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Coastal Land Degradation, Seawater Intrusion and Delta Erosion Mechanism in Thatta and Sujawal Sindh Pakistan

Mukhtiar Ahmed Mahar[a], Sanaullah[b], Muhammad Farooq Buledi[c], Hameer Rebari[d], Aakash Bozdar[e], Abdul Rauf Odho[f], Abu Bakar Buledi[g], Abdul Khalique[h], Bakhtawar Shaikh[i]

[a] *Professor, Centre for coastal and Deltaic Studies, Sindh University Campus Thatta*
[b] *Department of Fisheries and Aquatic Sciences, University of Sindh Jamshoro, Sindh Pakistan*
[c] *Department of Coastal and Marine sciences, University of Sindh Jamshoro Sindh Pakistan*
[d] *Department of Coastal and Marine sciences, University of Sindh Jamshoro Sindh Pakistan*
[e] *Office of Deputy Commissioner Sujawal, Sindh Pakistan*
f Department of Coastal and Marine sciences, University of Sindh Jamshoro Sindh Pakistan
[g] *Department of Coastal and Marine sciences, University of Sindh Jamshoro Sindh Pakistan*
[h] *Department of Coastal and Marine sciences, University of Sindh Jamshoro Sindh Pakistan*
[i] *Department of Coastal and Marine sciences, University of Sindh Jamshoro Sindh Pakistan*

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Abstract

The coastal line of Thatta and Sujawal on the left and right sides of Indus River is about 185 km. Thatta district occupies 133 km and Sujawal coastal area approximately 52 km left side of the Indus River. It is too difficult to calculate the proper figure of seawater intrusion and coastal erosion at Thatta and Sujawal coastal area. However, according to revenue data of Thatta district about 52 dehs with area 170,198 acres are significantly affected by seawater intrusion. About 23,930 acres have been submerged in 14 dehs in Mirpur Sakro. In Ghorabari, 07 dehs have lost a total of 32,060 acres to the advancing sea, making the situation equally bad. The most damage has been felt in Keti Bunder, where 114,208 acres are currently underwater and an astounding 31 dehs have been impacted. The data received from district administration Sujawal shows 707,352 acres out of 1,805,617 are destroyed by seawater, and 81 dehs out of 256 dehs are partially eroded and flooded. The taluka wise details indicated as in taluka Kharo Chhan area has a saline potential under sea incursion with 31 dehs under seawater intrusion with incredible 173,210 acres (90.87%) out of total number 190,610 acres, only 17,400 (9.13%) acres of its barren land mass remain after in the taluka, the dehs are; Karfully, Leepto, Thori, Palki, Moosa, Authrki, Mutni, Lailpur, Chotkiyon, Takro, Rappar, Kenjhar, Padwari, Shore, Chorgujo, Joshewari, Ghorah, Meeran, Kun, Tango, Dhoodhati, Takro, Warasiyo, Kalikpot, Garho, Pakhiaro, Eracho, Nind, Adhyari, Lakhogot and Sultan Pur. Similarly, 34 Dehs and 534,142 acres of taluka Shah Bunder merged in seawater intrusion out of total number of 92 dehs and 735,634 acres, only 201,492 (27.39%) acres are productive in nature, the effected dehs are; Shah Bunder, Khumbhati, Ladhai pato, Qasim Soomro, Lari Sanhro, Suhpur, Thul, Jhalyoon, Leyari, Khanai, Warai, Allah Dino Wada, Pir Jani Shah, Gul Muhammad Jakhani, Ukerpur, Karsia, Wari, Nabi Bux Jakhani, Bagh Deh, Pehlo Hindo, Gujjo, Babli, Bagh Bahar, Takio Sanyo Shah,

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Dhatoria, Kathore, Purano Deero, Shah Mehro, Bagh Wah, Hajia, Imam Bux, Umer Jawan, Morlo and Bux Ali Kalhoro. In taluka Jati, 16 dehs out of 133 and 292254 acres out of 879,373 are merged currently under seawater, or 33.23%. Effected dehs of taluka Jati; Gandho, Sari, Lakha, Oranga, Chalko, Dhang, Mehri, Aapan, Lass, Gadap, Chan Belo, Chubatti, Jhim, Toberro, Hetman and Doohar. Therefore, the seawater affected the area in district Thatta about 688.766 km2 while in Sujawal district the area of about 2,862.81 km² damaged which was calculated from different data sources. This has usually occurred with 45 years period from 1979 to 2025, due to insufficient supply of freshwater and nutrient solid budget through the River Indus which is drastically affected by manmade interventions such as building of dams, barrages and diversions of freshwater through canals someone else sides. If situation remains same as it has been for the last 30 years, then the Indus delta will lose its actual position. The national and international authorities are urged to ensure the ecological flow of freshwater into River Indus from Kotri downstream to save the Indus delta ecosystem. The Sindh Forest department took some initiatives for mangrove plantation in Karachi and Thatta zones that is clear indication of restoration mechanism. But the situation at Sujawal and Badin is quite difficult which needs strong attention.

Keywords: Seawater intrusion, Sindh coastal zone management, Indus delta shrinking, costal land degradation, coastal land erosion.

1. Introduction

Coastal land degradation is a major environmental problem in the coastal regions of Sindh, Pakistan, particularly in District Thatta and Sujawal. The districts are particularly susceptible to changes in sea level, river discharge, tidal dynamics, and sediment supply because of its large tidal creeks, mangrove forests, mudflats, agricultural areas, and low-lying coastal towns (Siyal., 2017). Changes in the natural sedimentary and hydrological processes of the Indus Delta are directly related to the degradation of coastal land. The Indus River once transported freshwater and sediment to the delta, maintaining soil fertility, sustaining mangrove habitats, and counteracting the effects of saltwater. However, the decline and seasonal variability in freshwater discharge as well as the sediment retention brought on by upstream dams and barrages have compromised the delta's natural capacity to maintain its ecological and geomorphological stability (Siyal., 2018). The coastal environment has become more vulnerable in recent decades due to the combined effects of decreased freshwater supply from the Indus River, shifting climatic conditions, sea level rise, and human activity. Land degradation, soil salinization, seawater intrusion, coastline erosion, and the decline of natural ecosystems and agricultural production are all caused by these processes. Therefore, evaluating environmental change and creating sustainable coastal management plans in District Sujawal require an understanding of the relationships between coastal land degradation, seawater intrusion, and erosion mechanisms.

1.1. Sujawal District

The Sujawal district is situated in Sindh, Pakistan, in latitude 68°4′45” E and longitude 24°36′11” N at the end of the Indus River. On October 12, 2013, it attained full district status. It is located at the point where the Indus River empties into the Arabian Sea on its left bank. The Sujawal district covered roughly 55 kilometers of coastline (Siyal, 2018). The district consists of 5 talukas (Fig.1). Gaghiar, Khar, Wari, and Khajar are the district's four major creeks. These streams are fruitful and support mangrove forests, which are the last crossing site of Sir Creek at the Pakistani Indian border and a natural breeding ground for hundreds of marine creatures. The six-hour high tidal motions go downstream toward the sea and toward marine water on mudflats twice in a 24-hour period. Its high-water elevation, which happens in line with the gravity of the earth and moon, is well known. Sujawal district's coastal environment is dominated by the network of Indus River tributaries that connect to the Arabian Sea on the left bank of the Indus delta eco-region, which acts as a natural spawning ground for thousands of marine and non-marine organisms. The marine biodiversity of Sindh's coastal regions in general and Sujawal district in particular is seriously threatened by climate change, sea intrusions, reduced Indus River flows, and excessive use of natural living and non-living resources.

In District Sujawal, saline water from the Arabian Sea seeps into tidal creeks, coastal aquifers, and low-lying agricultural areas, posing a major hydrogeological and environmental problem (Khatri, 2025). This process occurs when the natural balance between freshwater and saltwater is disturbed, particularly because of tidal flooding, reduced

river discharge, excessive groundwater extraction in some places, and increasing sea levels. Intrusion of saline water degrades groundwater quality and may make it unsafe for drinking, irrigation, or animal consumption. Furthermore, salt accumulation in agricultural soils affects seed germination, restricts plant growth, reduces crop yields, and may finally render productive land unsuitable for cultivation. In areas with shallow groundwater tables, high evaporation rates can further concentrate salts on the soil's surface, aggravating soil salinization and agricultural degradation (Solangi et al., 2019). These effects put rural livelihoods in jeopardy and make coastal communities more vulnerable since they rely on fertile land and freshwater supplies.

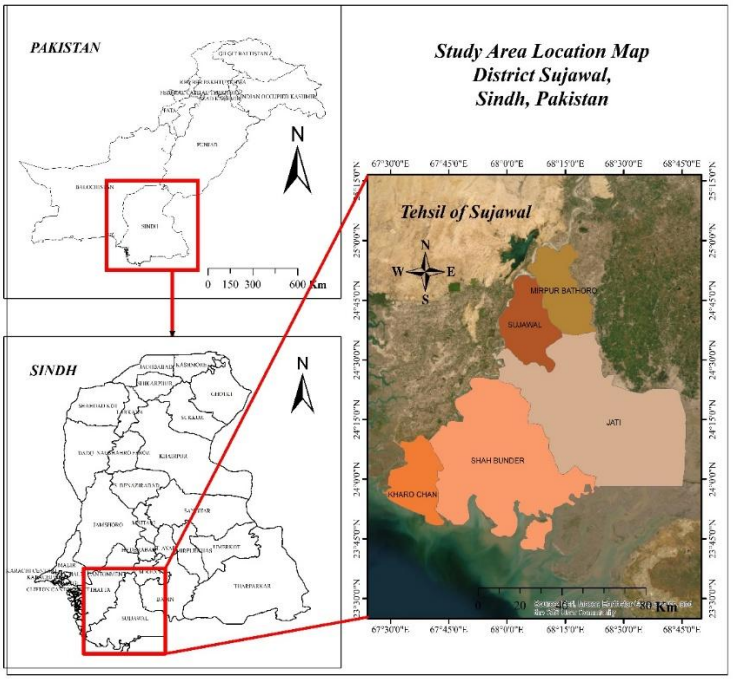


Fig.1. Map of District Sujawal showing its talukas

1.2. Thatta district

Thatta district is located between 23° 48” 44ˡ to 25° 26” 35ˡ North latitudes and 67° 20” 48ˡ to 68° 44” 52ˡ East longitudes. It is one of Sindh Province's most productive districts in terms of trade, industries, livestock, fisheries, agriculture, and sociocultural aspects. The more than 0.1 million people who live along a long coastal taluka, namely Mirpur Sakro, Ghorabari, and Keti Bundar of Thatta district, are affected by a number of hydro-meteorological hazards, including sea level rise, coastal erosion, frequent cyclones, degradation of the Indus River delta, sea intrusions, soil degradation, floods, droughts, and an overall loss of once a very productive ecosystem due to changing climate patterns. Coastal and marine biodiversity is thought to be negatively impacted by pollution, freshwater scarcity, climate change, and the local condition of natural resources (Rabani, 2018). In Sindh's coastal regions, sudden and intense rainfall patterns during the past few decades have often significantly changed the hydrological cycle and the morphology of the shoreline. Even while rising earth's surface temperatures are altering wind and rain patterns globally, coastal towns are more vulnerable due to sea level rise, sea invasions, and warming ocean water bodies.

In Pakistan, severe monsoon rains, powerful storms, and super floods in 2010 resulted in substantial property damage and human casualties during the preceding 20 years. There are severe food and water shortages as a result of marine invasions alone destroying millions of acres of agricultural land and water resources in the area. Despite all of this, Pakistan's climate migrant issue is terribly deficient in specific governance structures and policy frameworks.

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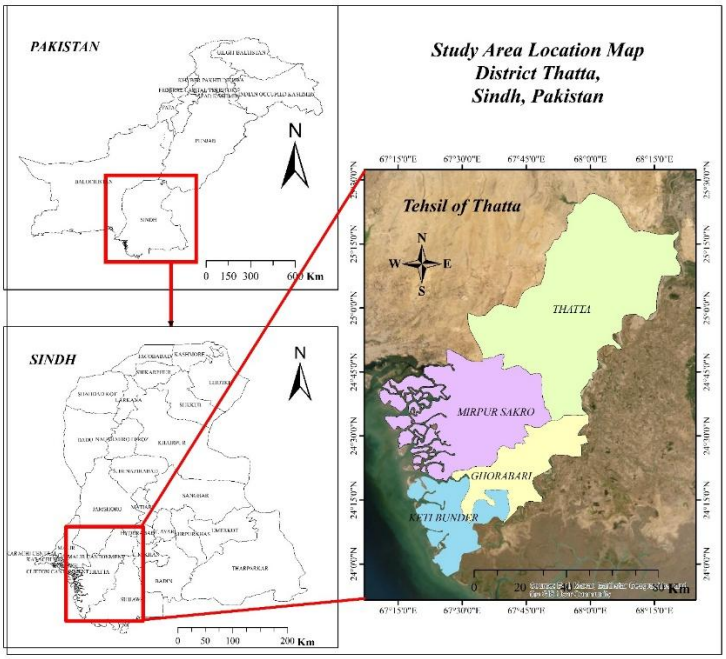


Fig. 2. Map of Thatta District showing 4 tehsils

Coastal erosion is another important element contributing to environmental degradation in the coastal zone of Sujawal and the Indus Delta. Soil and silt are removed and redistributed by waves, tidal currents, river movement, and other hydrodynamic processes. The sediment transported by the Indus River contributes to the formation and maintenance of deltaic landforms, coastal wetlands, and mudflats in the natural world. However, reductions in freshwater discharge and sediment delivery have hindered the natural replenishment of damaged coastal areas. Therefore, waves, tidal currents, and storm surges can remove material faster than is deposited, leading to shoreline erosion, the loss of intertidal ecosystems, and increased exposure of coastal communities and agricultural land to marine processes. Waves, tidal currents, and storm surges can therefore remove material faster than is produced, leading to coastline retreat, the loss of intertidal ecosystems, and increased exposure of coastal communities and agricultural land to marine processes. Studies using satellite imagery and GIS techniques have documented significant coastline changes and mangrove destruction in a few Indus Delta locations, underscoring the importance of salinity and sediment dynamics in influencing coastal vulnerability (Aeman et al., 2023). Coastal land deterioration and seawater intrusion are strongly related to the erosion process in Sujawal. Seawater can enter farther inland through surface channels and permeable subsurface formations as erosion eliminates protective sediments and modifies the architecture of tidal creeks and coastal borders. However, mangrove vegetation and other natural coastal barriers that aid in stabilizing sediments and lowering wave energy can be harmed by saline inundation. Therefore, shorelines may become more susceptible to erosive processes due to mangrove loss or degradation, creating a violent cycle of vegetation loss, sediment instability, and land retreat. Sea level rise and changing storm patterns may make these processes worse, especially in low-lying deltaic areas. The combined effects of erosion, seawater intrusion, and coastal land degradation have serious social, economic, and environmental repercussions for District Sujawal. These processes put freshwater supplies, fisheries, mangrove ecosystems, agricultural production, biodiversity, and the security of coastal people at danger.

The current study attempts to understand the mechanisms and geographical patterns of coastal erosion, seawater intrusion, and coastal land degradation in District Sujawal, Sindh, Pakistan. It examines the primary natural and man-made drivers of these environmental changes, assesses the potential impacts on soil conditions, groundwater resources, shoreline stability, and coastal ecosystems, and identifies potentially vulnerable areas. The findings may provide a scientific basis for developing plans for sustainable coastal management, improving freshwater resource management, restoring mangrove ecosystems, protecting agricultural land, and strengthening local communities' resistance to ongoing environmental changes.

2. Materials and Methods

A quantitative, spatial, and field-based study approach were used to evaluate the land degradation, seawater intrusion, and shoreline erosion in Thatta and Sujawal Districts. The proposed data was collected through focus group discussions (FGDs), key informant interviews (KIIs) and organization of workshop (OW), remote sensing (RS), GIS, laboratory analysis, and statistical techniques to identify environmental changes and their potential links to saline-water incursion. By combining field-based observations, satellite imaging, geographic information systems (GIS), and relevant environmental data, it is possible to evaluate changes in land cover, soil salinity, and coastal position over time (Siyal., 2017; Siyal, 2018; Sloangi et al., 2019; Amed et al., 2024). The technique seeks to differentiate between land deterioration linked to seawater intrusion, degradation of coastal land and erosion mechanism which can happen inland through tidal floods, saline groundwater, and the flow of saltwater through surface-water channels, and direct coastal erosion brought on by coastline and tidal-channel modifications. Because soil salinization and coastline retreat are connected but represent distinct environmental processes, this distinction is crucial. The recommended sources of satellite data were documented through Google Earth Engine, Copernicus Data Space, or USGS Earth Explorer. Information on dehs (revenue villages) affected by seawater intrusion was supplied by the District Administration in Sindh, Pakistan. The best line of action was to formally request in writing from the Deputy Commissioner (DC) of the relevant district the documents held by the revenue, agriculture, irrigation, and disaster management departments.

3. Results and Discussions

Seawater intrusion is one of Pakistan's most damaging environmental problems, which mostly affects the coastal districts of Thatta, Sujawal, and Badin in Sindh (Dawood and Ehsan, 2024). The National Institute of Oceanography (NIO) held an international symposium on seawater intrusion, which affects coasts, ecosystems, and livelihoods, at a nearby hotel on Tuesday. These were some of the key themes discussed (Bablani, 2015; *DAWN*, 2015). Thatta district occupies 133 km and Sujawal coastal area approximately 52 km left side of the Indus River. According to revenue data of Thatta district about 52 dehs with area 170,198 acres are significantly affected by seawater intrusion. About 23,930 acres have been submerged in 14 dehs in Mirpur Sakro. In Ghorabari, 07 dehs have lost a total of 32,060 acres to the advancing sea, making the situation equally bad. The most damage has been felt in Keti Bunder, where 114,208 acres are currently underwater and an astounding 31 dehs have been impacted. The data received from district administration Sujawal shows 707,352 acres out of 1,805,617 are destroyed by seawater, and 81 dehs out of 256 dehs are partially eroded and flooded. The taluka wise details indicated as in Taluka Kharo Chhan area has a saline potential under the incursion of seawater with 31 dehs under seawater intrusion with incredible 173,210 acres (90.87%) out of total number 190,610 acres, only 17,400 (9.13%) acres of its barren land mass remain after in the taluka. The distribution of land covers in the tidal floodplain, which has a total size of 4,695 square kilometers (469,500 hectares). It indicates the proportion of area that is covered by water, barren land, and mangroves. The entire water area is 136,100 hectares, or 1,361 square km (Table 3 to 6). It accounts for about 28.99% of the total tidal floodplain. This area may have creeks, tidal channels, and other bodies of water. The tidal floodplain is mostly made up of barren ground, covering 3,005 square kilometers, or 300,500 hectares. It accounts for 64% of the total area. This implies that most of the floodplain is classified as barren or unvegetated land. Mangroves cover 329 square kilometers, or 32,900 hectares. They comprise 7.01% of the total tidal floodplain. Mangroves are essential coastal ecosystems that provide habitats for wildlife, protect shorelines from erosion, and support fisheries. The total area is 4,695 square kilometers, or 469,500 hectares.

3.1. Seawater Intrusion and Degradation of Groundwater

According to one of the studies, subsurface seawater intrusion affects approximately 88% of the Indus delta (Solangi et al., 2023). Seawater from the Arabian Sea has seeped into the coastal sediments of southern Sindh, Pakistan, because of extremely little rainfall in the region and insufficient freshwater flow downstream of the Kotri dam built on the Indus River. Additionally, the environment and ecosystem in the area have been harmed and the coastal aquifer system has become alarmingly contaminated because of significant seawater mixing with groundwater (Bablani and Soomro, 2006). Additionally, the research area's wells close to Thatta and Sujawal towns showed the effects of subsurface seawater intrusion. Nonetheless, the subsurface seawater intrusion still has little effect on around 12% of the delta. Seawater intrusion has been investigated by applying isotopic, chemical and geophysical techniques. Seawater intrusions have been detected collecting water samples at depths of 20, 35 and 50 ft vertically. The groundwater

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samples were examined from certified laboratory of Isotope Application Division, PINSTECH (Islamabad). Seawater contamination in groundwater chemistry as Oxygen (^{18}O) and Hydrogen (^{2}H) as well as Chlorine (Cl) and Bicarbonates (HCO_3) values were detected (Table 1). Relative mixing of seawater into groundwater ranges in percentage are given in table given below. The increase of level percentage is gradually towards coastal land during the drought season vertically and horizontally especially peak drought months (May, June and July). While the chemical values of groundwater aquifers decrease after rains and floods. The increase of level percentage is gradually towards coastal land during the drought season vertically and horizontally especially peak drought months (May, June, July and August). While the chemical values of groundwater aquifers decrease after rains and floods. More than 1,200,000 acres of the Indus delta are at risk of water intrusion, according to a survey conducted by the Board of Revenue (Chandio et al., 2011).

Table 1. Analysis of ground water contamination of seawater and freshwater with percentage.

S. No.	Location/ Area	Sample collection at soil depth 20-30 ft (seawater contamination in percentage per 1liter (%)	Sample collection at soil depth 31-40 ft (seawater contamination in percentage per liter (%)	Sample collection at soil depth 41-50 ft (seawater contamination in percentage per 1liter (%)
1	Juho	1-19	3-49	17-92%
2	Village Akhtar Samo	1.4- 75	1.6-61	22-56
3	Garho	2-88	1.8- 34	23-72

Figure 3 illustrates the objective of the map, which compares changes in river and coastal landscapes between 1979 and 2015. Both pictures show changes in the river system and coastline, with a noticeable displacement of about 2 km. To determine the exact amount and direction of land growth or coastal erosion, the two images would need to be georeferenced, and their shorelines compared using the same reference system. The distribution of water, mangroves, and bare land in a coastal area in 2025 is depicted in Figure 4. distinct land-cover categories are depicted by distinct colors in this categorized satellite image. Rivers, creeks, tidal channels, and other bodies of water are represented by blue. Water is flowing through and around the coastal terrain, as seen by the vast blue network. depicts mangrove vegetation that grows next to tidal streams and around the coast. Mangrove cover is indicated by green patches, especially in the western and central regions of the map. Land with little or no visible vegetation is represented by pale yellow. Pale yellow represents land with little vegetation, such as exposed mudflats, sandy surfaces, or barren coastal areas. It covers a significant area of the mapped region. According to one of the studies of seawater intrusion, more than 2.95 million acres of agricultural land up to 70 km upstream effected from due to Tidal Link Canal, meanwhile, using satellite data, an average erosion rate of 30 m year-1 was determined for the tidal connection canal for the previous 17 years (Khaskheli et al., 2018). However, sea water intrusion and coastal erosion, which have a catastrophic impact on the environment and civilization close to the Left Bank Outfall Drain location, pose a serious threat to the entire lake ecology (Khaskheli et al., 2018). Negative effects of seawater intrusion include reduced cultivated area, low agricultural output, decreased livestock productivity, and a decrease in fishing quantity (Jagirani et al., 2021). The present findings are confirmed.

Table 2. The data took from GIS shows the Sujawal coastal area occupied by seawater, mangrove and barren land.

S. No	Land cover Sujawal	Area sq km	Hectors	Percentage % at tidal plain
1	Water	1361	136100	28. 99
2	Barren land	3005	300500	64.00
3	Mangroves	329	32900	7.01
4	Total area of tidal floodplain	4695	469500	100

Table 3. The data took from GIS shows the Thatta coastal area occupied by seawater, mangrove and barren land.

Thatta	Year	year
Classes	1990	2026
Barren Area sq.km	439.2571	291.0147
Water sq.km	212.5459	264.5811
Greenery sq.km	157.5746	252.647
Settlement sq.km	1.282905	2.446524

Table 4. Temporal variations in Landsat Satellite imagery between 1979, 2015 and 2025.

Land use under:	Land Utilization Area (ha) 1979	Total Geographical Area (%) 1979	Land Utilization Area (ha) 2015	Total Geographical Area (%) 2015	Land Utilization Area (ha) 2025	Total Geographical Area (%) 2025
Vegetation	232,235	26.5	241,379	28	315,373	36.6
Barren land	543,721	63.11	492,222.3	57.1	453,884	52.7
Water bodies	85464.8	9. 92	127,819.5	14.9	92,163.2	10.7
Total	861,420.8	100	861,420.8	100	861,420.8	100

Table 5. Details of Dehs Under Sea Intrusion in Taluka Kharochan District Sujawal

S. No.	Total area of Taluka	Total area affected under sea	Total No. of Dehs in Taluka	Total No. of Dehs affected under sea	Name of Deh under sea intrusion	Fully affected / partially affected
01	190610	173210-17	31	31	Karfully	Partially
02					Leepto	Partially
03					Thori	Partially
04					Palki	Partially
05					Moosa	Partially
06					Authrki	Partially
07					Mutni	Partially
08					Lailpur	Partially
09					Chotkiyon	Partially
10					Takro	Fully
11					Rappar	Partially
12					Kenjhar	Fully
13					Padwari	Partially
14					Shore	Partially
15					Chorgujo	Partially
16					Joshewari	Fully
17					Ghorah	Fully
18					Meeran	Fully
19					Kun	Partially
20					Tango	Fully
21					Dhoodhati	Fully
22					Takro	Fully
23					Warasiyo	Fully
24					Kalikpot	Fully
25					Garho	Fully
26					Pakhiaro	Fully
27					Eracho	Fully
28					Nind	Fully
29					Adhyari	Fully
30					Lakhogot	Fully
31					SultanPur	Partially

Table 6. Details of Dehs Under Sea Intrusion in Taluka Shah Bunder District Sujawal

S. No.	Total area of Taluka	Total area affected under sea	Total No. of Dehs in Taluka	Total No. of Dehs affected under sea	Name of Deh under sea intrusion	Fully affected / partially affected
01.	735634.36	5,34142-11	92	34	Shah Bunder	Fully
02.					Khumbhati	Fully
03.					Ladhai pato	Fully
04.					Qasim Soomro	Fully
05.					Lari Sanhro	Fully
06.					Suhpur	Fully
07.					Thul	Fully
08.					Jhalyoon	Fully
09.					Leyari	Fully
10.					Khanai	Fully

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S. No.	Total area of Taluka	Total area affected under sea	Total No. of Dehs in Taluka	Total No. of Dehs affected under sea	Name of Deh under sea intrusion	Fully affected / partially affected
11.					Warai	Fully
12.					Allah Dino Wada	Partially
13.					Pir Jani Shah	Partially
14.					Gul Muhammad Jakhani	Partially
15.					Ukerpur	Partially
16.					Karsia	Partially
17.					Wari	Fully
18.					Nabi Bux Jakhani	Partially
19.					Bagh Deh	Partially
20.					Pehlo Hindo	Partially
21.					Gujjo	Partially
22.					Babli	Partially
23.					Bagh Bahar	Partially
24.					Takio Sanyo Shah	Partially
25.					Dhatoria	Partially
26.					Kathore	Partially
27.					Purano Deero	Partially
28.					Shah Mehro	Partially
29.					Bagh Wah	Partially
30.					Hajia	Partially
31.					Imam Bux	Partially
32.					Umer Jawan	Partially
33.					Morlo	Fully
34.					Bux Ali Kalhoro	Partially

Table 7. Details of Dehs under Sea Intrusion in Taluka Jati District Sujawal

Sr. No.	Total area of Taluka	Total area affected under sea	Total No. of dehs in Taluka	Total No. of Dehs affected under sea	Name of Deh under sea intrusion	Fully/ Partially affected
1	879373	292254	133	16	Gandho	Fully
2					Sari	Partial
3					Lakha	Partial
4					Oranga	Partial
5					Chalko	Fully
6					Dhang	Partial
7					Mehri	Partial
8					Aapan	Partial
9					Lass	Partial
10					Gadap	Partial
11					Chan Belo	Partial
12					Chubatti	Partial
13					Jhim	Partial
14					Toberro	Partial
15					Hetman	Partial
16					Doohar	Partial

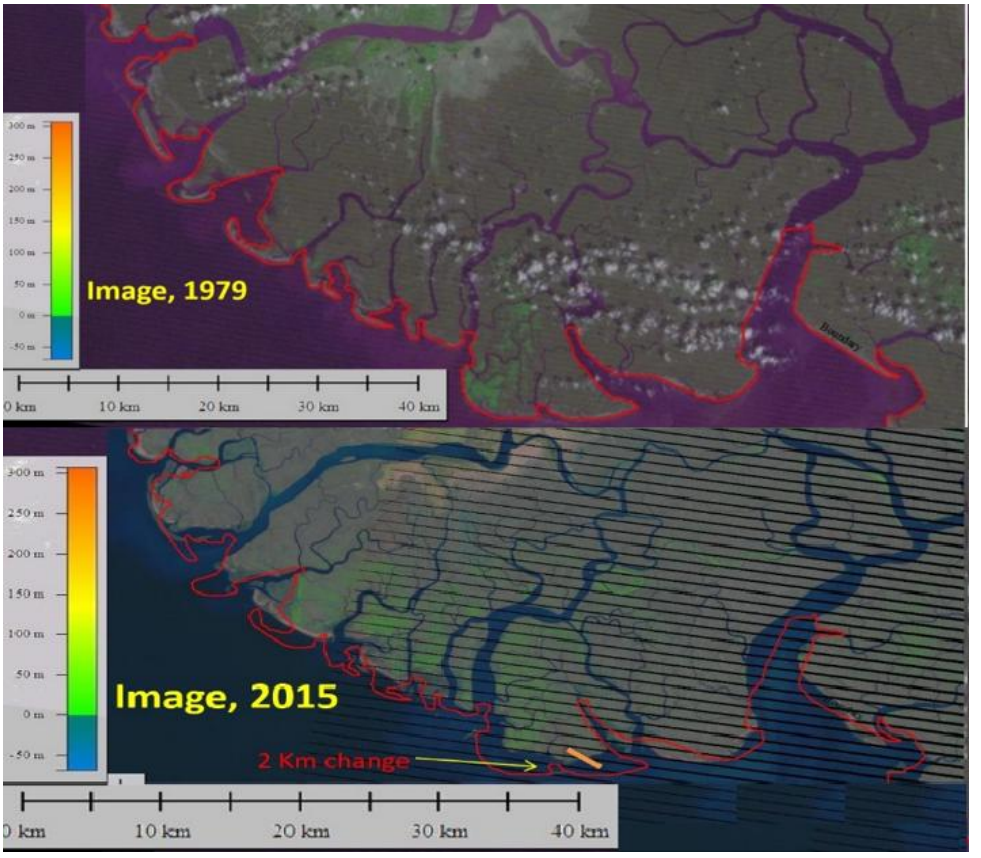


Fig.3. Sat light images show difference of 2 km coastal land erosion in Thatta and Sujawal

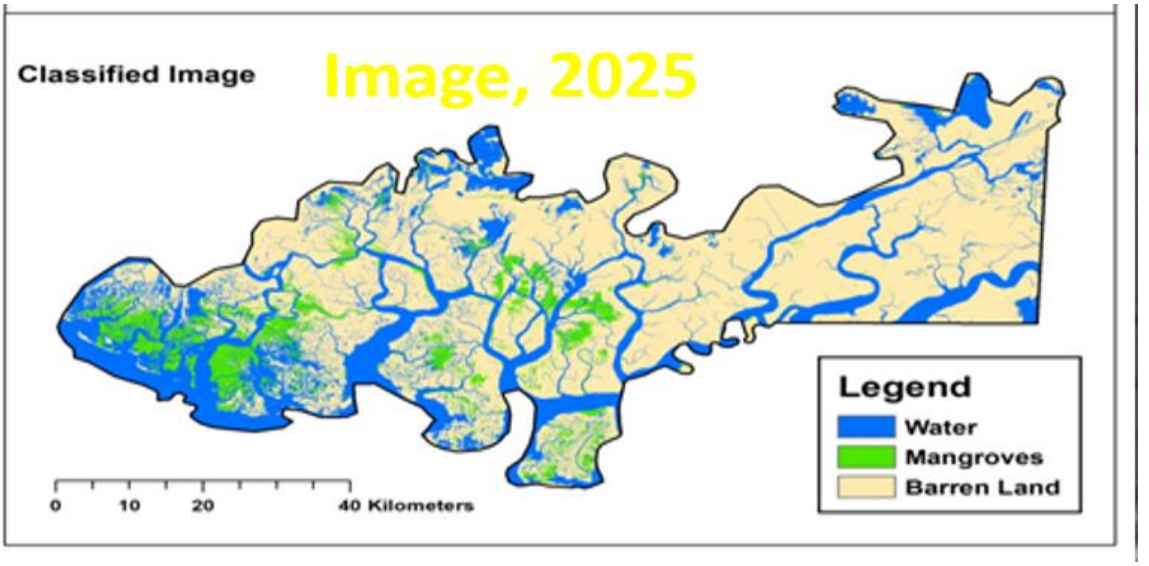
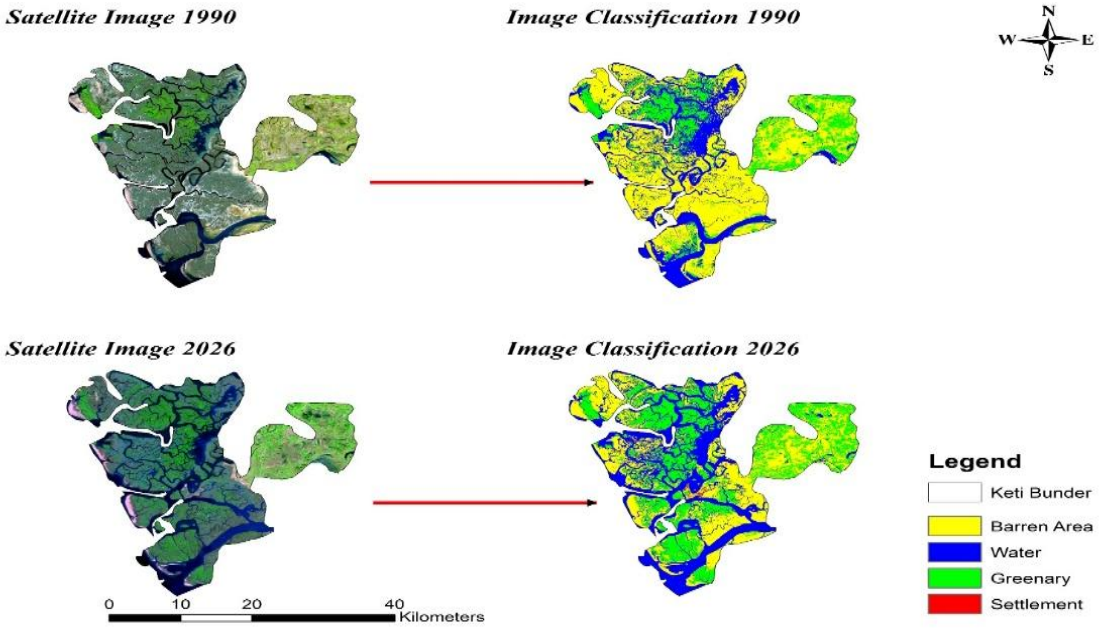


Fig. 4. Present position of coastal zone in Sujawal district during 2025.

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4. Conclusion

The Indus Delta, a coastal area, is closely connected to the flow of the Indus River. The Indus River's silt depositional system controls erosion and halts degradation. The Indus delta ecology is being restored by freshwater flow and siltation, which fertilize mangrove forests and other species. Man-made projects like dams and barrages had a substantial impact on the amount of siltation required. Consequently, highly salinized seawater seeped into the land. A significant amount of agricultural land becomes barren due to the concentration of salt. Continuous data collection visits have been carried out since 2021 to ascertain the actual level of infrastructure damage and agricultural land degradation. A questionnaire was developed to collect data from farmers, landowners, tapedars of deh, and mukhtiarkars of talukas. The Dehs maps were compared with new digital satellite maps. The primary and secondary data of land degradation and marine encroachment were analyzed. During the current investigation, it was discovered that coastal mudflats cracked in several different places. Mangrove trees in deep rivers topple due to tidal action during the drought era. Mangroves need 40–70% of soft loam silt's adhesive property, which can be found in sources of flooded water. The loam silt not only binds and repairs mudflats but also promotes the development of mat-shaped mangrove spats. The freshwater flow from Kotri downwards may need to be regularized for the health of Sindh's coastal ecology. It is determined which mudflats are suitable for mangrove plantations in terms of the environment. The first phase of the plantation will start in March 2023 in collaboration with the Sindh Forest Department. While the local population and university students can participate in direct seed sapling at mudflats, nurseries are also built to cultivate the seedlings for one to three months prior to planting them in suitable spots. Samples of soil silt and water were collected from the project sites. The most recent digital meters, equipment, standard chemical kits, glassware, plastic ware, nets and gears, and surgical instruments were also used to optimize the results. The percentage of soil sediments was as follows: 40–45% for silt clay, 30–35% for sandy clay, 20–25% for fine sand, and 10–15% for miscellaneous. When mudflats were visible, soil samples were taken using a drill machine from creeks and mudflats at a depth of two to three feet. The quality of the soil was determined to be appropriate for halophyte and mangrove growth. Assessing the quality of the soil (sediment) is crucial for the growth and support of the organisms that thrive in specific environments. Temperature (12-26°C), pH (7.4-8.2), alkalinity (208-275 mg/l), carbon (0.64-1.1 wt%), sodium (3.36-7.12 wt%), magnesium (1.71-1.9 wt%), potassium (0.7-1.95 wt%), calcium (3.9-7.93 wt%), silicon (8.6-18.24 wt%), iron (2.8-8.04 wt%), aluminium (1.8-2.51 wt%), and sulphur (0.2-0.59 wt%). The percentages for silt clay (41–43), sandy clay (10–36), and fine sand (35–48) were displayed (Imad et al., 2024). Ensuring that everyone has access to affordable, safe drinking water is one of the Sustainable Development Goals (SDGs). The decline of coastal aquifer

water quality is a major worldwide concern, particularly in the Indus River delta. Therefore, by analysing the regional variability of different groundwater quality parameters, it is useful to monitor and manage the susceptibility of groundwater pollution (Solangi et al., 2017).

5. Suggestions

Therefore, the seawater affected the area in district Thatta about 688.766 km^2 while in Sujawal district the area of about 2,862.81 km² damaged which was calculated from different data sources. This has usually occurred with 45 years period from 1979 to 2025, due to insufficient supply of freshwater and nutrient solid budget through the River Indus which is drastically affected by manmade interventions such as building of dams, barrages and diversions of freshwater through canals someone else sides. If situation remains same as it has been for the last 30 years, then the Indus delta will lose its actual position. The national and international authorities are urged to ensure the ecological flow of freshwater into River Indus from Kotri downstream to save the Indus delta ecosystem. The Sindh Forest department took some initiatives for mangrove plantation in Karachi and Thatta zones that is clear indication of restoration mechanism. But the situation at Sujawal and Badin is quite difficult which needs strong attention. The scientific community has asked for recommendations on practical ways to prevent seawater erosion and protect mangroves. The scientists provided the following comments on Facebook. Prof. Dr. Rasool Bux proposed some structural solutions, such as building baffle walls in the bays to reduce flow velocity and planting more trees with more nested roots along the banks. According to Mr. Mohammad Moazzam Khan, there is very little that can be done to stop the erosion in Kalka Chani because it is primarily caused by natural phenomena. I assume that this occurrence is unavoidable and generally natural. Making groins along the income tidal path is the only significant change, but it will be expensive and necessitate thorough engineering and hydrographic research. Mr. Mohammad Moazzam Khan claims that because saplings cannot halt erosion, it may be useless to plant young plants in high-erosion locations. A hydrodynamic and engineering solution must exist. I recall that the regime shift in the Port Qasim area put an end to reports of severe erosion in a section of Phitti Creek. I'll share the picture and trace it. He shared an old photo of a mangrove tree that showed severe damage that was difficult to fix. It was unable to determine the exact location of erosion due to latitude and longitude. According to Mohammad Moazzam, a study on extensive erosion in Isaro Creek was conducted in 1986. Subsequent years saw a shift in the wind pattern, which fertilised the soil and covered the mangrove roots, restoring them. When I returned in 2012, the region was covered with lush mangroves. Dr. Jawaid Mustaqeem claims that mangroves stop erosion. Mangrove roots help create peat, which is incredibly resistant to erosion. Stop cutting down mangrove trees. Investigate and learn about erosion. One of the various methods to lessen erosion is reforestation. According to Dr. Shoab Kiyani, there are several causes of erosion in this region, including poor mangrove cover due to unfavorable environmental circumstances and deforestation, high tidal velocity due to capillary action produced by narrow creeks, and constantly declining sediment intake from the Indus River. Rehabilitating mangrove habitats and ensuring the River Indus flows sufficiently throughout the year are the most appropriate and environmentally favorable actions for this region. Creeks' meandering course serves as a natural barrier to lessen water force. Preserving current mangrove habitats will help guarantee the coast's long-term safety without any Creeks' meandering course serves as a natural barrier to lessen water force. Long-term, cost-free coastal protection will also be ensured by protecting the current mangrove areas. "This is a natural process of erosion at specific locations along coasts," Abdul Qayoom Bhutto explained. Monsoon winds tend to degrade beaches exposed to wind directions, which are subsequently restored by regular winds. Therefore, it is natural. Mr. Allah Wadhayo Mahar suggested in his speech that dry wooden bamboos could be used to restore eroded areas. Erosion can be controlled in this way for some time. He continued by saying that if this is a log region, it may be divided into zones and sections. A certain department or organization could be assigned to each segment.

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