

What is Coastal Erosion?

Coastal erosion occurs when rising sea levels, powerful wave dynamics, and coastal flooding collectively erode, remove, or transport rocks, soils, and sands along the shorelineⁱ. Coastal areas host critical infrastructures, ecosystems and about 40% of the world's global populationⁱⁱ. Many of the world's major cities, have developed within the coastal zones, however, data suggest that out of the world's coastal areas, 20% are sandy, and 70% out of them have shown erosion over the past few decadesⁱⁱⁱ.

Figure 1: Model of landward coastal retreat under Sea Level Rise (SLR)

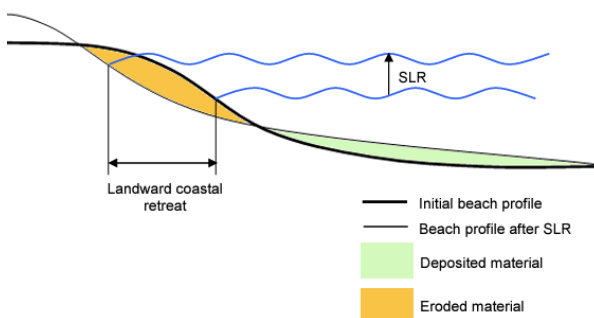


Figure 2: View of coastal erosion on Coney Island, New York^{iv}

An example of the ecological impact of coastal erosion in South Asia can be seen in the city of Cox's Bazar, Bay of Bengal, in Bangladesh. The rising sea level caused coastal erosion in the area, severely impacting the mangrove forests, marine biodiversity, and bird species and the area's tourism^v. In Cemarajaya, situated 100 km north of Jakarta on the West Java coastline, Indonesia, over the past 16 years, coastal erosion has displaced over 300 households^{vi}. Since 2016, the shoreline has receded by 2 km, resulting in the ocean encroaching upon thousands of hectares of land. As a consequence, one entire hamlet is now submerged underwater. The city of Dakar, Senegal, located on the West African, provides an example of coastal erosion. Due to heavy sand mining and rising sea levels between 1954 and 2018, the country's coastline retreated by an average of 3 meters per year. This coastal retreat has destroyed several houses, tourist buildings, agricultural land and fishing infrastructures and led to beaches disappearing^{vii}.

Causes of Coastal Erosion:

The coastal erosion can be caused both by natural factors as well as anthropogenic factors.

Natural Factors

- **Wave Action:** Coastal areas with rocky coastlines are continuously exposed to waves generated by winds and tides in varying degrees. This overtime leads to a process called abrasion, where there is physical grinding and wearing down of rocks as sediment such as sand, pebbles, etc., causing the retreat of shoreline, causing the land to recede inland^{viii}. In Cox's Bazar, Bangladesh, one of the longest natural sea beaches in the world, with a coastline of 120 km along the Bay of Bengal, a 24-km road observed coastal retreat caused by strong monsoon winds and cyclones^{ix}.
- **Storm Surges:** Powerful storms, such as hurricanes and cyclones, generate intense waves and surges that can cause rapid and severe erosion by carrying away large amounts of sediment, affecting

coastlines. The storm surge, Hurricane Katrina, that struck the Gulf Coast in August 2005, produced powerful waves of 5 m depths, causing widespread erosion that permanently altered the shape of the coast in southern Louisiana^x.

- *Tides and Currents*: The ebb and flow of tides can expose the coastlines to waves and current action, leading to erosion.
- *Sediment Imbalance*: Natural shifts in sediment supply, such as changes in river sediment delivery or sediment movement due to currents, can disrupt the balance between erosion and deposition.
- *Geological Factors*: The geological composition of the rocks can also influence erosion rates. Softer rocks and sediments are often more susceptible to erosion than harder ones.

Anthropogenic Factors

- *Construction of man-made structures*: Construction of structures like buildings, roads, and seawalls near the coast can disrupt natural sediment transport patterns, which can affect wave energy and lead to coastal erosion. In the coastal area of Miami Beach, Florida, heavy construction of infrastructures like high-rise buildings and hotels leads to alteration in natural coastal dynamics, making it susceptible to coastal erosion. Hence, the area is now undergoing a sand renourishment process where the city dumps fresh sand on the beach worth \$16 million to mitigate erosionⁱ.
- *Beach Mining*: Extracting sand and gravel for construction materials from beaches and coastal areas can deplete sediment sources, leading to beach and dune erosion.
- *Dams and River Diversion*: Dams constructed along rivers can trap sediment that would otherwise flow to the coast, which can alter and affect coastlines and cause erosion.
- *Deforestation*: Clearing natural vegetation along coastlines removes protective barriers like dunes and vegetation that help prevent erosion. It also reduces soil stability, making it more susceptible to erosion.

How does Coastal Erosion affect city systems?

City Infrastructure

- *Roads and Transportation Networks*: Coastal erosion can affect connectivity and cause disruptions in roads, bridges, and other transportation infrastructure; roads near eroding coastlines may become unstable or collapse due to erosion-induced land loss.
- *Water Supplies and Sewage Systems*: It can disrupt essential services like water, sewage and power lines.
- *Buildings and Residential Areas*: Coastal erosion causes the foundation's instability, resulting in collapse or structural damage to buildings and houses.
- *Coastal Infrastructure*: Erosion can impact coastal protection infrastructure, such as sea walls, dikes and groins, and contribute to costly repairs or replacements.
- *Tourism and Recreation Facilities*: Erosion can impact the beach areas that are recreational and tourist attraction spots, which can affect the place's overall economy.
- *Cultural and Historical Sites*: Some cultural and historical infrastructures critical to indigenous communities may also be at a loss due to the potential damage caused by coastal erosion.

Social Impacts

- *Displacement and Relocation*: Due to the risks of erosion, coastal land communities may be forced to relocate to safer areas, causing disruption in daily life and adding mental and emotional stress.

- *Livelihood Threats:* The livelihoods of coastal communities relying heavily on fishing and agriculture are impacted the most due to erosion.
- *Community Disruption and Social Inequity:* Displacement can fragment communities and cause social inequity as they are forced to start their lives elsewhere.
- *Health and Safety:* Erosion can increase the risk of accidents and injuries. Access to healthcare, emergency services, and safe drinking water may also be hampered.
- *Migration and Urbanization:* The displacement caused by erosion can also lead to migration to urban areas, causing overcrowding, competition for resources, and social challenges.

Ecosystem Disruption

- *Habitat Loss:* Coastal erosion results in the alteration and loss of habitats of ecological importance, such as beaches, dunes, salt marshes, and mangroves.
- *Mangrove Destruction:* Mangrove forests are natural means to protect from floods and storm surges. Erosion can destroy mangroves, diminishing their capacity to support the land and its biodiversity.
- *Impact on Coral Reefs:* The deposits caused by erosion underwater can affect the coral reef systems, affecting the penetration of sunlight. This can lead to coral bleaching, reduced growth, and overall degradation of these vital ecosystems.
- *Altered Coastal Dynamics:* Changes in coastal geomorphology due to coastal erosion can affect the breeding and nesting grounds of species like turtles and shoreline birds.
- *Water Quality Impact:* Erosion can cause pollution and contaminate coastal waters, affecting water quality and harming both people's and aquatic lives.
- *Loss of Biodiversity:* Alteration in the habitat of plant and animal species can result in loss of overall biodiversity of the area.

How does Climate Change impact Coastal Erosion?

- *Rising sea levels:* As outlined in the Sixth Assessment Report (AR6) by the IPCC, the average global sea level exhibited a yearly increase of 3.7 millimetres from 2006 to 2018 which was nearly three times greater than the 1.3 millimetres per year observed from 1901 to 1971. The rise in sea levels results from the melting of glaciers and ice caps, along with the thermal expansion of seawater. This rise in sea levels augments the intensity of coastal erosion, as waves and storm surges can infiltrate more extensively inland, causing the deterioration of shorelines and coastal infrastructure.^{xii}
- *Altered Wave Patterns:* Research suggests that there is an increase in wave extremes up to 15% (~1 m) over Southern Hemisphere high latitudes and tropical Pacific, particularly at 3 °C warming^{xiii}. Climate change can alter wave patterns, leading to more erosive conditions. Changing wind patterns and ocean currents can influence wave energy and direction, resulting in greater erosion in certain areas.
- *Altered Sediment Supply:* The rising sea level and changes in wave patterns can cause coastal sediments' displacement, weakening the foundation and causing erosion. The Feiyan Beach, situated in the northern sector of the Yellow River Delta, experienced extensive shoreline retreat. The reduction in sediment supply originating from the Yellow River, coupled with the solid hydrodynamic forces exerted by the Bohai Sea^{xiv}.
- *Ocean Acidification:* The increasing carbon dioxide from human activities is also leading to a process called ocean acidification. Excess carbon dioxide absorbed by seawater can affect coral reefs and shellfish beds, which are natural barriers against erosion. Coral reefs provide ecosystem goods and services worth ~\$375 billion annually to 500 million people worldwide^{xv}.

- *Saltwater Intrusion*: Rising sea level is causing saline water to move inland, affecting the aquifers and making it prone to coastal erosion^{xvi}. Following the Deepwater Horizon incident 2010, the spill in the Gulf of Mexico heavily impacted the vegetation and oyster habitats. Due to a lack of vegetation and the inward flow of seawater, cases of erosion rose between 2010 and 2013, impacting a stretch of more than 100 miles across the Gulf of Mexico^{xvii}.
- *Permafrost Melt in Polar Regions*: In polar regions, permafrost is thawing due to warmer temperatures caused by climate change. This causes the coastal land to sink and erode. Thawing permafrost and waves erode the Arctic coastline at an average rate of 0.5 meters (1.6 feet) per year^{xviii}.

Adaptation Strategies for Coastal Erosion

Community Level

- Considering sustainable beach management practices by reducing heavy usage or traffic in erosion-prone sensitive beaches
- Adopting nature-based solutions like managing and conserving mangroves that act as natural barrier against erosion^{xix}.
- Restoration of dunes along coastlines to provide a buffer against erosion and storm surges.
- Diversify the livelihoods of coastal communities to reduce their dependence on activities that contribute to erosion, such as unsustainable fishing practices or overexploitation of natural resources^{xx}.
- Engage community members to map areas with a high erosion risk and encourage vulnerable communities to plan relocation.
- Organize community-led efforts to restore damaged or eroded areas by planting native vegetation and salt-tolerant plants.
- Monitoring and research of erosion patterns, sediment dynamics, and the impacts on ecosystems to plan mitigation strategies.
- Community Engagement by involving local communities in the planning and implementation of conservation efforts and raising awareness about the importance of coastal ecosystems,
- Erosion awareness and educate local communities about erosion risks, its causes, and the importance of adaptation through community workshops, training, information campaigns, and programs in schools and communities.
- Capacity building of local communities by providing them with training and education in the risks and management of coastal erosion.
- Collaboration and networking through combined workshops and engagements by bringing in residents, technical experts, environmental experts, businesses and local leaders, and regional and municipal government bodies for consultation.
- Establish early warning systems to monitor and create communication systems about erosion to alert residents to potential threats^{xxi}.

Municipal/Government Level

- Developing and implementing Integrated Coastal Zone Management (ICZM) plans that coordinate various sectors (environment, development, tourism) to balance conservation and development goals^{xxii}.

- Beach Nourishment or replenishing coastal areas with suitable quality sand that has been lost due to erosion^{xxiii}.
- Creation of artificial dunes using various materials such as sandbags, geotextile containers, or other structures^{xxiv}.
- Construction of sea walls and sea dikes along the coastline to protect land from the impact of waves, storm surges, and coastal erosion^{xxv}.
- Establish coastal erosion regulations that guide development, construction, and land use in erosion-prone areas.
- Creation of detailed erosion hazard maps using GIS technology to identify high-risk areas and guide land-use decisions
- Update or develop infrastructure and building codes that require erosion-resilient designs and elevated foundations for structures in coastal zones^{xxvi}.
- Fund research and innovation initiatives aimed at developing new erosion adaptation technologies, materials, and strategies
- Participate in international agreements and conventions that address coastal erosion, promoting cooperation and shared knowledge.
- Allocate dedicated funds for ongoing erosion management and adaptation efforts, ensuring sustained protection for coastal communities.

Case Examples

Case Example 1

The Dhaka Community-Based Adaptation to Coastal Erosion project is a success story in adapting to the impacts caused by coastal erosion and sea level rise through a participatory and community-based approach. It is a collaborative effort involving local communities, non-governmental organizations, government agencies, and international partners. The project promoted nature-based solutions, including planting and restoring mangrove forests and establishing coastal vegetation instead of relying solely on complex infrastructures. Taking a grassroots approach, Dhaka community-based adaptation has focused on offering people climate-resilient livelihoods, restoring greenbelts, and strengthening early warning and preparedness for disasters, incorporating gender sensitivity^{xxvii}.

Case Example 2

The Integrated Coastal Zone Management Plan (ICZM) Plan for the Gulf of Guayaquil serves as another success story in tackling the problem of coastal erosion. It adopted an inclusive approach through collaboration between government agencies, local communities, non-governmental organizations, and academic institutions. It emphasized the importance of using nature-based solutions to manage erosion, including conserving and restoring coastal habitats such as mangroves, which offer erosion protection and support local biodiversity. The plan also incorporated strategic infrastructure upgrades such as coastal defenses, breakwaters, and erosion-resistant materials in vulnerable areas. It promoted sustainable tourism practices that minimize negative impacts on coastal ecosystems and communities^{xxviii}.

End notes/references

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