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Research Article

Coastal Geomorphological and Land Use and Land Cover Study on Some Sites of Gulf of Kachchh, Gujarat, West Coast of India using Multi-Temporal Remote Sensing Data

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Abstract The coastal rapid changes are monitored by Remote sensing (RS) and Geographical information (GIS) tools for the conservation and management. Aims of this paper are to monitor morphological, total vegetation, and water index changes in last two and half decades (1989, 2002, 2016) using Remote Sensing and GIS. The study area is rapidly changing at an alarming rate due to anthropogenic and natural activities. Morphological changes on study area are presenting major anthropogenic actions. Between 1989 and 2016 period, a tropical cyclone in 1998 caused a major change in mudflat area which reduced from 1143.97 to 459.07 km^2. More than fifty percent changes were observed in the built-up area and salt pan which increased from 9.18 to 18.17 km^2 and 51.55 to 90.32 km^2 respectively. The mangrove class increased from 180.63 to 296.5 km^2 showing better restoration and conservation practices of Gujarat government. The NDVI supports these results by increasing maximum positive index value from 1989 to 2016. This study indicates that Gulf of Kachchh coastal is undergone excessive pressure due to the rapid development of the surroundings artificial landscape, where socio-economic factors lead to changes in the near environment, as well as proliferative activities of salt production affecting the quality in the coastal ecosystem. For coastal conservation, the government introduced socio-economic activities, designing strict management policies and awareness programs for local communities about the importance of coastal for protection and management.
Keywords *Coastal conservation; Kachchh; Western region; LULC; Remote sensing*

1. Introduction

The coastal ecosystem is known as a unique environment where terrestrial, marine and atmosphere meet, interact and interplay with each other (Ramsar Convention Secretariat, 2010; Space Applications Centre, 2012). It provides various ecosystem services such as flood control, natural cycling of sediments and nutrients and water purification (Dagar, 2005; Zhang & Shao, 2013). Periodically interval shows rapid changes take place in its area morphology and productivity. In 1991, the Government of India (MoEF, 1991) declared tidal effects stretch the coastal area as Coastal Regulation Zone (CRZ). Coastal ecosystems are under pressure due to the anthropogenic activities and natural disasters. Increasing industries, urban population, and development process are the leading cause of the ecological destruction of coast area. In addition, natural disasters like flood, tsunami, and cyclone are also responsible for the higher rate of changes in this area (Balamurugan &

Aravind, 2015; Pascual-Aguilar et al., 2015). In order to evaluate and predict the ecological and geomorphological changes in coastal zones require immense individual sites studies, by the feature of complexities associated with them (Mani Murali & Dinesh Kumar, 2015). Despite great ecological value, coastal wetlands are graded at less priority for conservation and their rate changes remain limited and debated.

Therefore, monitoring and assessment of different classes of the ecosystem are a need for change detection. Remote sensing (RS) and Geographical information system (GIS) are an efficient and coast effective tool for a change detection of natural resources, reliable alternative to a ground survey that provides a useful source of information coverage (Ibharim et al., 2015; Nayak & Bahuguna, 2001). From the RS data inventorying, mapping, monitoring and recently for the management and development planning activities are proceeding for the optimal sustainable exploitation of natural resources (Klemas, 2012; Prasad et al., 2002). It is also beneficial in functioning relevant observations, which can bring out the impact of deforestation on global climate (McGuffie, 1995). To expose it from several decades monitoring and change detection concept has been widespread (Srivastava et al., 2012). RS data gives information about the changes in a time interval with better accuracy in short time. It also provides a better understanding the relationships and interactions of natural and man-made phenomena from multi-temporal data. From the LULC data, we can obtain information about the current sites cumulative output of the interactions between natural and man-made activities (Misra & Balaji, 2015; Srivastava et al., 2014). Hence, these tools are helpful to develop information sources and support judgment making process in a plethora of coastal zone applications.

Several studies have been carried out for LULC and related subjects in Gulf of Kachchh region. In comparison to other Gulf and coastal sites of Gujarat, Gulf of Kachchh is most productive by diverse habitat. It covered around 77% of mangrove area of Gujarat (Rodrigues et al., 2011). Previously this area was evaluated for biodiversity assessment of dominant plant communities along with the mangroves, seaweed, seagrass beds and dune vegetation mapped with accuracy by IRS data. This study helped in planning various management actions for protecting and conserve this ecosystem (Nayak & Bahuguna, 2001). Srivastava et al., (2014) evaluated mangrove forest change detection from 1994 to 2010 by hybrid classification approach using LISS-II and LIS-III imagery data in Mundra forest region. The study found total 11 classes showed significant change due to anthropogenic and sea level rise activities in the forest area. Nayak, Pandeya, & Gupta (1989) carried out a study on tidal wetland changes by Landsat MSS and TM data from 1975 to 1986 owing to the accessed use of fuel and fodder, and the proliferation of salt pan activities. Previously LULC study performed on hotspots of Gulf of Kachchh from 1977 to 2015 and from six class total 33 positives and 11 negative change discovered in this area. The major changes were found in mangrove, salt pans and built-up lands (Pasha, Reddy, Jha, Rao, & Dadhwal, 2016).

With this background, the present study performed to evaluate LULC change detection in a periodic interval from last two and half decades (1989, 2002, and 2016). The long term interval information also provides an interchange of various classes. Previous literature (Pasha et al., 2016) available for this region hotspot change within 6 class digitization. Further, more clarity in different class anthropogenic and natural pressure, we evaluated LULC, NDWI, NDVI, and data accuracy assessment for the study area. For the LULC total area classified in nine classes and total area change and percentage variability calculated by visual classification technique. Habitually occurring climatic variables changes, rapid growing industrialization and other local factors are key factors to perform this study. The present study aimed to generate an accurate database on land use/land cover and identify total vegetation and water index difference for 1989, 2002 and 2016 year.

2. Description of the Study Area

The Gulf of Kachchh (GK) region situated at the Arabian Sea-facing of western Indian site. The geographical location is 22.7443° N and 69.9550° E. It is included in the rich biodiversity area of the few coastal zones in the world. Around 77% of western Indian mangroves are covered by the Gulf of Kachchh. The essential components of this ecosystem are coral reefs and mangrove vegetation. The GK is having shallow depth around 60 m at the mouth to less than 20 near the head and covered 7350 sq. km enrich marine biodiversity area. It is semi-enclosed basin with a high tidal range of about 4 m at its mouth and 7 m at its head. The temperature of the region varies from 12 °C to > 36 °C. Humidity is higher in monsoon i.e. up to 80% while remaining year around 55 to 70 %. Alteration rainfall pattern is responsible for the higher vegetation diversity in this area. Annual maximum rainfall reported in 2011 from Jamnagar coast (605.0 mm), Okha and Dwarka (500.9 mm), Saurashtra received less than 630 mm, and the least amount reported from Mandvi to Bhachau (400.0 mm). The study area (Figure 1) shows that Gulf of Kachchh mainly covered by Kachchh and Jamnagar districts (Rodrigues et al., 2011; Coastal zones of India, 2012; SERCME, 2012)

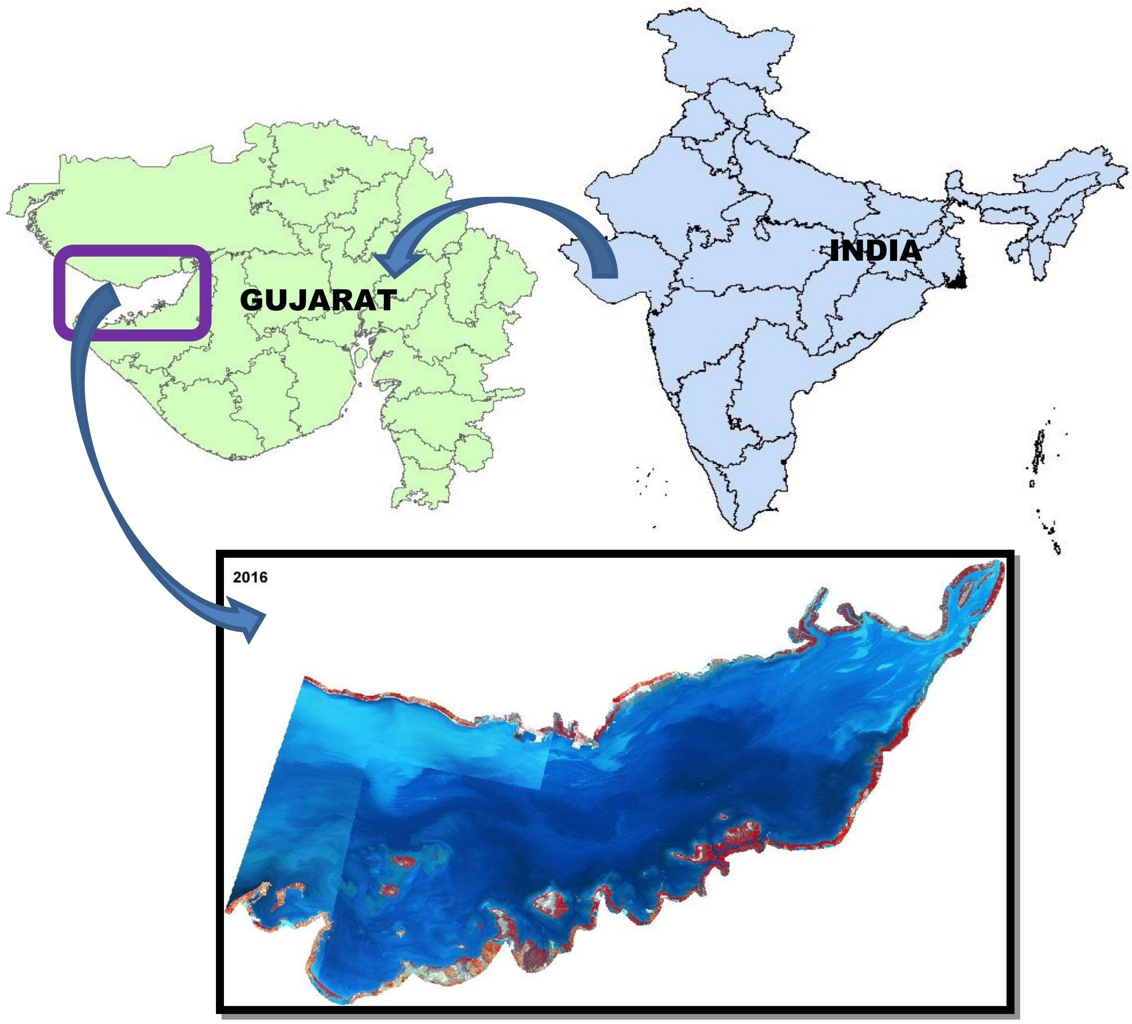

Figure 1: *Study Area*

3. Materials and Methods

3.1 Datasets used

In this study, we used three satellite images for each year (Table 1). The LANDSAT data was acquired from USGS, Earth Explorer (U.S. Department of the Interior U.S. Geological Survey).

Table 1: *Details of satellite data used in the study*

No	Satellite/Sensor	Pixel size	Spectral resolution	Swath width	Band used	Path/Row	Date
1	LANDSAT 5	30 m	Multispectral (6 bands)	185 km	1,2,3,4 B,G,R,NIR	150 / 044	Dec 17, 1989
						150 / 045	Dec 17, 1989
						151 / 044	Dec 24, 1989
2	LANDSAT 7	30 m	Multispectral (8 bands)	185 km	1,2,3,4 B,G,R,NIR	150 / 044	Dec 13, 2002
						150 / 045	Dec 13, 2002
						151 / 044	Dec 04, 2002
3	LANDSAT 8	30 m	Multispectral (11 bands)	185 km	2,3,4,5 B,G,R,NIR	150 / 044	Nov 09, 2016
						150 / 045	Nov 09, 2016
						151 / 044	Nov 16, 2016

3.2 Image data and pre-processing

Geographically rectified images were downloaded with UTM (Universal Transverse of Mercator) projection system; spheroid WGS 84 (World Geodetic System) and zone 42 North projection system were used for this study region. Further, images open in ERDAS 14 software and blue, green, red and near-infrared bands were stacked. Stacked layer images were mosaicked, and clipped with the reference boundary to extract out the study area. Subsequently, pan-sharpening of images was performed to enhance the resolution of images. The study area digitized at 1:25,000 and 1:50,000 scale using Arcgis 10.3 software. The digitized study area for 1989, 2002 and 2016 was converted in the vector format (.shp) which was used for change detection (Balasaraswathi et al., 2016; Misra & Balaji, 2015; Scopélitis et al., 2009).

3.3 Classification System for Land Cover

Study area classification provides a framework for categorizing information which can be extracted from image data. The images were classified according to NRSC classification Level II and it is important for the study and discernible from the data. Mainly nine classes were considered for land-cover classification i.e. barren land, built-up area, scrub, cropland, mudflat, mangrove, saltpan, sand beach and water bodies. Cropland includes lands with vegetation as well as land just after harvested crop. The Gulf area covered by major water body class.

3.4 Mapping of study area

In this study, various Land-use/Land-cover classes for the GK coastal covered area extracted from 2016, 2002 and 1989 Landsat imagery by digitizing the study area. For the change detection field studies were carried out in the approx 3-decade interval. Ground truth was collected with the help of False Color Composite (FCC) of specific locations of the study area. On screen digitization was embraced for the land cover mapping as the explanation of the finer type variation was possible. Steps included loading satellite data, rectification and restoration, image enhancement and information extraction. Arcgis 10.3 was used for visual interpretation and for assigning attributes to an individual polygon for various classes. LULC change detection was carried out by calculating the area of each class. Further time interval variation calculated by using pivot table analysis for each class (Pasha et al., 2016; Srivastava et al., 2014).

3.5 Normalized Difference Vegetation Index (NDVI)

NDVI is used for calculation of vegetation indexed from the remotely sensed data. Vegetation index is a number which generated by some combination of remote sensing bands. In that near infra-red strongly reflectance and lower red light reflectance by vegetation and soil. It is calculated by,

$$NDVI = (NIR - RED) / (NIR + RED) \qquad (1)$$

where NIR is the near-infrared band response for a given pixel (band 4 (L4, L7) & band 5 (L8) and RED is the red response, (band 2 (L4, L7) & band 3 (L8). The resulting index can range from -1 to +1 in which vegetation surface gave positive, soil near about zero and water features have negative values (Hurley et al., 2014; Tucker, 1979).

3.6 Normalized Difference Water Index (NDWI)

Normalize Differences Water Index (NDWI) used for the assessment of the water resources, both regarding quality and quantity measurement. In remote sensing, NIR strongly absorbed by the water and green band gave an average reflectance of water features. The values of radiance or reflectance converted into the digital number and compared with other data sets for calculating water index. It is calculated by,

$$NDWI = (Green – NIR) / (Green + NIR) \qquad (2)$$

In this visible green and NIR band gave positive value for water; while soil and terrestrial vegetation have zero or negative values (McFeeters, 1996) The detailed methodology is shown in Figure 2.

3.7 Accuracy Assessment

Accuracy assessment is required for image classification study. Land cover maps derived from remote sensing and classification technique has some error. To derived land-cover maps and the supplementary resource statistics, the errors quantitatively explained in terms of classification accuracy. In the present study for accuracy assessment, error matrix method was used (Berberoğlu et al., 2010). For the assessment 90 points selected and could be assigned to each class on land cover maps, then the results were recorded in an error matrix. For the classified data overall accuracy and kappa coefficient were calculated in the accuracy assessment report. Percentage of overall accuracy measured for each class after image classification. The kappa coefficient expressed the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Bishop et al., 1975; Sharma et al., 2011; Srivastava et al., 2014)

$$\kappa = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \qquad (3)$$

Where N is the total number of sites in the matrix, r is the number of rows in the matrix, x_{ii} is the number of observations in row i and column i, x_{i+} is the total row i and x_{i+} are the total for column i.

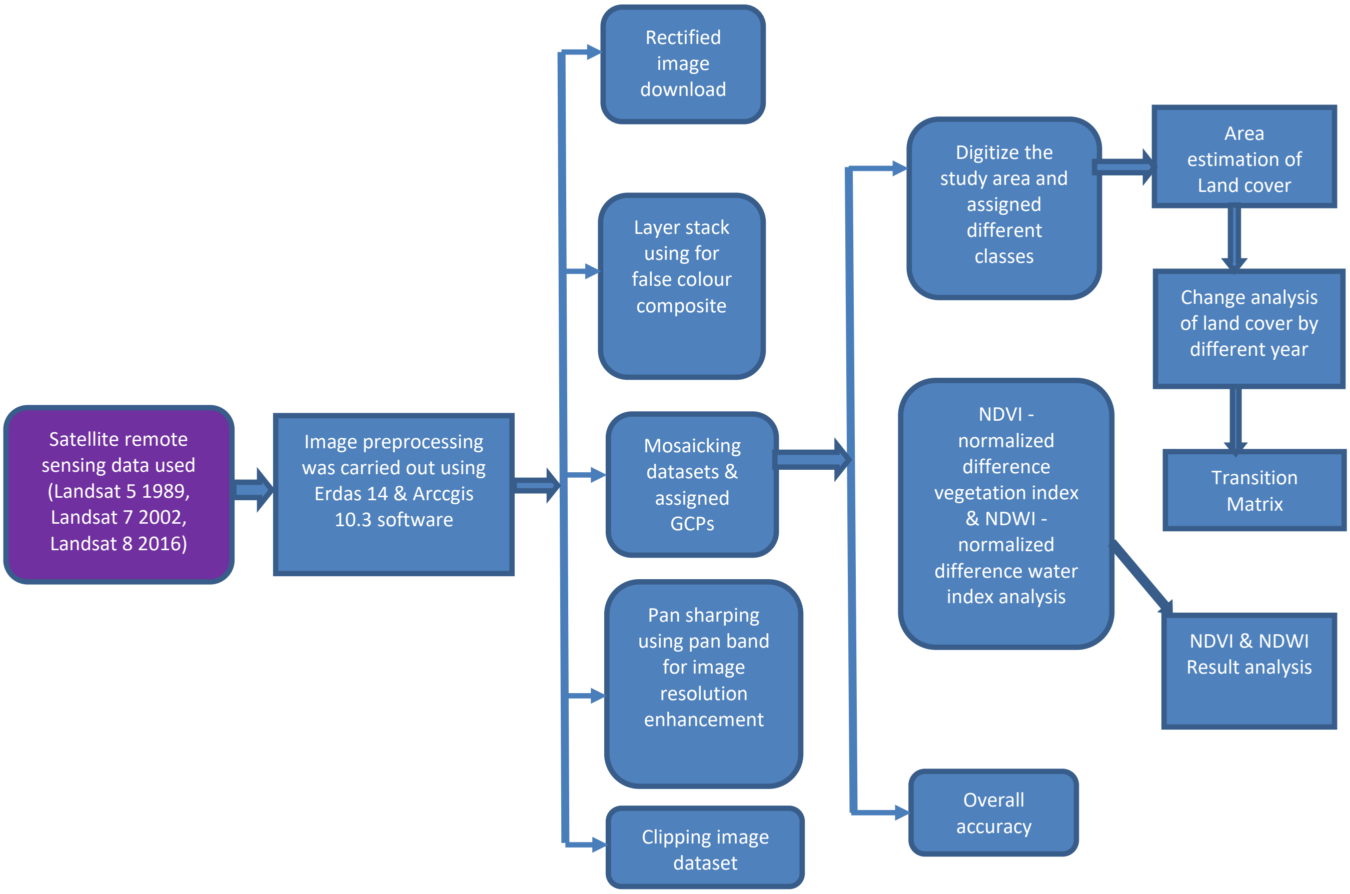

Figure 2: *Flow chart of the methodology used in the present study*

4. Results and Discussion

4.1 Land use and land cover change (LULC)

The LULC assessment was carried out for some of sites of Gulf of Kachchh in the year 1989, 2002 and 2016 from Landsat TM, ETM and OLI satellite image respectively. The classification maps produced by visual classification techniques are illustrated in Figure 3. The three satellites images have been classified into nine classes, namely 1) barren, 2) built-up, 3) cropland, 4) mangrove, 5) mudflat, 6) saltpan, 7) sand beach, 8) scrub, 9) water. Information derived from the analysis of satellite data pertaining to land use and land cover revealed that the major class covered by water body ranged from 76.33 % to 84.38 %. It showed around 8.05 % water level increased from 1989 to 2016. The estimated area as the percentage of total study area under this classification approach for barren 0.72 %, 0.59 %, 0.43 %; built-up 0.13, 0.15, 0.27; scrub 1.028 %, 1.24 %, 1.23 %; cropland 0.81 %, 0.88 %, 0.82 %; saltpan 0.77 %, 0.95 %, 1.36 %; mudflat 17.25 %, 8.76 %, 6.92 %; mangrove 2.72 %, 2.81 %, 4.47 %; sand beach 0.19 %, 0.22 %, 0.08 % obtained for 1989, 2002 and 2016 year respectively (Table 2). However, results obtained from this classification showed according to decade interval decreased barren, mudflat and sand beach area while, increased built-up and mangrove area. Therefore, the study indicates that barren and sand beach area may occupy by built-up area. Another significant change was observed for scrub and cropland area.

Table 2: *Decade interval Land-use/land cover area changes of Gulf of Kachchh sites*

	LULC change area km^2											
Year	Barren	Built-up	Scrub	Cropland	Saltpan	Mudflat	Mangrove	Sand beach	Water body	Total	% of Overall accuracy	Kappa coefficient
1989	48.09	9.18	68.22	54.34	51.55	1143.97	180.63	13.15	5061.85	6630.98	88.88	0.86
% of area	0.72	0.13	1.028	0.81	0.77	17.25	2.72	0.19	76.33			
2002	39.63	10.12	82.74	58.5	63.6	581.29	186.64	14.7	5593.76	6630.98	92.41	0.905
% of area	0.59	0.15	1.24	0.88	0.95	8.76	2.81	0.22	84.35			
2016	28.93	18.17	81.58	54.91	90.32	459.07	296.5	5.89	5595.61	6630.98	97.11	0.96
% of area	0.43	0.27	1.23	0.82	1.36	6.92	4.47	0.08	84.38			

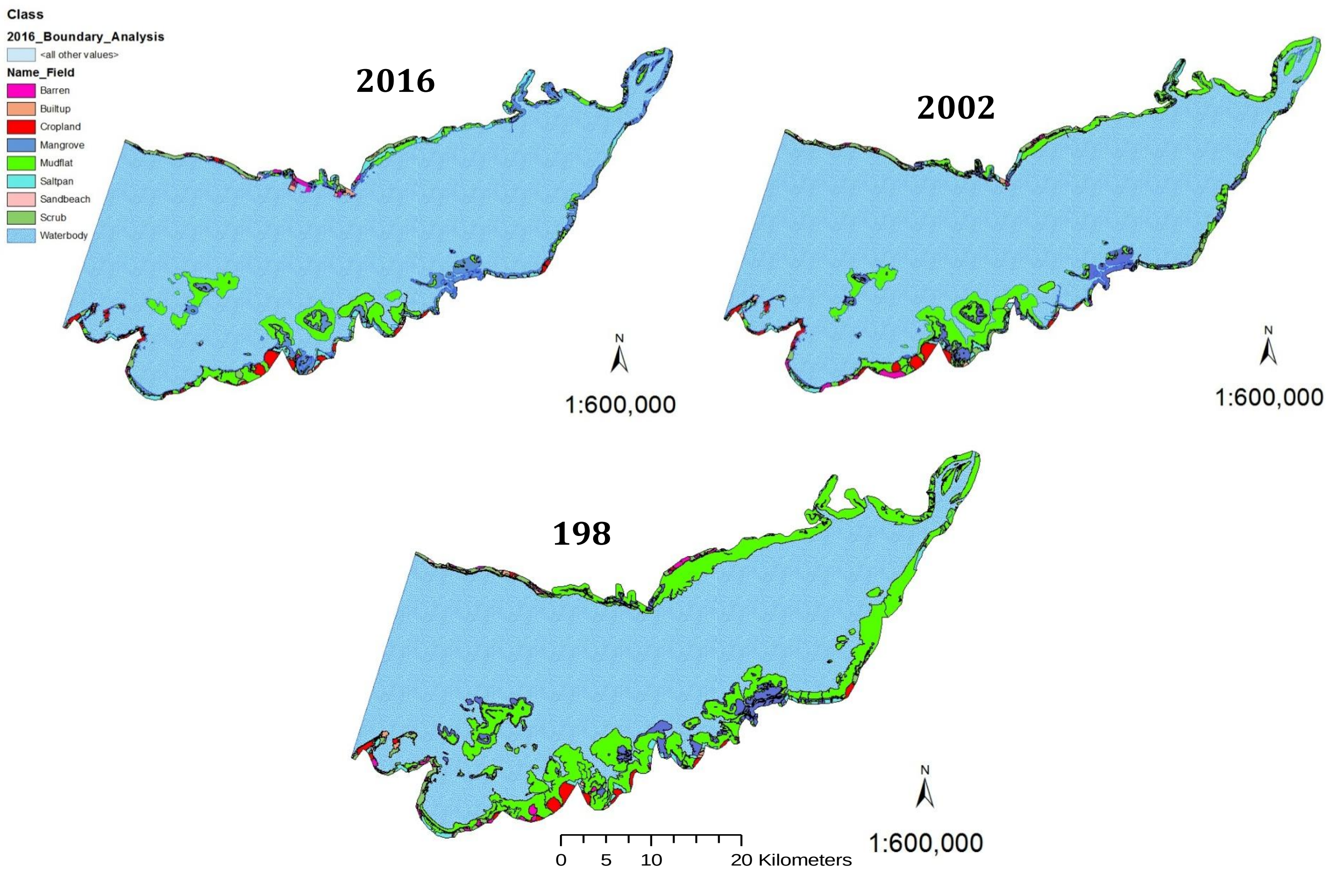

Figure 3: *Land use/land cover imagery 1989, 2002, and 2016*

In the cropland two different class included before and after harvested crops and scrub area also interlinked so, the varied changes observed at a different year. Due to 1998, ARB 02 cyclone effect on Gulf of Kachchh area mudflat observed drastic change and decrease the area from 8.49 % during 1989 to 2002 and 1.84 % from 2002 to 2016 (Ministry of Earth Sciences Govt. of India). In all sites mangrove area covered by *Avicennia marina* abundance along with some woody and grassy halophytic communities at intertidal zone. Interestingly, the mangrove area increase from 180.63 to 296.5 km^2, i.e., 2.72 % to 4.47 % in two and half decade's interval. This was increased due to the major participation in the Government initiatives for conservation and sustainable development of this ecosystem. According to Pasha et al., (2016) around 130 km^2 mangrove plantation and restoration have been afforested by the Gujarat Forest department from the first 5-year plan to 1999. Gujarat is the largest producers of salt in India and occupied the second position to export in the world (Discovered India). This statement support to this study and we observed salt pan area increased from 51.55 km^2, 63.6 km^2 and 90.32 km^2 between three-decade intervals. Some of the sand beach areas are also converted into the salt pan, indicating, degrading sand area by changing environmental conditions. For all the three-year class variable changes represented in Figure 4. The LULC result observed a severe change occurs in a various class of coastal area due to anthropogenic and natural disasters activity. Rapid industrialization and urbanization also may affect this area productivity (Mahapatra et al., 2015; Nagendra et al., 2013; Srivastava et al., 2014).

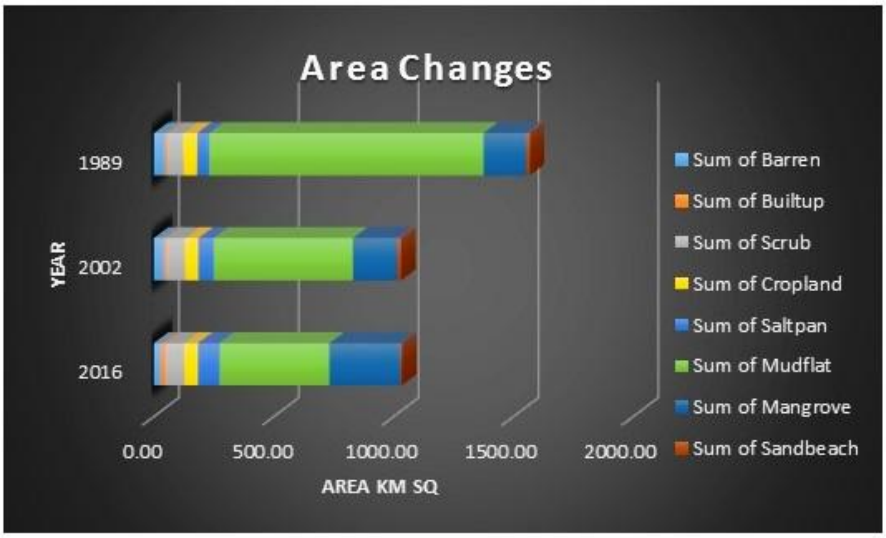

Figure 4: *Different class area change among three the different year 1989, 2002, and 2016*

4.2 Result of Normalize Vegetation Index (NDVI)

NDVI gave the information about vegetation cover from the remotely sensed imagery at a different year. It produced a result in the form of digital numbers by some combination of remote sensing band according to Eq. 1. Satellite images phenological differences identified among vegetation types. Here, the result of the index can range from -1 to +1. Vegetated surface gave positive value, the soil may have near zero and for water features negative value obtained (Defries & Townshend, 1994; Hurley et al., 2014). In our study, NDVI result presented non-significant variation between decade intervals. During 1989 to 2002 the positive range dropped down from 0.84 to 0.64, which indicate 23.80 % vegetation index decreased. For that 1998 tropical cyclone activities responsible for major affection in this area (Ministry of Earth Sciences Govt. of India). From 2002 to 2016 period showed increased range of vegetation index. On account of the government mangrove afforestation and conservation program active participation involved in it. The vegetation index range increased 30.43% having a range from 0.64 to 0.92. For all the three-year NDVI changes described in Figure 5.

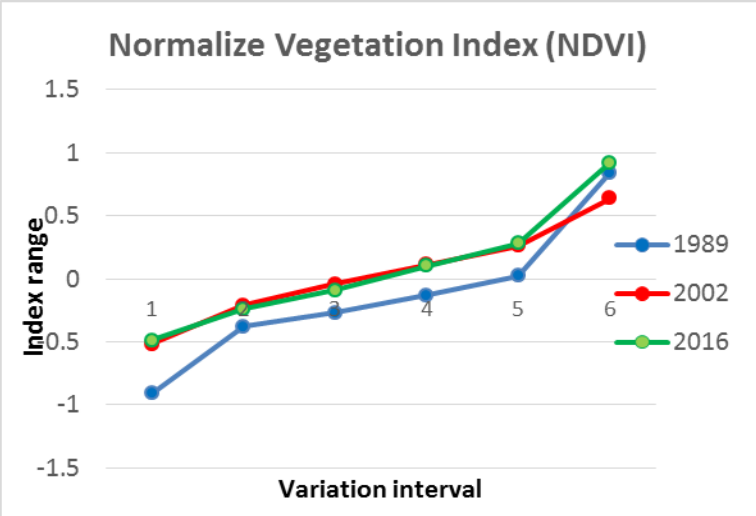

Figure 5: *Vegetation index range from -1 to +1. Total vegetation variability demonstrated for all three years 1989, 2002, and 2016*

4.3 Result of Normalize Water Index (NDWI)

The NDWI derived from the Green and NIR band, to increase the reflectance of water features by green light wavelength, decrease low reflectance of water features by NIR, and it also gives a high reflectance of NIR by terrestrial vegetation and soil features. The calculated NDWI from Eq. 2 gave positive value for water; while soil and terrestrial gave zero and negative values, owing to their higher reflectance of NIR than the green band (Alsaaideh et al., 2013; McFeeters, 1996). In our study NDWI 0.76, 0.56, and 0.77 maximum positive value obtained for 1989, 2002, and 2016 year respectively. The result showed that, from 1989 to 2002 water level decreased around 26.31 % and from 2002 to 2016 again increased around 27.27 %. Interestingly, the water level changes occurred since thirty year period attributable to the climate change effect and varied rainfall pattern in this area. Water level changes for all three years mentioned in Figure 6.

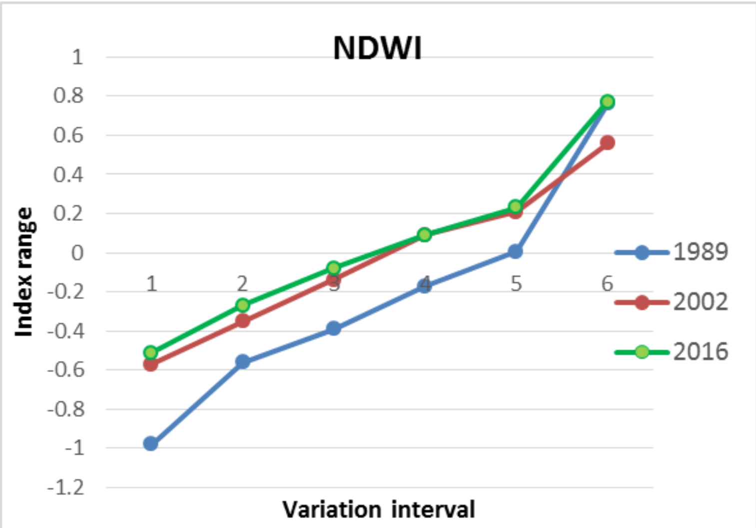

Figure 6: *Water index range from -1 to +1; a positive value indicates water level and zero or negative value refer soil and vegetation in the terrestrial land. Water level changes demonstrated for all three years 1989, 2002, and 2016*

4.4 Accuracy assessment

Accuracy assessment was done by error matrix and kappa coefficient calculated for each year using Eq. 3. The overall accuracy analysis indicated the highest accuracy obtained for 2016 image followed by 2002 and 1989. The overall accuracy 97.11 %, 92.41 % and 88.88 % and kappa coefficient 0.96, 0.90 and 0.86 obtained for 2016, 2002 and 1989 years respectively (Table 2). The kappa statistics represented clear picture and accuracy of visual classification. It showed in the year 2016 lesser error found in individual class digitizing process. OLI sensor gave a clearer picture in compared with ETM and TM satellite imagery. A higher difference of kappa value (0.06) and overall accuracy percentage (4.7 %) was observed between 2002 to 2016 intervals. This result indicates that classified land-cover maps for different years have sufficient accuracy for change detection. Moreover, heterogeneity of different classes present in the study area and their classification accuracies obtained is in fair agreement for each year. Although the classified result has some error in 2002 and 1989 image classes but overall it shows good results in terms of overall accuracy and kappa coefficient for change detection evaluation.

5. Conclusions

The coastal ecosystem known to be Kidney of Earth and its role in the environment functions are undebatable. It is the most productive ecosystem and enriches source of flora fauna diversity. Protection and conservation of the coastal ecosystem are essential because it works as a natural ecological barrier against natural disasters. Coastal assimilation, monitoring, and evaluation climate change impacts need to conserve it. For that, the present study performed by RS and GIS coast effective techniques to understand the dynamic changes in the study sites In this study we found the rapid growth of industrialization for salt production may responsible for ecological degradation. Although mangrove is a crucial link of marine ecology; in recent decades, several mangroves is being destroyed due to anthropogenic activities. The study also indicates the climate change and natural disasters adverse effect on the study area. The impact of sea level rise and changes in natural conditions causes the decrease in ecological diversity. This approach, as well as products thereby created, have the likely to make it easier for managers and practice persons with a simple practical understanding of RS to produce information on conservation status regularly, rapidly and quite economically, with reasonable levels of accuracy, which can be useful for adaptive management of protected areas as well as in their geographic context. For that our strong recommendation to the Government of India and the Ministry of Environment and Forests (MoEF) is that the coastal ecosystem is a sensitive zone and need to be protected for environment services.

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