The whole GoC suffers different climatic situations, due to seasonal variations beside the high and low tides phases. The geological set up of is distinct throughout Gulf. Geomorphologically, the onshore areas around the Gulf of Khamxbhat, are of great interest and provide a striking diversity of landscapes [28]. The general trend of the coast line is NE-SW, N-S, and NNE-SSW to N-S. If the line is stretched in the mid of Gulf of Cambay has to follow almost N-S trend [24]. The shoreline configuration is highly indented, dissected, carved out through the coastal belt of Gulf of Cambay. The coastal morphology show variation at spatial scale ranging from rocky platforms, beaches, mudflats, cliffs and coastal submerged dunes along Diu Bhavnagar segment to vast mudflats backed by prominent alluvial cliffs, drowned river mouths and alluvial plains of Cambay-Dahej segment [28]. The inter tidal zone covered with recent mud have extensive width due to deltaic estuary nature of the rivers debouching their water in the Gulf at their confluences. The gulf has literally separated Saurashtra peninsular to the Main land Gujarat crafting western flank of Gulf i.e. Saurashtra and eastern flank of Gulf i.e. Main land Gujarat [24]. The rivers from east are active and sediments laden bring voluminous quantity of sediments from the high regions and the rest from west are drain with negligible water flow while Sabarmati along with Bhogavo and Bhadar empty its water from north end of GoC, without recognising the physical entrance, shows extensive development of mud-flats and mud-bank and shoals. For the Bhogavo-Bhadar-Sabarmati river confluence at GoC, represents almost gradient less plain, illustrating the nature of old age rivers and demonstrates almost meandering pattern developing deltaic estuary towards north of Gulf. The tides are very high in inner gulf attains heights more than 10 mts, almost second highest than the Bay of Fundy, with high tidal energy [5].

3.0 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. Area is selected along the coast, based on the vulnerability entrusted due to change in shoreline and over thrusting of urban development and industrialisation or even terra forming to Anthropocene act of human in the vicinity. Data used are shown in TABLE: 2

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 and intensely selected this part to check the natural dynamics and anthropogenic influence of the whole study area over this selected region. The chosen area is based on the uniqueness of geology, geomorphology and physiography of the region with consideration of presence of estuarine delta. Here the dimensions, size and shape of the cell and or 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. The different landforms features used here are having essence of geomorphology as well as ecology as referred into various papers, not defined here.

<table>
<thead>
<tr>
<th>S. N</th>
<th>Verti ces</th>
<th>Latit ude</th>
<th>Longit ude</th>
<th>S. N</th>
<th>Verti ces</th>
<th>Latit ude</th>
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<td>22</td>
<td>72 30E</td>
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<td>RB</td>
<td>22</td>
<td>72 89E</td>
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</tbody>
</table>
...region and for given time frame. Similarly at ..., mainly tical ...

This is surely due to release of sewage water as well as organic activities are highest in Sabarmati followed by Mahi. Phosphate concentration is in increasing for Mahi to Narmada. Similarly Nitrates and DO and BOD and level are lowest in Sabarmati then estuaries viz. Sabarmati, Mahi an Narmada of Gulf concludes study based on Physico-chemical parameters in three main oscillatory estuaries. The significant change that could be seen is for industry (7.4 %), mangrove up to 1% while mudflats have high fluctuating trend but from the year 2000 onwards it is increasing.

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

It could be observed from Geostatistical graphs that the agricultural activity and vegetation cover is unaffected and that has remained almost 30% to 35% of the total area for the selected region and for given time frame. Similarly at the spatio-temporal scale the population has growth of <1.5%. These both the parameter clearly indicates that the region is comparatively least attracted. The significant change that could be seen is for industry (7.4 %), mangrove up to 1% while mudflats have high fluctuating trend but from the year 2000 onwards it is increasing.

4. Results and discussion

4.1 Landform cover change: General overview of the region

It is important to supplement brief evidences of geological and structural influence on the existing geomorphological and landforms features that has developed in past along the GoC. The structural faults have shaped up the drainage morphology, landforms and subsequent geology [32]. The rocks are not exposed and are covered by huge accumulated alluvium onshore [28]. This aspect is needed to understand the genesis of landform feature and progression of mudflats. The rivers entering the Gulf from North is Sabarmati accompany with Bhadar and Bhogavo, do not carry too much of water, mainly after the constructions of various small, medium civil structure, also true for river Mahi entering from NE. Out of 50 nos. of major, minor and small dam structures, 12 weirs for Sabarmati river basin almost 85% (counted) have executed after the year of 1985 and in case of Mahi river, out of 134 dam structure and 4 weir structures almost 65% (counted) are functional after the year of 1985 [33]. The entire landscape of Bhadar – Bhogavo- Sabarmati is barren wasteland occasionally saline also (Some part) referred as “Bhal” almost gradient less flat terrain. Bhogavo, Bhadar are season, sluggish rivers which near the actual shore-line come under strong tidal influence, literally encroached and flooded with tidal mud and represent the vast inter tidal zone as well supra tidal zones. Mudflats represent the most dominant landform stretching Sabarmati 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. Interesting study, in other direction 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]. Yet another study based on Physico-chemical parameters in three main estuaries viz. Sabarmati, Mahi an Narmada of Gulf concludes DO and BOD and level are lowest in Sabarmati then increasing for Mahi to Narmada. Similarly Nitrates and Phosphate concentration is in reverse order. 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.

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

In connection to increasing mudflats, we are tempted to focus some of the eye opener truth for this region, eventually, the study area is selected. Since last few decades, the rivers were not endanger and they were rejuvenating but the threat of civil structures, population encroachment, chemical pollution from industry, agriculture, huge dose of sewage water just to quote terraforming and Anthropocene human act has created issues
not only to the rivers but also to their connections and here is the Gulf as well as the surrounding landforms. Some concerned facts as reported [33], [34],[35] earlier, make a sense that the rejuvenation of sediments brought by rivers in to Gulf has checked and become infrequent supply.

5. Validation

Photograph description in favour of ground Truthing in figure 4 are given below:

(a) One of the creek flooded with tide water leaving behind the recent mud flats. (Near Bhadar-Sabarmati) (b)Comparatively low and bland, unremarkable terrain. Tidal mud deposits or saline wastelands. Gradient less region get inundated due to high tide. Sediments are brought by and tide water get deposited at inter tidal zone forming recent mud flats. (Sabarmati River) (c) Inundation region during high tide leaving behind the salt affected land bounded by thick accumulation of alluvial (d) Aquaculture activity at Khambhat (e) Aquaculture activity at Khambhat receiving the tide water (f) Intertidal zone with dry scrubs and tide channels (g) Salt encrusted dried land (Inter tidal zone) (h) Vast mudflats at Dhuvaran thermal power station site, Mahi river (i) Mud deposition, channel formations by powerful tide water at Kavi site (Mahi river) (j) Enormous square kilometres area of coastal region of Sabarmati river estuary is forming the delta near Wadgam village at confluence of Sabarmati, Bhogavo river and Bhadar river.

6. 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. Followings are the conclusion: 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 is eye catching may excel prograding nature of shore line. The region is under fluvial marine deposition, but fluctuating contribution from river side, need more study on chemical analysis for refined work.

Acknowledgment:

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

<table>
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<th>Coastal Length (km)</th>
<th>Area of Continental Shelf (up to 200 m depth)</th>
<th>Territorial Sea (Up to 12 nm)</th>
<th>Claimed Exclusive Economic Zone</th>
<th>Exclusive Fishing Zone</th>
<th>Total Potential Maritime Area</th>
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Table: 2 Satellite data used for the study

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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.

Fig: 2 Geostatistical graphs
Fig. 4: Field photographs for ground truth validation.