IDENTIFICATION OF SHORELINE CHANGES USING DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS): A CASE STUDY OF KARACHI COAST, SINDH, PAKISTAN

S. Shafique, F. Sarwar*, S. Kausar, S. Abbas & M. Khalid

Institute of Geography, University of the Punjab, Lahore, Pakistan.
*Corresponding Email: faizasarwar.geog@pu.edu.pk

ABSTRACT: Shorelines are a very important feature of the coast. It is continuously changing due to natural activities like waves, and currents, and anthropogenic activities like construction. These changes cause morphological changes to the coast due to erosion and accretion. In case of erosion, coasts are at risk. For this purpose, Shoreline Changes were calculated by using the Digital Shoreline Analysis System (DSAS) for the last two decades at the Karachi coast. Shoreline changes showed both erosion (at bin Qasim town) and accretion (at Korangi town) but erosion dominated the entire coastline, especially in 2015. Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR), and Linear Regression Rate (LRR) are 427.76 m, -46.02 m, -3.22 m/yr. and -2.16 m/yr. respectively in the last two decades.

Keywords: DSAS, Shorelines, Morphological changes, Erosion, Accretion.

(Received 01.04.2024 Accepted 01.06.2024)

INTRODUCTION

A shoreline is a natural boundary between sea and land. A crucial component of the earth's surface is the shoreline. The shoreline was acknowledged by the International Geographic Data Committee as being among the 27 features (Khan *et al*., 2020). Shoreline change is frequently worse by a mix of anthropogenic and natural forces and thus raises the dangers to coastal communities (Siyal *et al*., 2022). Altered by anthropogenic activities such as the building of unnatural harbors, ship breaking industry, and natural factors such as currents, tides, waves, sea level (Gopinath *et al*., 2023), and movement of sediments (Karamma *et al*., 2022). The shoreline's position can change by a few millimeters or tens of meters, and after 100 years, it can change by a hundred meters (Narayana and A.C., 2016). The shoreline movement involves aspects that change on a daily, yearly, or seasonally, based on a geological time scale (Camfield *et al*., 1996). Shoreline changes are the vital character of the coast (Siyal *et al*., 2022). Because of nature's physical, chemical, and biological processes, coasts are changing (Gomez-Pazo *et al*., 2021). Nowadays, due to increasing urbanization, the alteration of the coastline has accelerated (Ahsanullah *et al*., 2021) When sediments are removed from the coast results in land moving inland called erosion while sediments being deposited on the coast results from land moving outward side (Gibb and J.G., 1978). Some of the most varied and vital resources are found in coastal areas. In the world, 40 % of the population lives near shore (Nazeer *et al*., 2020) and approximately, 70 % of coasts are vulnerable to erosion that resulted in the movement of people away from the afflicted places (Biswas *et al*., 2017). For example, in Ghana, the maritime estuary degraded at the rate of 0.58 meters per year on the western side and 1.94 meters per year on the eastern side in 120 years (Appeaning Addo *et al*., 2020). In addition to anthropogenic activities, big natural occurrences like cyclones, tsunamis, tectonic plates, sea levels, and climate change also contribute to morphological changes (accretion and erosion) (Khan *et al*., 2020). Sea level causes erosion, especially in laying low (Mentaschi *et al*., 2018) in Pakistan, Bangladesh, and many more (Kanwal *et al*., 2019). According to UNEP, Pakistan is prone to a rise in sea level (Khan *et al*., 2002). The Sindh coast is at more risk of morphological changes than the Balochistan coast (Khan *et al*., 2002). Due to natural forces and human activities, Karachi is always undergoing erosion and accretion (Ahsanullah *et al*., 2021). Shoreline changes are not easy to detect but it is detected by using remote sensing data (Khan *et al*., 2020). The purpose of this study is to use the Digital Shoreline Analysis System (DSAS) to calculate shoreline changes and morphological changes in the last two decades.

MATERIALS AND METHODOLOGY

Study Area: The study area is located on the coast of Karachi approximately 90 km. Karachi is located at 24°51′39.47″ N latitude and 66°59′25.80″ E longitude. Karachi is the most populous and densely inhabited metropolis and capital city of Sindh. From, cape Monze to Gharo Creek, the coastline of Karachi is present. Karachi's coastline is made up of diverse landforms such as sandy beaches, rocky coast, and creeks such as Korangi Creek, Khuddi, Phitti (Fig.1).

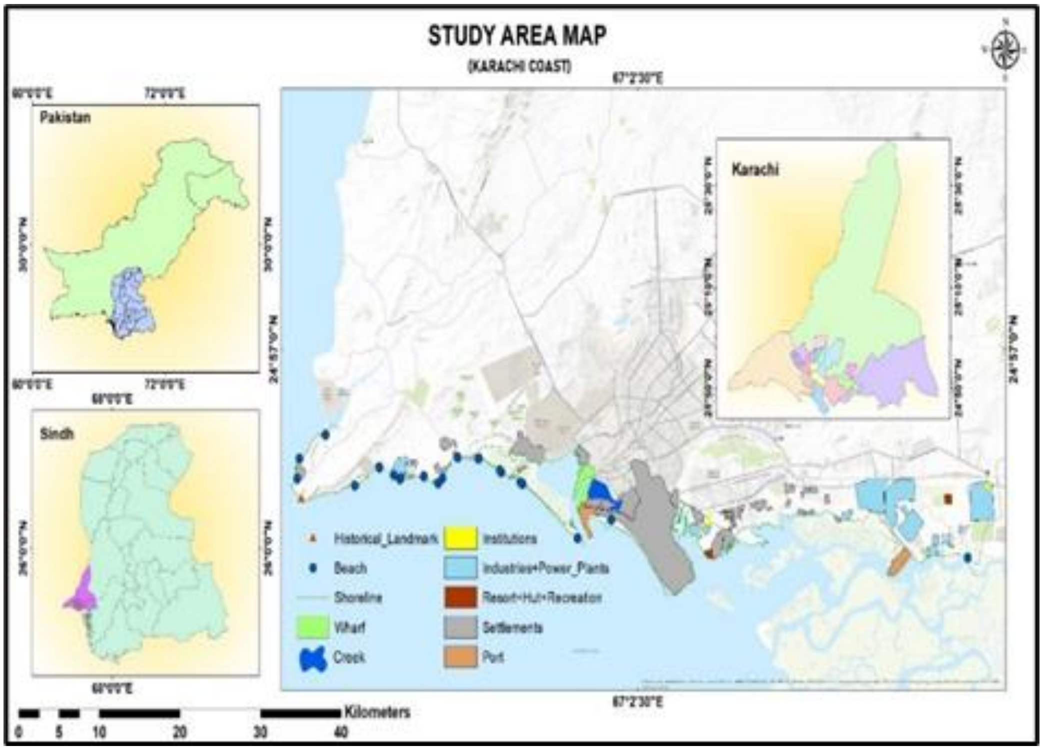

Fig 1: Study Area

Methodology:

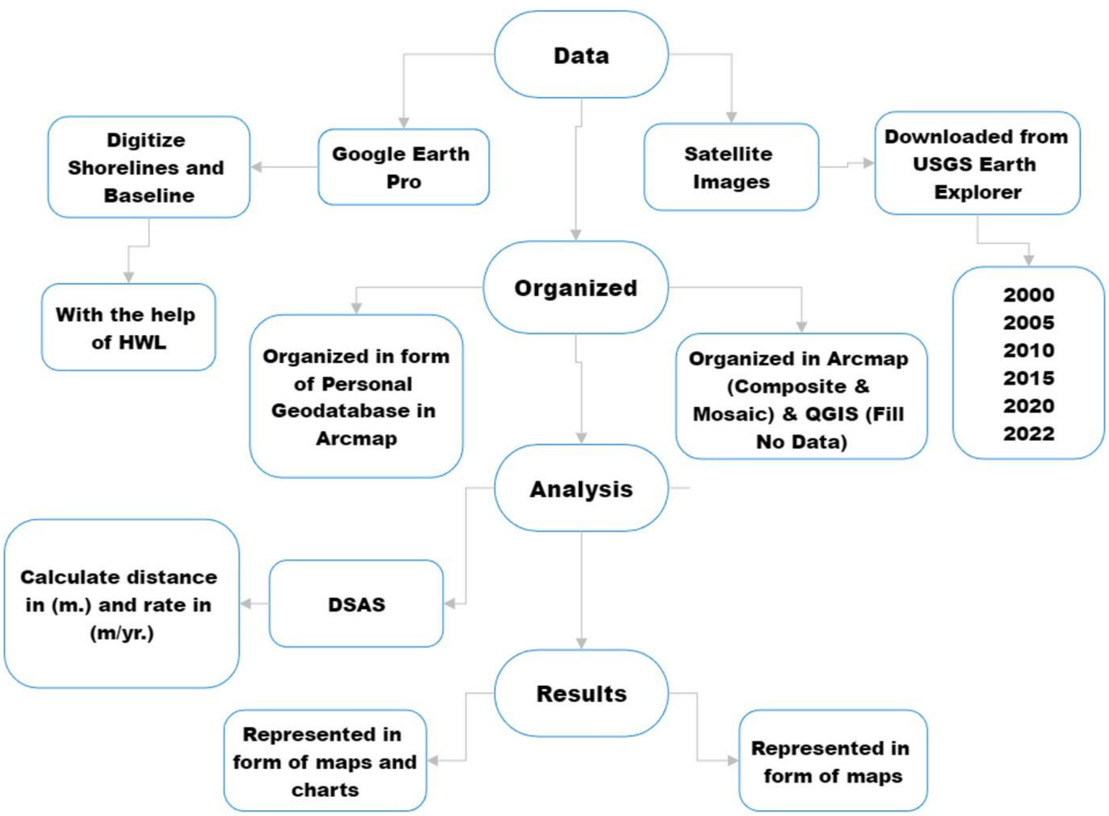

Fig 2: Methodological Framework

Table 1: Characteristics of Landsat Satellite Imageries used in this study

Landsat	Sensor	Path	Row	Date
		152	042	08/03/2000
Landsat 7	ETM+	152	043	08/03/2000
		153	043	15/03/2000
		152	042	22/03/2005
Landsat 7	ETM+	152	043	22/03/2005
		153	043	29/03/2005
		152	042	20/03/2010
Landsat 7	ETM+	152	043	20/03/2010
		153	043	27/03/2010
		152	042	11/04/2015
Landsat 8	OLI/TIRS	152	043	11/04/2015
		153	043	18/04/2015
		152	042	07/03/2020
Landsat 8	OLI/TIRS	152	043	07/03/2020
		153	043	14/03/2020
		152	042	30/04/2022
Landsat 8	OLI/TIRS	152	043	30/04/2022
		153	043	29/04/2022

Shorelines and baseline (2022) were digitized in Google Earth Pro (2000, 2005, 2010, 2015, and 2020) for DSAS. All shorelines were digitized at 385 ft except 51221 ft for the year 2000 (due to low resolution) using the path tool. These digitized shorelines were organized in ArcMap (shapefiles and personal database). DSAS was used to calculate shoreline changes (distance *i.e.*, NSM, SCE, and rate LRR, EPR) in ArcMap (Figure 2). Also, DSAS helped in forecasting shoreline changes for the next 20 (2034) or 40 (2044) years (Table 1).

Table 2: The rate of change statistics used in this study (After; Thieler *et al*., 2019; Kilar, H., 2023)

Statistics	Description	Unit
NSM	The total distance between the earliest and most recent shoreline for each transect	m
SCE	Shoreline change envelope	m
LRR	A linear regression rate of change statistic can be determined by fitting a least square regression line to all shoreline points for a particular transect	m/yr
EPR	Dividing to distance of the shoreline movement by the time elapsed between the oldest and the most recent shoreline	m/yr

Data was obtained from USGS Earth Explorer with an interval of 5 years for Landsat 7 ETM+ (2000, 2005, and 2010) and Landsat 8 OLI/TIRS (2015, 2020, and 2022) in Table 1. These satellite images were organized in ArcMap and QGIS. All these satellite images are represented in charts and maps.

RESULTS

The DSAS calculates the shoreline changes in the distance (m) *i.e.*, NSM, SCE, and in rate (m/yr.) *i.e.*, EPR and LRR. These are the most widely used statistics in various studies (Esmail *et al*., 2019; Hossain *et al*., 2021; Siyal, *et al*. 2022; Kilar, H., 2023). Results showed 769 total transect IDs. While 680 transect IDs showed shoreline changes. And, 89 transects ID showed no shoreline changes.

Fig 3 (a, b) showed SCE, NSM, LRR, and EPR approximately 427.76 m, -46.02 m, -2.16 m/yr. and -3.22 m/yr. respectively at the Karachi coast in the last two decades. NSM, erosion distance about -232.93 m and accretion distance about 217.76 m. SCE, maximum distance about 1967.18 m and minimum distance about 0.27 m. EPR, -about 15.41 m/yr. erosion rate and accretion rate of about 13.98 m/ yr. LRR, erosion rate around -14.07 m/yr. and accretion rate around 14.71 m/yr. erosion. 49.29 % erosion and 25.59% accretion were observed in the last two decades. Erosion and accretion were observed in the western, southern, and eastern sides of the Karachi coast. Accretion is mostly observed in the southern part of the Karachi coast while erosion is mostly observed in the eastern part of the Karachi coast, especially Bin Qasim Port. This is due to the industrial activities and decrease in the mangrove area in front of the island to Bin Qasim Port (Ahsanullah *et al*., 2021).

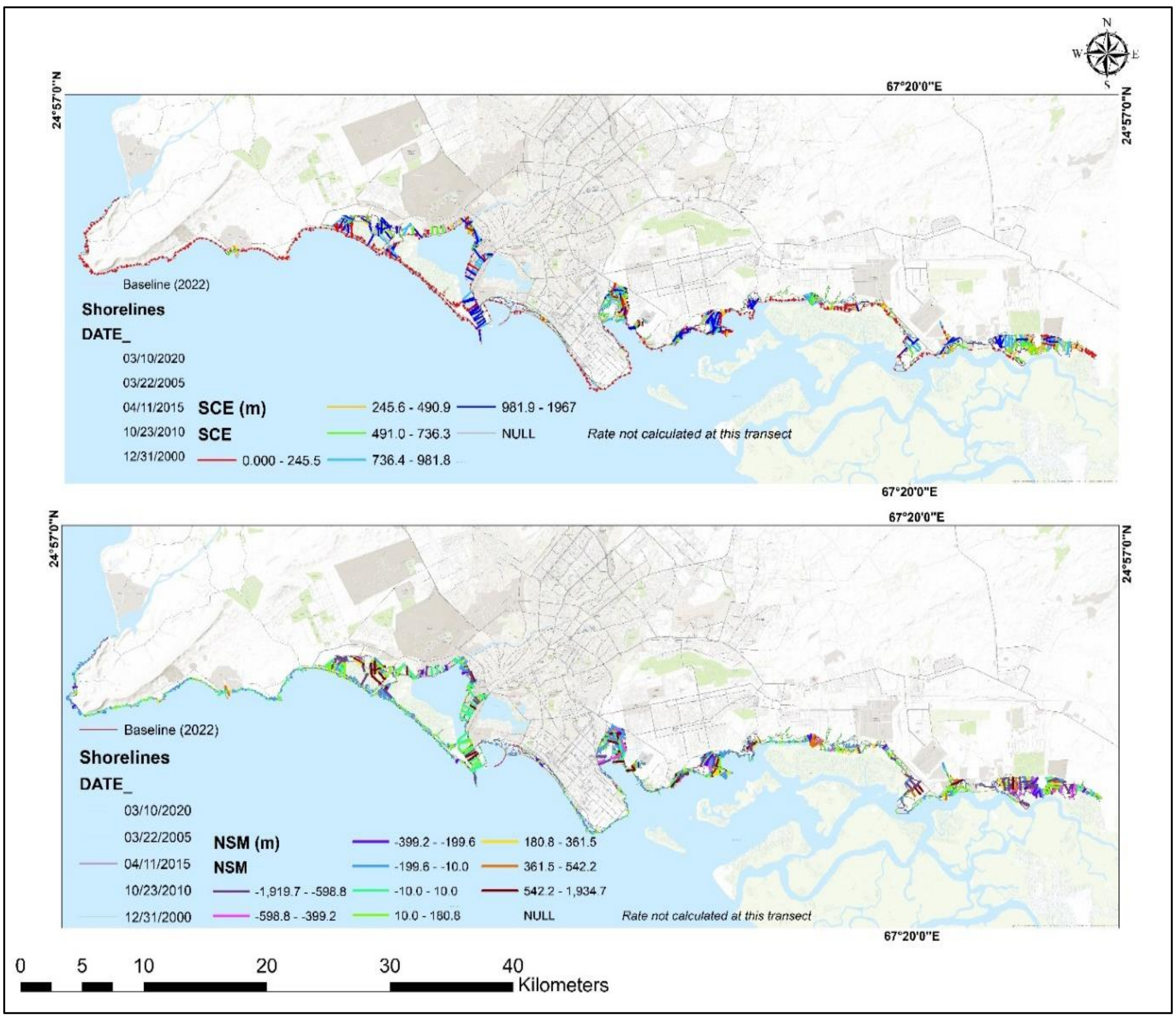

Fig 3(a): SCE and NSM

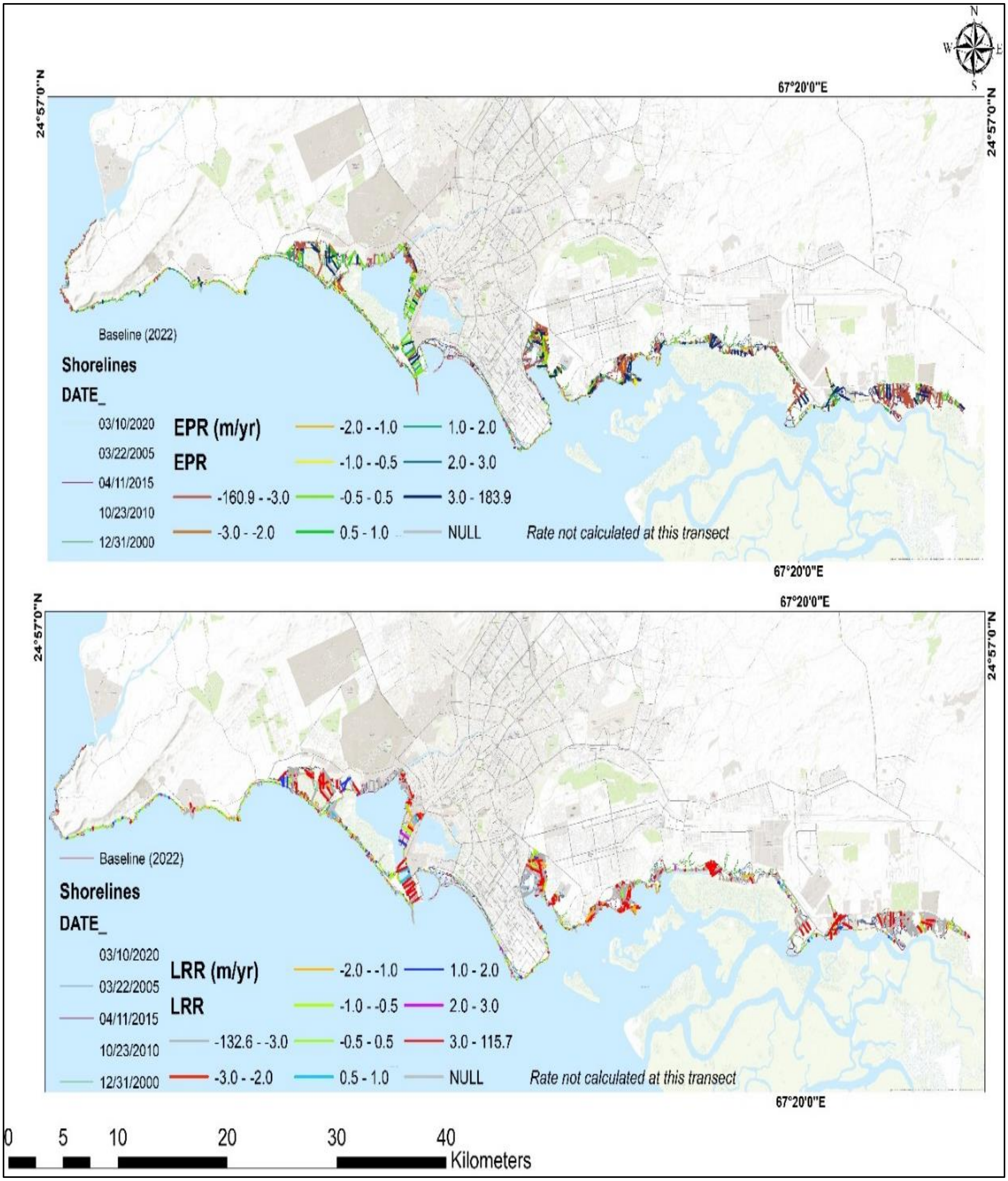

Fig 3(b): EPR and LRR

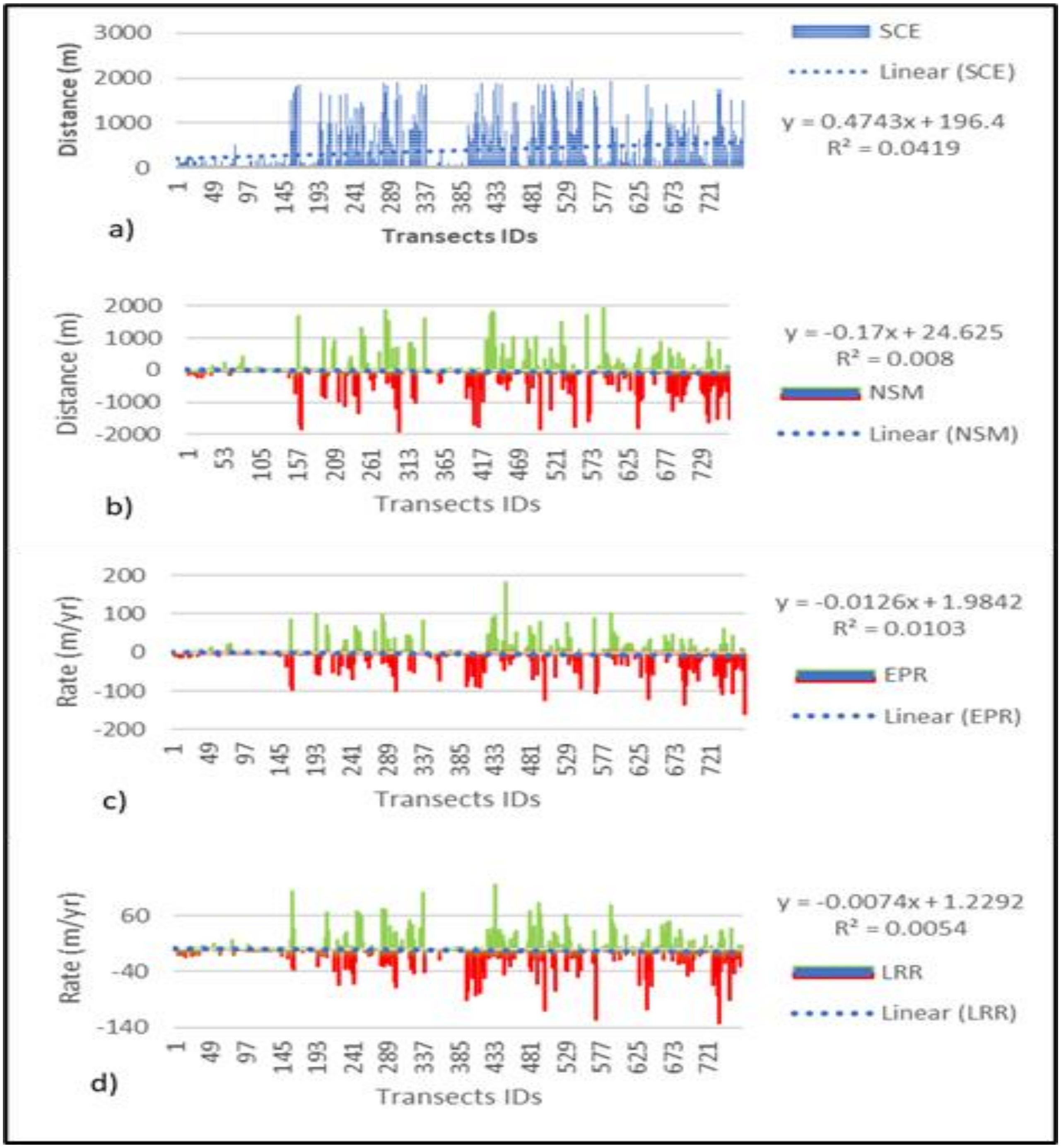

Fig 4: Erosion and Accretion (a) SCE (b) NSM (c) EPR (d) LRR

Fig 4 showed variations in erosion (in red) and accretion (in green) at each transect ID in the last two decades at the Karachi coast. Mostly the process of erosion (40.29 %) was observed than accretion (25.59 %).

SCE, Ibrahim Hyderi showed a maximum distance at transect ID: 536 about 1967.18 m. Bin Qasim town showed a minimum distance at transects ID: 693 about 0.27 m. NSM, Rehri showed accretional distance at transect ID: 590 about 1934.69 m. Machar colony showed erosional distance at transect ID: 301 about -1919.65 m. EPR, Bin Qasim town showed erosion at transect ID: 768 about -160.87 m/yr. Korangi town showed accretion at transect ID: 448 about 183.83 m/yr. LRR. Korangi town showed accretion at transect ID: 434 about 115.7 m/yr. bin Qasim town showed erosion at transect ID: 738 about -132.58 m/yr.

Table 3: Shoreline changes in each year

Years	SCE	NSM	EPR	LRR
	(m)	(m)	(m/yr.)	(m/yr.)
2000	0	0	0	0
2005	154	-75	-6	0
2010	301	-38	-3	-3
2015	419	-126	-8	-6
2020	629	13	1	1

Table 3 describes the shoreline changes each year. Shoreline changes represented erosion and accretion each year. Whereas most changes were observed in 2015. Figure 5 also shows how shorelines were changed in the past with average distance each year. It has been reported that most shoreline changes occur due to intense human interventions (Fan D *et al*., 2019).

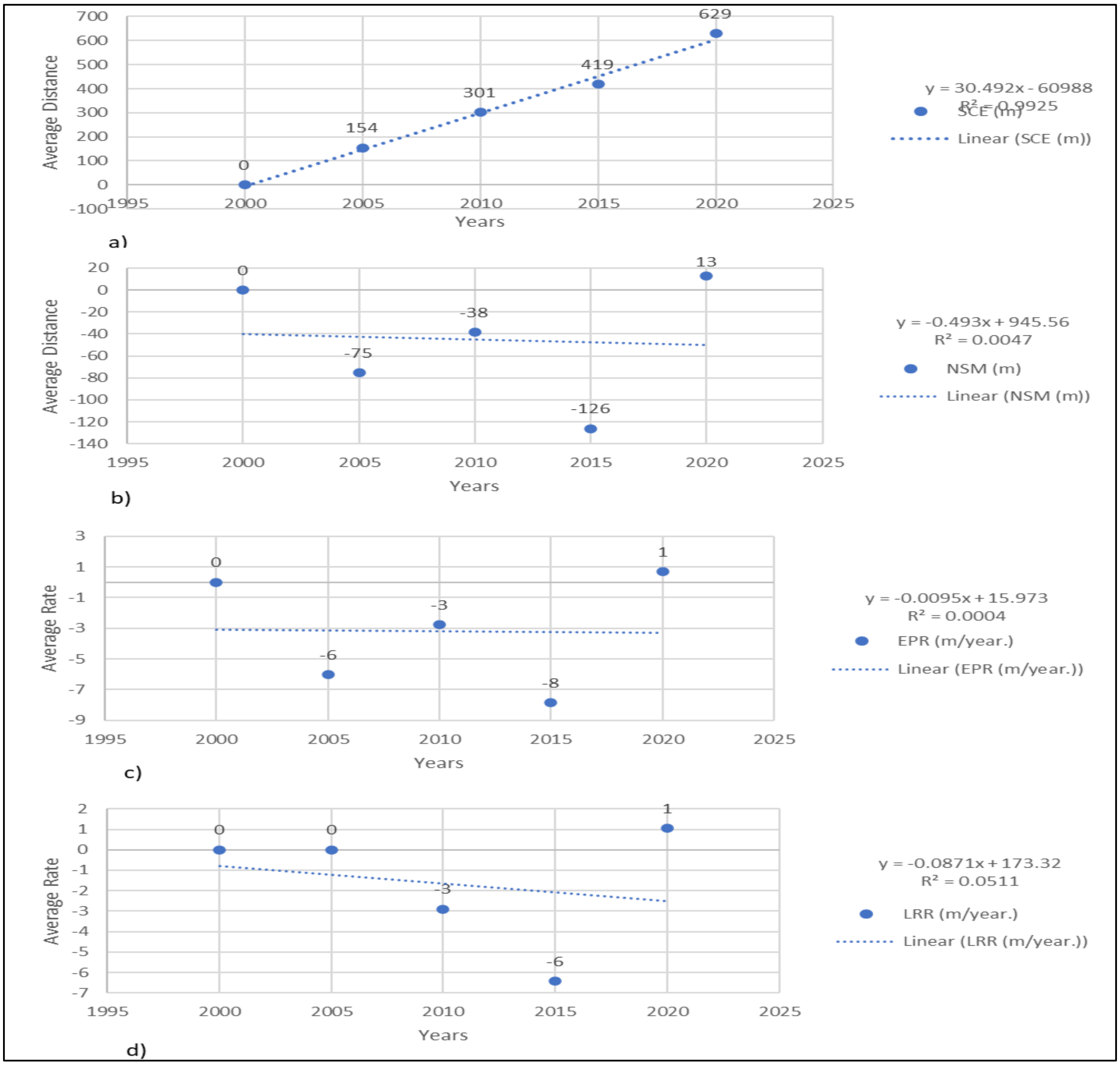

Fig 5: Shoreline changes in each year (a) SCE (b) NSM (c) EPR (d) LRR

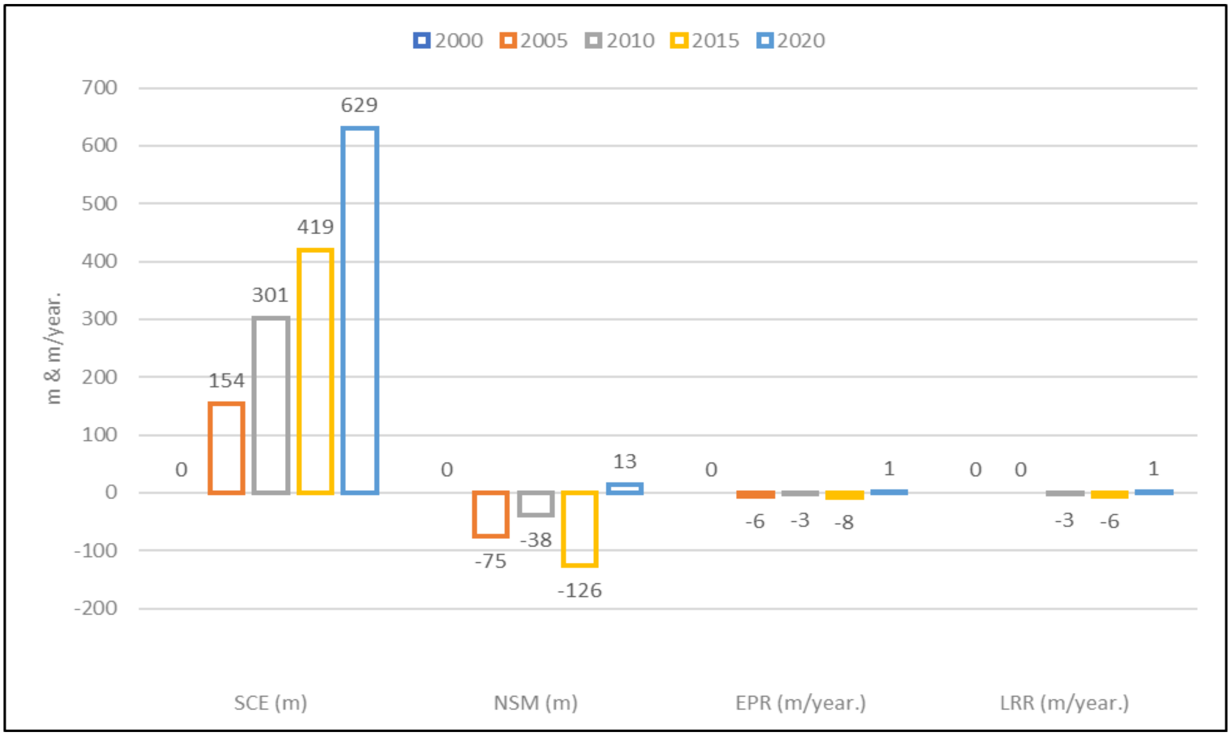

Fig 6: Shoreline changes in each year from 2000 to 2020.

Figure 6 shows shoreline changes in terms of SCE. NSM, EPR, and LRR from 2000 – 2020. It showed changes in shoreline at each year from 2000 to 2020. Mostly erosion was observed in 2015 and accretion was observed in 2020. Many changes were observed in 2020 due to intense human intervention (Fan D *et al*., 2019).

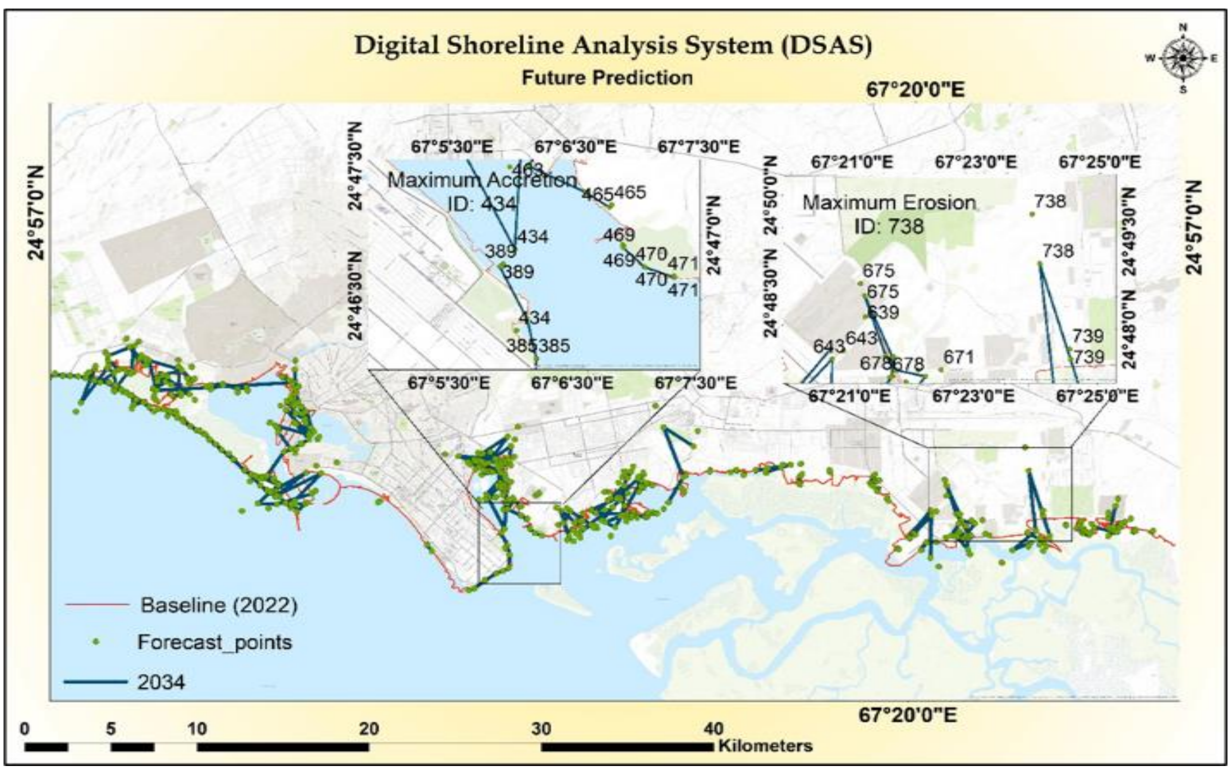

Fig 7 (a): Future Prediction for 2034 year

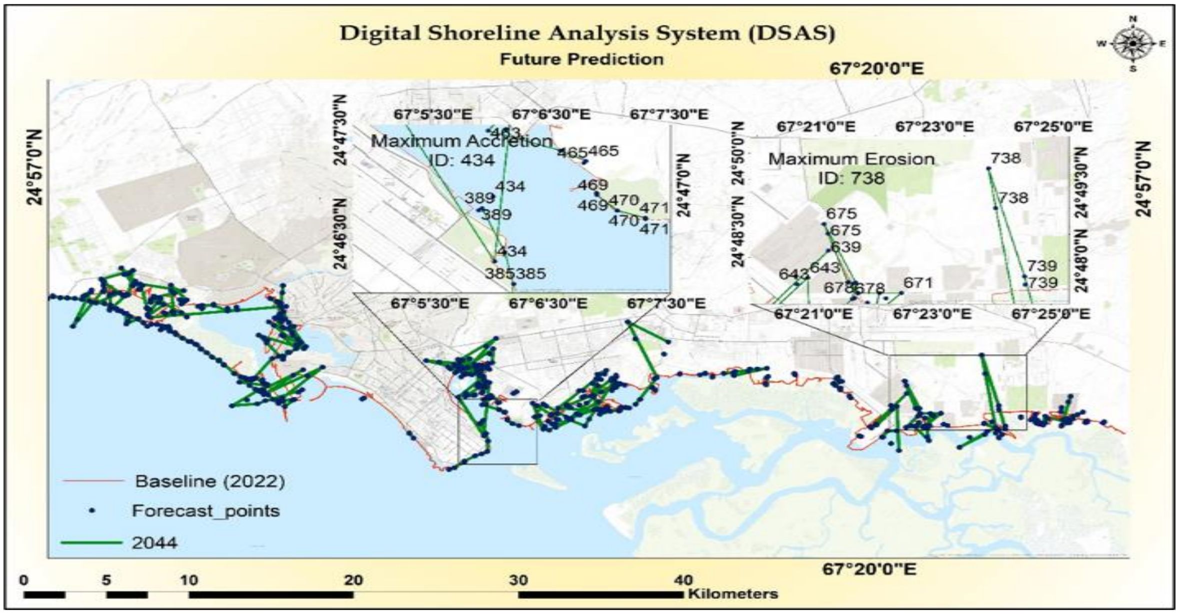

Fig 7 (b): Future Prediction for 2044 year

Fig 7 (a and b) shows the future prediction of shorelines for the years 2034 and 2044. It shows how shorelines will change in both years at an increasing rate. It showed average distance will be 42.80 m and 15.26 m for 2034 and 2044 respectively. Accretion will be 2899.704 m for 2034 and 4052.49 m for 2044 at the southern region of the coast. While erosion will be -2977.36 m for 2034 and -4399.34 m for 2044 at Bin Qasim town. The long-term morphological changes to the Karachi coast can be due to continued human intervention, and the removal of mangroves that ultimately affect on biodiversity and coastal defense (Brown *et al.*, 2018).

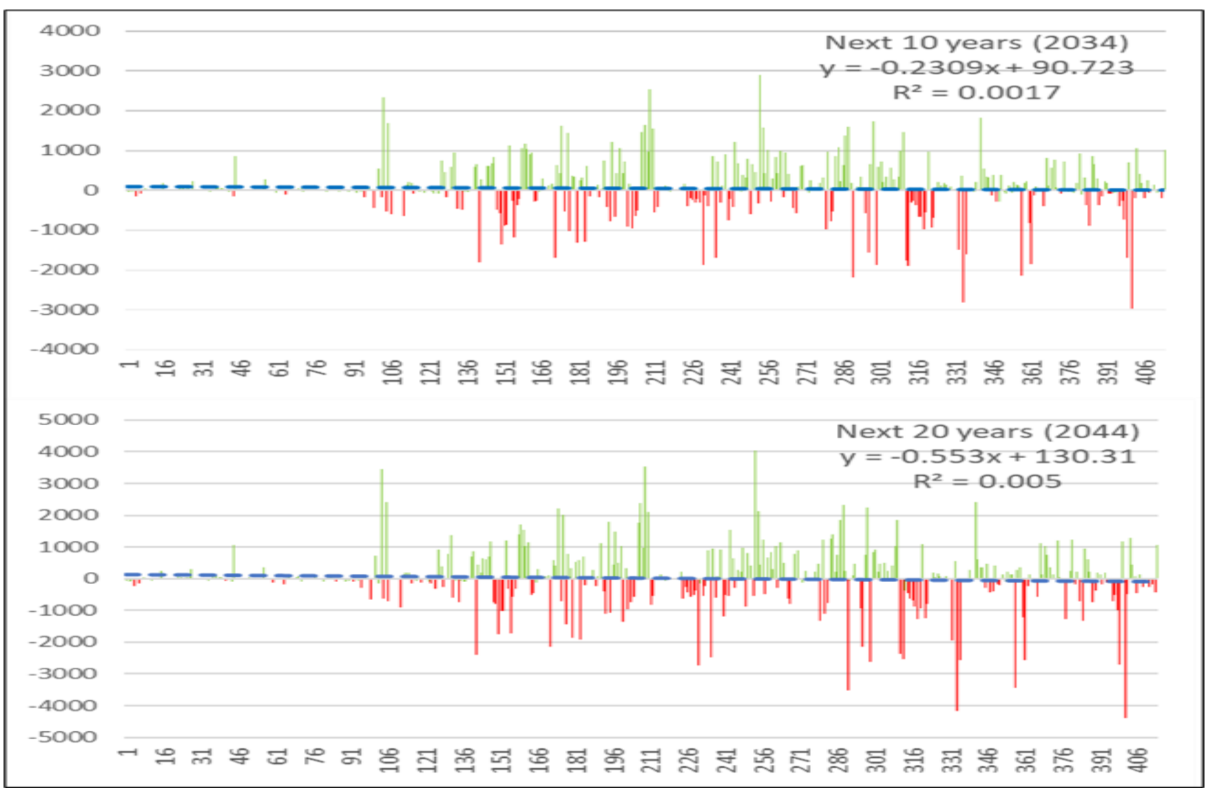

Fig 8: shows change at each transect (a) next 10 years (b) next 20 years

Fig 8 (a) shows shoreline changes at each transect for the next 10 years *i.e.*, 2034. It will represent both minimum and maximum distance at transect ID: 738 and 434 about -2977.36 m and 2899.7 m respectively.

Fig 8 (b) shows shoreline changes at each transect for the next 20 years *i.e.*, 2044. It will represent maximum and minimum distance at transect ID: 434 and 738 about 4052.49 m and -4399.34 m respectively.

DISCUSSION

In the previous three decades, morphological changes have been seen along the whole coastline region of Sindh (1989 - 2018). Using satellite pictures from 1989, 1999, 2009, and 2018, DSAS was utilized to identify coastline modifications such as LRR, LMS, and EPR. The whole coastline region of Sindh was shown to be more eroded than accreted. The greatest rates of erosion and accretion were noted in Kharo-Chann and Southern Karachi, respectively. In the Indus delta, erosion has been dominated, particularly in the Kharo-Chann region at a rate of -19.76 ± 0.55 m/yr. about -0.85 ± 0.45 m/yr. of erosion in Karachi, particularly in the eastern zone. At Karachi, the rate of accumulation was 8.34 ± 0.45 m/yr. (Kanwal *et al*., 2019).

At Karachi, morphological changes (accretion and erosion) were brought on by the rising sea level. The NOAA tides and currents were used to determine the rising sea level data, which showed 0.002 mm/year. growing at a rate of 0.0032 mm/year between 1916 and 2016. Sea level rise in 2020. Shorelines from Google Earth Pro were taken in 1985, 2001, 2003, 2010, and 2021 to show the accretion in the southern region and erosion in the eastern region, or DHA phase 6. Goth Manjar and the southern coastline region saw changes (Shafique *et al*., 1985)

Ahsanullah, *et al* (2021) have studied morphological changes along the Karachi coast using 50 years of time-scale data. They used an erase tool from ArcGIS software to measure Accretion and erosion rates at the coast. They have been analyzed that erosion and accretion were higher during 1979-2020 particularly erosion at Bin Qasim port due to the removal of mangrove cover.

Nazeer *et al* (2020) analyzed the Karachi coast vulnerability assessment using Landsat imageries from 1942-2018 through DSAS. They have concluded that 94% of the Karachi coast is highly vulnerable due to anthropogenic activities near the coast. Similarly, 24% of the transect showed erosion on the western side of the coast.

Shorelines are the boundary between land and sea. Shoreline changes are observed on the Karachi coast due to both natural and man-made factors. Both factors are running side by side (Shafique *et al*., 1985). Tidal currents, waves, sea level, and strong winds of southwest monsoon are the natural factors. On the other hand, anthropogenic factors are the construction or development of coastal areas for economic purposes, the building of residential areas due to increasing urbanization, and recreation, and the building or construction of jetties and ports (Ghazal *et al*., 2014).

Shorelines are a very important asset of the coastal area. These shorelines are protected by the construction of sea walls, dolos, jetties, bulkheads, etc. (Guthrie *et al*., 2023). Whereas, mangroves play an important role in protecting shorelines from erosion. Nowadays, the living shoreline concept plays a role in the nourishment of coasts. Wetlands also help to protect against shorelines.

Conclusion: In this study, DSAS model has been used to not only observe the changes during past years but also to make future predictions. Erosion is mostly observed in bin Qasim town while accretion is in the southern part. This study shows the comprehensive significance of remote sensing and GIS techniques in coastal risk assessment and prediction. Rapid development along the coast changes the morphology of the coast significantly. The net shoreline change (NSM and SCE) and rate of shoreline change (LRR and EPR) indicated that sea level rise due to anthropogenic activities is the greatest concern for the Karachi coast shortly.

REFERENCES

Afsar, S., Masood, H., & Bano, S. (2013). 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(2), 237-246.

Ahsanullah, Khan, S. H., Ahmed, R., & Luqman, M. (2021). Morphological change detection along the shoreline of Karachi, Pakistan using 50-year time series satellite remote sensing data and GIS techniques. *Geomatics, Natural Hazards, and Risk*, *12*, 3358-3380. https://doi.org/10.1080/19475705.2021.2009044

Appeaning Addo, K., Brempong, E. K., & Jayson-Quashigah, P. N. (2020). Assessment of the dynamics of the Volta river estuary shorelines in Ghana. *Geoenvironmental Disasters*, *7*(1), 19. https://doi.org/10.1186/s40677-020-00151-1

Biswas, A., & Islam, R. (2017). *Coastal Erosion and Accretion on the Island of Bhola, Bangladesh*.

Brown,MI.,Pearce, T., Leon, J.,Sidle, R.,& Wilson, R. 2018. Using Remote sensing and tranditional ecological Knowledge (TEK) to Understand Mangrove change on the Maroochy River, Queen's Land, Australia. Applied Geograph. 94:71-83. https://doi.org/10.1016/j.apgeog.2018.03.006

Camfield, F. E., & Morang, A. (1996). Defining and interpreting shoreline change. *Ocean & Coastal Management*, *32*(3), 129-151. https://doi.org/https://doi.org/10.1016/S0964-5691(96)00059-2

Esmail, M., Mahmod, W,H., & Fath, H. (2019). Assessment and Prediction of Shoreline Change Using Multi -Temporal Satellite Images and Statistics: A Case Study of Damietta coast, Egypt. *Applied Ocean Research*. Vol 82, 274-282. https://doi.org/10.1016/j.apor.2018.11.009

Fan D, Nagvyun, DV, Su, J, Bui, VV, Tran, DL.2019. Coastal morphological changes in the Red River Delta under increasing natural and anthropic stresses.Anthropocene Coasts 2(1): 15-71. https://doi.org/10.1139/anc-2018-0022

Ghazal, L., & Kazmi, S. J. H. (2014). Monitoring and measuring surface water in semi-arid environment using satellite data: A case study of Karachi. Journal of Basic & Applied Sciences, 10, 484

Gibb, J. G. (1978). Rates of coastal erosion and accretion in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *12*(4), 429-456. https://doi.org/10.1080/00288330.1978.9515770

Gómez-Pazo, A., Payo, A., Paz-Delgado, M., & Delgadillo Calzadilla, M. A. (2021). Open Digital Shoreline Analysis System: ODSAS v1.0. *Journal of Marine Science and Engineering*, *10*, 26. https://doi.org/10.3390/jmse10010026

Gopinath, G., Udayar Pillai, S., & N P, J. (2023). Long Term Shoreline and Islands Change Detection with Digital Shoreline Analysis Using RS Data and GIS. *Water*. https://doi.org/10.3390/w15020244

Guthrie, A., Stafford, S., Scheld, A., Nunez, M. K., & Bilkovic, D. M. (2023). Property owner shoreline modification decisions vary based on their perceptions of shoreline change and interests in ecological benefits. *Frontiers in Marine Science*, *10-2023*. https://doi.org/10.3389/fmars.2023.1031012

Hossain, M., Yasir, M., Wang, P., Ullah, S., Jahan, M., Hui, S & Zhoa, Z . (2021). Automatic Shoreline Extraction and Change Detection: A Study on the Southeast Coast of Bangladesh. Marine Geology . Vol 41 10668. https://doi.org/10.1016/j.margeo.2021.106628

Kanwal, S., Ding, X., Sajjad - Ph.D., M., & Abbas, S. (2019). Three Decades of Coastal Changes in Sindh, Pakistan (1989-2018): A Geospatial Assessment. *Remote Sensing*, *12*, 2020. https://doi.org/10.3390/rs12010008

Karamma, R., Hatta, M., Mustari, A., Manda, S. P., Ilda, A., & Ihsan, M. (2022). Numerical Modelling of Shoreline changes of Galesong, Takalar's coast. *IOP Conference Series: Earth and Environmental Science*, *1117*, 012067. https://doi.org/10.1088/1755-1315/1117/1/012067

Khan, R., H, N., & Thanappan, D. S. (2020). Shoreline Change Analysis along the Chennai Coast: Digital Shoreline Analysis System. https://doi.org/10.37896/jxu14.11/034

Khan, T. M. A., Razzaq, D. A., Chaudhry, Q.-U.-Z., Quadir, D. A., Kabir, A., & Sarker, M. A. (2002). Sea Level Variations and Geomorphological Changes in the Coastal Belt of Pakistan. *Marine Geodesy*, *25*(1-2), 159-174. https://doi.org/10.1080/014904102753516804

Kilar, H. (2023) Shoreline change assessment using DSAS technique: A case study on the coast of Meric Delta (NW Turkiye). *Regional Studies in Marine Science*, *57*, *2352-4855* https://doi.org/10.1016/j.rsma.2022.102737

Mentaschi, L., Vousdoukas, M. I., Pekel, J.-F., Voukouvalas, E., & Feyen, L. (2018). Global long-term observations of coastal erosion and accretion. *Scientific Reports*, *8*(1), 12876. https://doi.org/10.1038/s41598-018-30904-w

Narayana, A. C. (2016). Shoreline Changes. In M. J. Kennish (Ed.), *Encyclopedia of Estuaries* (pp. 590-602). Springer Netherlands. https://doi.org/10.1007/978-94-017-8801-4_118

Nazeer, M., Waqas, M., Shahzad, M., Zia, I., & Wu, W. (2020). Coastline Vulnerability Assessment Through Landsat and Cubesats in A Coastal Mega City. *Remote Sensing*, *12*, 749. https://doi.org/10.3390/rs12050749

NIAZ, N., ALEEM, S., KAZMI, J. H., & AFSAR, S. MAPPING OF HALOPHYTES AND CHANGE DETECTION ANALYSIS OF KARACHI COAST USING GIS AND REMOTE SENSING.

Shafique, S., Zia, S., & Nasar-u-Minallah, M. (1985). Mapping and Analyzing Coastal Morphological Changes due to Rising Sea Level: A Case Study of Karachi Port, Pakistan.

Siyal, A. A., Solangi, G. S., Siyal, Z.-u.-A., Siyal, P., Babar, M. M., & Ansari, K. (2022). Shoreline change assessment of Indus delta using GIS-DSAS and satellite data. *Regional Studies in Marine Science*, *53*,102405. https://doi.org/https://doi.org/10.1016/j.rsma.2022.102405

Thieler, ER., Himmlesloss, E.A., Zichichi, J.L & Ergul, A. (2019). The Digital Shoreline Analysis System (DSAS) version 4.0. An ArcGIS Extension for calculating shoreline change. US Geological Survey.