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MONITORING OF THE SHORELINE CHANGE AND ITS IMPACT ON MANGROVES USING REMOTE SENSING AND GIS: A CASE STUDY OF KARACHI COAST, PAKISTAN

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ABSTRACT

The present study used remote sensing images and GIS to identify and measure shoreline changes and its impact on Mangroves in Karachi coast. It has been observed that shoreline change in the study area results from both erosion and accretion processes. The accretion occurred at the southern part of Clifton beach as well as on the northern part of the bundal island. Their distribution throughout the world is affected by climate, salinity of the water, fluctuation of the tides, type of soil in the area and, more recently, by development of tidal wetlands for residential use as well as industrial, i.e. shrimp farms.

The information extracted from the remote sensing data using digital enhancement techniques can thus play a key role for monitoring and mapping shoreline changes in the coastal area, which may lead for better understanding of coastal processes and help for planning reclamation work in the Bundal Island, for recreational purpose for the people of Karachi city.

Keywords: remote sensing, shoreline, coastal changes

INTRODUCTION

The shoreline, the boundary between land and sea keeps changing its shape and position continuously due to dynamic environmental conditions.

The change in shoreline is mainly associated with waves, tides, winds, periodic storms, sea-level change, the geomorphic processes of erosion and accretion and human activities (Selvavinayagam, 2008).

However, the coastal zone is increasingly under pressure from human activities such as fishing, and sand mining, mangrove harvesting, sewage disposal, and urban expansion. Of particular note are dynamite fishing, over-harvesting of mangroves, coral and sand mining, all of which have profound negative impacts on coastal stability and are thought to lead to coastal erosion and shoreline change (Griffiths, 1988).

The coastline of Pakistan, from the Iranian border on the west to the Indian border on the East is about 970 Km long. The coast here is associated with a narrow continental shelf, except off Indus delta. The coast of Pakistan is divided into the Makran coast, Las Bela coast, Karachi coast, and Indus delta coast.

The Sindh coastal region stretches in the southeastern part of the country between the mouth of the Hub River in the west to the Sir Creek area in the east bordering the Indian coast. The length of the present high water line of the Sindh coast is about 270 Km. While the seaward limit of the Sindh coastal zone is about 100 Km with an average area about 33000 Km^2 (Farah and Meynell 1992).

A number of studies conducted to provide a detailed account of existing natural resources in the area. Studies have documented evidence of geomorphological changes and sea level rise in the coast of Karachi (Siddiqui and Maajid, 2003).

The land water interface comprising of the coastal zone is modified all the time by oceanic currents, waves and tidal oscillations. The dynamic coastal activities coupled with strong winds during the monsoon season play an important role in shoreline erosion and other modifications like land accretion along the coastline. However, the area nearby Karachi is more vulnerable to coastal erosion and accretion than the other deltaic region, mainly due to human activities together with natural phenomena such as wave action, strong tidal currents, and rise in sea level.

Review of Literature

From 1807 to 1927, all coastline maps have been generated through ground surveying. In 1927 the full potential of aerial photography to complement the coastline maps was recognized. From 1927 to 1980, aerial photographs were known as the sole source for coastal mapping. However, the number of aerial photographs required for coastline mapping, even on a regional scale, is large (Lillesand *et al*., 2004).

Collecting, rectifying, analyzing and transferring the information from photographs to the map are costly and time consuming. In addition to cost, using black and white photographs creates several other problems.

First, the contrast between the land and water in the spectral range of panchromatic photographs is minimal, particularly for the turbid or muddy water of the coastal region, and the interpretation of the coastline is difficult (Jong and Meer, 2004). Second, the photographs and the resultant maps are in a non-digital format, reducing the versatility of the data set. Labor intensive digitization is required to transfer the information to a digital format, and this process introduces additional costs and errors. The geometric complexity and fragmented patterns of coastlines compounds these problems. In addition to the above, other possible limitations are: (1) the lack of timely coverage, (2) the lack of geometrical accuracy unless ortho-rectified, (3) the expense of the analytical equipment, (4) the intensive nature of the procedure (Miao and Clements, 2002), and (5) the need for skilled personnel. In addition to high costs and difficulties, generation of coastline maps has fallen sadly out of date. From 1972 the Landsat and other remote sensing satellites provide digital imagery in infrared spectral bands where the land-water interface is well defined. Hence remote sensing imagery and image processing techniques provide a possible solution to some of the problems of generating and updating the coastline maps (Winarsoet *et al*., 2001).

Study Area

Karachi is located in southern Pakistan in the north of Arabian Sea. It lies 67°00′36″east longitudes and 24°51′36″ north latitudes comprising 3,527 Km². Altitude of 8 meters average mean sea level **(Fig. 1).**

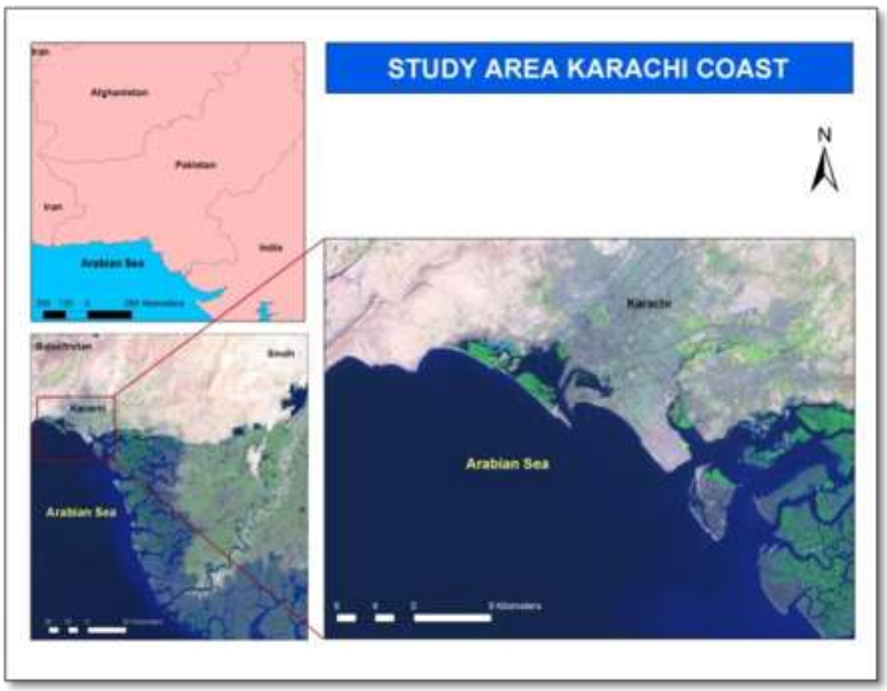

Fig.1. Study Area.

The Karachi coast, about 90 Km in length from Ras Muari to Clifton beaches consist of low rocky cliffs and sandy beaches of almost equal length. Marine terraces, sea caves and arches are common in the sandstone and shale rocks. Sandy barriers beaches, spit (the longest one 15 Km in length) Shallow lagoons, tidal flats, and salt evaporation ponds are common along the sandy beaches. Four major inlets, Manora Channel (Karachi Harbour), Korangi Creek, Phitti Creek, and Khuddi Creek invaginate the coastline. A small crescent shaped sand bar exists at the mouth of the Korangi Creek. The Cape Monze beach is an example of raised beaches along the coast of Karachi. The eastern coast has tidal creeks with mangrove and mud flats. In the region the seabed is generally smooth. The bed slope has a low gradient and is in the order of 1/500 to 1/**1000** (Government of Pakistan, 2005).

Physically it is mostly comprises flat or rolling plains with hills on the western and northern boundaries of the urban sprawl. Two rivers pass through the city: the Malir River (northeast to centre) and the Lyari River (north to south). The Karachi Harbor is a protected bay to the south west of the city. The southern limit of the city is the Arabian Sea and forms a chain of warm water beaches that are rich in natural beauty.

Because Karachi is located on the coast and as a result has a relatively mild climate. The level of precipitation is low for most of the year. However, due to the city's proximity to the sea, humidity levels usually remain high throughout the year. The city enjoys mild winters and hot summers. Since summer temperatures are quite high (the end of April through the end of August are approximately 35 to 40 degrees Celsius), the winter months (November through March) are the best time to visit Karachi.

Today, its population exceeds 15 million. The main attractions of Karachi are the sea, the shopping and some fine specimen of Victorian architecture and modern buildings and international cuisine.

Karachi is growing fast, and the growth rate is attributed to its potential for several economic activities, the existing pressure of urban expansion. The physical infrastructure existing near the coastline includes hotels as well as training and research institutions.

Coastal Geology and Geomorphology

The coastal zone of Karachi is a highly dynamic area where a number of marine and terrestrial processes are responsible for changes taking place along the coastal belt.

Based on physiographic features Karachi coastal area can be divided into three different regions viz.

- West coast,
- South coast and
- Southeast coast

- **West Coast of Karachi**

The coast, west of the Manora breakwater to Buleji consists of sand beaches (**Fig. 2)**, (Manora, Sandspit and Hawks Bay) rocky protruding points separate these beaches from each other. From Bulleji to Cape Monze the coast consists of hard conglomerate and shale cliffs. Beyond Hawks Bay towards west up to the Cape Monze, the unconsolidated sandy clays are exposed to coastal weathering and erosion. Small rivers supply sediments to the coast during the rainy periods. The rivers are the predominant sources of sediment to the sandy beaches. The Lyari delta is well protected from the direct influence of the ocean surf by the belt of sand.

Fig. 2 a. &. b. Sandpit and c. & d.Turtul beache Source: Author

- **B- South Coast**

The southern coast of Karachi lies between Keamari at Korangi Creek mouth and includes fine sandy beaches of Clifton and Defense Housing Authority (DHA) with a very low angle of the beach slope resulting in large shallow intertidal and sub-tidal areas spreading up to 1-5 Km. The coastal features of Clifton and DHA beach have been greatly modified and considerable area from Korangi - Clifton has been reclaimed by filling, low marshy lands. The coastal belt of Karachi from Karachi Harbour inlet at Keamari along Clifton and DHA Beach up to Gizri Creek is 14 Km long. It has a very gentle surface gradient of about 1:50.

The Clifton beach is largely composed of dark, grey silty materials with minute flakes of mica. The particular soil formation in and around the project area revealed the presence of (Qsb) sand bar deposits (which is occupying around 60 percent of the DHA proposed area) comprising of medium to coarse sand, and micaceous shifting sand dunes. The second largest formation is (Qcsd) coastal sand dune deposits and beach sand deposits (Qbs) and whereas (Qms) mangrove swamp deposits are also found in the area **(Fig. 3).** The fine micaceous sand drifted from the mouth of the river Indus by the strong littoral currents. The sand, after it compiles on the beach by the waves is blown inland in large quantity by wind action. Further, east of Clifton there are agglomerations of Ghizri hills. The beaches of Karachi are a source of recreation for the local habitants and attract large number of people.

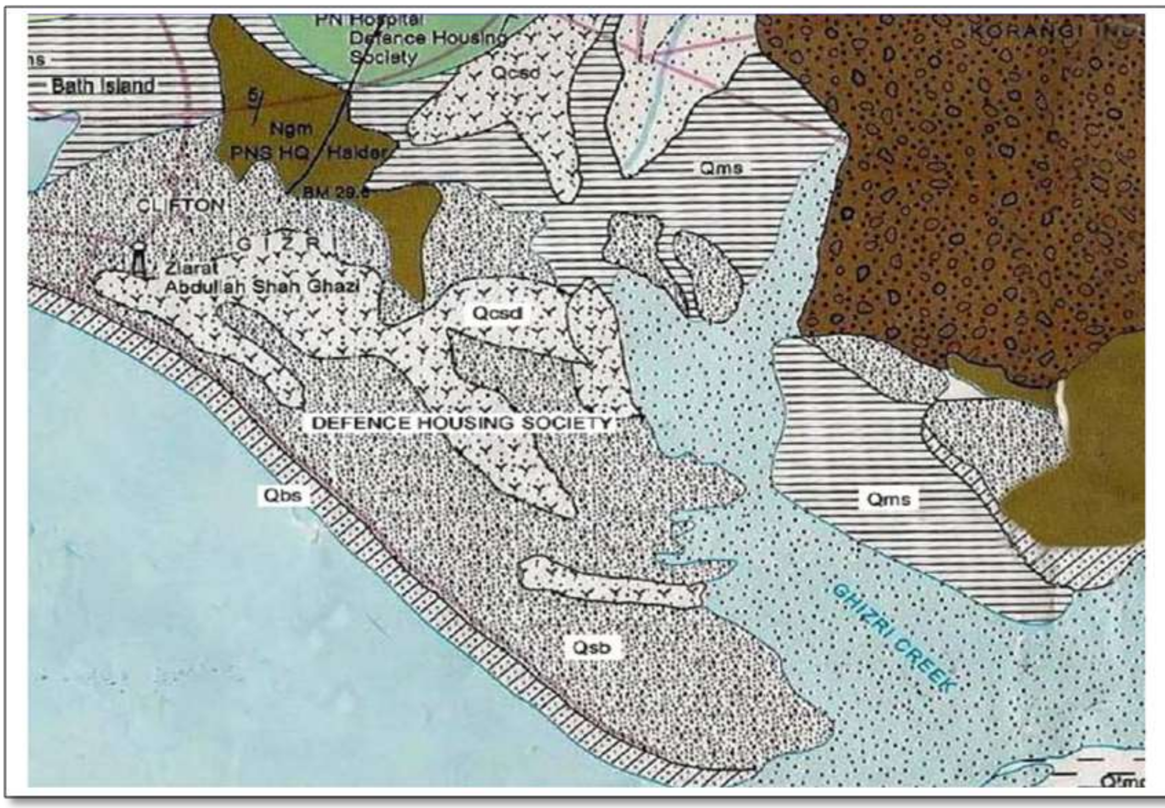

Fig. 3. Coastal Geology Source: GOP,2005

- **Southeast Coast**

The Southeast coast of Karachi coastline lies between Korangi creek inlet and Khuddi Creek. It encompasses the coastline of four islands; Bundal Island, Buddo Island, Miran Island and Khuddi Island and two large and deep openings towards the sea the Phitti Creek Mouth (Approach channel of Port Qasim) and the Khuddi Creek Mouth. The eastern coast has tidal creeks with mangrove and mudflats, which are linked by a network of creeks of the Indus Delta. The seabed at the eastern and southeastern coast is generally smooth and regular as depicted by the bed contours. The led slope is gentle, usually being in the order of 1/500 to 1/1000. Climate The coastal meteorology and hydrography of Karachi is controlled by the seasonal change in the North Arabian Sea i.e. monsoonal system.

Composition of Beaches

a. Clifton Beach

The beach is located in the transition zone between the rocky / sedimentary coastline and the Indus Deltaic Creeks. The beach has higher concentration of fine sand and silt at its northern and northwestern part and more sand and less silt sand at its southern part. A considerable accretion has taken place on this beach particularly in the northern part. The sea wall demarcates the boundary between the sea and land. The bottom of the sea wall is located at tidal height of about 2 - 2.5 m. The actual beach starts from the bottom of the sea wall and extends up to several kilometers towards the sea. The intertidal area has a very gently slope and the low water mark is about 1 - 3 Km. The fine sand and silt has considerable quantities of mica and is black in colour.

b. DHA Beach

This is a long beach which is a southeast extension of Clifton beach and is mostly sandy. The fine sand and silt constitute the most part while the high water zone has some coarse sand in addition to the fine sand. The black sand and mica is also present at this beach. The intertidal sand dunes near high water zone mostly constitute fine sand. The sea wall starting from Clifton beach also continues all along this beach. There is a large accretional area near the confluence of the southern tip of this beach and the Gizri Creek. The beach slope along this beach is also very gentle. The beach slope forms the bottom of about 5 meter high sea wall up to the low water mark. The intertidal area is very wide (1 - 3 Km).

Major Objectives

The basic objectives of the paper are;
1. To detect the coastline change detection using multitemporal satellite images form 1990 to 2010.
2. To map the shoreline of Karachi
3. To monitor the shoreline change and its impact on mangroves forest in DHA.

METHODOLOGY

Data sources

The extent of shoreline changes of the Karachi area was acquired using satellite images from SPOT XS 1986, 1991 and Landsat TM 1990, 2000,2011, QickBird 2005, and 2010. Satellite image of Karachi has been acquired from Landsat TM (30 m resolution) and Quickbird (0.61 m resolution).

Data Processing

Quick bird images acquired from Google Earth and Mosaic in Adobe Photoshop. ERDAS imagine9 .1 software was used for satellite image processing, enhancing. ArcGIS 9.2 software was used for the Georefrencing satellite image. Digitization and layout was done in ArcGIS.

The Landsat TM data were processed and georefrenced in Erdas 9.1 and ArcGIS 9.2 software. Make a subset to enhance the images. The georefrenced images were further enhanced by using enhancement technique. Histogram and inverse were applied for extract coastline boundaries.

Data Analysis

Image analysis includes, extraction, change detection, digitization and enhancement. The shoreline was therefore identified and digitized on the screen.

For change detection the two images of different years were overlaid in Erdas Imagine 9.1 software. Calculate the area with the help of area tool.Visual interpretation of SPOT XS 1986, 1991 and Landsat TM 2011 satellite images for shoreline change and its impact on Mangrove forest.

RESULT AND DISCUSSION

The standard image processing technique such as image extraction, rectification, and enhancement were applied in this paper. The image 1990 & 2000, 2005 was Landsat TM and Quickbird image 2010 obtains from Google Earth.

The result shows that there is a significant change of shoreline either erosion or accretion **(Fig. 4 and 5).** The results were also divided into three sections, where significant change was observed.

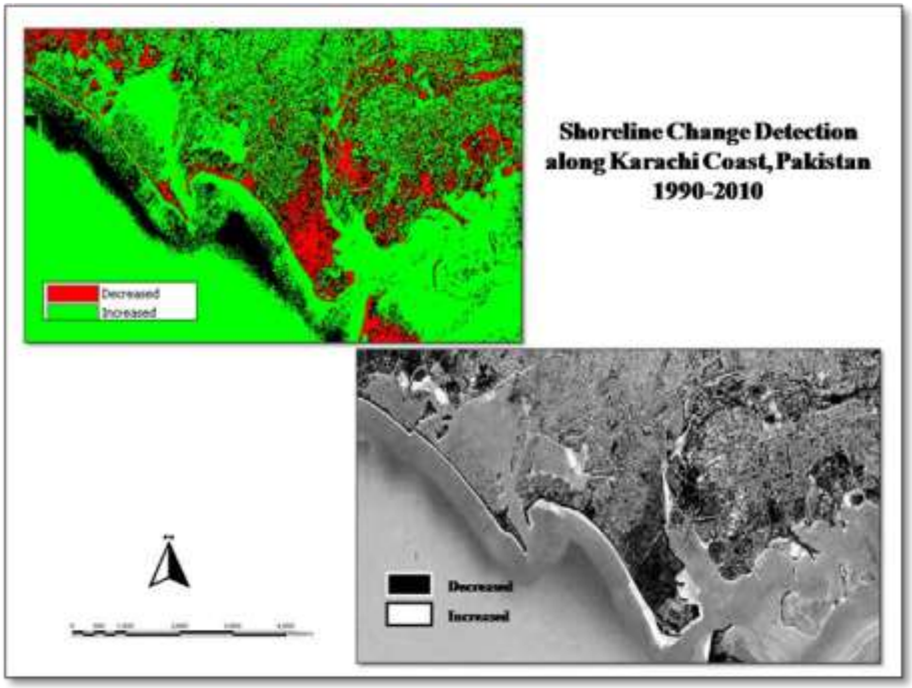

Fig.4. Karachi Shoreline Change Detection (1990-2010)

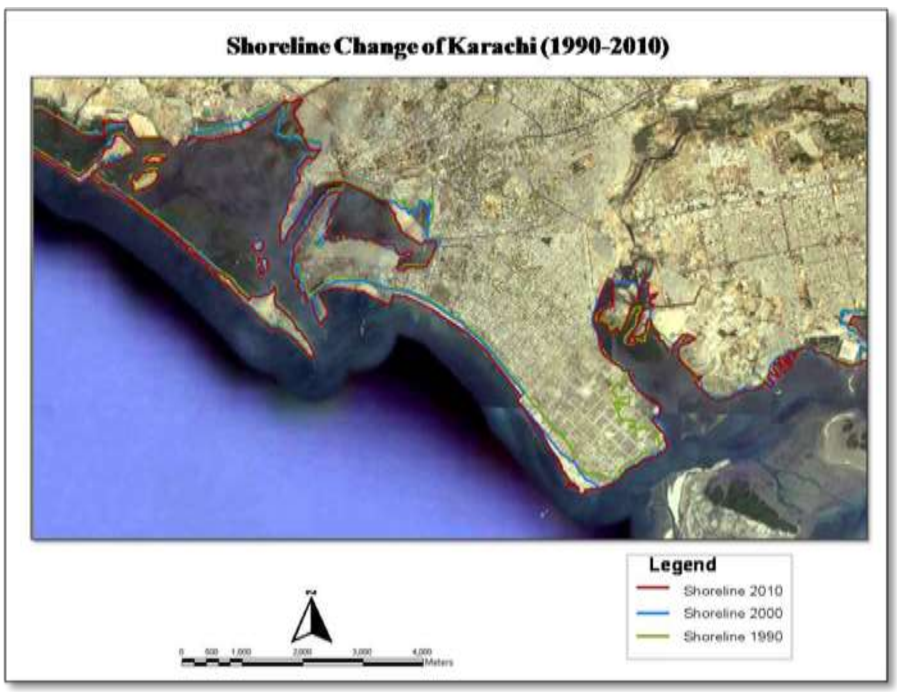

Fig.5. Karachi Shoreline Change (1990-2010)

[1]. DHA (Defense Housing Authority)

- **DHA Change Detection (1990-2000)**

The analysis on the shoreline change between 1990 and 2000 is shown in **Fig. 6.** About **379.58ha** of land were extended due to the reclamation/accretion activities at the southern and southwest part of the Defense Hosing society and on the left bank of Gizri creek for urban Development. The blue line on the map represents the shoreline in 1990 whereas the green line represents the position of the shoreline in 2000. However, this is not an accretion from a natural process, but is a man made for real estate development.

- **DHA Change Detection (2000-2010)**

Fig.6 also shows the shoreline change between 2000, 2005 and 2010. About 211.44ha of land was accreted from the shore in the southern part. A green line on the map represents the shoreline in the 2000 whereas the red line represents the position of the shoreline in the 2010.

- **DHA Change Detection (1990-2010)**

About 591.02ha of land were accreted from the southern part of the creek between 1990 and 2010 **(Fig. 6).** The blue line on the map represents the shoreline in 1990 whereas the red line represents the position of the shoreline in 2010.

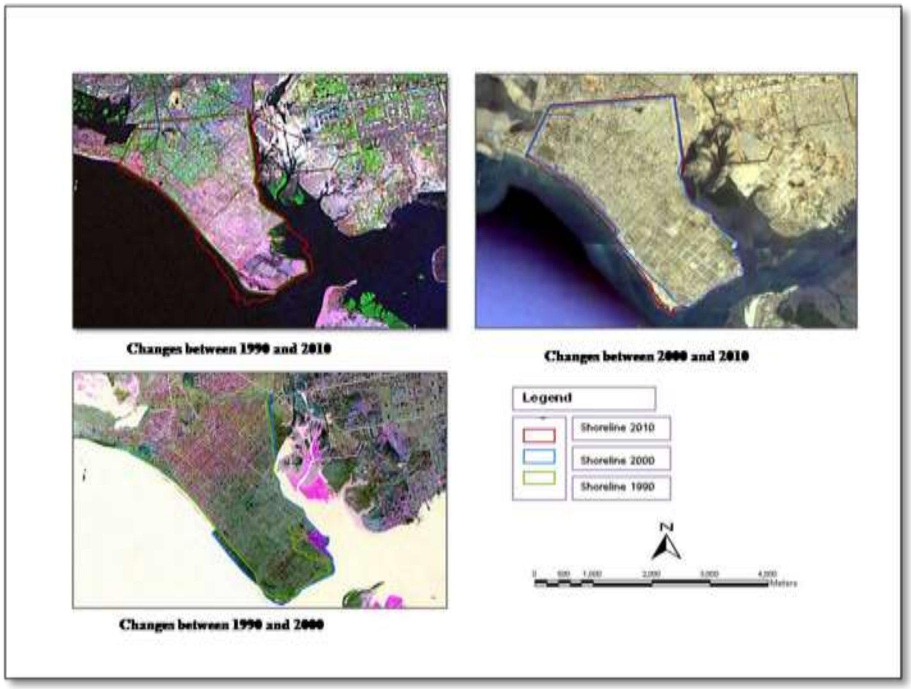

Fig. 6. DHA Change Detection (1990-2010)

[2]. Bundal and Buddo Island Change Detection (2005-2010)

Due to data deficient only two images (2005-2010) were used to identify the changes of bundle and buddo island **(Fig. 7).**

- **Bundal and Buddo Island Shoreline Change (2005-2010)**

Between 2005 and 2010 about 0.293ha of land, were eroded from the shore in the southern part of the Island. The yellow line on the map **(Fig. 8)** represents the shoreline in the 2005 whereas the red line represents the position of the island in 2010. There was an accretion of the upper part of the bundle island occurred. About 0.550 ha., of land accreted.

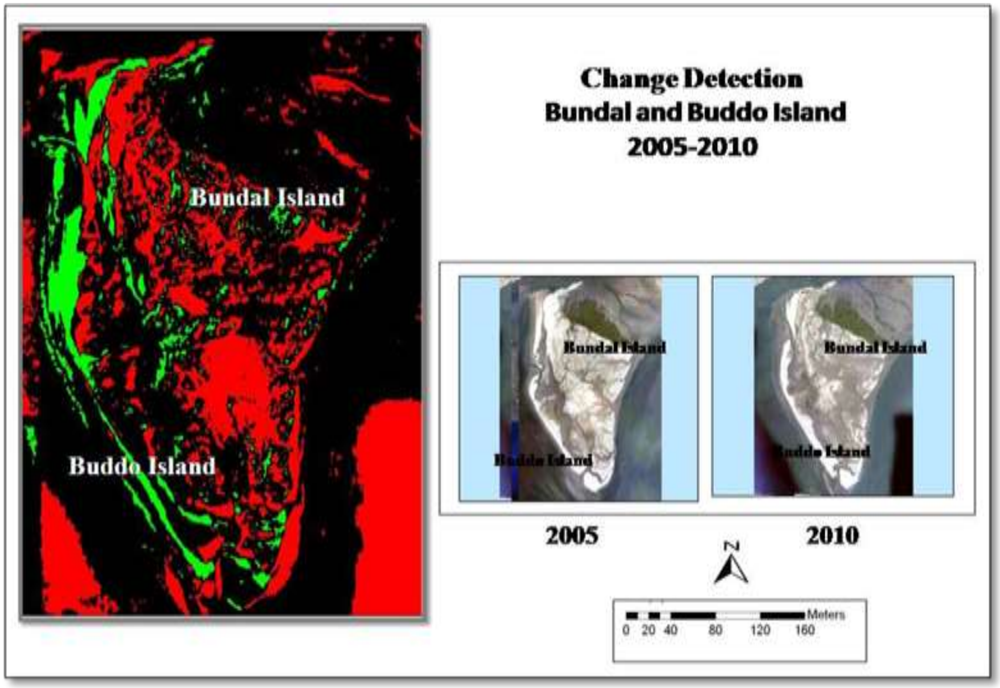

Fig.7: Bundal and Buddo Island Change Detection (2005-2010)

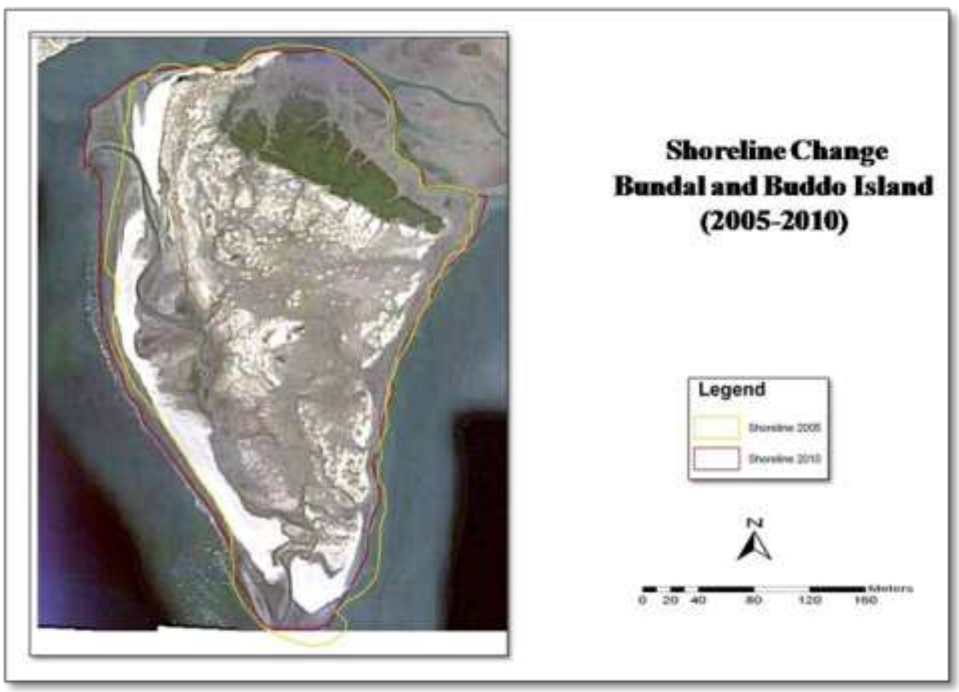

Fig. 8. Bundal and Buddo Island Shoreline Change (2005-2010)

[3]. Other parts of Study Area

Other parts include the western part of Karachi such as Sandspit. In this area erosion were also seen. The Karachi harbor area has also extended both eastern and western wharf **(Fig. 9).**

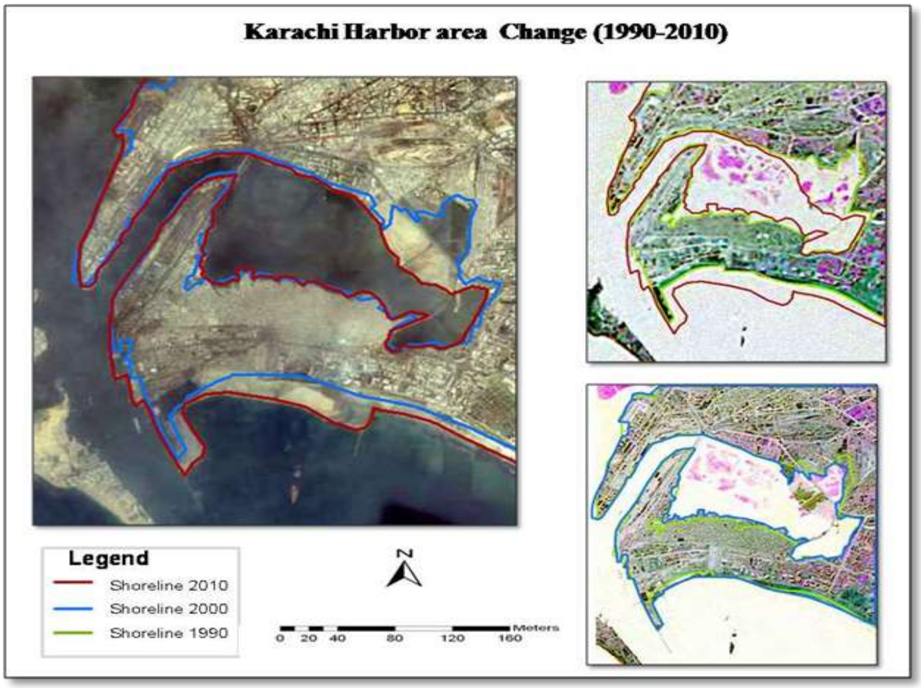

Fig.9. Karachi Harbor area Change (1990-2010)

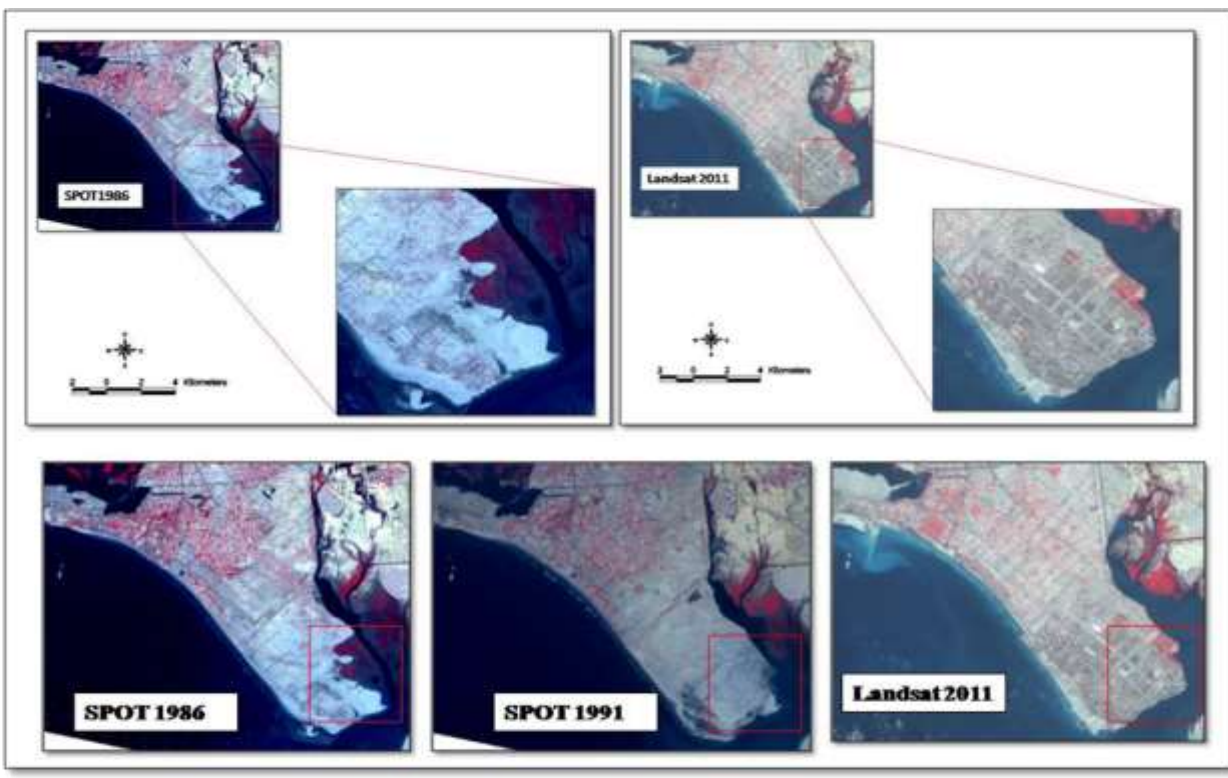

Fig. 10. Shoreline Change and its impact on Mangroves (1986-2011).

Shoreline Change and its impact on Mangroves form 1986 to 2011

Mangroves are tropical plants, which are found along much of the world's tropical coasts. They grow in loose, wet soils, and salt water. They found in the intertidal zone and occupying large tracts along shallow coasts, estuaries, and in the delta. Their distribution throughout the world is affected by climate, salinity of the water, fluctuation of the tides, type of soil in the area and, more recently, by development of tidal wetlands for residential use as well as industrial, i.e. shrimp farms. As a whole community, mangroves are capable of thriving in a wide range of harsh environmental conditions and share unique adaptive traits such as salt excreting leaves, exposed breathing root system, and production of viviparous propagules (Duke, 1992).

Fig. 10 shows the shoreline change impact on mangroves. In 1986 satellite image of SPOT XS mangroves present but in 1991 and 2011 saltellite image of SPOT XS and Landsat TM the southern and southwest part of the Defense Hosing Society Phase VII and Clifton land were extended due to the reclamation/accretion activities for urban Development.

Conclusion

Shoreline variations are caused by both natural processes and human activities. Natural processes include tides, waves, currents, storms, and major geological events such as tsunamis. Human activities affecting the shoreline are construction of ports and coastal structures, land reclamation, and land use practices. Shoreline accretion results in more usable land, while shoreline erosion has been reported to cause potential problems with the infrastructure, community and ecosystems along the coast.

The present study used remote sensing images and GIS to identify and measure shoreline changes in Karachi. It has been observed that shoreline change in the study area results from both erosion and accretion processes. The accretion occurred at the southern part of Clifton beach as well as on the northern part of the bundal island.

Hence accurate demarcation and monitoring of shoreline variations (long-term and short-term) are necessary for a scientific understanding of coastal processes and for assessing the nature of impact - natural or human mediated, for devising effective coastal management strategies in the future.

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