Mangroves as Climatic Solution: Ecology, Hydrology and Conservation

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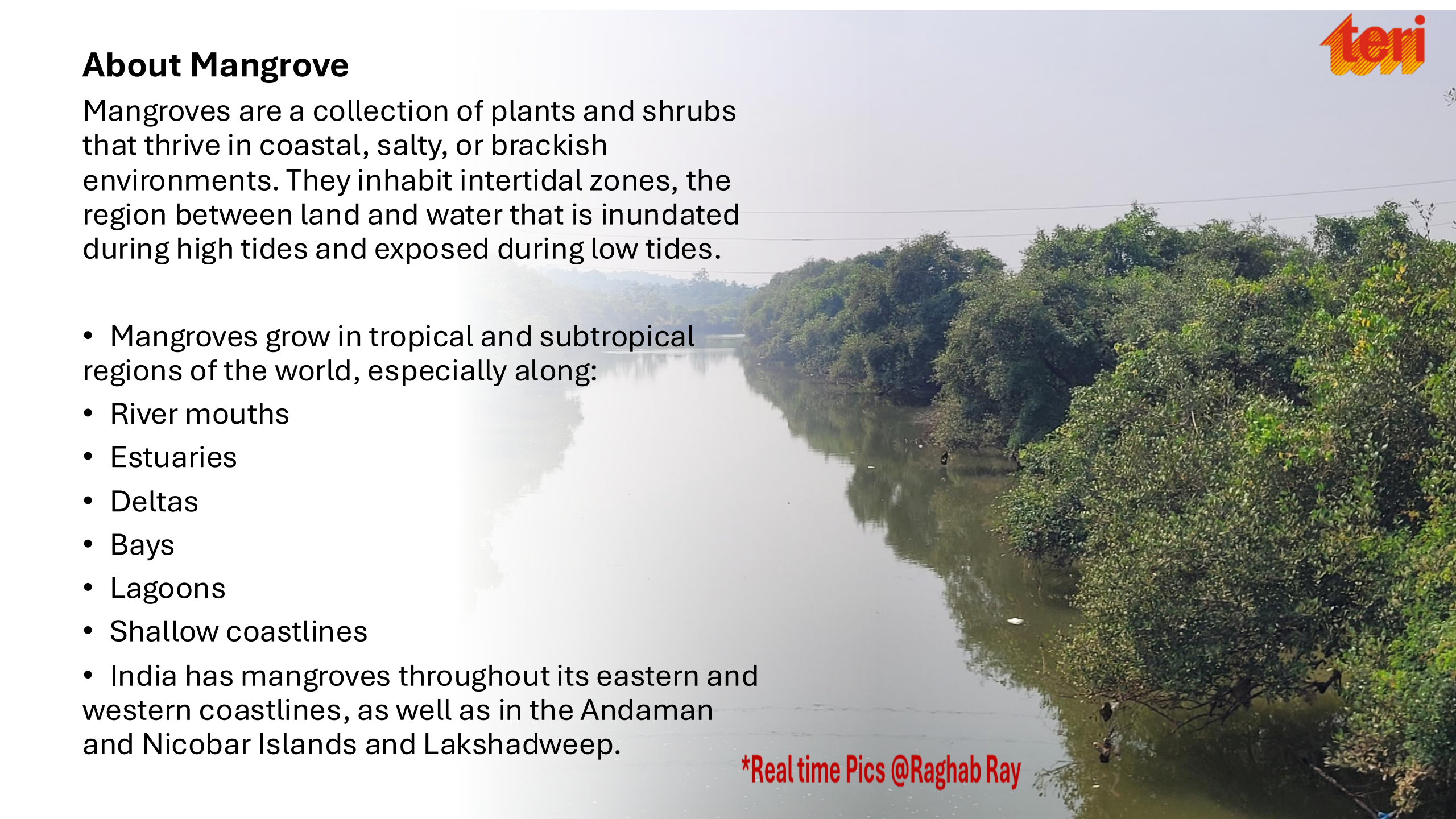
About Mangrove

Mangroves are a collection of plants and shrubs that thrive in coastal, salty, or brackish environments. They inhabit intertidal zones, the region between land and water that is inundated during high tides and exposed during low tides.

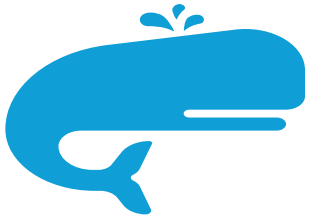
- Mangroves grow in tropical and subtropical regions of the world, especially along:
- River mouths
- Estuaries
- Deltas
- Bays
- Lagoons
- Shallow coastlines
- India has mangroves throughout its eastern and western coastlines, as well as in the Andaman and Nicobar Islands and Lakshadweep.



Types of Mangroves

Red Mangrove - aka Rhizophora mangle. Found along the coastlines

Black Mangrove –as Avicennia species. Major feature of such mangrove trees is their dark bark. They have access to more oxygen.



White Mangrove – as Laguncularia species. Compared to Red and Black mangroves; they grow at the highest elevation.

Characteristics of Mangroves Ecosystem

Mangroves' Salt Tolerance
- Survives high salinity environments.
- Specialized salt-filtering mechanisms.
- Salt-excreting leaves.

Mangrove Aerial Roots
- Specialized pneumatophores emerge from waterlogged soil.
- Allows gas exchange through pores.
- Some have prop roots for stability against waves and currents.

Mangrove Viviparity
- Seeds germinate while attached to parent tree.
- Mature propagules detach, float to new rooting locations.

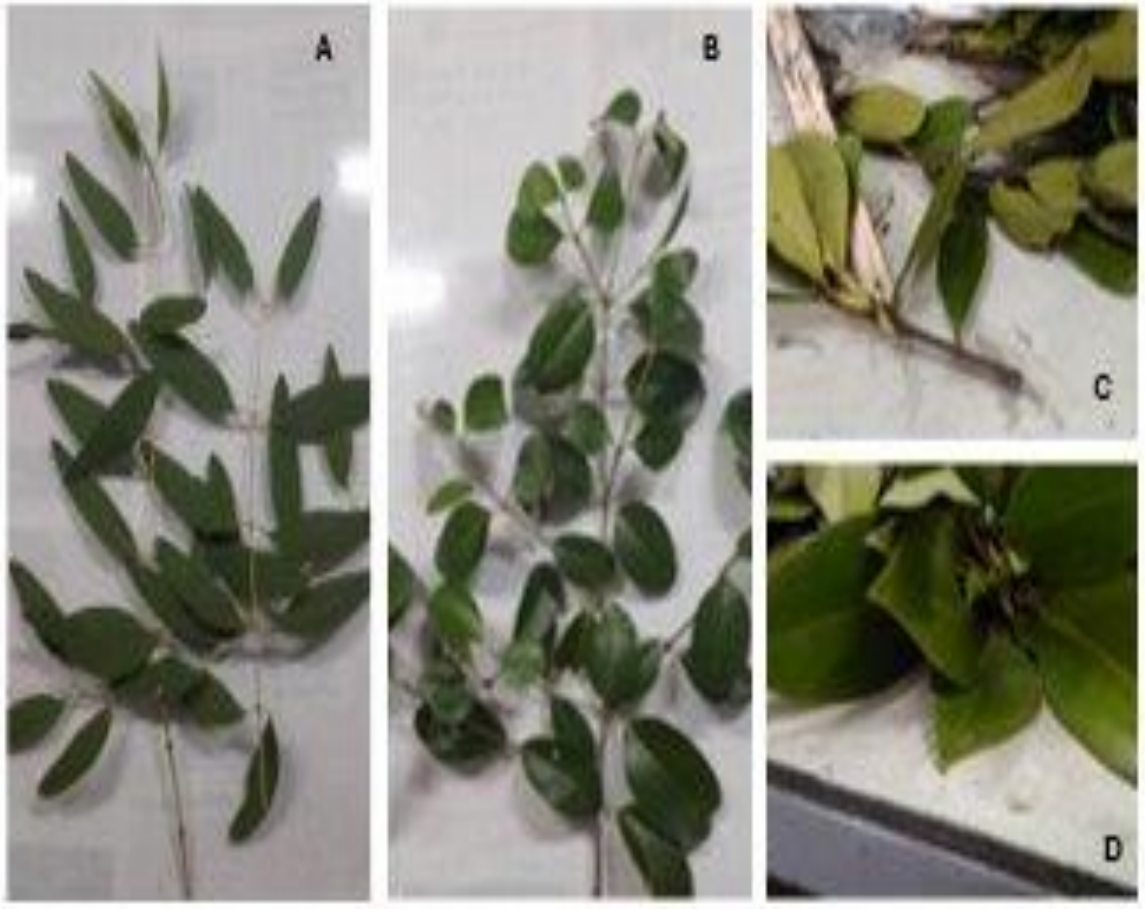
Tidal Influence on Mangrove Forests
- Regular floods expose forests to saltwater.
- Influences survival of organisms.

Mangroves' Sediment Stabilization
- Complex root systems prevent erosion.
- Protect coastlines from storms.

Mangrove Forests: Biodiversity Support
- Provide habitat for diverse marine/terrestrial species.
- Contribute to overall coastal ecosystem biodiversity.

Temperature Requirements:
- Mangroves thrive in warm, tropical, subtropical climates
- Temperature range: 25°C-35°C.

Some important species of Mangrove found in India



Real time pics@ Raghab Ray

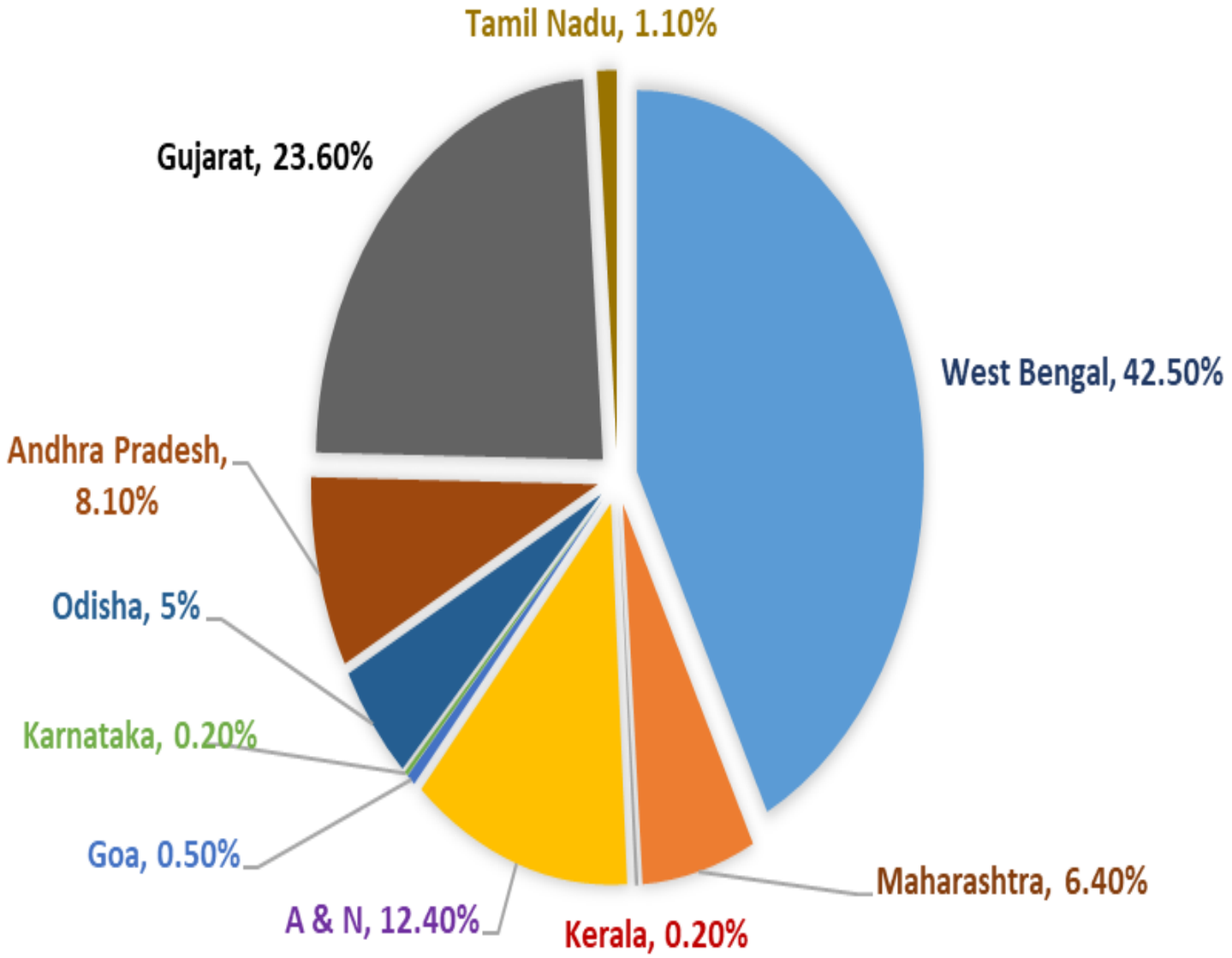
- Avicennia Officinalis
- Xylocarpus granatum
- Kandelia candel
- Rhizophora mucronata
- Bruguiera gymnorrhiza
- Sonneratia apetala
- Avicennia Alba
- Excoecaria agallocha
- Ceriops Tagal

(A) Sonneratia apetala
(B) (B) Avicennia marina
(C) Avicennia officinalis, and
(D) Bruguiera gymnorrhiza

Distribution of Mangrove Forest

*Real time Pics @Raghab Ray

State-wise Distribution of Mangroves in India



West Bengal - Sundebans

Orissa - Bhitarkanika, Mahanadi, Subernarekha,

Andhra Pradesh - Coringa, East Godavari, Krishna

Tamil Nadu - Pichavaram, Muthupet, Ramnad,

Andaman and Nicobar - North Andamans, Nicobar

Vembanad, Kannur (Northern

Karnataka - Coondapur, Dakshin Kannada

Goa – Mandovi-Zuary

Maharashtra - Coondapur, Dakshin Kannada

Gujarat – Gulf of Kutchh, Gulf of Khambhat, Dumas-Ubhrat

Top 10 Mangrove Forests in the World

1. **Sundarbans Mangrove Forest**
   (India & Bangladesh)
   - World's largest mangrove forest
   - UNESCO World Heritage Site
2. **Gulf of Gabes Mangroves**
   (Location – Tunisia)
3. **Amazon Mangroves**
   (Brazil)
4. **Borneo Mangroves**
   (Malaysia & Brunei)
5. **Ganges Delta Mangroves**
   (India and Bangladesh)
6. **Gulf of Thailand Mangroves**
   (Thailand)
7. **Congo River Mangroves**
   (Republic of Congo)
8. **Northern Territory Mangroves**
   (Location - Australia)
9. **Andaman & Nicobar Islands Mangroves (India)**
10. **Southeast Asian Mangroves**
    (Indonesia, Malaysia, Philippines)

Significance of Mangrove in Climate Actions

Mangrove roots sequester large amounts of carbon in soil and sediments. It reduces greenhouse gases.

Dense root systems stabilize coastal soil, mitigating erosion.

Roots absorb wave energy and protect coastal areas from storm surges, sea-level rise, and cyclones.

Roots facilitates natural climate adaptation for at-risk coastal communities.

Roots filter pollutants and sediments, improving water quality and biodiversity.

Robust ecosystems resist climate change better.

Support diverse marine ecosystems that boost local economies and food security.

Module 2 – Role of Mangroves as Blue Carbon Ecosystem and Climate Change

2.1 Blue Carbon

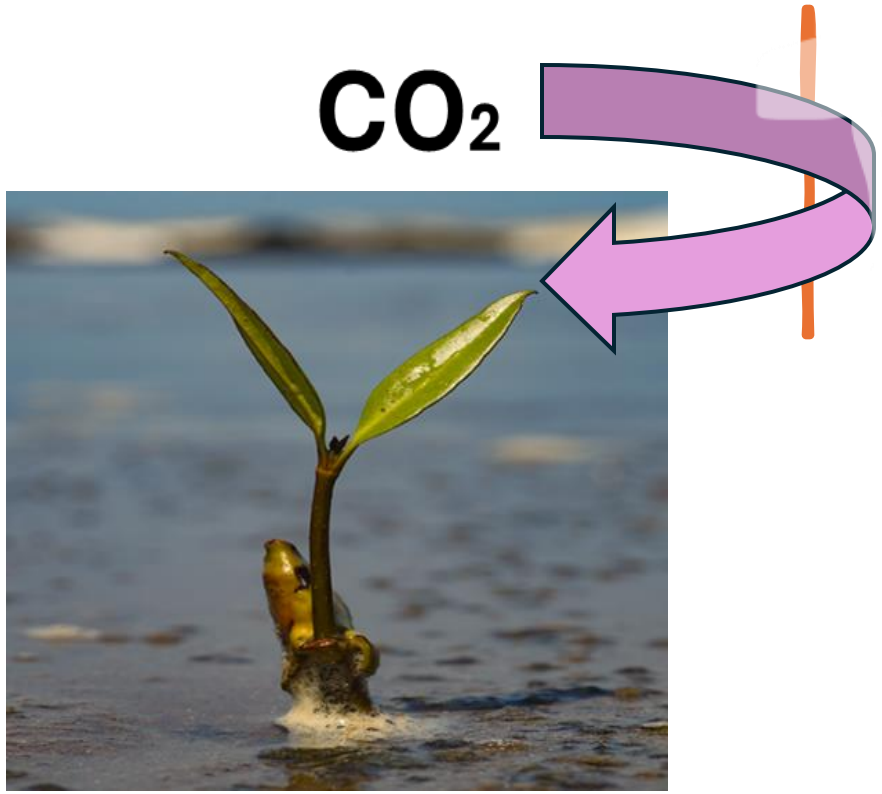
2.2 Carbon Sequestration

2.3 Estimates of Mangrove Carbon Sequestration

2.4 Role of Mangroves in Global Climate Mitigation

2.5 Mangroves' Alignment with UN Sustainable Development Goals

What is Blue Carbon?



Coastal and marine habitats, such mangroves, seagrass beds, and salt marshes, are effective natural carbon sinks that help slow down climate change by storing carbon in their vegetation and underlying soils.

How Blue Carbon works?

- Absorb CO2 through photosynthesis.
- Convert CO2 into organic matter.
- Store organic matter in plant biomass and sediments.
- Prevent soil erosion and preserve carbon for millennia.

What is Carbon sequestration ?

Carbon sequestration refers to the absorption and retention of atmospheric carbon dioxide (CO_2) in vegetation, soils, geological formations, and seas to diminish atmospheric CO_2 levels and alleviate climate change.

How does carbon sequestration work?

Captures, removes, and stores CO2 from the Earth's atmosphere.

Recognized as a key method for removing carbon from the atmosphere.

Prevents further emissions from contributing to global warming.

Can occur biologically or geologically.

Encouraged artificially through various methods

Also occurs naturally in the environment on a large scale.

Estimates of Mangrove Carbon Sequestration

- Mangroves sequester up to three to five times more carbon than tropical forests.
- Mangroves retain over 1,000 metric tons of carbon per hectare, more than most forest species.
- Mangroves store up to 90% of their carbon in soil.
- Mangroves and other coastal wetlands store carbon 10 times faster than mature tropical forests.
- Mangroves reduce greenhouse gas emissions from coastal ecosystems.
- Mangrove root systems trap organic material and sediments, increasing soil carbon accumulation.
- Mangroves help mitigate methane and nitrous oxide emissions.
- Mangrove carbon sequestration increases with forest age and stability

Role of Mangroves in Global Climate Mitigation

1. Mangroves' Climate Impact Protection

- Reduces climate change impacts.
- Act as a storm surge buffer.
- Stabilize coastlines and prevent land loss.

2. Mangroves' Role in Climate-Resilient Communities

- Support sustainable livelihoods and adaptation.
- Underpin small-scale fisheries and food security.
- Offer low-carbon livelihood options through ecotourism and sustainable harvesting.

3. Enhancing Coastal Water Quality

- Mangroves maintain healthy coastal ecosystems.
- Filter pollutants by trapping sediments, heavy metals, and nutrients.
- Promote seagrass & coral support.
- Expand blue carbon potential through healthy adjacent ecosystems.

4. Blue Carbon and Long-Term Storage

- Mangroves are key blue carbon ecosystems.
- Organic matter retained in anoxic sediments.
- Mangroves account for 10-15% of global marine carbon burial.

5. Mangroves as Biodiversity Hotspots That Support Carbon Sequestration

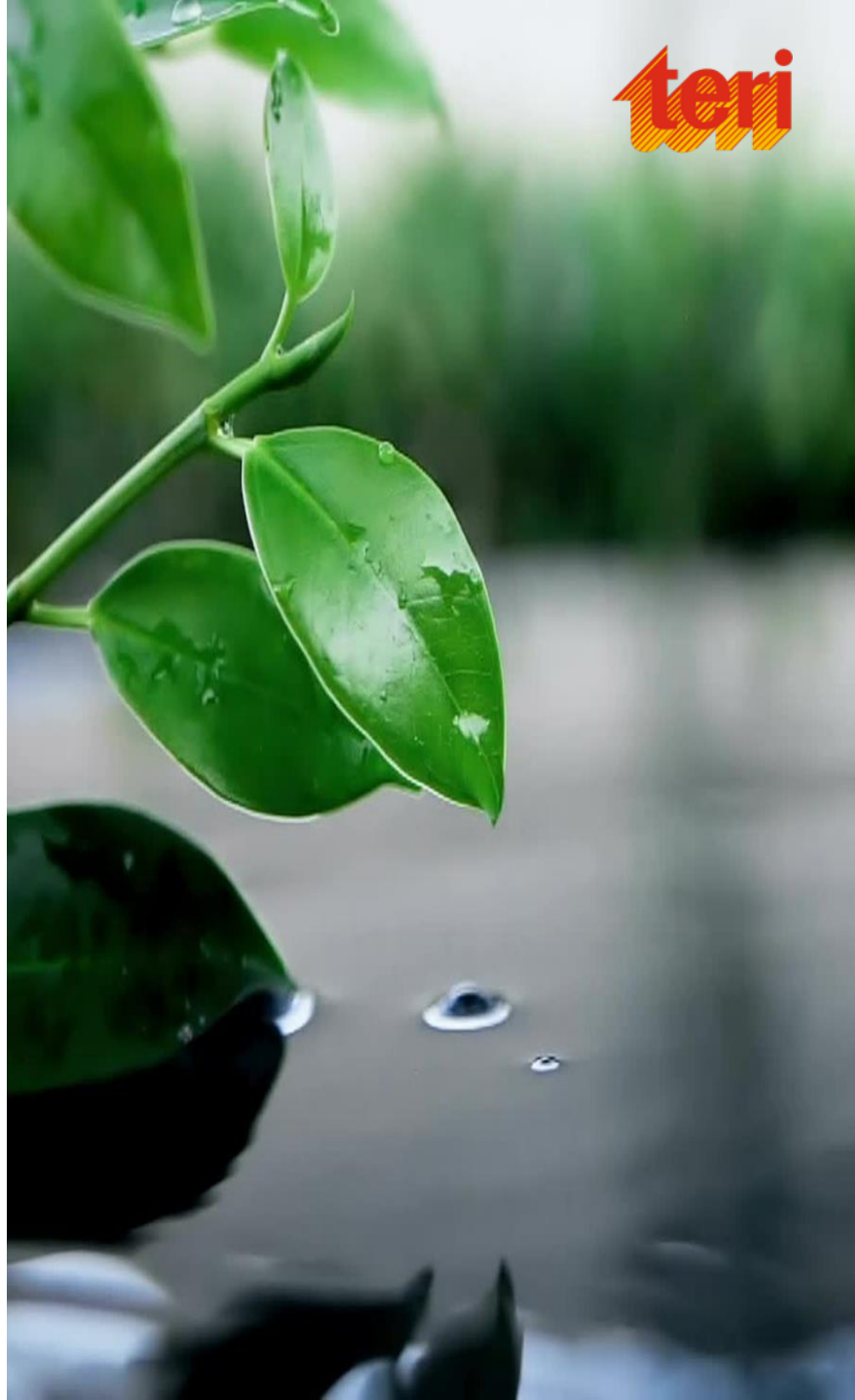
- Contributes to ecological stability and carbon retention.
- Supports endangered species' habitats.
- Relies on over 75% of commercial fish species.
- Maintains resilience to climate stressors.

6. Mangroves Enhance Soil Quality

- Roots slow water flow, settling sediments.
- Support microbial activity for nutrient cycling.
- Absorb and filter heavy metals, excess nutrients, toxins from runoff water.

7. Mangroves in Climate Policy

- Recognized in NDCs under Paris Agreement.
- Part of forest conservation efforts to reduce deforestation and degradation emissions.



Mangroves' Alignment with UN Sustainable Development Goals

SDG 1 & SDG 2: Poverty Reduction & Food Security

- Mangroves boost local economies via fisheries, fuelwood, and carbon credit markets.
- Enhances food security via fishing resources and alternative livelihoods.

SDG 13: Climate Action

- Mangroves trap carbon and serve as natural barriers against climate threats.
- Restoration and protection augment resilience for at-risk coastal communities.

SDG 14: Life Below Water

- Mangroves serve as habitats and nurseries for fish and marine organisms.
- They guarantee the sustainability of fish populations vital for food security and livelihoods.

SDG 15: Life on Land

- Mangroves restore and protect productive ecosystems at land and sea interface.
- They maintain soil stability and water quality.

Module 3 – Mangroves Roots and Climate Actions

3.1 Mangrove Roots: Natural Architects

3.2 Types of Mangrove Roots

3.3 Rooted in Salt: The Salt

3.4 Exclusion Mechanism of Mangroves

3.5 Unique root systems of mangroves

3.6 Why Mangrove Roots Matter for Wildlife

Mangrove Roots: Natural Architects

Mangrove ecosystems rank among the most biodiverse coastal habitats globally. Mangrove trees have specialized root systems — such as **prop roots**, **pneumatophores**, and **buttress roots** — that:

- Stabilize sediments
- Slow down water currents
- Create a complex, three-dimensional habitat

This creates **microhabitats** for countless organisms.

Types of Mangrove Roots

- Prop Roots
- Pneumatophores Roots
- Cable Roots
- Stilt Roots

Prop Roots

Structure:

• Thick roots grow from trunk or lower branches, acting like props.

Function:

• Provide mechanical support in loose, muddy, waterlogged soils.

• Help tree withstand strong tides, waves, storms.

Species Examples:

- *Rhizophora mucronate*
- *Rhizophora apiculata*

Pneumatophores Roots

Structure:

- Specialized vertical root structures from underground roots.
- Looks like spikes or snorkels.

Function:

- Facilitates gas exchange by absorbing oxygen.
- Contain lenticels for respiration.

Species Examples:

- *Avicennia marina*
- *Sonneratia alba*

Cable Roots

Structure:
- Thick, horizontal roots spread laterally through soil.
- Give rise to other root types like pneumatophores or feeder roots.

Function:
- Anchor tree over wide area.
- Play key role in sediment stabilization and erosion control.
- Support growth of other root structures.

Species Examples:
Avicennia officinalis:
Bruguiera gymnorhiza

Stilt Roots

Structure:

• Similar to prop roots, grows diagonally from trunk or lower branches.
• Appears like "stilts" raising tree above ground.

Function:

- Provides additional support in tidal areas.
- Maintains balance during water level fluctuations.

Species Examples:

- *Rhizophora stylosa*
- *Rhizophora mangle*

Rooted in Salt: The Salt Exclusion Mechanism of Mangroves

- Mangroves have evolved their root morphology to exclude salt through filtration.
- Root membrane only allows water molecules to pass through while preventing salt (sodium chloride) to penetrate .
- Mangroves can exclude up to 95% of salt they absorb from seawater with a special filter in root.
- Additional salt that passes through the membrane are excreted via salt glands in leaves.
- These salts in crystal forms are visible on leaf surface.
- Some salts are lost by transpiration from the leaf surface.

Unique root systems of mangroves

Mangrove Roots and Sediment Trapping

- Tangled root structures capture suspended particles in tidal water.
- Sediment accumulation promotes vertical land growth, countering sea-level rise.
- Roots enrich soil and increase sediment volume.
- Roots reduce water speed, settling heavier sediments.
- Creates microhabitats stabilizing sediment through biological activity.

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Barrier Against Sea-Level Rise

- Promotes sediment accretion for land elevation.
- Reinforces coastal margin to minimize shoreline retreat.
- Provides natural alternative to sea walls.
- Facilitates ecosystem resilience through mangrove migration.
- Supports blue carbon stability.

Wave Energy Dissipation in Coastal Erosion

- Above-ground roots break wave force, reducing erosion.
- Wave energy is absorbed and diffused by deep root maze..
- Reduces storm surge impact, acting as defense.
- Decreases tides and currents' energy, limiting inland damage.

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Why Mangrove Roots Matter for Wildlife

- Provide nursery grounds for juvenile fish, shrimp, and crabs.
- Attachment sites for various animals, forming the food chain.
- Habitat for birds like herons, egrets, and kingfishers.
- Habitat for reptiles like crocodiles and snakes.
- Supports endangered species like dugong, Bengal tiger, and saltwater crocodile.

Module 4 – Tidal Dynamics of Mangroves as Climate Vault

4.1 Impact of high tides on Mangrove roots

4.2 Impact of low tides on Mangrove roots

4.3 Tidal Influence on Blue Carbon & Carbon Sequestration in Mangroves

4.4 Significance of Mangrove Roots in Climate Actions

Submerged mangroves during high tide

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Impact of high tides on Mangrove roots

- Impact of high tides on Mangrove roots
- Seawater rises and floods the mangrove area.
- Tides bring in nutrients and sediments from the sea and rivers.
- Roots are submerged in salty, low-oxygen water.
- Marine life such as fish, crabs, and shrimp move into the mangroves to feed and hide.
- Organic matter is trapped by roots, adding to carbon storage.

Impact of low tides on Mangrove roots

- Water recedes, revealing the muddy woodland floor.
- Visible roots include pneumatophores (air roots) and prop roots.
- Organisms include mudskippers, snails, and crabs inhabit the mudflat.
- Soil is aerated, allowing roots to take in oxygen.
- Sediment and carbon-rich particles settle around roots, promoting soil formation and carbon sequestration.

*Real time Pics @Raghab Ray

Exposed mangroves and mudflat during low tide

Tidal Influence on Blue Carbon & Carbon Sequestration in Mangroves

(A) Role of Tides in Mangrove Ecosystems

- Mangroves grow in intertidal zones - areas between high and low tide.
- Tidal movements bring in water, nutrients, organic matter, sediments.
- Tide removal removes waste materials and excess salts.
- Regular tidal flows vital for mangrove root system survival.

B) Tides Enhance Blue Carbon Storage

- Incoming tides carry organic debris and nutrient-rich sediments.
- Mangrove roots trap this, forming carbon-rich soil layers.
- Slowing tide water within root zones settles sediment and organic carbon.
- Adds stored carbon layers, contributing to blue carbon buildup.

(C) Tides Support Carbon Sequestration

- Photosynthesis absorbs atmospheric CO_2.
- Carbon stored in tree trunks, leaves, and roots and sediments.
- Tide maintenance slows organic decomposition and allows long-term carbon burial.
- Restoration of tidal flow is crucial in blue carbon project planning

(D) Tidal Actions reduces Soil Erosion

- Stabilizes coastal soils, preventing carbon erosion.
- Reinforces root systems, protecting below-ground carbon.
- Helps mangroves adapt to sea-level rise, preserving carbon sequestration.
- Removes salts and toxins, improving soil health and promoting vegetation growth.

(E) Tides Movement Supports Biodiversity

- High tides attract estuarine and marine species.
- These species enhance carbon pool.
- Greater biodiversity boosts ecosystem resilience.
- Tidal movements support diverse microbial communities.

(F) Tidal fluctuation for Climate Action

- Healthy tidal flows increase carbon storage rates.
- Disrupting tides reduces mangrove carbon sequestration.
- Tidal balance vital for blue carbon ecosystems.
- Mangrove conservation should consider climate-effective tidal hydrology.

Module 5 – Challenges and Conservation Policies

5.1 Challenges to Mangrove Ecosystems

5.2 Consequences of the destruction of mangrove ecosystems

5.3 Regulatory Measures for Mangrove Protection

5.4 Promotional Initiative for Mangrove Conservation

5.5 India's Mangrove Cover – Status and Trends

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Challenges to Mangrove Ecosystems

Urban Expansion

- Clearing mangroves for cities, ports, and infrastructure.
- Disrupting natural tidal flow and root systems.

Aquaculture & Agriculture

- Widespread conversion for shrimp farms and paddy fields.
- Altering salinity and water quality, degrading ecosystems.

Industrial Development

- Causes habitat destruction and pollution.
- Harms sensitive species via thermal discharges and chemical effluents..

Climate Change

- Rising sea levels and changing rainfall patterns.
- Temperature shifts impacting species composition and productivity

Deforestation & Wood Collection

- Local use of mangrove wood leads to overharvesting.
- Repeated cutting hampers regeneration.

Pollution

- Plastic waste clogs root zones, reducing oxygen availability.
- Oil spills and chemical runoff poison soil and water.

Consequences of Mangroves Destruction

Loss of Blue Carbon sinks — ecosystems turn from carbon storage to carbon sources

Increased coastal erosion due to lack of root structures to hold soil

Higher vulnerability to cyclones, storm surges, and flooding in coastal communities

Decline in fish and marine life — loss of nursery grounds affects fisheries and local livelihoods

Collapse of biodiversity — species that depend on mangrove habitats disappear

Loss of livelihoods — coastal communities lose protection, resources, and income

Soil degradation — exposed soil loses nutrients and releases methane and CO_2

Carbon emissions -Dry, deteriorated mangroves become fire prone

Regulatory Measures for Mangrove Protection

Coastal Regulation Zone Notification, 2019

- Enacted under Environment (Protection) Act, 1986.
- Restricts activities in ecologically sensitive coastal areas.

Wild Life (Protection) Act, 1972

- Protects mangrove ecosystems within wildlife sanctuaries and national parks.

Indian Forest Act, 1927

- Regulates forest conservation, including mangrove forests.

Biological Diversity Act, 2002

- Recognizes mangroves as biodiversity hotspots.

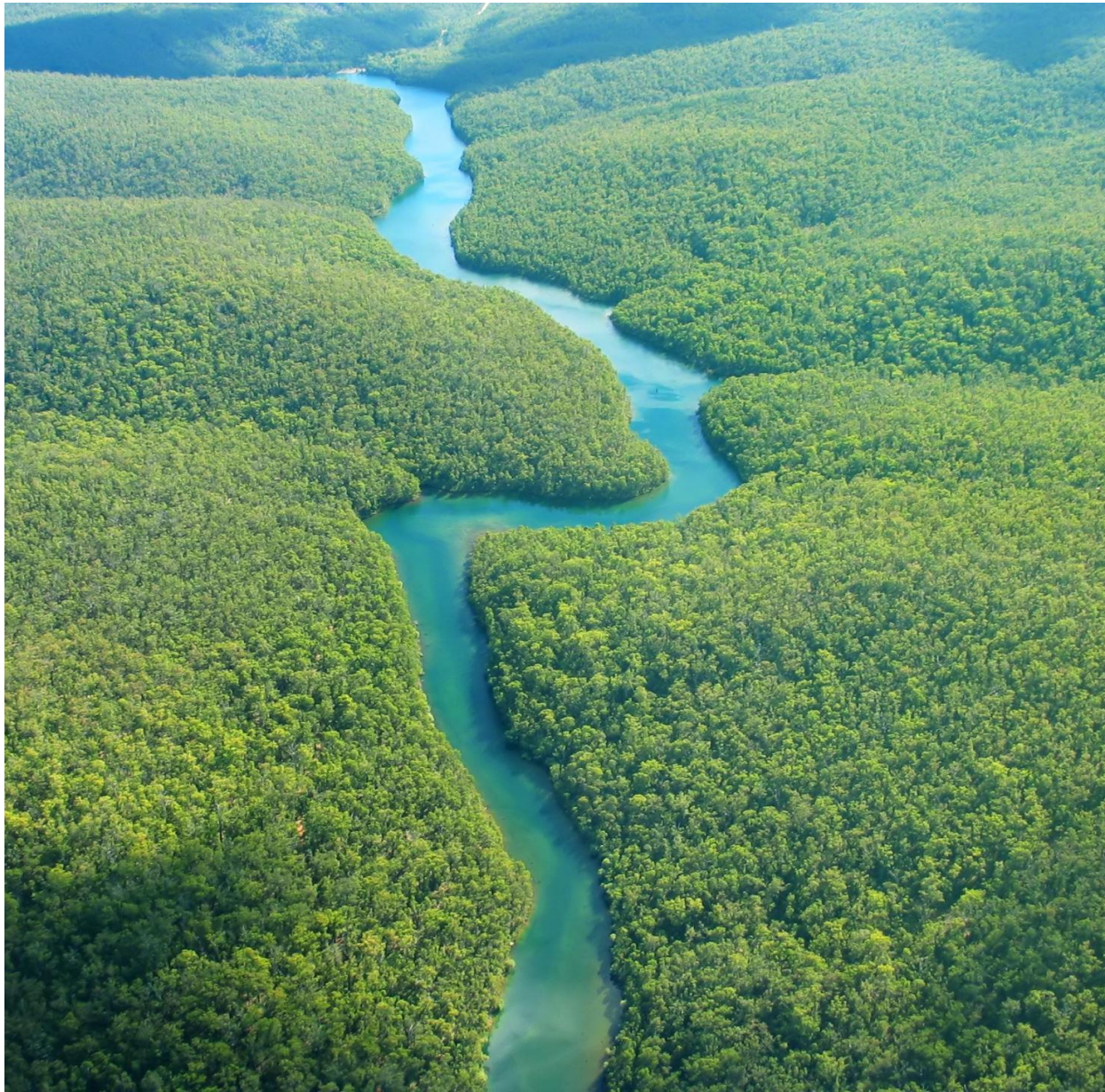
Promotional Initiatives for Mangrove Conservation

Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI)

- Recognizes mangroves as biodiversity hotspots.
- Launched by the Indian Government on June 5, 2023.
- Promotes mangrove forests in 9 coastal states and 4 Union Territories.
- Afforests 540 km² of degraded mangrove land.
- Converged with CAMPA funding

Financial Support for Restoration (2024-25)

- ₹17.96 crore allocated to Andhra Pradesh, Gujarat, Kerala, Odisha, West Bengal, and Puducherry.
- Restored degraded mangroves for biodiversity and coastal resilience.



India's Mangrove cover: Status and Trends

Current Status (as of ISFR 2023)

Key Figures:

- Total mangrove cover: 4,991.68
- Share of India's area: 0.15%
- Change since ISFR 2019: +16.68 km^2

Density breakdown:

- Very dense mangrove: 1,463.97 km^2 (≈ 29.33 %)
- Moderately dense: 1,500.84 km^2 (≈ 30.07 %)
- Open mangrove: 2,026.87 km^2 (≈ 40.60 %)

In a nutshell

Mangrove regeneration and conservation are crucial for climate regulation, coastal protection, and biodiversity. Mangrove destruction releases carbon into the atmosphere, negating its climate benefits. Protecting and restoring mangroves is essential for environmental and human benefits.

Summary

Module 1: Mangrove Ecosystem Overview – Mangrove types, species, India's and world's top 10 mangrove forests. It discusses 10 fascinating mangrove facts and their ecological and socioeconomic value.

Module 2—Blue Carbon Sequestration and Mangroves – Discusses mangrove carbon sequestration and blue carbon. Their carbon dioxide capture and storage to combat global warming is examined.

Module 3: Mangroves and Climate Actions – Mangroves are biodiversity hotspots and blue carbon ecosystems. This module shows how mangrove root systems sequester carbon and form soil, emphasizing climate action

Module 4: Climate Vault Mangrove Tidal Dynamics – As natural climate vaults, high and low tides enhance blue carbon storage, carbon sequestration, and soil formation in mangrove ecosystems.

Module 5: Mangrove destruction risks and effects. It examines India's mangrove cover and trends and mangrove protection regulations and promotions.

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