COASTLINE CHANGE DETECTION USING MODERATE RESOLUTION SATELLITE IMAGERY: A CASE STUDY OF MAKRAN COAST, ARABIAN SEA, PAKISTAN

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ABSTRACT: *The coastline change detection analysis is an important task that has application in different fields such as coastal planning, disaster management, rate of erosion, environmental management and conceptual or predictive modeling of coastal morphological changes. The development of remote sensing and GIS technologies are nowadays proved to be the most powerful and reliable tools for shoreline changes mapping. The objectives of this research are (1) to use the geo-informatics techniques to analyze the spatio-temporal change in coastline both at a regional and local level and (2) to assess the localized trend of the variation in degree of erosion along the coastline. In this study the multi temporal Landsat Imagery from 1995 to 2014 was utilized for coastline detection and water index technique was for shoreline extraction. Total 37 cross sections were divided in 7 spatial zones based on their rate of erosion. The results revealed that overall there is not uniform spatio-temporal change in Makran coastal line. The maximum change was observed in time period of 1995-2000. Among 7 different zones three zones, including Hingole National Park, Sonmiani Tehsil and Pasni observed maximum coastal line degradation. This change can be associated with the massive cutting of mangroves and human activities in the coastal line areas. The results of this study can be used by different stakeholders for proper management for policy making.*

INTRODUCTION

The coast is a highly dynamic environment with many physical processes, such as tidal fluctuations, wave and long shore current, littoral cell circulation, ridge and runnel system and rip currents. These processes play a significant role in varying the coast and shoreline changes. Coastline is the transitional line between land and sea [1]. It is considered to be one of the most complex, dynamic and sensitive geomorphic unit that need to be under constant observation to follow and monitor the continuous changes, occurring there [2,3].

The change in the coastline has large environmental importance due to physical as well as anthropogenic processes [4]. Coastline change is the direct result of coastal erosion and accretion, the effect of near shore currents. Due to sediments supply, Coastline length can have a deficit, balanced or surplus sediment budget. A large scale reduction or increase in the sediment supply, in a short period of time or a long period, creates a deficit/surplus in the sediment budget which causes coastline change.

Coastline change detection, rate of change occurred in position and future prediction play an important role in any coastal zone management, such as hazard zonation, island development studies, marine transport, sediment budget and the modelling of coastal morph dynamics [5-7].

Multi-temporal coastline detection and mapping are considered to be a valuable task for coastal monitoring and assessment. In recent years, Geographic Information System (GIS) in conjunction with satellite remote sensing data is being used in coastline extraction and mapping [8-10]. Remote sensing plays an important role for spatial data acquisition from economical perspective [11].

Optical images are simple to interpret and easily obtainable. Furthermore, absorption of the infrared wavelength region by water and its strong reflectance by vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water [12-15]. These characteristics of water, vegetation and soil make the use of the images that contain visible and infrared bands widely used for coastline mapping [16]. Examples of such images are: TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper) imagery [17]. In this study the multi temporal Landsat Imagery was utilized for coastline detection. The localized trend of the variation in degree of erosion was estimated by dividing the coastal stretch in several erosion-prone regimes.

MATERIALS AND METHODS

Study Area

The Makran coast is Balochistan's southern strip and stretches for 754 km. long sandy beaches, rugged promontories and tidal creeks characterize the coastline. There, the ranges of hills, rising to over 1500 meters, run parallel to the coast: the Coastal Makran Range, 30 km inland; the Central Makran Range, 130 km inland; and the Siahan Range, 200 km away from the sea. There is very little rain in the Makran region; the few villages and towns along the coast and between the hills are sustained by spring water.

The study area was stretched between the Kirthar and Central Makran mountains of the Makran range, located 360 Km west of Karachi on Arabian Sea [18]. Ormara is a small port (25° 16' 29N 64° 35' 10E) located on the Makran coastline along the Arabian Sea in Baluchistan province of Pakistan. It is located 450 kilometers west of Karachi, and east of coastal village Pasni. Pasni is a medium-sized town and a fishing port along the Makran coastline Baluchistan, Pakistan. It is located about 300 km from Karachi. Jiwani is a small fishing harbor holds strategic importance in the region, located immediately adjacent to the shipping lanes to and from the Persian Gulf. Jiwani is located at the eastern end of Gwadar Bay, which is shared between Iran and Pakistan. The area around the bay includes an important mangrove forest extending across the international border, and is an important habitat for a wide variety of wildlife, especially the endangered Olive Ridley and Green Turtles. Being free from pollution, Jiwani is reminiscent of a South Sea island, with vast stretches of sandy beaches giving onto the clean, clear green waters of the Arabian Sea. Khor Kalamat, Hingol National Park and Sonmiani are located along the Makran coast of Balochistan Province, Pakistan. Khor Kalmat is a lagoon located approximately 350 Km west of Karachi while Sonmiani lies about 145 kilometres northwest of Karachi. Hingol National Park is situated within sections of Lasbela District, Gwadar District, and Awaran District.

Figure 1. Location Map of Study Area, Makran Coast, Arabian Sea, Pakistan.

Remotely Sensed Satellite Data

Remote Sensing imagery from Landsat was used for Spatio-temporal change analysis of coastline. Data repositories of Landsat 5 and Landsat 8 were used. Landsat 5 & Landsat 8 are equipped with Thematic Mapper (TM) sensor and Operational Land Imager (OLI) Sensor respectively with the spatial resolution of 30m. The temporal analysis was done for the years 1990, 2000, 2010 using Landsat TM data while the data for the year 2014 was acquired from Landsat 8. Four tiles of Landsat data were utilized for each year listed in Table 1 along with row and path. These tiles were mosaicked and further processed towards analysis.

Table 1. Landsat Tiles used along with path and row.

Years	Landsat Tiles	Path	Row
1995 (Landsat 5)	LT51530421995069ISP00	153	42
	LT51530431995069ISP00	153	43
	LT51540421995076ISP00	154	42
	LT51540431995076ISP00	154	43
2000 (Landsat 5)	LT51540422000282XXX02	154	42
	LT51540432000282XXX02	154	43
	LT51530422000259XXX02	153	42
	LT51530432000259XXX02	153	43
2010 (Landsat 5)	LT51530422010350KHC00	153	42
	LT51530432010350KHC00	153	43
	LT51540422010341KHC00	154	42
	LT51540432010341KHC00	154	43
2014 (Landsat 8)	LC81530422014361LGN00	153	42
	LC81530432014361LGN00	153	43
	LC81540422015003LGN00	154	42
	LC81540432015003LGN00	154	43

Image Pre-Processing

Atmospheric scattering caused by atmospheric particles often alters the reflectance values of the ground features by adding some values with the original reflectance [19]. If the analyses involve consideration of multi temporal data, then this process becomes even more important as the atmospheric condition is expected to change all the time. Thus, it is nlikely to produce same scattered energy in two different times. In this study, four multi date satellite images were considered. Therefore, to overcome the atmospheric contributions, atmospheric correction of the images was necessary. For this, the images were rectified for path radiance using Dark Object Subtraction method [20]. For the simplicity and rapidity, the method is chosen. While applying this method, the pixel having a minimum brightness value in each band of each image was detected and that value was subtracted from the pixel values in the corresponding band. This resulted into the atmospherically corrected images.

Accurate geometric corrections and referencing are the indispensable prerequisites to perform change detection analyses. Without this, the results will lose its reliability, and analyses would fail to diagnose changes accurately [21].

Land Water Mask

Separation of land and water body was done by band rationing using Visible and Infrared Bands of Landsat Imagery. The Water Index is one of the band ratios where the sum of visible bands are divided by the sum of the infrared bands [22]. The procedure aims at obtaining the sharp edge between water and land as water reflectance is more pronounced in visible bands, while absorption is dominant in the infrared band. Using this characteristic, this technique was applied on the images and threshold level slicing was done to distinct separate landmass from the water. The sharp edge between the two classes refers to the coastline. These sharp edges were manually digitized for the year 1995, 2000, 2010 & 2014 to extract the multi temporal coastline. For Spatio temporal change analysis these line features were overlaid to analyze how frequently change occurred over the passage of time.

Cross Sections along Shoreline

To study spatial change pattern along shoreline, 37 cross sections were taken arbitrarily almost at the 90 degree angle across all shorelines, digitized and amount of shift during certain time period was measured in different zones. Seven zones were created occupied by five cross sections in first six zones while zone 7 consist of seven cross sections (Fig. 2). It gives the spatial shift and erosion rate of shoreline in different zones over the time from the year 1995 to 2014.

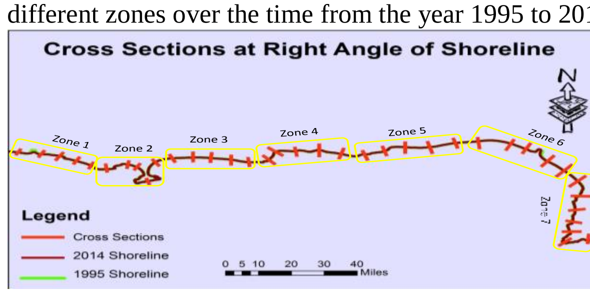

Figure 2. Map of cross section along coastline in different zones.

Coastal Line Erosion Rate

A methodology was devised to find the erosion rate that caused the change in shoreline. Seven zones, each containing 5 points were made except 7th zone which contain 7 points. Average shift in meters was calculated and using duration of occurrence of change over the span of 19 years, erosion rate was calculated using following rate erosion formula.Change detection maps were produced for each zone and area changed over time was calculated using simple pixels multiply the area covered by pixels formula.

$$Rate\ of\ Erosion\ meter/year = \frac{Average\ shift\ in\ zone}{Total\ Time\ period}$$

RESULTS AND DISCUSSION

Spatio-Temporal Change in Coastline Position

The coastline under study showed a continuously changing pattern over the period of time, from 1995 to 2014. Spatio temporal variation in each zone of coastline was observed. The temporal window from 1995 to 2000, 2000 to 2010 and 2000 to 2014 was used to assess the change in the coastline. Overall non-uniform change was observed in shoreline. The local change in the pattern of liner shift of the coastline was estimated by dividing the coastline stretch in several zones using the cross sections. In the time period from 1995 to 2000 minimum change was observed in Zone 2 followed by zone 1 and 3. The aximum intrusion of water body into land was witnessed in Zone 4 after that in zone 6, 5 and zone 7 (Fig. 3).

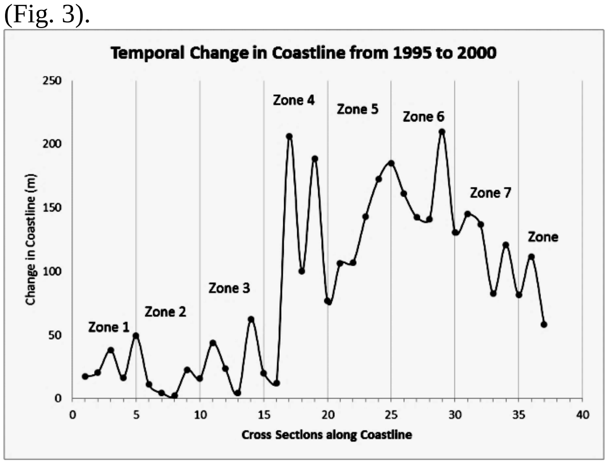

Figure 3. Temporal Change in Coastline from 1995 to 2000.

Temporal interval from 2000 to 2010 significant variability in coastline was noticed in the zone 1 that is near Khor Khalamat near Pasni tehsil. While in zone 6 the considerable change was detected at the Sonmiani tehsil and also in Zone 7, which is attached with the Karachi city (Fig. 4).

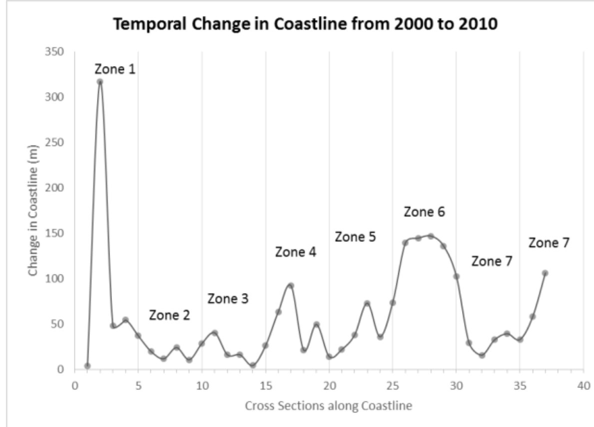

Figure 4. Temporal Change in Coastline from 2000 to 2010.

During the temporal interval of 2010 to 2014, large variability in linear shift of coastline was detected in the zone 5 that is Hingole National Park, classified as coastal semi desert. Apparently minor change was witnessed in other zones of shoreline as compared to zone 5 (Fig. 5).

The changing trend of shoreline showed the continued degradation and intrusion of sea into land.

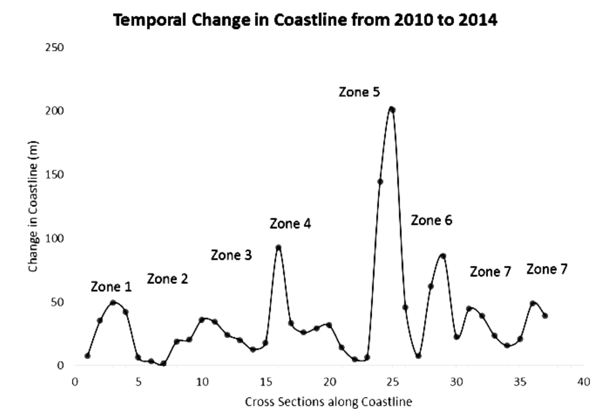

Figure 5. Temporal Change in Coastline from 2010 to 2014. From figure 6 and 7 the changing trend support the fact that shifting of shoreline is continuous over the time.

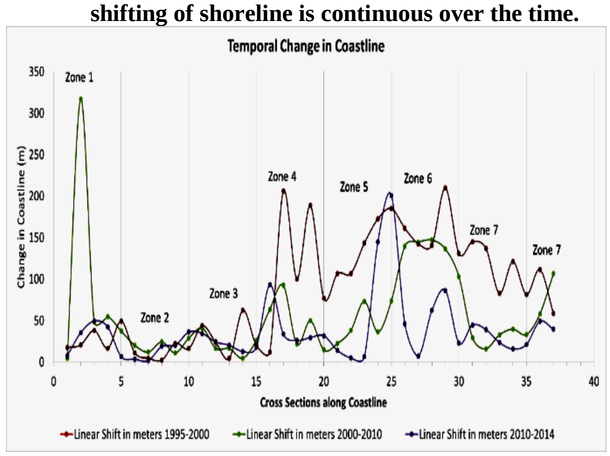

Figure 6. Temporal Change in Coastline during temporal interval 1995 to 2000, 2000 to 2010 & 2010 to 2014.

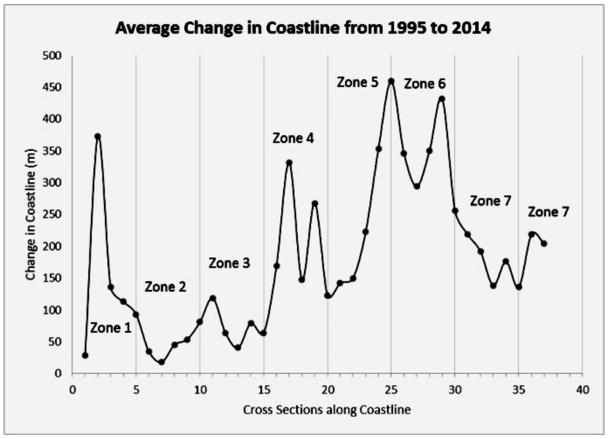

Figure 7. Average Change in Coastline from 1995 to 2014.

Overall the maximum variability and change was witnessed in the zone 4, 5, 6 and 7 due to the cutting of mangroves, climate change, increase in global greenhouse gasses and sea level. While the insignificant change was noticed in zone 2 and 3. Maps of localized spatio-temporal change and erosion at each cross section of coastline from 1995 to 2014 shown in figure 8.

Erosion Rate of Coastline

Erosion rate was estimated at each zone of shoreline. Figure 10 give the significant evidence of the erosion in the eastern part shoreline that is near to the Hingole National Park and Karachi. While in the western part of the coastline the erosion was detected near the Pasni tehsil. It exclusively show the degradation and erratic contraction of shoreline due to the decrease in vegetation

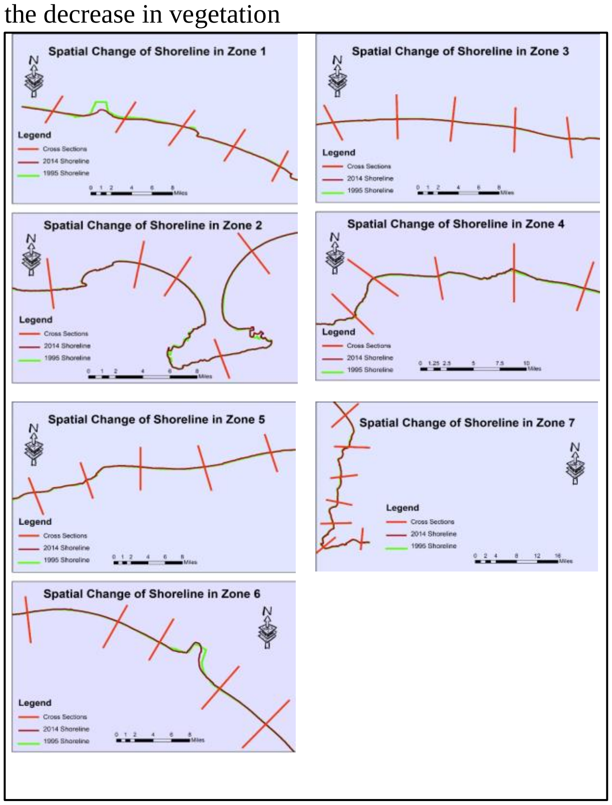

Figure 8. Localized Spatio temporal change of shoreline in different zones from 1995 to 2014.

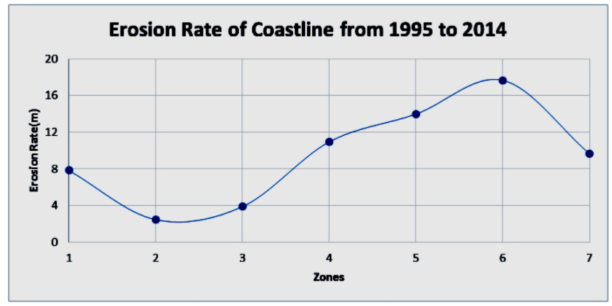

Figure 10 - Erosion Rate of Coastline from 1995 to 2014.

In 2012, Climate Change Policy stated that mangroves must be secured and plantation should be done to avoid coastline erosion and consequently to minimize the hazards [23]. From figure 7, during the time period of 2010 to 2014 minimum erosion was observed this can be attributed due to establishment of climate change policy in 2012 while during the time span of 2000 to 2010 the less erosion was observed as compared to the temporal interval of 1995 to 2000 this can be result of the National Forest policy in 2002 that stated the importance of mangroves forest that should be protected as they play essential role to control the coastline erosion and protect an important habitat for fishes and shrimps.

CONCLUSION

From this research study, spatial and temporal variability in coastline position, rate of change and erosion were assessed with moderate resolution satellite data. The coastlines extracted from satellite images in 1995, 2000, 2010 and 2014 were overlaid to establish the coastline changes in the Makran coast, Arabian Sea, Pakistan. Overall there is no significant change in coastal line was observed. The maximum change was observed in time period of 1995-2000. Among 7 different zones three zones including Hingole National Park, Sonmiani Tehsil and Pasni observed maximum coastal line degradation.

Moderate resolution satellite imagery Landsat is proved to be effective to assess the coastal line change and erosion mapping. The results of the study can be further enhance by using high resolution satellite data. This study can be used as a base line to develop management and environmental policies and strategies to reduce the coastal degradation.

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