7th Intercontinental Geoinformation Days

igd.mersin.edu.tr

Analysis and forecasting of coastline morphology in Pakistan using digital shoreline analysis

Mazhar Shakoor [*1], **Shakeel Mahmood** [1]

[1]Government College University, Department of Geography, Lahore, Pakistan

Keywords
Remote sensing
Coastline detection
DSAS
Liner Regression Rate

Abstract

A sustainable protective strategy's design and informed coastal management depend on the assessment of coastal erosion and accretion. This study analyses Pakistani coastal dynamics from 1990 to 2020 using the Digital Shoreline Analysis System (DSAS) version 5.1 linked with ArcGIS software. The study, which focuses on erosion and accretion, uses metrics like Liner Regression Rate (LRR), End Point Rate (EPR), and Shoreline Change Envelope (SCE) to divide the area into four segments (a, b, c, and d) within the western zone. The findings show that the rates of erosion and accretion along Pakistan's coastline vary significantly. Maximum erosion rates are found on Transect Id 49, which reaches -42.28 m/yr; maximum accretion rates are found on Transect Id 105, which reaches 2.27 m/y to 2.77 m/y. Significantly, regions bordering Iran—segment d, in particular—accrete more than the original section between 1990 and 2020. The predominant process is erosion, which affects a large amount of Pakistan's coastline, especially in areas with a high concentration of industry and areas recently devastated by disasters. These results highlight the necessity of customized coastal management plans that take into account the intricate interactions between anthropogenic and natural elements in the area.

1. Introduction

Globally, coastal regions belong to the most valuable and vulnerable ecosystems (Kron, 2013; Hossain et al., 2020). According to researchers like, coastal regions are essential because they serve as transitional zones between terrestrial and aquatic ecosystems (Golla et al., 2020). By decreasing storm surges (Tognin et al., 2021), increasing carbon sinks (Lovelock and Reef, 2020, Ward et al., 2021), balancing sediment and nutrient cycling (Lonborg et al., 2021), and creating biodiversity conservation areas, they reduce exposure to natural hazards (such as coastal flooding and tsunamis) (Hopper et al., 2021). In contrast to 20% of the world's coastlines that are retreating at less than 10 meters per year and only 10% of the coasts that are either stable or advancing, over 70% of the world's coasts are retreating at rates of about 10 meters per year or more (INOC, 1991). Brunn's, (1962) rule says that, the near shore bottom adjusts in response to sea level rise to try and find a new equilibrium and restore the ratio between the distance offshore at which the waves hit the bottom (L) and the water depth at that distance (D). Equilibrium is created by the shore's erosion, which is equivalent to the sea level rise multiplied by the ratio (L/D).

Even though Pakistan's coastline is important, there haven't been many efforts to assess how erosion has affected it's roughly 1000 km of coastline. The majority of studies done to evaluate erosion and accretion along the Pakistani shoreline are small-scale and localized. In particular, Waqas et al. (2019) investigated the spatiotemporal variability of the offshore barrier islands (BIs) of the Sindh coast from 1974 to 2017, whereas Ijaz et al. (2017) examined the evolution of the main tidal creeks of the Islamic Republic of Pakistan (IDR) coastline from 1979 to 2017. As a result, reliable and efficient shoreline mapping is required for the implementation of proactive planning strategies for the future maintenance and control of coastal resources (Thomas et al., 2017). In order to accomplish this, extracting shoreline features from digital remote-sensing imagery is a potential and useful technique (Narayana, 2016).

In order to accomplish this, extracting shoreline features from digital remote-sensing imagery is a potential and useful technique (Narayana, 2016). With gratitude to enhanced sensor technology, open access data policies, and near real-time data collection, remote sensing has the unique feature of delivering geographically unlimited data at a lower cost than conventional ground-based evaluation (Szuster et al.,

* Corresponding Author

*(shakeelmahmoodkhan@gmail.com) ORCID ID 0000-0001-6909-0735

Cite this study

Shakoor, M., & Mahmood, S. (2023). Analysis and forecasting of coastline morphology in Pakistan using digital shoreline analysis. Intercontinental Geoinformation Days (IGD), 7, 9-12, Peshawar, Pakistan

2011). Remote sensing has greatly helped coastal observation for more than 40 years by supplying timely, cost-effective data at various geographic scales (Luijendijk et al., 2018). Furthermore, its abilities provide a rare window into past events to track the morphology of the shoreline over time and predict potential changes to the shoreline in the future using historical data.

2. Method

This study utilizes a combination of remote sensing data and existing databases for data collection. High-resolution satellite photos capture the research area at various times. Additionally, preexisting databases from governmental organizations, academic institutions, and prior studies supplement the data collection. The section provides a comprehensive overview of the Digital Shoreline Analysis System (DSAS) and its relevance to shoreline change analysis. DSAS, a widely-used tool employing GIS techniques, analyzes historical shoreline positions, quantifies erosion and accretion rates, and offers statistical tools for assessing significance. The section highlights DSAS's efficiency, accuracy, and ability to handle large datasets.

To digitize shorelines for different time periods, DSAS and GIS software will be used, and shoreline positions will be manually digitized based on visual indicators. The digitized shorelines will then be used to determine rates of shoreline change, erosion, and accretion. DSAS's statistical tools, including linear regression, will assess the scope and significance of shoreline changes over time. Spatial analysis approaches will identify hotspots of coastal change and vulnerable segments by superimposing shoreline change data on relevant spatial information. The analysis of shoreline change findings will unveil the primary causes and patterns of coastal erosion and accretion in the research area, presented through maps, charts, and statistical summaries to illustrate geographical and temporal changes in coastal dynamics.

Remote sensing data and pre-existing datasets will all be used in the data gathering for the Digital Shoreline Analysis System (DSAS) assessment of coastal erosion and accretion processes in Pakistan. For conducting a thorough research of shoreline dynamics and comprehending the coastal processes in the study area, precise and complete data gathering is essential.

A single database will be created from every piece of information that has been gathered, including remote sensing images, and existing datasets. Through this aggregation, the data may be easily managed and accessed throughout the analytical process. Georeferencing is an essential step in spatially aligning various datasets. Techniques for data resampling can be used to uniformly scale and standardize the spatial resolution of the datasets. By taking into account several elements that affect shoreline dynamics, this integration makes it possible to analyze patterns of coastal erosion and accretion in great detail. In order for the data to be used in the DSAS analysis, it may be necessary to convert or standardize it into a consistent format. In order to do this, data may need to be converted into GIS-compatible forms, like shape files or raster formats, while maintaining metadata and attribute information.

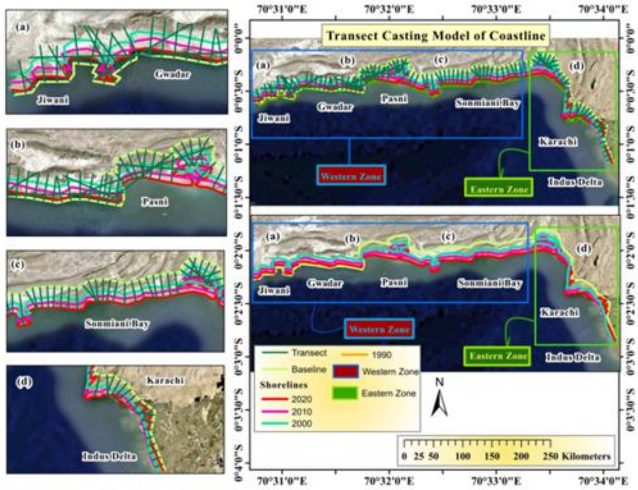

Figure 1. Transect generation for Study Area.

2.1. Study Area

Pakistan's shoreline is about 1050 km-long coastline. This shoreline can be divided into two parts: the Sindh Coast (270 km) and the Makran Coast (720 km). The Exclusive Economic Zone (EEZ) of the nation is approximately 240,000 square kilometers in size, and its maritime zone, which includes the continental shelf, stretches up to 350 nautical miles from the shore. The Indus canyon, which covers the coastal shelf, is a notable feature of the region (Figure 1). Along the coasts of the two provinces, Sindh and Baluchistan, the extent of the continental shelf differs noticeably. The two provinces share authority over the seaward coastal zone up to 12 nautical miles (NM) from the coastline.

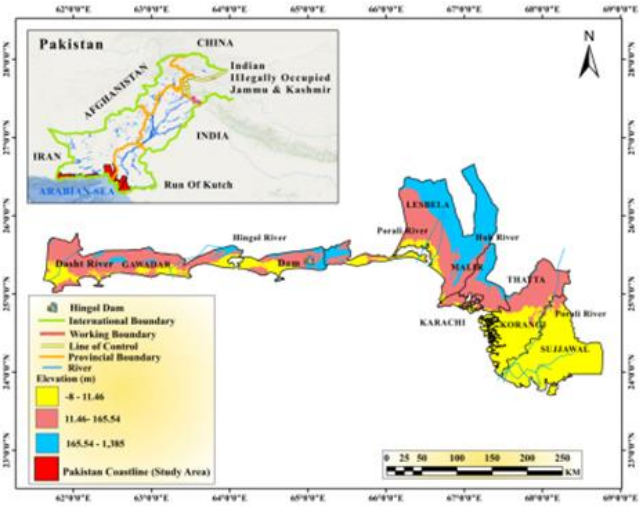

Figure 2. Location of study area.

The topography of Pakistan's coastline is heavily influenced by the nearby mountain ranges and the gradual deposition of sediments from the Indus River, resulting in a wide coastal plain in some areas. Overall, Pakistan's coastline varies significantly in elevation and topography, depending on the location. The central and eastern parts of Pakistan's coastline are typically flat and susceptible to flooding during monsoon season, with much of the land barely rising above sea level.

The weather is typically hot and humid all year long, reaching highs of up to 40 degrees Celsius (104 degrees Fahrenheit) in the summer. Heavy rainfall is brought to the maritime regions, especially in the east, during the monsoon season, which lasts from June to September. During the monsoon season, the Indus River delta is especially vulnerable to flooding, and the rains can seriously harm the area's infrastructure and crops.

3. Results

By fitting a regression line to all shoreline sites along a transect, the least squares regression (LRR) approach is used to calculate the rate of shoreline variation. Positions of the shoreline in the future and their corresponding confidence intervals can be predicted by this method, which considers all data points independent of changes in trend or accuracy. The overall average LRR rates for all segments exhibit a degradation tendency with values of -144.59 m/yr, -289.4 m/yr, -21.92 m/yr, and -84 m/yr, and an accumulation trend with values of 1.0 m/yr, 2.11 m/yr, 3.21 m/yr, and 8.48 m/yr for segments 1, 2, 3, and 4, accordingly. It shows more erosion along segment (b) and moderate to low along segment (c) to (d) while more accretion along segment (d). Segment (a) shows moderate erosion in Sky Blue colour,Segment (b) and (c) shows High to low erosion in Orange and Purple color respectively. Segment (d) show high accretion in Light Green color.

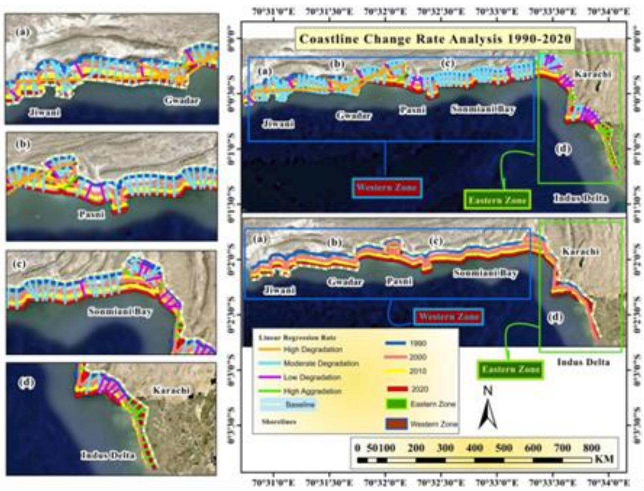

Figure 3. Coastline Change Analysis in terms of LRR.

The end point rate (EPR), a straightforward statistical metric, is calculated by dividing net shoreline movement (NSM) by the interval between the earliest and latest shoreline measurements. EPR average rate is shown in Figure 3 with the number of erosional transects at -6.15: 96% of all transects are subject to erosion of all transects with statistically significant erosion, 88.07%: highest value depreciation in 86.24%: While the average of all erosional rates is: -40.73 at transect ID: 49, -7.14. Number of accretions transects in an EPR 13 percent of all transects are incremental transects: Among all transects with statistically significant accretion, 11.93% are: 10.09%, 2.77 as the maximum value accretion at transect ID 105, and 1.16 as the average of all Accretion rates. The coastline is primarily subject to segment-wise degradation, as indicated in table 4.14, according to the rates of coastal position.

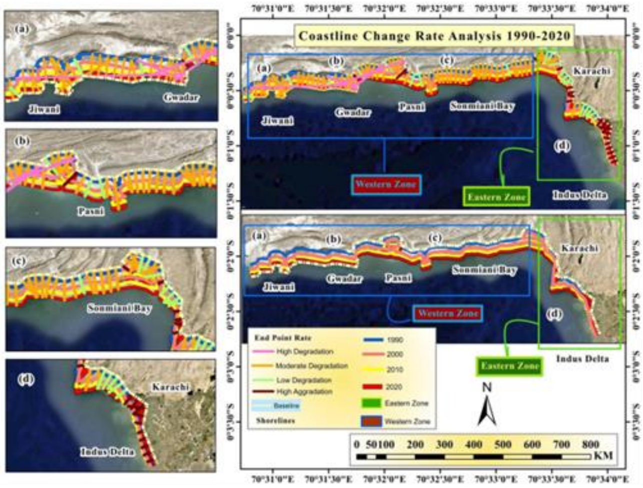

Figure 4. Coastline Change Analysis in terms of EPR.

4. Discussion

The Digital Shoreline Analysis System (DSAS) evaluation of coastal erosion and accretion trends in Pakistan has shed important light on the dynamics of the nation's coastline. The study has successfully identified rates of shoreline change and the primary hazards to the coastline by analyzing historical shoreline sites and using cutting-edge methods like DSAS version 5.1. The data point to segment-by-segment degradation as an important concern for Pakistani coastal communities. The study also identifies variances in the dynamics of other segments, highlighting the demand for specialized management approaches. This study utilized GIS and RS to evaluate 30 years (1990 to 2020) of data for the Pakistan coastline. Results indicate that erosion is noticeable along the coastline. The EPR approach is effective if the coastline experiences a steady movement whether toward the ocean or landward, but the LRR method is advantageous for segment-specific examination of coastal change.

5. Conclusion

Analyzing the spatiotemporal changes in the shoreline might be a useful non-structural strategy for coastal area decision-making. The current study may help in determining how susceptible the shoreline is. Human activity and environmental factors have significantly altered the coastline landscape over the past thirty years. The probable trends in shoreline alterations were predicted using the DSAS model, making it easier to create plans to reduce coastal risk. The shoreline in the western zone eroded significantly as a result of the development of Gwadar Port and its ancillary infrastructure, including breakwaters and jetties, whilst the shoreline in the eastern zone eroded comparatively little. Such constructions have the potential to interfere with natural coastal processes, change sediment transport and deposition patterns, and cause erosion and coastline retreat in the area. The results of the study indicate that natural coastal accretion, which entails sediment deposition and land creation along a coastline, is not a prominent process over Pakistan's entire coastline.

Acknowledgement

I would like to express my sincere appreciation to my co-author, Dr. Shakeel Mahmood, for his vital contributions and unflinching support during this project. His knowledge and commitment have made our joint work much more effective.

References

Addo, K. A., Walkden, M., & Mills, J. T. (2008). Detection, measurement and prediction of shoreline recession in Accra, Ghana. ISPRS Journal of Photogrammetry and Remote Sensing, 63(5), 543-558.

Anitha, P., & Natesan, U. (2014). Assessment of short term shoreline changes along Tuticorin, Southeast coast of India using Geospatial Techniques. Disaster Advances, 7(7), 1-7.

Arabadzhyan, A., Figini, P., García, C., González, M. M., Lam-González, Y. E., & León, C. J. (2020). Climate change, coastal tourism, and impact chains – a literature review. Current Issues in Tourism, 24, 2233 - 2268.

Baig, M. R. I., Ahmad, I. A., Shahfahad, Tayyab, M., & Rahman, A. (2020). Analysis of shoreline changes in Vishakhapatnam coastal tract of Andhra Pradesh, India: an application of digital shoreline analysis system (DSAS). Annals of GIS, 26(4), 361-376.

Beetham, E. P., & Kench, P. S. (2014). Wave energy gradients and shoreline change on Vabbinfaru platform, Maldives. Geomorphology, 209, 98-110.

Bera, R., & Maiti, R. (2019). Quantitative analysis of erosion and accretion (1975–2017) using DSAS—A study on Indian Sundarbans. Regional Studies in Marine Science, 28, 100583.

Blott, S. J., Pye, K., Van der Wal, D., & Neal, A. (2006). Long-term morphological change and its causes in the Mersey Estuary, NW England. Geomorphology, 81(1-2), 185-206.

Brantley, S. T., Bissett, S. N., Young, D. R., Wolner, C. W., & Moore, L. J. (2014). Barrier island morphology and sediment characteristics affect the recovery of dune building grasses following storm-induced overwash. PLoS One, 9(8), e104747.

Brooks, S. M., & Spencer, T. (2010). Temporal and spatial variations in recession rates and sediment release from soft rock cliffs, Suffolk coast, UK. Geomorphology, 124(1-2), 26-41.

Cabezas-Rabadán, C., Pardo-Pascual, J. E., Palomar-Vázquez, J., & Fernández-Sarría, A. (2019). Characterizing beach changes using high-frequency Sentinel-2 derived shorelines on the Valencian coast (Spanish Mediterranean). The Science of the total environment, 691, 216–231. https://doi.org/10.1016/j.scitotenv.2019.07.084

Chen, L. C. (1998). Detection of shoreline changes for tideland areas using multi-temporal satellite images. International journal of remote sensing, 19(17), 3383-3397.

Choung, Y., & Jo, M. (2016). Shoreline change assessment for various types of coasts using multi-temporal Landsat imagery of the east coast of South Korea. Remote Sensing Letters, 7, 100 - 91.

Cooper, J. A. G., Masselink, G., Coco, G., Short, A. D., Castelle, B., Rogers, K., ... & Jackson, D. W. T. (2020). Sandy beaches can survive sea-level rise. Nature Climate Change, 10(11), 993-995.

Mahmood, S., & Rahman, A. U. (2019). Flash flood susceptibility modeling using geo-morphometric and hydrological approaches in Panjkora Basin, Eastern Hindu Kush, Pakistan. Environmental earth sciences, 78, 1-16

Moore, L. J. (2000). Shoreline Mapping Techniques. Journal of Coastal Research, 16(1), 111–124. http://www.jstor.org/stable/4300016

Mukhopadhyay, A., Mukherjee, S., Mukherjee, S., Ghosh, S., Hazra, S., & Mitra, D. (2012). Automatic shoreline detection and future prediction: A case study on Puri Coast, Bay of Bengal, India. European Journal of Remote Sensing, 45(1), 201-213.

Tariq MAUR, Giesen VDN (2012) Floods and food management in Pakistan. Phys Chem Earth 47–48:11–20. https://doi.org/10.1016/j.pce.2011.08.014