Odisha’s Coastal Erosion Crisis: Climate Change, Shoreline Dynamics, Human Vulnerability and the Need for Integrated Coastal Management

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Recent Developments:

- The Union Minister for Ports, Shipping and Waterways informed the **Rajya Sabha** that **28.3% of Odisha’s coastline is undergoing erosion**, based on the **National Centre for Coastal Research (NCCR)** assessment of shoreline changes during **1990–2022**. The latest parliamentary data place Odisha’s assessed coastline at **565.12 km**, with **17.6% stable** and **54.6% accreting**.
- At the national level, the same NCCR assessment found that **34.2% of India’s coastline is eroding, 39.5% is stable and 26.3% is accreting**, highlighting that coastal erosion is a nationwide phenomenon rather than an Odisha-specific problem.
- Odisha is particularly vulnerable because its coastline faces the **Bay of Bengal**, a region exposed to tropical cyclones, storm surges, coastal flooding, sea-level rise and changing sediment dynamics.
- Earlier assessments by the Odisha Government had also identified severe localised erosion and reported that **16 villages in Kendrapara district had been submerged**, while **247 people had faced displacement** because of rising sea levels and coastal erosion.
- The Odisha Government has undertaken shoreline-management measures, including a **505-metre geotextile-based sea wall at Pentha in Kendrapara**, under its broader shoreline-management efforts.

Understanding Coastal Erosion:

Meaning and Process:

- **Coastal erosion** refers to the progressive removal and landward displacement of sediments from beaches, dunes and other coastal landforms due to the action of **waves, tides, currents, storm surges and sediment transport**.
- Coastal erosion is a dynamic process because coastlines constantly experience a balance between **sediment erosion, transportation and deposition**.
- A coastline may therefore experience **erosion in one stretch and accretion in another**, even during the same period.
- **Accretion** refers to the accumulation of sediments that causes the shoreline or coastal landform to advance seaward.
- Odisha’s NCCR assessment demonstrates this dynamic nature because **54.6% of its assessed coastline is accreting**, even though **28.3% is eroding**.

Why Odisha is Particularly Vulnerable:

- Odisha has a long, low-lying and sediment-rich coastal environment containing **deltas, beaches, estuaries, lagoons, mangroves and tidal wetlands**.

- The coast is exposed to frequent tropical cyclones originating over the Bay of Bengal, which can produce intense **storm surges, high waves and coastal flooding**.
- The interaction between natural coastal processes and human interventions can alter the **sediment budget** and accelerate erosion in specific stretches.
- Therefore, coastal erosion in Odisha should be understood as a combined outcome of **natural geomorphic processes, climate change and anthropogenic interventions** rather than as a consequence of climate change alone.

Status of Odisha's Coastal Erosion:

NCCR Shoreline Assessment, 1990–2022:

- The NCCR assessment used **remote-sensing datasets and in-sitobservations** to evaluate shoreline changes over the period **1990–2022**.
- Odisha's assessed coastline measures approximately **565.12 km** in the latest parliamentary dataset.
- **28.3%** of the coastline is classified as **eroding**.
- **17.6%** of the coastline is classified as **stable**.
- **54.6%** of the coastline is classified as **accreting**.
- The data demonstrate that coastal management must distinguish between **erosion hotspots and naturally accreting stretches**, rather than treating the entire coastline as uniformly vulnerable.

Spatially Vulnerable Districts:

- Earlier district-level assessments identified **Jagatsinghpur, Ganjam and Kendrapara** among the severely affected coastal districts.
- Jagatsinghpur has faced significant shoreline pressure around the **Paradip port region**, demonstrating the interaction between coastal infrastructure and sediment dynamics.
- Kendrapara has experienced severe social consequences because several coastal settlements have been affected by **shoreline retreat, sea-level rise and saline conditions**.
- Ganjam has also witnessed displacement from erosion-affected settlements, including areas around **Podampeta and Ramayapatna**.

Major Causes of Coastal Erosion in Odisha:

Natural and Climatic Drivers:

- **Tropical Cyclones:** Odisha is highly exposed to Bay of Bengal cyclones, whose storm surges and powerful waves can remove large quantities of beach sediment within a short period.
- **Storm Surges:** Cyclonic storm surges temporarily raise sea levels and push seawater far inland, producing severe erosion and flooding along low-lying coastal areas.
- **Sea-Level Rise:** Rising sea levels increase the baseline from which tides and storm surges operate, thereby increasing the exposure of coastal land to inundation and erosion.
- **Changing Wave and Current Regimes:** Changes in wave direction, wave energy and coastal currents can alter sediment transport and redistribute beach material.
- **Riverine Sediment Dynamics:** Deltas and beaches depend heavily on sediment supplied by rivers, and changes in river discharge or sediment delivery can affect the ability of coastlines to replenish themselves.

Climate Change:

- **Thermal expansion of seawater and the melting of land-based ice** contribute to global sea-level rise, increasing long-term coastal risks.

- The IPCC notes that sea-level rise, coastal flooding, erosion and salinisation pose growing risks to coastal communities and ecosystems.
- Climate change can therefore amplify existing coastal vulnerabilities even when local erosion is also driven by non-climatic factors.
- The appropriate policy response is consequently **climate adaptation combined with disaster-risk reduction and ecosystem restoration**, rather than relying exclusively on engineering structures.

Human Interventions and Sediment Disruption:

- **Ports, breakwaters, groynes and seawalls** can interfere with natural longshore sediment transport and produce erosion on the downdrift side of a structure.
- **Sand mining** can remove sediments that would otherwise contribute to beach replenishment.
- **Dams and reservoirs upstream** can trap sediments and reduce the quantity of sediment reaching downstream deltaic and coastal environments.
- **Destruction of mangroves and coastal dunes** removes natural barriers that dissipate wave energy and stabilise sediments.
- Unplanned coastal construction can also produce **coastal squeeze**, where natural coastal ecosystems lose the space required to migrate inland as sea levels rise.

Environmental and Socio-Economic Implications:

Displacement and Climate Mobility:

- Persistent shoreline retreat can destroy houses, agricultural land and community infrastructure, forcing coastal populations to relocate.
- Earlier Odisha Government data reported the **submergence of 16 villages in Kendrapara** and displacement of **247 people** in connection with rising sea levels and coastal erosion.
- Such displacement can create problems involving **land rights, rehabilitation, livelihood security, social networks and cultural identity**.
- Coastal displacement should therefore be approached as both a **climate-adaptation issue and a human-development issue**.

Agriculture and Food Security:

- Coastal erosion can remove agricultural land and expose remaining fields to **saline-water intrusion**.
- Increasing soil salinity reduces agricultural productivity and can make conventional cropping systems economically unviable.
- Loss of agricultural land can consequently increase dependence on wage labour, migration and alternative livelihoods.
- Salinisation can also affect freshwater resources, creating an additional burden for coastal households.

Fisheries and Coastal Livelihoods:

- Coastal communities depend heavily on **fishing, aquaculture, agriculture and coastal trade**.
- Erosion can damage fish-landing facilities, boat-storage areas, access roads and other livelihood infrastructure.
- Changes in coastal habitats can also affect nursery grounds and ecosystems supporting fisheries.
- Loss of mangroves and wetlands can simultaneously increase physical vulnerability and reduce the ecological services available to coastal communities.

Infrastructure and Urbanisation:

- Shoreline retreat threatens **ports, roads, tourism infrastructure, settlements, communication networks and coastal industrial facilities**.
- The vulnerability of the **Paradip region** illustrates the importance of integrating sediment dynamics into infrastructure planning.
- Repeated reconstruction after erosion and cyclones can create substantial fiscal costs and produce a cycle of **damage–repair–damage**.

Biodiversity and Marine Ecosystems:

- Coastal erosion can damage **mangroves, dunes, wetlands, estuaries and turtle-nesting beaches**.
- Odisha is particularly important for **Olive Ridley sea turtles**, which use coastal areas such as the Gahirmatha region for mass nesting.
- Habitat degradation can therefore have consequences extending beyond local erosion to **marine biodiversity conservation**.
- The IPCC finds that restoration of coastal habitats can contribute to shoreline protection, biodiversity conservation, livelihood support and climate adaptation.

Freshwater Security:

- **Saltwater intrusion** can contaminate shallow coastal aquifers and reduce the availability of potable freshwater.
- The problem can become more severe when sea-level rise, storm surges, groundwater extraction and reduced freshwater recharge occur simultaneously.
- Coastal water security therefore requires integration of **groundwater management, freshwater conservation and coastal-zone planning**.

Existing Institutional and Policy Response:

National Centre for Coastal Research:

- The **National Centre for Coastal Research** undertakes scientific assessment and monitoring of coastal processes using remote sensing, field observations and other scientific techniques.
- Its long-term shoreline datasets help identify **erosion, accretion and stable stretches** and provide evidence for coastal planning.

Coastal Regulation Zone Framework:

- The **Coastal Regulation Zone framework** seeks to regulate development activities in environmentally sensitive coastal areas and reduce ecological degradation.
- Effective implementation requires scientifically updated hazard information, appropriate development restrictions and coordination among coastal States, local authorities and central agencies.
- Coastal regulation should therefore be integrated with **shoreline management, disaster-risk reduction and ecosystem conservation**.

Integrated Coastal Zone Management:

- Odisha has undertaken shoreline-management planning under its broader **Integrated Coastal Zone Management** efforts.
- Earlier State-level planning identified vulnerable stretches around **Kendrapara, Balasore, Jagatsinghpur, Puri and Ganjam** for erosion-management interventions.
- Integrated management is preferable to isolated engineering projects because coastal processes operate across **district, river-basin and marine boundaries**.

Why Hard Engineering Alone Is Insufficient:

Limitations of Seawalls and Similar Structures:

- **Seawalls, groynes and breakwaters** can protect specific assets but may modify sediment transport and transfer erosion to adjacent or downdrift areas.
- Hard infrastructure can also create **maladaptation** if it locks communities and infrastructure into increasingly hazardous locations.
- The IPCC assesses hard protection as useful in particular high-value or densely populated locations but emphasises that it has technical, financial and ecological limits.
- Therefore, hard engineering should be selected through **site-specific scientific assessment** rather than adopted as a universal response.

Way Forward:

Nature-Based Coastal Protection:

- **Mangrove restoration, dune conservation, wetland restoration and coastal vegetation** should form a central component of shoreline management.
- Healthy coastal ecosystems can dissipate wave energy, stabilise sediments, support biodiversity and provide livelihood benefits.
- The IPCC identifies **nature-based solutions and ecosystem-based adaptation** as capable of delivering multiple environmental, social and economic co-benefits when appropriately designed.

Hybrid Engineering:

- Odisha should adopt a combination of **soft engineering, nature-based solutions and carefully selected hard structures** according to local geomorphology.
- **Beach nourishment and geotextile-based interventions** can be considered where scientifically justified and environmentally appropriate.
- The Pentha intervention demonstrates Odisha's experience with geotextile-based coastal protection.
- Such interventions should be periodically evaluated to determine whether they protect the target area without transferring erosion elsewhere.

Integrated Sediment Management:

- Coastal erosion cannot be addressed effectively without understanding the **entire sediment budget** of rivers, deltas, beaches and nearshore waters.
- Upstream dams, river modification, sand mining, ports and coastal structures should therefore be assessed collectively.
- **River-basin management and coastal-zone management** should be better integrated because sediment generated upstream can determine the long-term stability of downstream deltas and beaches.

Climate-Resilient Coastal Planning:

- Development should be restricted in **high-risk erosion and inundation zones**, particularly where long-term protection is technically or economically unviable.
- Hazard-line mapping should incorporate **sea-level rise, storm surges, erosion rates and future climate projections**.
- The IPCC recommends adaptation pathways that anticipate changing risks and avoid irreversible maladaptive investments.

Planned Relocation and Climate Rehabilitation:

- Where erosion makes permanent habitation unsafe, **planned retreat** may become necessary alongside protection and accommodation measures.

- Rehabilitation should provide **secure land rights, housing, basic services, livelihood opportunities and social integration** rather than merely relocating households physically.
- Climate-induced displacement should be addressed through a **rights-based and livelihood-centred framework**.

Community-Based Monitoring:

- Local communities should participate in monitoring **shoreline changes, illegal sand mining, mangrove degradation and unusual coastal hazards**.
- Satellite-based remote sensing should be combined with **ground-level observations and local ecological knowledge**.
- Community participation can improve early detection while strengthening local ownership of adaptation measures.

Conclusion:

- Odisha's coastal erosion demonstrates how **climate change, sea-level rise, cyclones, sediment disruption and human intervention** can interact to produce compound coastal risks.
- The fact that **28.3% of Odisha's assessed coastline is eroding**, while **54.6% is accreting**, also shows that coastal dynamics are spatially differentiated and require location-specific management.
- The policy objective should therefore not be to artificially freeze the entire coastline but to **manage shoreline change while protecting people, ecosystems and critical infrastructure**.
- A resilient strategy should combine **nature-based solutions, selective engineering, integrated sediment management, coastal regulation, scientific monitoring, disaster preparedness and planned relocation**.
- The IPCC similarly emphasises that no single intervention can address all coastal risks and that a portfolio combining **hard protection, soft protection, accommodation and managed retreat** may be required according to local conditions.
- Odisha can therefore serve as an important case study for India's broader transition from **reactive coastal defence to integrated climate-resilient coastal management**.

Value Addition for UPSC:

Prelims Linkages:

- **National Centre for Coastal Research:** Scientific assessment and monitoring of Indian coastal processes.
- **Coastal erosion:** Removal and landward displacement of coastal sediments.
- **Accretion:** Addition and accumulation of coastal sediments.
- **Coastal Regulation Zone:** Regulatory framework governing specified activities in ecologically sensitive coastal areas.
- **Olive Ridley turtles:** Important mass nesting sites occur along the Odisha coast.

UPSC Analytical Framework:

- **Coastal erosion ? Sediment imbalance ? Infrastructure and livelihood losses ? Displacement ? Ecological degradation ? Need for integrated adaptation.**
- **Best approach: Protect where necessary + accommodate where possible + restore ecosystems + retreat where unavoidable.**
- **Core principle:** *A resilient coastline is not necessarily a coastline without change; it is a coastline where ecological processes, human settlements and development are managed within scientifically understood limits.*