

## Blue Carbon: The Climate Solution Hidden Along Our Coasts

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### *Abstract*

Blue carbon ecosystems, including salt marshes, mangroves, and seagrass beds, play a vital role in climate change mitigation by capturing atmospheric carbon dioxide and storing it in coastal soils and sediments for decades to centuries. Carbon fixed through photosynthesis is transferred to waterlogged, low-oxygen sediments, where decomposition is slow. Among these systems, mangroves store the greatest belowground carbon because of their woody biomass, dense root networks, and high sediment-trapping capacity. Although they occupy limited coastal areas, blue carbon ecosystems make a disproportionate contribution to long-term carbon sequestration while also supporting shoreline protection and livelihoods, highlighting the importance of their conservation and management.

### **Blue Carbon**

Coastal ecosystems play a critical yet often overlooked role in regulating the global carbon cycle and mitigating climate change. Blue carbon refers to the carbon captured and stored by coastal and marine vegetated ecosystems, primarily mangroves, tidal saltmarshes, and seagrass beds. These ecosystems capture carbon through plant growth, but most of the stored carbon is preserved in underlying waterlogged soils and sediment, enabling long-term sequestration occurs.



**Mangroves of Muthupet, Tamil Nadu: (a) intact mangrove forest and (b) degraded mangrove wetland forest.**

In India, extensive mangrove systems along the east and west coasts represent a significant but underutilized blue carbon resource, with substantial potential for enhancing

national climate commitments while supporting coastal livelihoods.

### Distinctive Features of Blue Carbon

Like all vegetation, coastal plants absorb carbon dioxide from the atmosphere. In mangroves, salt marshes, and seagrass beds, dead plant material is buried in waterlogged, low-oxygen sediments, where decomposition



is greatly slowed. As a result, carbon can remain stored for decades to centuries. Even small areas of these ecosystems can therefore make a substantial climate difference. For example,

1. Mangroves and salt marshes can store 3-5 times more carbon per hectare than many terrestrial forests, largely because of deep and carbon-rich soils.
2. More than 50-90 percent of blue carbon is stored below ground making it far more stable than carbon stored in aboveground biomass.

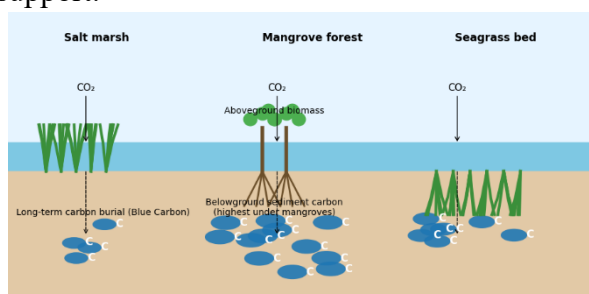
### Carbon Storage in Blue Carbon Ecosystems

Although blue carbon ecosystems occupy less than 2 percent of the global ocean area, they account for an estimated up to 50 percent of total carbon burial in marine sediments.

Typical carbon storage figures highlight their importance:

1. Mangroves: 800 to 1,200 tonnes of carbon per hectare (biomass + soil)
2. Salt marshes: 200 to 900 tonnes of carbon per hectare
3. Seagrass meadows: 100 to 600 tonnes of carbon per hectare

These figures demonstrate why conserving even relatively small coastal areas can deliver climate mitigation benefits comparable to those of much larger terrestrial ecosystems. Increasing recognition of blue carbon has led to its inclusion in national greenhouse gas inventories and climate mitigation strategies in several countries. Protecting and restoring coastal vegetated ecosystems is now considered a nature-based solution that simultaneously contributes to climate mitigation, climate adaptation, and biodiversity conservation. Despite their limited spatial extent, blue carbon ecosystems provide disproportionately large climate mitigation benefits through long-term carbon storage, shoreline protection, and livelihood support.



**Figure: Conceptual coastal transect of blue carbon sequestration and relative belowground carbon storage.**

### Implications of Blue Carbon Ecosystem Degradation

Blue carbon ecosystems are highly vulnerable to anthropogenic disturbances such as mangrove clearance, seagrass dredging, marsh reclamation, and hydrological modification. Such disturbances can rapidly expose long-stored organic carbon to oxidation, resulting in substantial emissions of carbon dioxide and other greenhouse gases. Globally, the degradation and loss of coastal vegetated ecosystems are estimated to release approximately 0.15-1.0 Pg CO<sub>2</sub> yr<sup>-1</sup> offsetting a significant portion of their climate mitigation potential. Once disturbed, these ecosystems often shift from long-term carbon sinks to persistent carbon sources, while simultaneously losing their capacity for future carbon sequestration. In addition to climate impacts, ecosystem degradation leads to reduced fisheries productivity, increased coastal erosion, and heightened vulnerability of coastal regions to extreme weather events and sea-level rise.

### **Management and Conservation of Blue Carbon Ecosystems**

Given the multiple climate, ecological, and socio-economic benefits provided by blue carbon ecosystems, their conservation and management are increasingly recognized as cost-effective and low-risk climate mitigation strategies.

- **Prioritizing protection over restoration**

Protecting intact blue carbon ecosystems prevents immediate emissions and preserves long-term carbon sequestration, making it more efficient than post-disturbance restoration.

- **Restoration under appropriate environmental conditions**

Restoration should focus on re-establishing natural hydrology and sediment dynamics, as addressing these controls can rapidly restore carbon accumulation and support long-term sequestration.

- **Support community stewardship**

Active involvement of local communities in managing blue carbon ecosystems reduces rates of degradation and promote sustainable resource use, thereby enhancing both ecosystem resilience and livelihood security.

- **Integration into climate policy and planning**

Incorporating blue carbon ecosystems into national climate strategies, greenhouse gas inventories, and carbon accounting frameworks can facilitate access to financial mechanisms and policy support, thereby strengthening long-term conservation and restoration efforts.

### **Conclusion**

Blue carbon ecosystems represent a powerful natural climate solution with benefits extending far beyond carbon sequestration. Their protection and restoration offer a rare

opportunity to simultaneously address climate change, coastal resilience, biodiversity conservation, and human well-being. Integrating blue carbon into coastal management and climate policy frameworks is therefore essential for achieving long-term, sustainable climate outcomes.