

Analysis of Karachi Coast Through Geo Spatial Technique from 2013-2022

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Abstract

Climate change is a burning issue at present time. The Intergovernmental Panel on Climate Change (IPCC) estimates global mean sea levels to upsurge from 0.43 m to 0.84 m by the 21st century's end. In the world, Pakistan is more likely to experience coastal hazards due to uncertain hydrodynamics in the Arabian Sea. Coastline erosion is one of the phenomena which are directly linked with increase in sea level rise.

Karachi coastline has been delineated by the action of waves, winds, currents and tides which are the consequences of sea level rise causing immense shoreline changes. Remote Sensing techniques play a crucial role in spatio-temporal analysis. In this study, medium spatial resolution of 30m multi sensor Landsat images from 2013-2022 along the 100m coast of Karachi are providing data. For the estimation of changing coast line, a digital shoreline analysis system (DSAS) tool is utilized. From Cape Monz to Hawksbay in western coast, the rate of erosion and deposition are not indicating an alarming situation. It means anthropogenic activities are negligible in these areas. In contrast, eastern coast of Karachi like Keemari, Korangi and Port Qasim show an imbalance of sediment budget. South of Karachi depicted high accretion. In DSAS technique, out of 567 transects, 41% reported as erosional while 58% are accretional.

This research will not only assist in providing data for coastal engineering but also recognition of coastal vegetation in order to maintain marine habitat .and minimize the incident and intensity of the catastrophic hazards.

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1. Introduction

Coastal zones and shorelines are very dynamic in nature. Anthropogenic activities coupled with global warming intensify tide level, wave height and sea level which will result in morphological shoreline changes. The Intergovernmental Panel on Climate Change (IPCC) estimates global mean sea levels to upsurge from 0.43 m to 0.84 m by the 21st century's end. The shape and location of the shoreline, which separates land from the sea, are always changing depending on the surroundings. Due to the Arabian Sea's coastal and riverine processes, this coastal region is subject to waves and tides brought on by the monsoon season.¹

Pakistan is ranked seventh in terms of vulnerability to climate change-related occurrences. Four severe floods and six previous cyclones have harmed the socio-economics of low-lying communities in the Sindh coastline region.² Coastal zones are commonly thought to be permanent and stable characteristics, however the truth is that shorelines are very dynamic in nature and susceptible to anthropogenic and natural processes. Global climate change phenomena such as sea level rise are also important in inducing mid- and long-term changes in coastal areas (IPCC 2007). Coastal vulnerability assessments continue to emphasize primarily on rise of sea level, with monitoring of historical shorelines serving as an important criterion for the assessment (IPCC 2007). The coastal belt of region of Indus Delta is constantly evolving due to natural phenomena like tidal action, waves, wind speed, rising sea

¹ Afsar, S., Masood, H., & Bano, S., "Monitoring of the shoreline change and its impact on mangroves using remote sensing and GIS: a case study of Karachi coast, Pakistan" (International Journal of Biology and Biotechnology 10, no. 2, 2013): 237-246.

² Kanwal, S., Ding, X., Sajjad, M., & Abbas, S. "Three Decades of Coastal Changes in Sindh, Pakistan (1989–2018): A Geospatial Assessment." Remote Sensing 12, no. 1 (2020): 8

level, and anthropogenic issues such as pollution, for example land encroachment near shoreline and alteration.^{3 4 5}

There are methods available to inquire coastal changes like survey of topo graphics, aerial Photogrammetry, unmanned aerial systems (UAS), and global positioning system (GPS) surveys.⁶

It's excellent to see that various researches have been done in different regions, including Bangladesh, Egypt, the Mediterranean Sea, the Delta of Yellow River, and the Delta of Pearl River in China, to understand coastline changes. While there has been substantial research in these areas, it's also notable that specific attention has been given to the Delta of Indus River's region (IDR) in Pakistan. Coastal infrastructure, such as ports, roads, and settlements, is at risk from shoreline changes.⁷ Coastal changes, especially those associated with sea-level rise and erosion, can lead to the intrusion of saltwater into freshwater sources. This poses a threat to drinking water supplies, agricultural irrigation, and overall water quality.⁸ The research by authors⁹ addressed about the vulnerability of the deltaic creek system, especially near Karachi.

³ Siddiqui, M.N., Maajid, S., "Monitoring of geomorphological changes for planning reclamation work in coastal area of Karachi, Pakistan," *Adv. Space Res.* 33 (2004): 1200–1205.

⁴ Waqas, M., Nazeer, M., Shahzad, M., Zia, I., "Spatial and Temporal Variability of Open-Ocean Barrier Islands along the Indus Delta Region," *Remote Sens.* 11 (2019): 437.

⁵ Shahzad, M.I., Meraj, M., Nazeer, M., Zia, I., Inam, A., Mehmood, K., Zafar, H., "Empirical estimation of suspended solids concentration in the Indus Delta Region using Landsat-7 ETM+ imagery," *J. Environ. Manag.* 209 (2018)

⁶ Kidwai, S., Ahmed, W., Tabrez, S. M., Zhang, J., Giosan, L., Clift, P., & Inam, A. (2019). Chapter 12 - The Indus Delta—Catchment, River, Coast, and People.

⁷ Kanwal, S., Ding, X., Sajjad, M., & Abbas, S. "Three Decades of Coastal Changes in Sindh, Pakistan (1989–2018): A Geospatial Assessment." *Remote Sensing* 12, no. 1 (2020): 8.

⁸ Zia, I., Zafar, H., Shahzad, M. I., Meraj, M., & Kazmi, J. H., "Assessment of sea water inundation along Daboo creek area in Indus Delta Region, Pakistan" (*Journal of Ocean University of China* 16, 2017: 1055-1060).

⁹ Khan, T.M.A.; Rabbani, M. *Sea Level Monitoring and Study of Sea Level Variations along Pakistan Coast: A Component of Integrated Coastal Zone Management*; National Institute of Oceanography: Karachi, Pakistan, 2000.

The vulnerability of twenty million people and forty percent of Pakistan's industry to the effects of coastal erosion is a significant concern. Coastal erosion can have wide-ranging impacts on both human communities and economic activities. Understanding the dynamics of coastline changes provides essential information for planning and implementing adaptation strategies. This may include the construction of protective structures, land-use planning, and the development of early warning systems for coastal communities.¹⁰ This research contributes to the broader understanding of the complex interactions between sea level rise and coastal dynamics particularly erosional activities in Karachi. Also attention is given about reduction of Mangroves within in ten years only.

2. Aims and Adjectives

- To give awareness about sustainable environment in order to advance coastal engineering.
- To determine an area engulfed by shoreline delineation through map using DSAS in GIS.
- To illustrate the relationship between rising sea level and coastal hazards in Karachi coast.
- To evaluate the reduction in mangroves
- To highlight the importance of mangrove forests in preventing coastal hazards.

3. Study Area

Karachi is one of the mega city of Pakistan, housing about 7% of its population. Karachi is located in Southern Pakistan in the north of Arabian Sea .67°00'36" east longitudes and 24°51'36" north latitude comprising 3,527 sq. km. physically it is mostly comprises flat, lies in Sindh coast and is operational as a harbor for last 125 years.

¹⁰ Waqas, M., Nazeer, M., Shahzad, M., Zia, I., "Spatial and Temporal Variability of Open-Ocean Barrier Islands along the Indus Delta Region," *Remote Sens.* 11 (2019): 437.

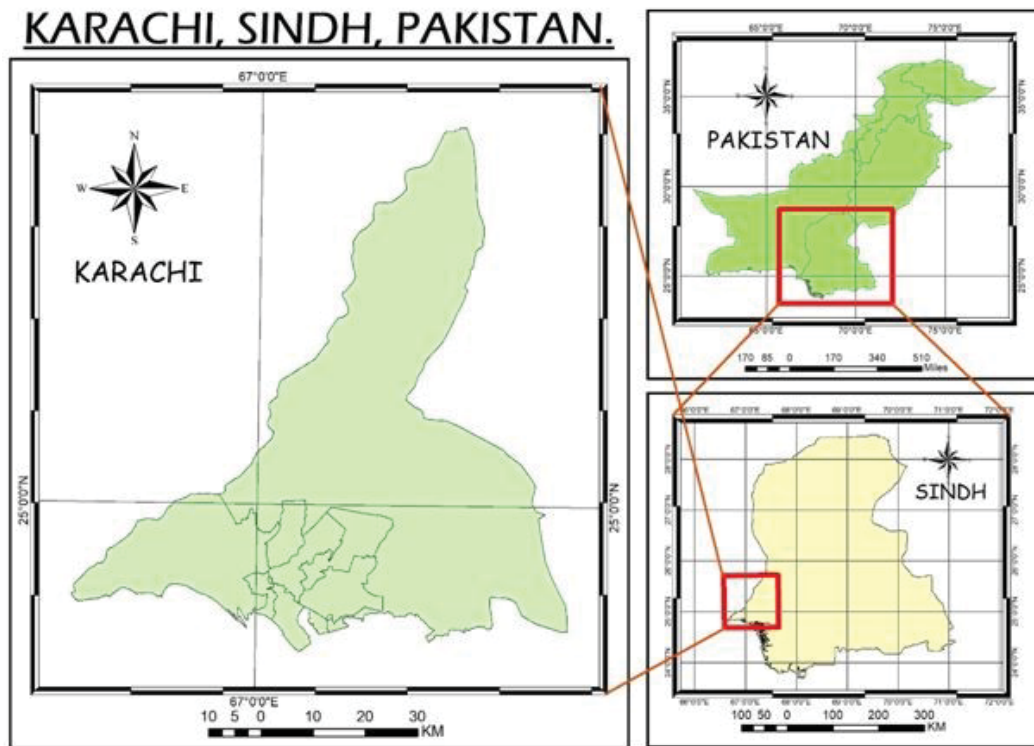


Figure 1 Study area along coast of Karachi, sea surface temperature varies from 24C-28C in summer and from 20C-24C in winter.

4. Importance of Study Area

The Karachi's coast Fig (1) is nearly 100 km between the Gharo creek on the east and the hub of river on the west. It is contemplated as financial center for Pakistan as 90% of maritime trade is accomplished through the Port of Karachi and the Port Qasim. Raised beaches with moderate climate and marine terraces are present along the coast which are 6m to 15m above sea level. The Malir and Lyari River passes through the city.

5. Methodology

Integrating these methods like topographic survey, unmanned aerial system, global positioning system GPS often provides a comprehensive understanding of coastal changes. Researchers and environmental managers can choose the most suitable combination

based on the specific goals, budget constraints, and the scale of the study area.

Addressing the financial and labor challenges associated with coastal assessments in developing countries requires a multi-faceted approach, combining technological innovation, capacity building, and international cooperation. Image got from Google Earth Engine, Land Sat_7 down loaded for the month of May in 2013. We chose only free of cloud and climatically accurate 30-m Landsat (TM: Thematic Mapper). Image was not clear 2012 May, that's why Land Sat 7 took under observations.

Image down loaded from United States Geological Survey (USGS) Earth Explorer of Land sat_8 and Land sat_9 respectively for the years of 2013 and 2022 in May.

Mosaicing needed for digitization of shore line and base line for both images. 2012 & 2022 of May. The tool of Digital Shoreline Analysis System (DSAS) was developed by the U.S. Geological Survey (USGS) under the Coastal and Marine Geology Program. DSAS is designed to analyze shoreline changes using digital data and is often used in conjunction with GIS (Geographic Information System) software like ArcGIS.¹¹ DSAS employs statistical algorithms to analyze the changes in the shoreline position over time. Common statistical measures include End Point Rate (EPR) The average rate of change between the oldest and most recent shorelines. Net Shoreline Movement (NSM): The algebraic sum of the distances the shoreline has moved landward or seaward. It considers both positive and negative values, indicating whether the shoreline is advancing or retreating.^{12 13}

Shoreline positions extracted from historical topographic sheets and multi-temporal photos are entered into the geodatabase. Each entry

¹¹ Kuleli, T., Guneroglu, A., Karli, F., & Dihkan, M. (2011). Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. *Ocean Engineering*, 38(10), 1141-1149.

¹² Kuleli, T., Guneroglu, A., Karli, F., & Dihkan, M. (2011). Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. *Ocean Engineering*, 38(10), 1141-1149.

¹³ Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., Ergul, A., "The Digital Shoreline Analysis System (DSAS) Version 4.0 - An ArcGIS Extension for Calculating Shoreline Change," U.S. Geological Survey: Reston, VA, USA, 2009

includes relevant attributes such as date, shape length, cast direction, and any other information deemed important for the analysis. Positive (+) and negative (-) values are assigned to the transects based on the direction of shoreline movement. Inward movement is denoted by positive value and landward movement is represented by negative value. This directional information is crucial for interpreting and understanding the dynamics of shoreline changes.¹⁴ The metrics — NSM, SCE, EPR, LMS, and LRR—are commonly used in shoreline change analysis to quantify different aspects of coastal dynamics.¹⁵ But in this paper we will discuss the NSM and EPR only. The EPR was used to estimate the rate of erosion and accretion per year at each transect, while NSM elaborated about the movement of shore line.

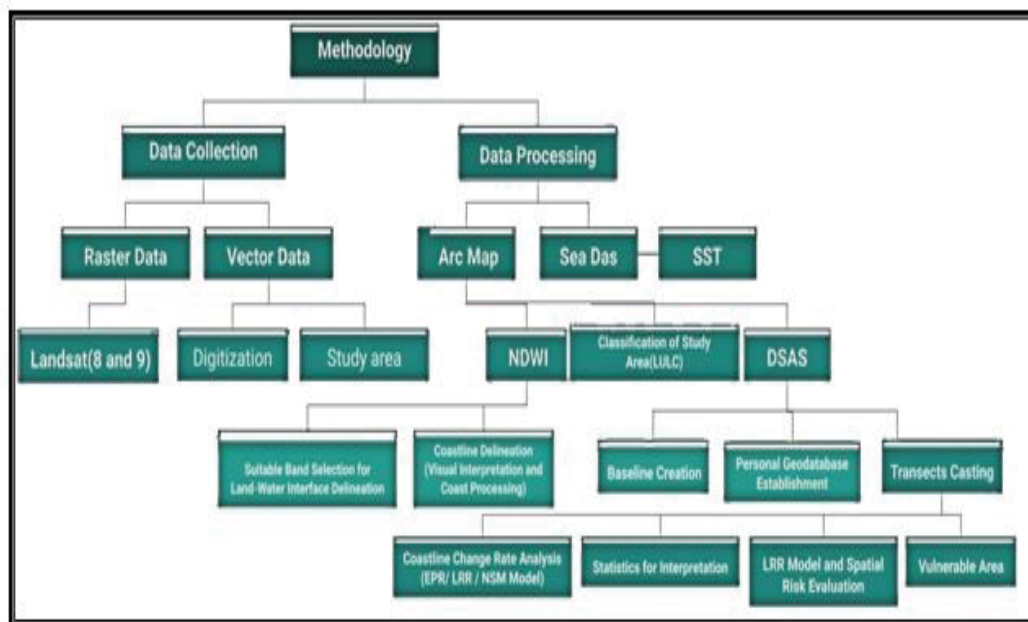


Figure 2 Methodology

¹⁴ Kuleli, T., Guneroglu, A., Karsli, F., & Dihkan, M. (2011). Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. *Ocean Engineering*, 38(10), 1141-1149.

¹⁵ Ozturk, D., & Sesli, F. A. (2015). Shoreline change analysis of the Kizilirmak Lagoon Series. *Ocean & Coastal Management*, 118, 290-308.

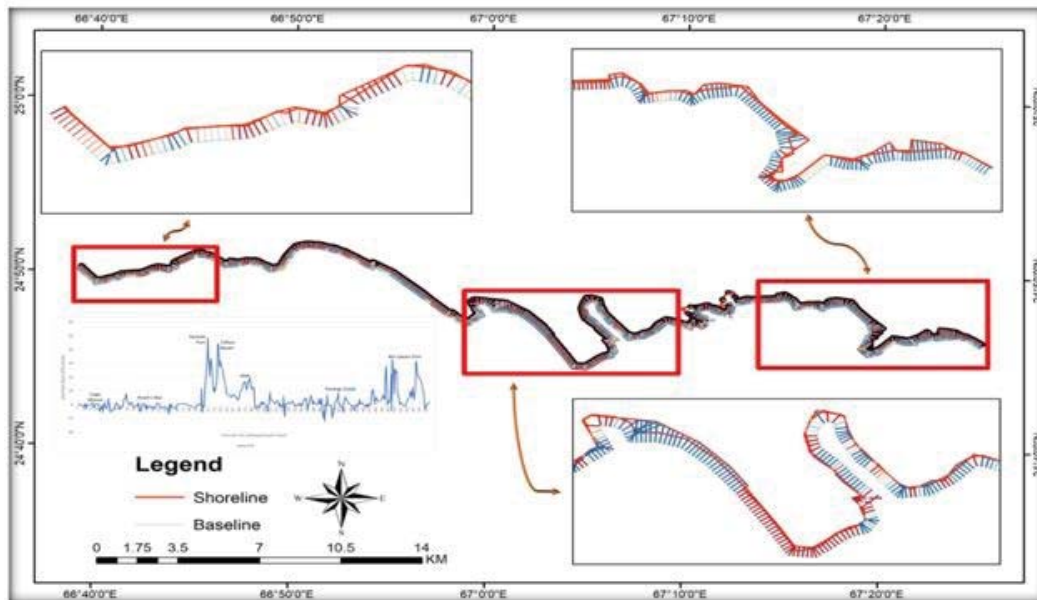


Figure 3 Digital Shoreline Analysis System

6. Result and Discussion

The usual consequences of rising sea level comprise of the inundation of low-lying areas, erosion of beaches, intrusion of sea water into creek area and surface waters, and amplified flooding and storm damages.¹⁶

It's important to note that coastal environments are subject to natural processes, including erosion, sedimentation, and changes in sea level. Understanding the geological and geomorphological features of the Karachi coastline is crucial for sustainable coastal management, especially in a highly urbanized and developed area where human activities may impact the natural coastal dynamics. The observation of coastline oscillation between erosion and accretion in the Karachi zone indicates the dynamic nature of coastal processes in this region. Coastal changes are affected by certain factors like physical processes, anthropogenic activities, and environmental conditions. The mention of subzones within Karachi, specifically Karachi South, Karachi West, and Karachi East.

¹⁶ Nicholls, R. J., & Leatherman, S. P. (1995). Global sea-level rise. 92-123p. Strezepek and Smith.

In summary, the use of Landsat TM and OLI satellite imagery to observe and analyze changes in land accretion in the Karachi South subzone underscores the significant retreat. According to Digital Shoreline Analysis System (DSAS) assessed the rate of systematic land loss and/or gain due to natural processes and human activities along the coastline. Here we found the rate of erosion by using EPR and NSM only. There are 556 transects Fig (3) are showing erosion and accretion. Out of 556, 231 are erosional transects while 325 transects showed accretion. It means 58.45% are not affected by erosion.

In western side of sandy beaches, sediment budget is stable and followed up the findings of author¹⁷ also.

Transect 210 showed highest accretion of about 48m land retreat in Kemari which is composed of loosed stone.

At Clifton beach (composed of tidal flat sand), 45m of land showed accretion on 221 transect ID. In DHA, 20m of land is reclaimed on transect 260-290 which is the highest accretion rate at the transects along the subzone Karachi South coastline, which is a potential result of coastal reclamation Erosional activities in external side of islands are highlighted in Gizri and Korangi Creek on transect 395-411. These observations are also parallel with author¹⁸ which depicted about the erosion of barrier islands near Karachi during 1974-2017.

Every year, along the coast of Karachi, -1.91 of land shows erosion and 7.14m of land shows accretion during a decade. The phenomenon of erosion allowed the sea water intrusion near shore and caused depletion of coastal vegetation.

¹⁷ Kanwal, S., Ding, X., Sajjad, M., & Abbas, S. "Three Decades of Coastal Changes in Sindh, Pakistan (1989–2018): A Geospatial Assessment." *Remote Sensing* 12, no. 1 (2020): 8.

¹⁸ Waqas, M., Nazeer, M., Shahzad, M., Zia, I., "Spatial and Temporal Variability of Open-Ocean Barrier Islands along the Indus Delta Region," *Remote Sens.* 11 (2019): 437.

7. Effects of Coastal Erosion

Mangroves are appeared in Chinna creek, entrance of Karachi port trust and also present in Gharo of port Qasim. In southern side Ghizri and eastern Karachi comprised of mangroves also.

From 2013-2022, increase in built up noticed as 3 percent from the image of land sat ,but the quick reduction in mangroves is alarming as 9 percent within ten years.

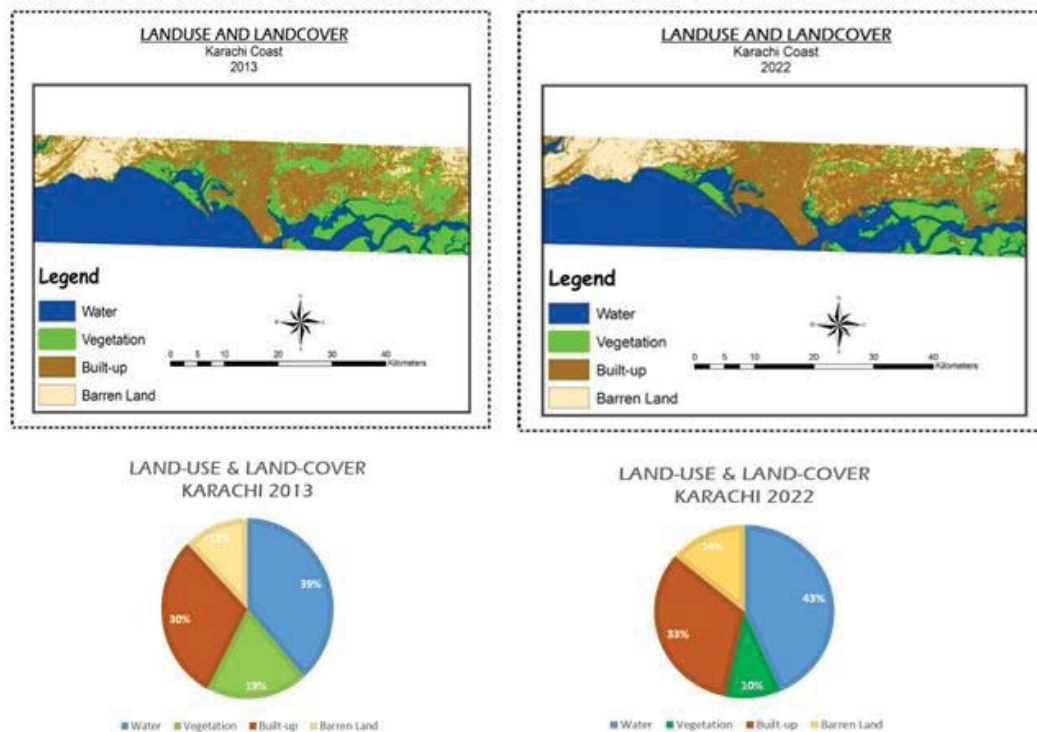


Figure 4 Patches of barren land are filled by built up due to increase in anthropogenic activities. Another important point is that gap between coast line and water has increased. This is the indication of sea water encroachment.

8. Outcomes of Erosion

Major coastal hazard, erosion endangers millions of people and coastal infrastructure near shore. Coastal delineation occurred and production of natural vegetation like mangroves decreased. Fishing activity reduced due to loss in marine habitat.

9. Measures

We stress that the coastal infrastructure should be planned with special care. Stabilization of coastline demands scientific seeding techniques for reforestation of mangroves and preservation of the remaining.

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