CLIMATE RESILIENT WATER MANAGEMANT

An India–West Bengal perspective from rivers to the coast - West Bengal Initiative

IIWW-Sept-2026 • NEW DELHI



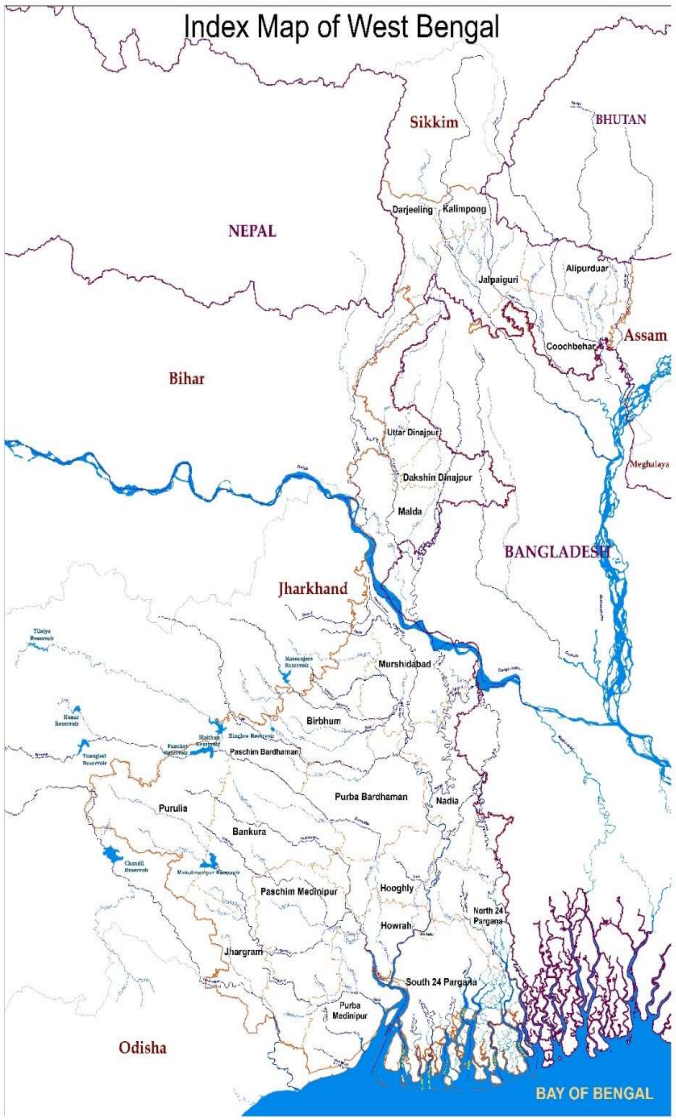
Floods • Cyclones • Erosion • Salinity
Risk-informed design • Nature-based solutions (STU, Mangroves)
• Adaptive management
IRRIGATION AND WATERWAYS DEPARTMENT GOVT. OF WB

IRRIGATION AND WATERWAYS DEPARTMENT GOVT. OF WB

22-26 September 2026 | Bharat Mandapam, New Delhi

Salient features of West Bengal

- **Geographic Area – 88,752 sq.km (2.7% of the Country)**
- **Total available Surface water – 136.9 BCM** (6.8% of the country- used for irrigation purpose – **103.6 BCM**, used for domestic purpose –**3.0 BCM**, used for industrial purpose – **9.2 BCM**)
- **Total available Ground water – 23.50 BCM** (6.00% of the country used for irrigation purpose – **8.98 BCM** , used for domestic purpose –**1.47 BCM**, used for industrial purpose – **0.17 BCM**)



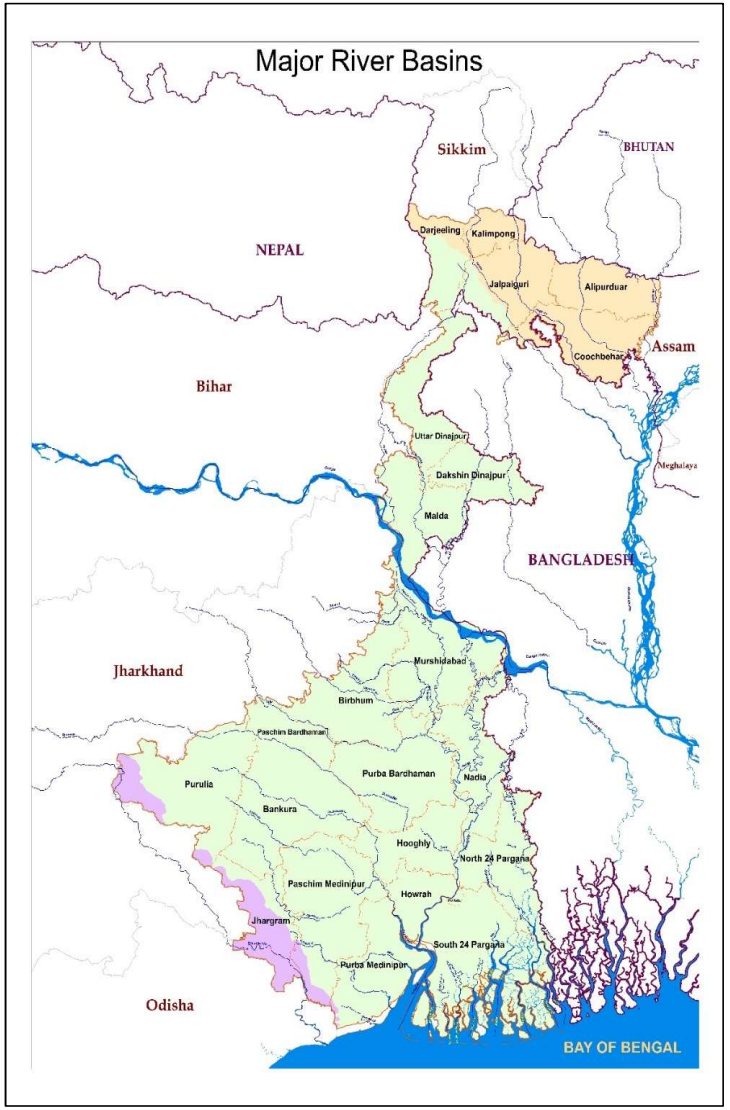
Major River Basins of West Bengal

A) Major river basins

- **Brahmaputra** Basin Area- **10539 sq.km** (12% of the State)
- **Ganga** Basin Area- **74731 sq.km** (84% of the State)
- **Subarnarekha** Basin Area- **3482 sq.km** (4% of the

B) Sub-basins of the State

- **No. of sub-basins** – **39** (some significant ones include Mahananda, Punarbhaba, Raidak, Sankosh, Dwarakeshwar, Mundeshwari, and Ajay, amongst others)



Earth maintained **280 ppm CO_2 & 15°C** in the past due to balanced carbon cycle

Fossil fuel combustion



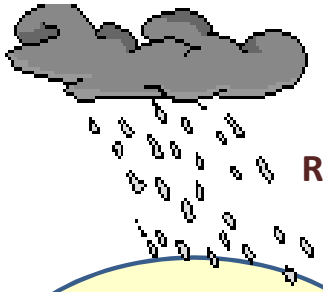
421 ppm due to **300 billion tons** of excess accumulation of CO_2

- **Zero CO_2 emission**, even if achieved; CO_2 already accumulated will continue to impact for 3-4 decades
- Emission is 1.2% more in 2022 than 2021



Global warming & Climate Change

Climate change issues



Reducing Rainfall

Increasing Temperature



Fresh water from **Upland**

Reduced Fresh water and sediment flow

Sundarbans

Salinity increases 1.09PPT/year
Erosion 4.84sqkm/year
Natural disasters
Human pressure

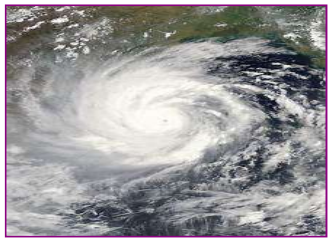
Sea Level Rise, Approx. 3mm/year, increasing 4-4.5mm/year after 2009.

Seawater

High tidal range 3.5-5 m;

Rise in **SST 0.005 degree centigrade per year** (Sea Surface Temperature)

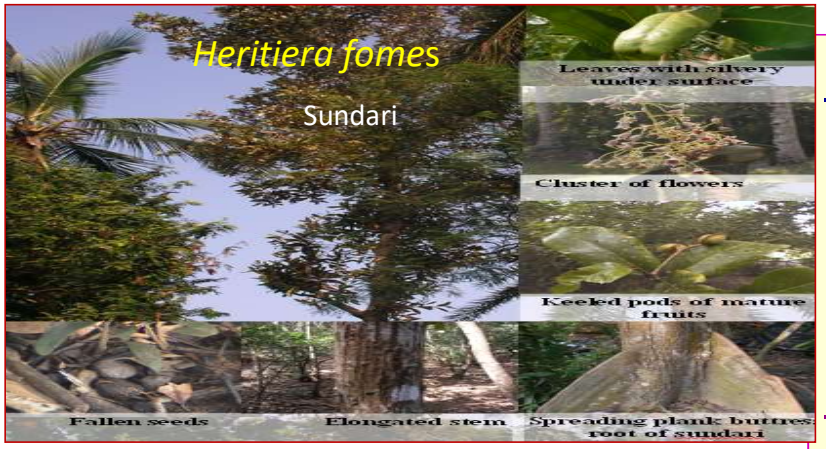
Reduced Fresh water flow from Farrakka barrage 18,953cumec (1990) to 9500cumec approx. 2023. It dispose to bay of Bengal via river Hoogly & sediment load reduces approx. 10million tonnes per year.



Severe Storms

Sundarbans: Most stressful environment

Reduced Freshwater flow





Cause:

- **Farakka dam** construction in **1970**
- Elevation of delta in western part due to tectonic tilting of Ganges plain

Effect:

- Increasing soil salinity (**increased from 2250sqkm in 1989 to 2670sqkm approx. in Sunderban**)

Need:

- **Rainwater harvesting systems & desilting of river distributories**
- **Increase of freshwater in lean period**



Cyclones/Storms

"Cyclone in West Bengal"

(Aila 110 kmh - 2009, Bulbul 130 - 2019, Amphan 220 - 2020, Yash 140 – 2021, From 2009-present approx 14 cyclone hits)



Cause:

- Climate change

Effect:

- High tidal surges
- Damaging human dwellings
- Erosion & Land loss (increased in past decades)

Action:

- Allow **natural recovery** of mangroves
- **Community involvement** for clearing debris & planting.

Erratic monsoons



Cause:

- Climate change

Effect:

- Concentrated rainfall increases (rainfall increases 4.7mm/year approx. with increase of 5-15% concentration).
- Longer period of drier monsoon
- Loss of productivity
  (Agriculture, fish & forest)

Need:

- Continuous Monitoring, Assessing, Analysing & Predicting the monsoons

Sea level Rise

- **4.5 mm/year** raise in past 2 decades approx. with fastest erosion in the world
- **Many parts of** Sundarbans may go under sea by **2050.**
- Hundreds of people displaced in 4 refugee colonies nearerby Sagar (Climate change hot spot) "Kapil muni" temple lost to sea 4 times (Gangasagar festival)
- **50%** loss of land in Ghoramara island

- Soil salinity increases
- Coastal erosion (**Approximately 4.84s sqkm/year**)
- Extensive embankment to prevent seawater entering in high tide

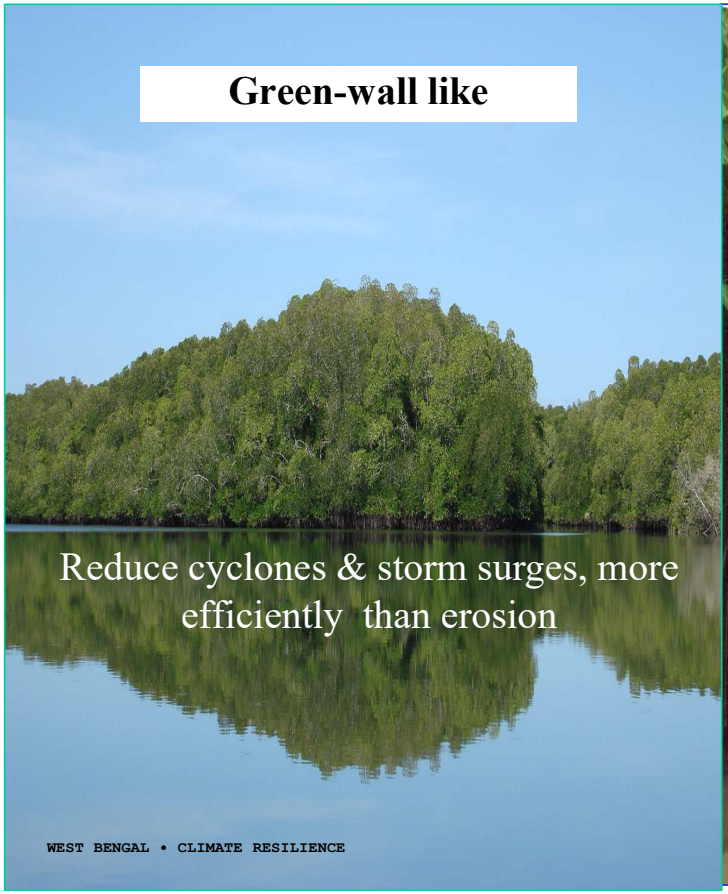
Need:

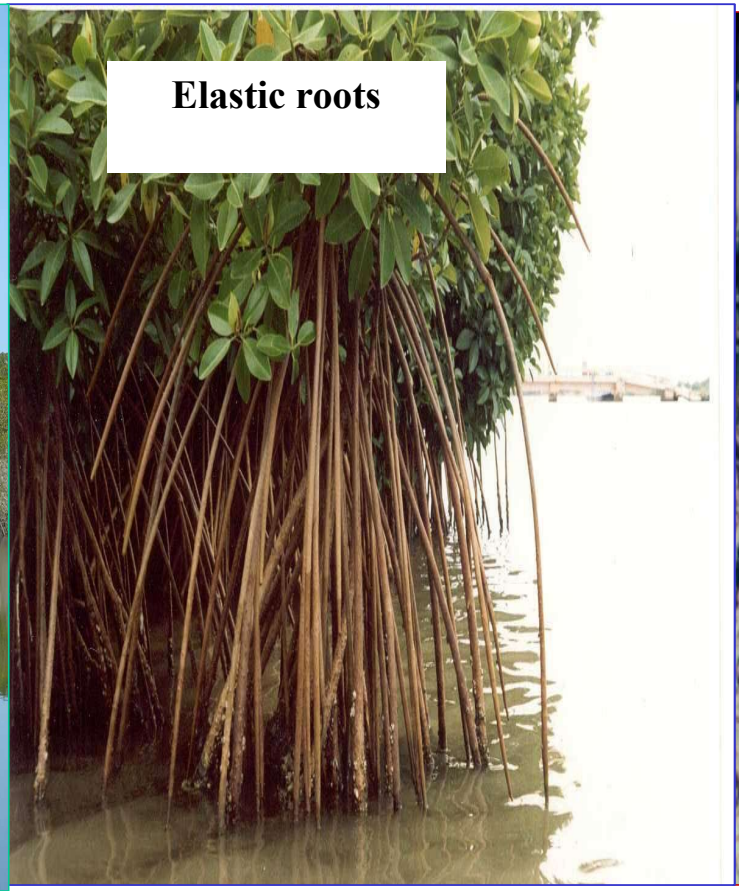
- Climate Adaptation/Mitigation
- Embankments (ring, inland)

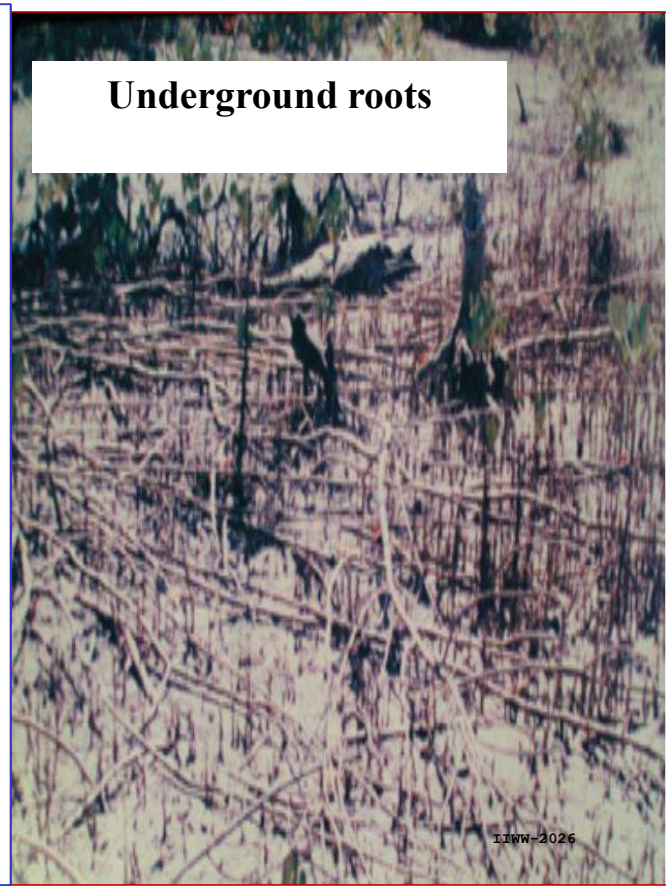




Reduce disaster risks
(Cyclone, Flood, Tsunami)





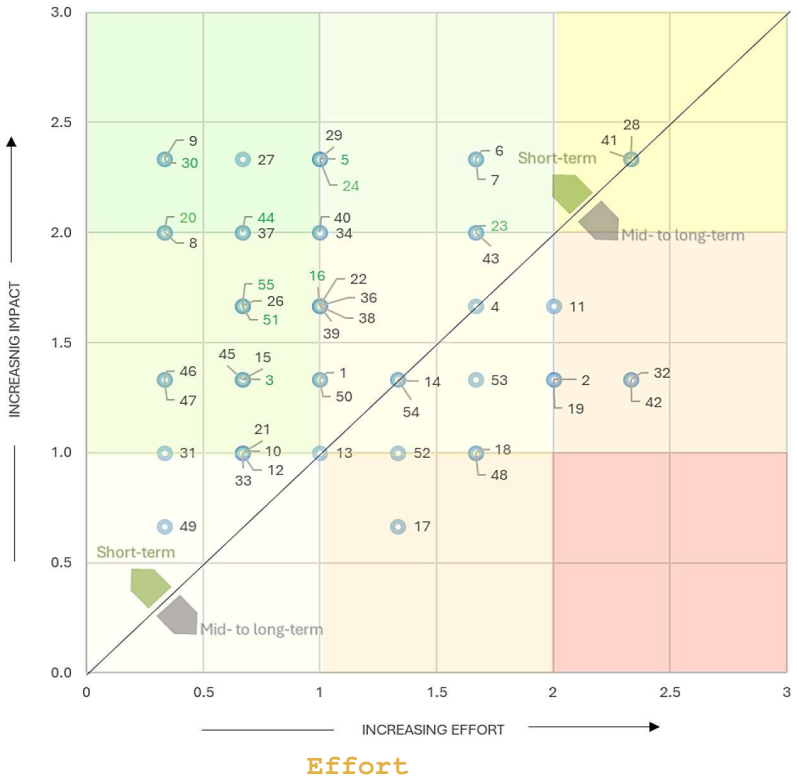




G20 World leaders planted mangroves in Indonesia in Nov. 2022
to reveal its importance to save our coast from climate change

Risk-Informed Design: A Practical Decision Matrix

Illustrative screening tool—site-specific thresholds r



Level of impact

S. No.	Element	0	1	2	3
1	Population	<500	500-2000	2000-5,000	>5,000
2	Livelihoods				
3	Places of cultural importance				
4	Biodiversity / Ecology				
5	Vulnerability (erosion)	Accretion/ stable	Low (…m/year)	Moderate (…m/year)	High (…m/year)
6	Vulnerability (climate change) – sea level rise / cyclones – for future impacts	Nil	Low	Moderate	High

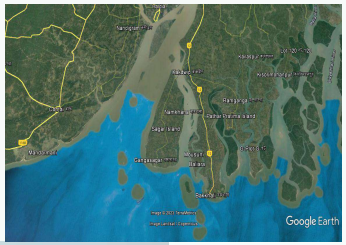
Level of effort

S. No.	Element	0	1	2	3
1	Requirement of land	100 m	100-200 m		
2	Estimated cost / km	<10 cr	10-20 cr	20-30 cr	>30 cr
3	Level of local support / tribal population	High	Moderate	Low	
4	Accessibility	Easy	Moderate	Tough	
5	Level of difficulty				

Use the matrix to structure discussion—not to replace hydraulic, geotechnical, ecological or social analysis.

Gangasagar: A Climate-Resilience Case Study

Sagar Island • Kapil Muni Ashram • pilgrimage • tourism • coastal protection







WHY IT MATTERS

- Severe shoreline erosion has repeatedly affected the beach.
- The beach is both a coastal defence zone and a public/pilgrimage space.
- Protection must address people, sediment, ecology and asset safety together.

Source: Down To Earth, 21 Dec 2024. Reported shoreline distances are observations—not design parameters.

Initial Effort with Trapbag and Tetrapod as a Pilot

Protection performance depends on the beach system, not only on the structure, our learning.





Gangasagar Pilot: Trapbag + Tetrapod

Learning from field performance

INTENDED FUNCTION

Tetrapods

- Reduce wave attack
- Promote sediment accretion

Trapbags

- Sand-filled high-strength geotextile units
- Intended slope / wave protection

FIELD LEARNING

- Tetrapods behave as a breakwater and require a firm foundation.
- No significant sediment accretion / effective breakwater action was observed at the site.
- Trapbags were washed away under prevailing wave attack.

Key lesson: protection performance depends on the beach system—not only on the structure.

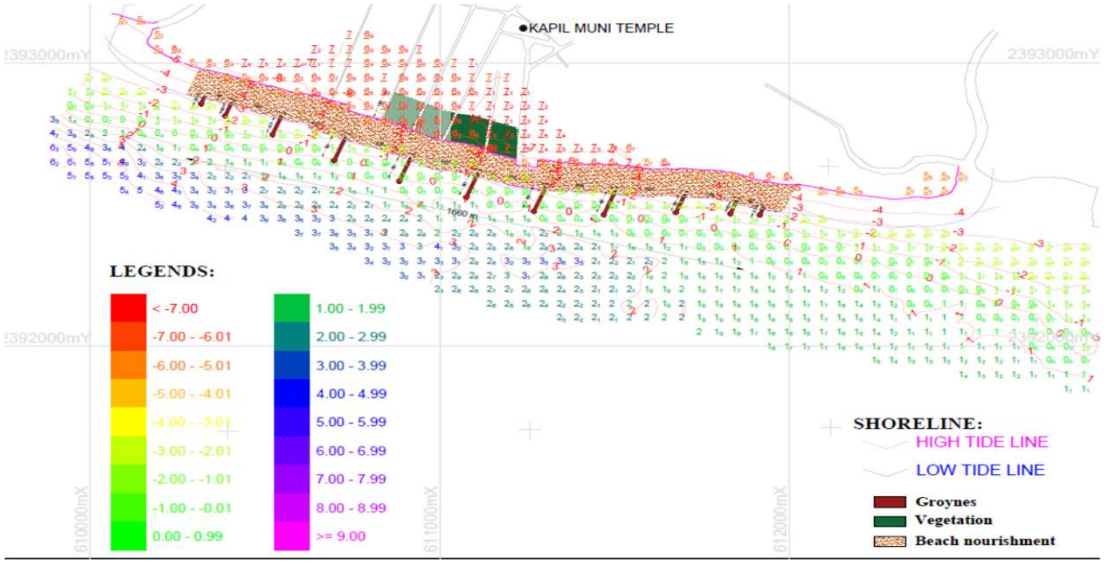
Adaptive Coastal Management at Gangasagar / Permanent So

A systems approach: sediment + waves + structures + public safety

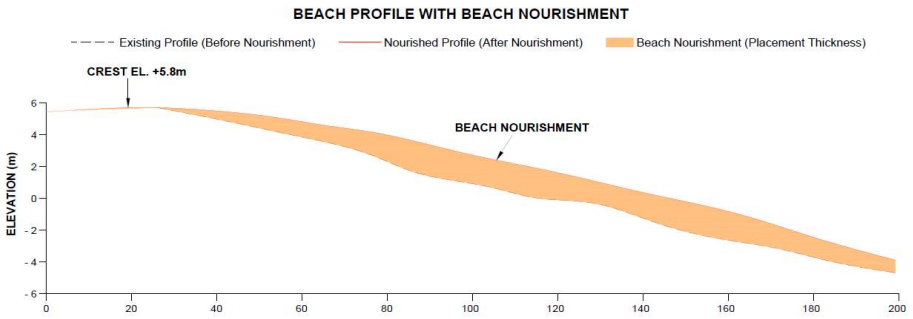
- Baseline shoreline and beach-profile survey
- Wave, tide and water-level observations
- Sediment budget and longshore transport assessment
- Numerical modelling of alternative interventions
- Beach nourishment / sand management where justified
- Spurs beyond LTL
- Targeted structural protection at critical reaches
- Post-monsoon and pre-monsoon performance monitoring

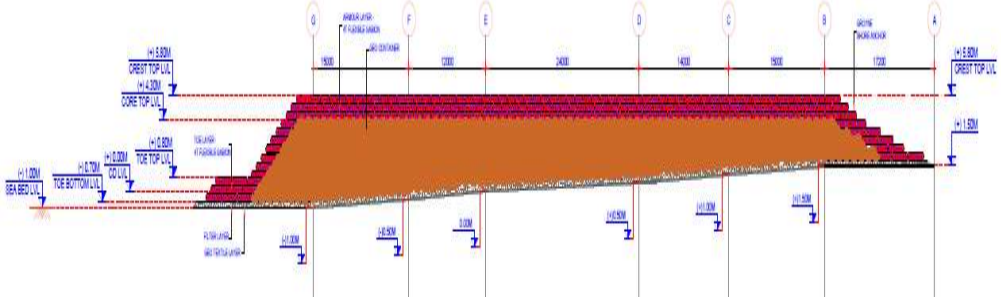
Adaptive Coastal Management at Gangasagar / Permanent So

A systems approach: sediment + waves + structures + public safety



- Baseline shoreline and beach-profile survey
- Wave, tide and water-level observations
- Sediment budget and longshore transport assessment
- Numerical modelling of alternative interventions
- Beach nourishment / sand management where justified
- Spurs beyond LTL with approx. 100m spacing.





Gangasagar: Adaptive Coastal Management

Permanent solution = sediment + waves + structures + public safety

1 BASELINE

Shoreline + beach profiles

2 OBSERVE

Waves + tides + water levels

3 UNDERSTAND

Sediment budget + longshore transport

4 MODEL

Calibrated numerical alternatives

5 MANAGE

Nourishment / sand management where justified

6 PROTECT

Targeted structures at critical reaches

7 LEARN

Pre- & post-monsoon monitoring

Compare alternatives on hydraulic performance, sediment response, environmental effects, public safety and life-cycle cost.

Temporary Protection vs Long-Term Resilience

Seasonal safety measures and permanent shoreline management have different objectives

TEMPORARY / SEASONAL

Rapid deployment for festival-season safety

- Bullah / local frames
- Sand or geobag measures
- Geotextile-wrapped units
- Emergency repair + access

Success: survive defined seasonal exposure and protect people safely.

LONG-TERM / ADAPTIVE

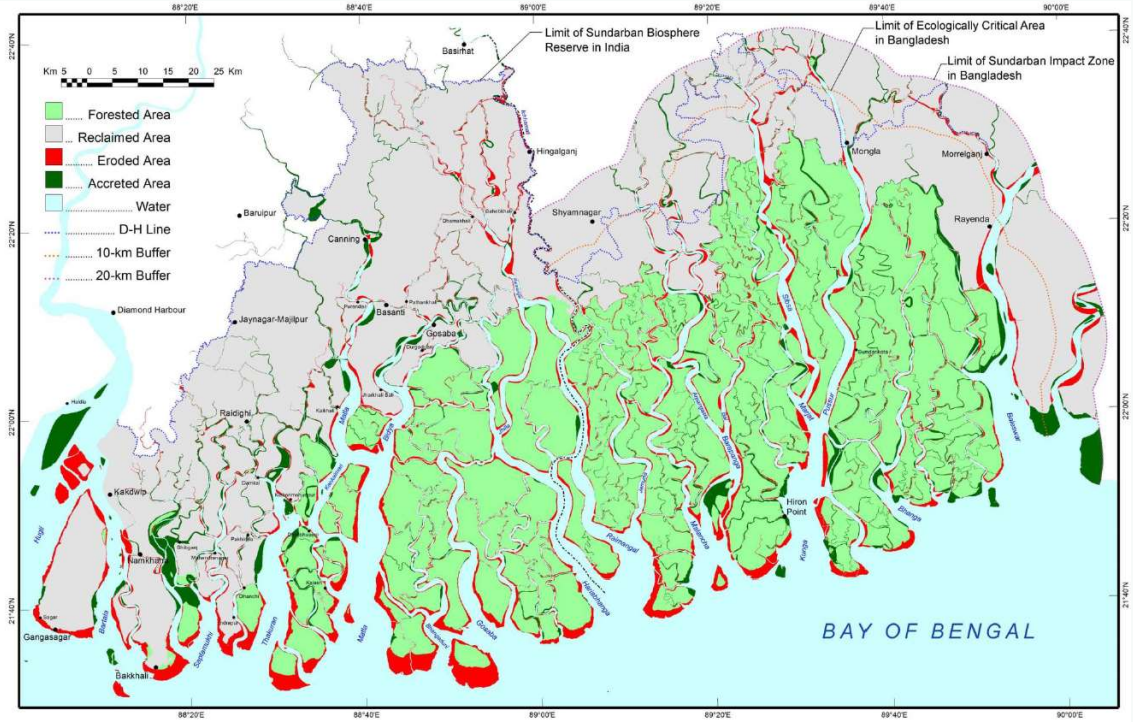
A multi-year shoreline strategy

- Beach nourishment / sediment management
- Targeted structural protection
- Dune / vegetation / hybrid measures
- Spurs
- Monitoring + model updating
- Maintenance + contingency planning

Success: reduce residual risk without avoidable sediment deficits.

Sundarbans: Plan at System Scale

Shorelines, channels and exposure change over time



WHY MASTER PLANNING MATTERS

- Channels and shorelines migrate.
- Problem locations can shift.
- Population and asset values change.
- Interventions themselves alter the system.

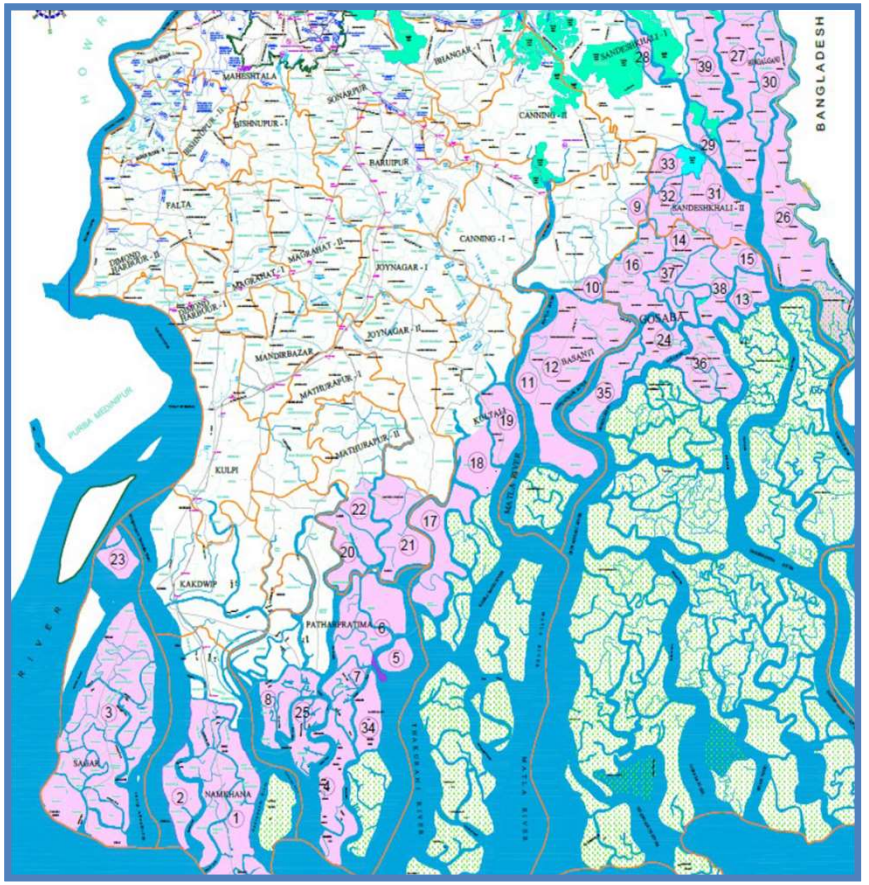
Coastline change: 1901–2015
Banyopadhyay et al., 2019

Questions for a Bigger Sundarban Programme

Scale, lifespan, affordability and long-term development

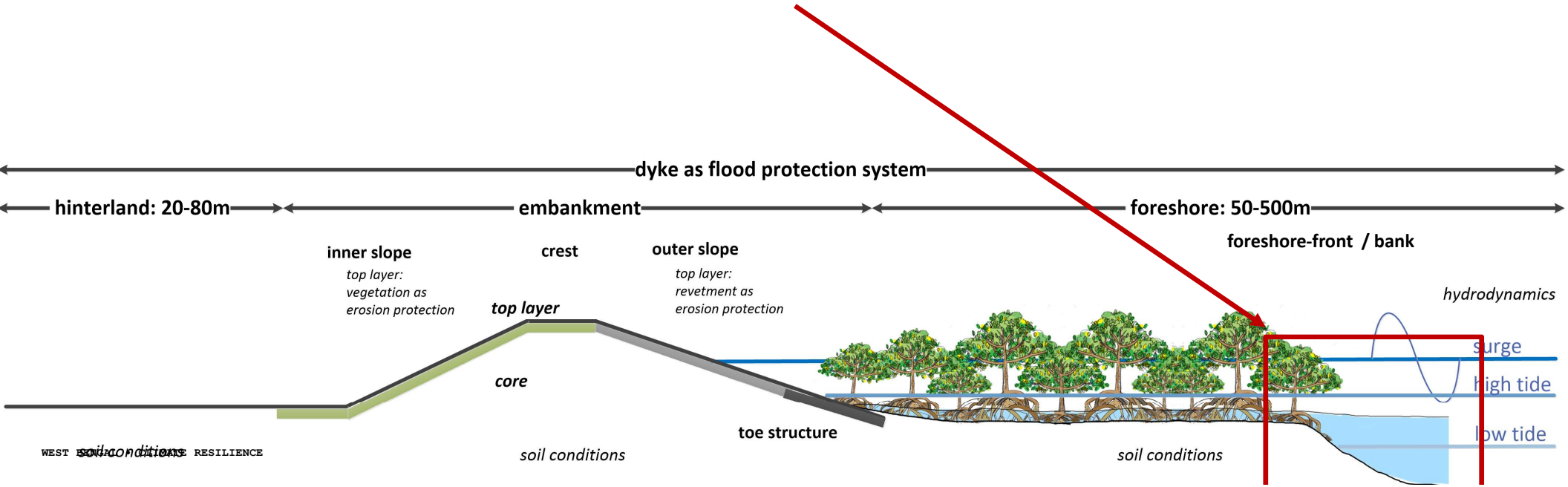
- **Scope: 39 vulnerable islands: pink area**
- **What is the duration of the program?**
- **What is the expected lifespan of the flood protection works?**
- **Is it possible to protect everything? (budget, logistics)**
- **How does it all fit into the long-term development strategy for the Sundarban?**





A Dyke Is Part of a Flood-Protection System

- Dyke is part of a larger flood protection system:
  - warning system, shelters, drainage, dykes, houses on poles
- Stability of dyke depends on the soil in front, in, under and behind it
- Early indication for problems in flood protection system, signal to take action



Selected pilot locations and Gangasagar & Digha



1. Patibunia
2. Gobindapur Abad
3. Atapur
4. Deulbari-Debipur
5. Mousuni - Baliara
6. Kumimari - Dakshinpara
7. Digha
8. Gangasagar

(1) Patibunia

"Direct human impacts are responsible for over 60% of mangrove loss"

Open ocean
Incoming cyclones

Big tidal flat, **used to be mangrove forest,** now eroding

Former toe of the dyke

Extreme length of dykes to maintain, hard to construction, hard to maintain



IIWW-2026

(1) Patibunia



- Severe damage during cyclone events.
- **Foreshore seems stable**; but improvement and maintaining of the foreshore is required



(4) Deulbari-Debipur

- The embankment was destroyed during Amphan: wave attack has damaged the revetment.
- **Foreshore is short but seems stable:** might be a risk of bank instability; maintenance and extending of the foreshore is required

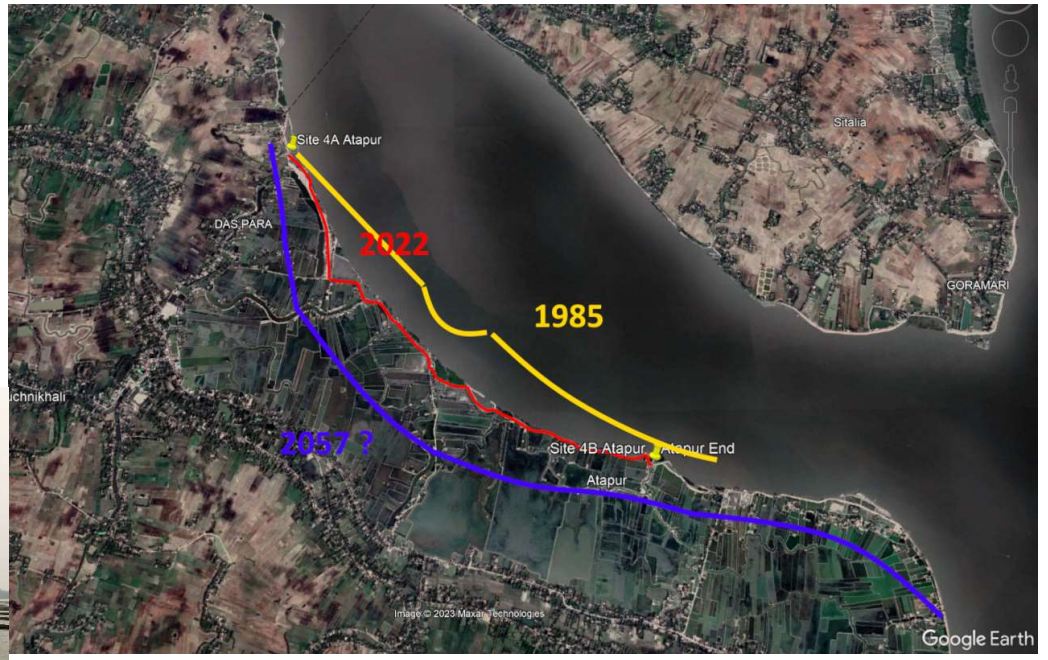




(3) Atapur

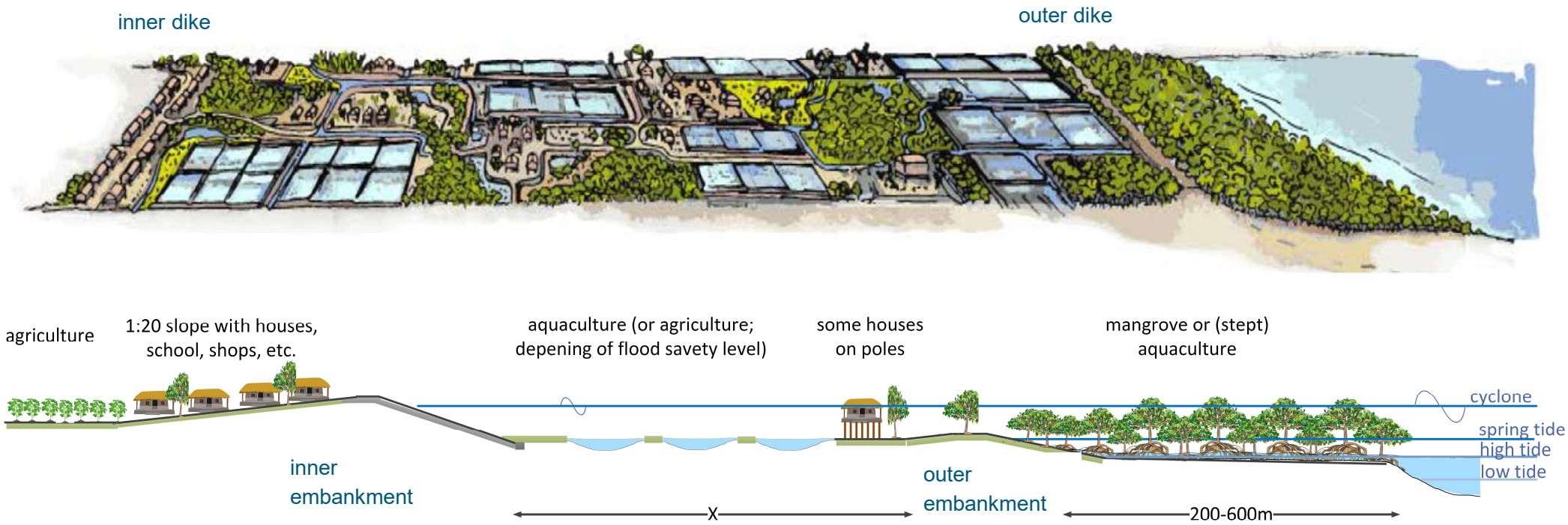
- 300m bank erosion in 37 years
- **Foreshore is not stable**: heavy erosion of the toe of existing embankments





Required land requires rethinking solutions

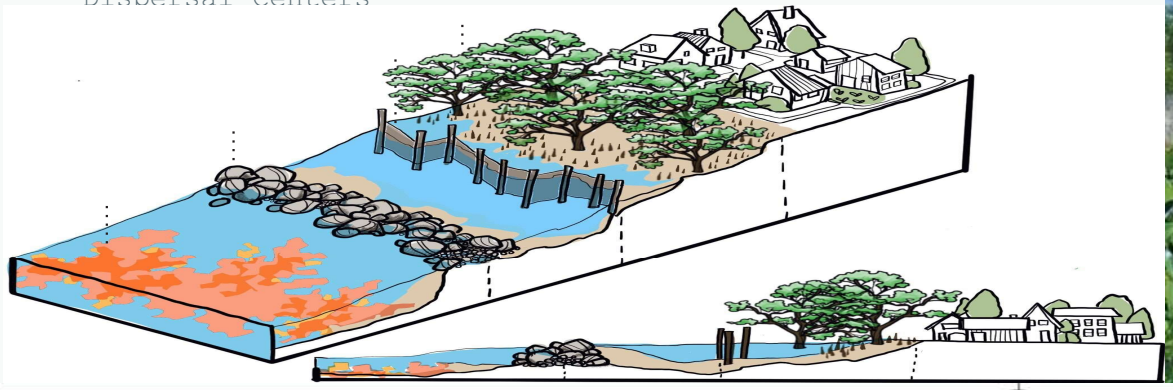
How can the land be used in a different way? In such way that livelihood and flood safety, and therefore economic security, is provided.



BREAKWATERS, DISPERSAL CENTRES, MANGROVES

Reduce wave energy and facilitate sediment accumulation for restoration

Dispersal Centers







A 7-Step Climate-Resilient Water Project Framework

Practical workflow for departments, consultants, researchers and funding agencies



Objective: not to predict the future perfectly—but to make decisions that remain robust when the future differs from today.

Field Photograph: Sunderban and Howrah (Silt Trapping Unit)

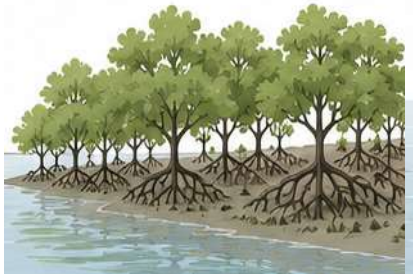
STU at Botanical Garden, Howrah



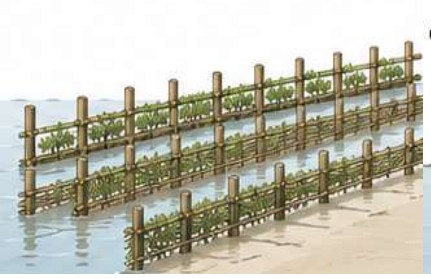


NATURE BASED SOLUTIONS (NBS)

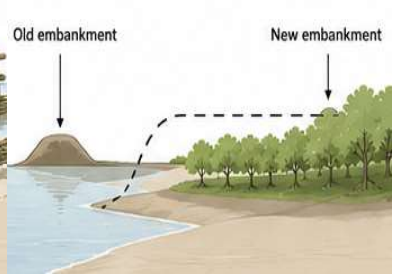
Mangrove restoration



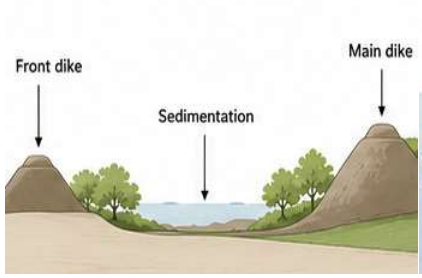
Sediment trapping unit



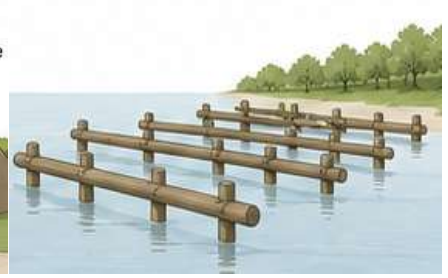
Managed realignment



Double dyke system



Spurs/ groynes/ porcupines



Nourishment



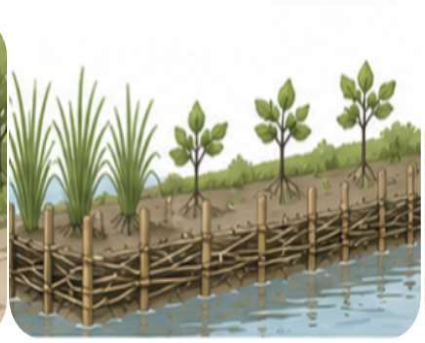
Fascine mattresses / Brushwood structure



Jute bag / Geotextile tubes



Bio-engineering



Cascade aquaculture



Key Messages

West Benga

1. Climate resilience is a water-system objective—not a single-project attribute.
2. West Bengal demonstrates why river, coast, magrove regeneration, sedimentation by using STU, ecosystem and livelihood planning must be integrated.
3. Gangasagar shows that coastal protection must be sediment-aware, model-supported and adaptive.
4. Beach nourishment, nature-based measures and structural protection should be compared on equal technical and life-cycle terms.
5. Monitoring and knowledge exchange are infrastructure: they reduce uncertainty and improve future decisions.

FROM RISK REDUCTION → LONG-TERM WATER RESILIENCE

THANK YOU

