ERODING EDGES, EMERGING LANDS

Mapping the Meghna Estuary

Natural sediment deposition along the eastern edges of the estuary has made it a major hotspot for new land emergence, according to satellite images taken between 1990 and 2024. During this period, older islands such as Sandwip and Urirchar have gained land, while two new islands—Bhashan Char and Swarna Dwip—have formed.

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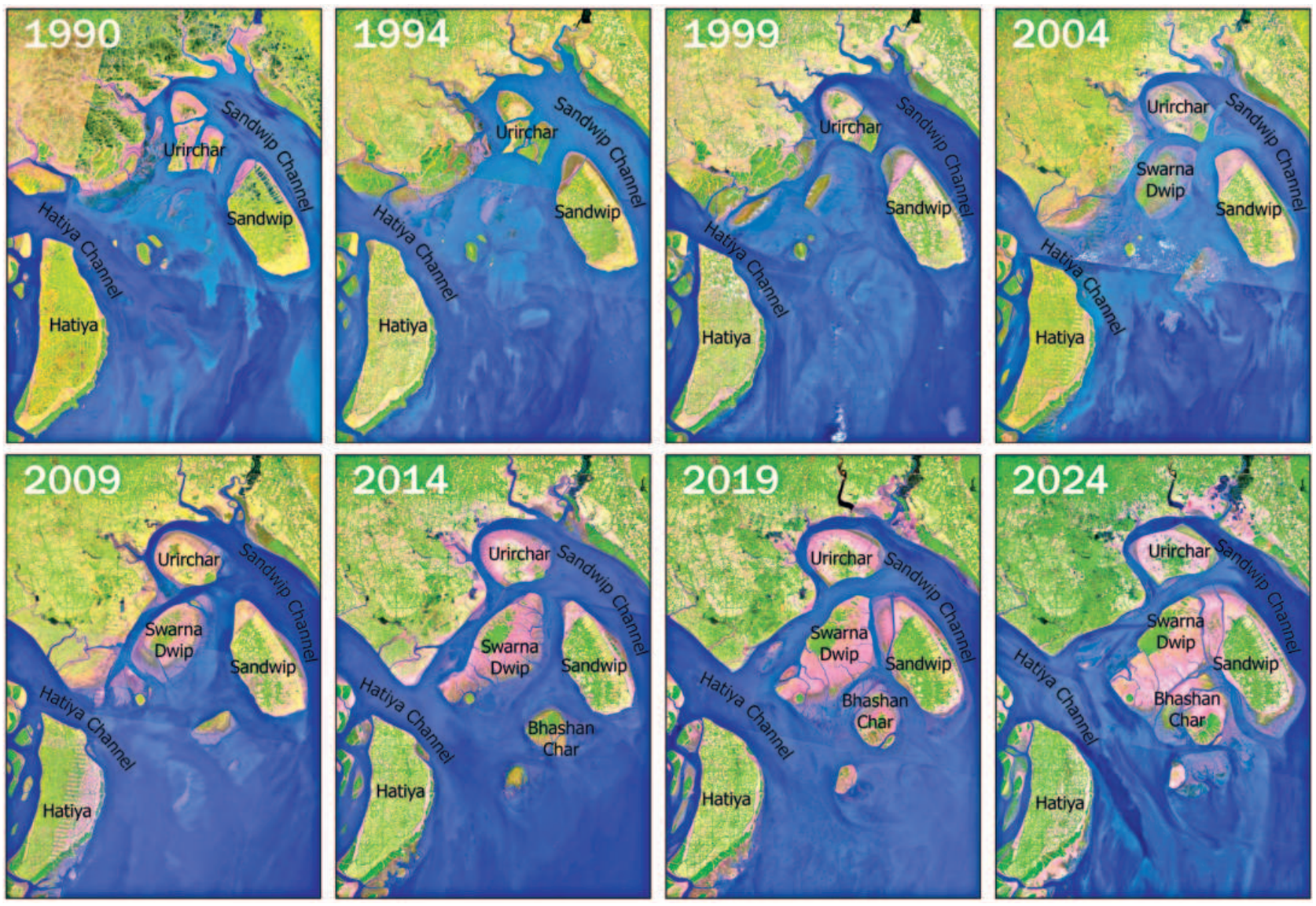
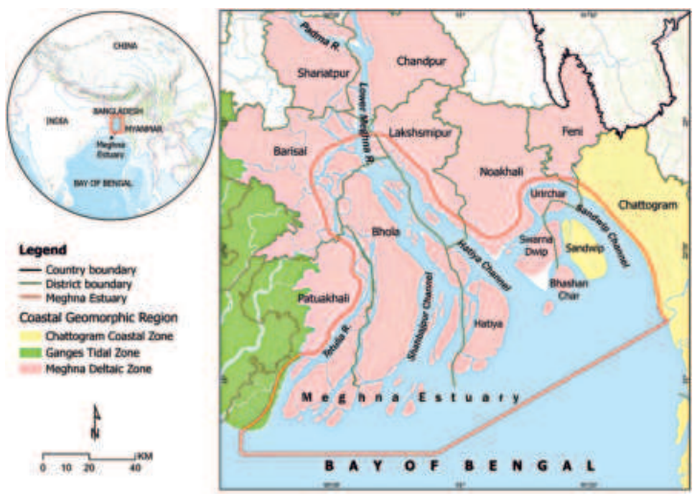
In the dance of land and sea, erosion carves away the edges, leaving behind a story of loss. What erosion takes may return through accretion, whispering hope, though always in a different form. To grasp the complex dynamics of this interaction, one must look to the estuarine regions of the world—ever-changing landscapes that represent both nature's force and its quiet promise. Bangladesh, the Meghna Estuary, situated where the mighty Ganges/Padma, Brahmaputra, and Meghna rivers converge with the Bay of Bengal, is one of the most dynamic coastal environments in the world. Shaped by the constant interplay of river flow, sediment dynamics, tidal activities, and wave action, it is an ever-changing landscape where new land is created even as other areas are lost to the sea. This unique natural system has profound implications for Bangladesh's economy, environment, and long-term resilience.

HYDRODYNAMIC PROCESSES IN THE MEGHNA ESTUARY

Spanning nearly 7,880 km² across districts such as Noakhali, Lakshmipur, Bhola, and Chandpur, the Meghna Estuary is the lifeline of coastal Bangladesh. Within this dynamic estuarine system, the combined flow of the Ganges–Brahmaputra–Meghna rivers (Lower Meghna River) empties into the Bay of Bengal through four primary channels: Tetulia (Ilsha), Shahbazpur, Hatia, and Bamni. Together, the Ganges, Brahmaputra, and Meghna rivers form the world's third-largest river system in terms of river flow and the largest in terms of total sediment discharge. According to the Bangladesh Water Development Board, discharge through this river system varies from approximately 10,000 m³/s in the dry season to 160,000 m³/s in the wet season, carrying nearly a billion tonnes of sediment each year. These forces together create a constantly changing landscape shaped by erosion, accretion, frequent channel shifting, and the formation or disappearance of *chars* in coastal areas such as Bhola, Hatiya, and Noakhali.



A significant emerging landscape in the Meghna Estuary



The Meghna Estuary with major riverways

According to the Institute of Water Modelling, based on interactions between river discharge and tidal volume moving through the channels in the Lower Meghna Estuary, the estuary is divided into three sub-units: (1) the Tetulia and west Shahbazpur channels (fluvial), (2) the east Shahbazpur and west Hatiya channels (fluvio-tidal), and (3) the east Hatiya and Sandwip channels (tidal). The *fluvial* and *fluvio-tidal* sub-units act as a tidal river with very high discharges during the monsoon, whereas the *tidal* unit behaves as a tidal estuary without significant freshwater discharge from the Feni River. Interaction between the tidal river and the tidal estuary is induced by the open-sea connection with the Bay of Bengal south of Sandwip Island, as well as by the two channels between the northern part of Sandwip Island and the Noakhali mainland. Differences in tide level and phase between the tidal river and tidal estuary induce flow through these two channels.

Depending on tidal range, the Meghna Estuary is further divided into three zones: micro-tidal (0–2 m) from the Tetulia River to Chandpur, meso-tidal (2–4 m) from South Bhola to North Hatiya, and macro-tidal (>4 m) from East Hatiya to Sandwip. In the Meghna Estuary, river outflow, tide, waves, and wind exert combined effects. However, it is not yet fully understood to what extent these parameters dominate circulation processes and drive sediment dispersal mechanisms.

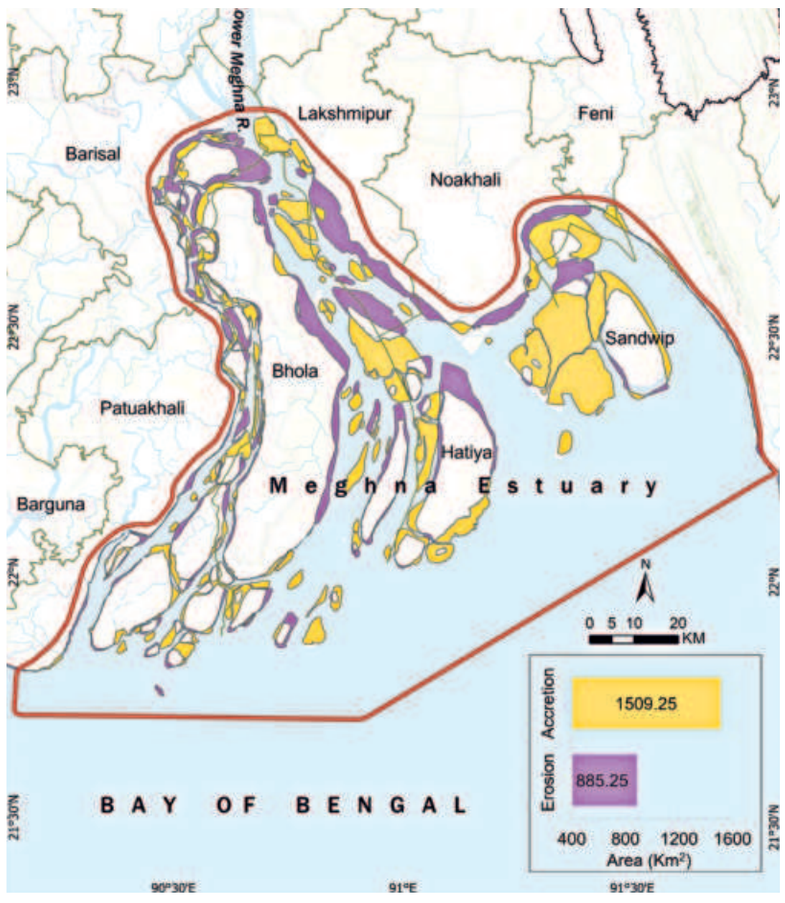
GEOGRAPHICAL AND ECOLOGICAL SIGNIFICANCE

The Meghna Estuary plays a central role in the environmental and socio-economic fabric of Bangladesh by shaping the livelihoods of its population. The channels within the estuary form a significant part of the country's inland transport network, serving as vital waterways connecting Dhaka, Chattogram, Noakhali, and Bhola. Despite severe local erosion, the Meghna–Tetulia–Feni estuarine system has gained over a thousand square kilometres of new land over the past five decades, highlighting the remarkable dynamism of this estuary. This continuous reshaping of the coastline has significant geographical implications, not only in terms of natural processes but also in influencing human settlement, agricultural expansion, and infrastructure development in one of the world's most densely populated coastal zones.

Beyond its shifting shores, the Meghna Estuary is a treasure trove of ecology and economy. For many aquatic species, including hilsa, the estuary serves as a crucial breeding and nursery ground, offering both cultural significance and economic benefits. Its wetlands and mudflats also enrich the soil, filter pollutants, and help moderate salinity intrusion.

At the same time, its vast expanse and high sediment flux serve as natural defences, dissipating tidal energy and buffering inland areas against cyclones and storm surges. Yet this very exposure makes the Meghna Estuary one of the most climate-vulnerable hotspots in South Asia. Rising seas and stronger storms threaten to intensify flooding, salinity intrusion, and displacement in the decades ahead. Recent studies have shown that dry-season salinity is intensifying and that the freshwater–brackish boundary is shifting northward. Salinity affects crop production, drinking-water supply, and aquaculture in nearby coastal districts. Its location also makes it highly exposed to cyclones and storm surges, which can devastate vulnerable coastal communities. Modelling research suggests that wind-driven surges, when combined with tides and waves, can significantly elevate water levels, leading to flooding.

Forecasts suggest a significant rise in both the frequency and severity of tidal inundation and cyclone surges, heightening risks for millions of people, agricultural land, and coastal infrastructure, with sea-level rise projected at around 0.34 m by 2050.



Morphological changes of land in Meghna Estuary between 1993 and 2023

At the same time, newly accreted and geomorphically unstable lands complicate development decisions, as infrastructure built without considering long-term shoreline movement can pose significant risks. Taken together, the background and geographical significance of the Meghna Estuary reveal a system that is both a gift and a challenge: a landscape born of the immense power of rivers and tides that sustains millions of people and unique ecosystems, yet remains fragile in the face of climate change, sea-level rise, and unplanned human interventions.

MORPHOLOGICAL CHANGES OVER TIME

The enormous flow through the Meghna Estuary makes it one of the most powerful river systems in the world, constantly redrawing the map of Bangladesh. Over the last three decades, the estuary has undergone significant morphological changes because of its remarkable and paradoxical nature. Morphological change in the estuary strongly depends on various physical factors, such as river discharge, wind, waves, and tides. Tide-induced circulation currents dominantly determine sedimentation processes. At the same time, tidal currents themselves are strongly influenced by ongoing morphological changes.

Based on analysis of satellite images from 1993 to 2023, estimated erosion and accretion in the Meghna Estuary are found to be 885.25 sq km and 1,509.25 sq km, respectively, resulting in a net accretion of 624 sq km at a rate of 20.8 sq km per year. Erosion hotspots are located along the northern coast of Hatiya Island, as well as the shores of Subarnachar and Companiganj upazilas in Noakhali District, and the coast of Lakshmipur District. In contrast, land has accreted to the north of Sandwip Island, in Urirchar, and to the south of Hatiya Island. Three islands—Char Nizam, Bhashan Char, and Swarna Dwip—emerged fully between 1993 and 2023, although their stability remains fragile. This simultaneous gain and loss underscores the estuary's dual nature, as it acts both as a land builder and a land eroder.

EROSION: A PERSISTENT THREAT

Erosion is not only a natural occurrence but also a daily struggle for the millions of people who live along the shifting shores of the Meghna Estuary, particularly in Bhola, Lakshmipur, Hatiya, and Noakhali. Local communities often face land loss, displacement, and threats to their livelihoods and health as river dynamics swallow up their land. Even though the estuary has gained land through sediment accumulation over the past 50 years, thousands of people are displaced each year due to erosion, losing their homes and crops in a matter of days. The threat is becoming more serious as climate change leads to rising sea levels and stronger cyclones. In addition to social isolation, insecurity, and the anxiety that accompanies them, factors such as displacement, loss of productive land, and uncertainty also result in lower income, unemployment, and a downward spiral into poverty. Erosion will continue to be one of the most significant challenges for communities living in the Meghna Estuary unless resilience measures are strengthened.

EMERGING LANDS: A NEW HOPE?

Continuous sedimentation, along with other hydrodynamic processes, further underscores the estuary's geographical significance by forming new lands and creating opportunities for land reclamation. While the dynamism of the shoreline erodes land in some places, new land emerges through massive sediment deposition in others. Natural sediment deposition along the eastern edges of the estuary has made it a major hotspot for new land emergence, according to satellite images taken between 1990 and 2024. During this period, older islands such as Sandwip and Urirchar have gained land, while two new islands—Bhashan Char and Swarna Dwip—have formed. As these islands continue to expand gradually and are likely to merge into a larger landmass, there is hope for settlement and sustainable livelihoods. These newly formed lands present both opportunities and challenges for reclamation, agriculture, and human settlement. If managed carefully to avoid uprooting vulnerable populations, these lands could be utilised for planned reclamation projects, providing opportunities to increase the amount of arable and habitable land.

HUMAN ADAPTATION AND POLICY CHALLENGES

The Meghna Estuary is more than just a geographical feature. It is a dynamic living system that embodies both the potential of its abundant natural resources and the risks that accompany its location. It represents two realities. While new islands emerge, offering prospects for expansion, erosion continues to claim land and displace lives. This paradox underscores the pressing need for adaptive management, sustainable planning, and climate-resilient strategies—not only to capitalise on opportunities but also to mitigate risks in one of Bangladesh's most dynamic and vulnerable landscapes.

Communities living along the estuary have long adapted to their environment through strategies such as floating agriculture, seasonal migration, and rebuilding homes after erosion. At the policy level, although the government has undertaken several measures and projects aimed at safeguarding vulnerable areas—including feasibility studies, the construction of embankments and flood shelters, the promotion of sustainable fishing practices, and the establishment of protected areas for conservation—more effective measures are still needed for the sustainable management of this critical resource, as challenges persist in addressing salinity, climate change, and disaster risk. Moreover, the Government of Bangladesh currently lacks a national policy for the resettlement of displaced people and also lacks comprehensive long-term planning.

Considering the importance of the Meghna River Estuary across multiple sectors in Bangladesh, its proper management has become crucial for the country's long-term development and environmental sustainability. To control erosion, utilise newly formed land, and safeguard communities from storm surges and increasing salinity, effective planning grounded in current scientific research is urgently needed. Estuarine change mapping and monitoring are also essential for long-term resilience and informed decision-making. Unstable *chars* should receive special attention when developing strategies for coastal land zoning and *char* development. If approached wisely, the estuary can continue to provide both protection and prosperity for future generations.

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