



Blue carbon ecosystems as a solution for climate change mitigation

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1. Introduction

The ocean, a key player in climate change mitigation, absorbs 20–35% of human CO₂ emissions. Coastal ecosystems—mangroves, salt marshes, and seagrass meadows—are threatened by human activities and climate change. Despite limited global extent, they play a disproportionate role in carbon sequestration. They act as critical carbon sinks, mitigating climate change when they are protected and releasing stored carbon when they are degraded. This exploration highlights their significance, threats, economic value, and the need for an urgent conservation of these ecosystems that are facing alarming decline.

2. Ecosystem services by blue carbon ecosystems and how they are endangered

Ecosystem services, essential for human well-being, encompass provisioning, regulating, supporting, and cultural benefits. Despite their relatively small global extent, vegetated coastal ecosystems (mangrove forests, seagrass beds, salt marshes) are disproportionately important in sequestering carbon dioxide when compared with terrestrial ecosystems¹. The latest report by the Intergovernmental Panel on Climate Change points out that mangroves, salt marshes and seagrass meadows can store up to 1,000 tonnes of carbon per hectare—much higher than most terrestrial ecosystems².

Blue carbon ecosystems, when protected, sequester carbon preventing its release as atmospheric CO₂ and mitigating climate change^{3,4,5,6,7,8,9}. But when they are degraded, they release stored carbon as greenhouse gasses, impacting the atmosphere and oceans¹⁰.

The sequestration occurs in various forms, including living biomass (aboveground and belowground), underlying sediments, and non-living biomass such as litter and dead wood. Blue carbon is stored in biomass over short-term (decennial) periods and in sediments over longer-term (millennial) scales^{7,11}.

Coastal ecosystems are facing alarming rates of decline. Globally, the estimated annual decline is 1–3% for mangroves, 2–5% for seagrass meadows, and 1–2% for saltmarshes. If this trend continues, only 15% of the coastal ecosystems' coverage from the mid-20th century will be left in the next 50 years. Numerous factors contribute to this decline, including coastal development, tourism, land runoff, pollution, invasive species, and climate change-related phenomena¹².

Seagrass

Seagrass ecosystems, crucial for marine life, water quality, and coastal resilience, provide diverse ecosystem services, including carbon sequestration. Despite covering less than 0.1% of the ocean floor, they store 10% of annual oceanic carbon. Threatened by human activities, 29% of global seagrasses have been destroyed. Public indifference and lack of awareness pose significant challenges to seagrass conservation, highlighting the need for measures to protect these vital ecosystems^{12,13,14,15,16}.

Mangrove

Mangrove forests, crucial coastal ecosystems, contribute approximately 218 ± 72 Tg C per year to the global carbon budget. However, over 50% of fixed carbon remains unaccounted for, estimated at approximately 112 ± 85 Tg C per year¹⁷. Mangrove decline, attributed to human activities, has reduced their original cover from 75% to less than 50% worldwide¹⁸. Despite threats, mangrove regions play a vital role in the global carbon cycle, contributing around 40% to terrestrial net primary production (NPP)¹⁹. The global estimate for carbon burial within mangroves ecosystems is about 18.4 Tg C/yr¹⁸.

Salt Marsh

Tidal marshes serve as natural buffers, protecting infrastructure and enhancing landscapes, providing regulatory and cultural services. Their biodiversity supports various ecological functions, offering additional services such as pollination. As providers of essential provisioning services, tidal marshes directly contribute to global food, fiber, and fuel sources²⁰. We show a net salt marsh loss globally, equivalent to an area double the size of Singapore (719 km²), with a loss rate of 0.28% year⁻¹ from 2000 to 2019²¹.

3. Where These Ecosystems are Found:

Mangroves

Mangroves are found in South Asia, Oceania, Central America, and part of the African coast with the highest concentration in Indonesia, a country that is still developing. Globally, the area of mangroves is estimated at 14.8 million ha²².

Salt marshes

Salt marshes are mainly located in North America, Europe and Oceania and are mostly located around developed countries²³. A recent estimate for the global total area is 54 950.89 km²²⁴.

Seagrass

Globally, over 300 000 km² are covered with seagrasses²⁵. The largest seagrass areas are found in Tropical Atlantic (41.06% of global total) and Tropical Indo-Pacific (44.22% of global total)²⁴.

These areas are predominantly composed of lower and middle income countries^{26,27}.

4. Economic aspects: valuation of ecosystem services

Mangroves

A study in Southeast Asia projected that mangrove ecosystem services could lose an annual value of \$2.16 billion by 2050, with Indonesia facing the highest impact at \$1.7 billion annually, and Malaysia at \$279 million²⁸.

Additionally, a World Bank study from 2022 analyzed monetary values (in USD) attributed for each of the 5 most vital services provided by mangroves in the areas in which they are most abundant. The average value of mangroves climate regulation ecosystem services was \$2,798/hectare and the total average for all services provided by mangroves was \$15,017/hectare²⁹.

Salt Marsh

While salt marshes cover a comparatively small portion of the Earth's surface, accounting for less than 1%, their economic significance derived from ecosystem services, cultural contributions, and employment is substantial. Estimates suggest an annual value of around US\$ 8,722 billion, representing approximately 29% of the global annual value of coastal wetlands³⁰.

Leaving the cost of loss aside, Mok (2019) presented a case study in Korea showing that salt marsh restoration can be profitable with blue carbon³¹.

Seagrass

Seagrass meadows are valued at 1.9 trillion USD³². More specifically, Mediterranean seagrass contributes 190 million euros yearly to fishing³³. Maribojoc Bay's seagrass is worth 1.1 million USD, with direct benefits at 708,000 USD³⁴. Urbanization causes a yearly loss of over 100 million euros in the Mediterranean Sea due to the loss of seagrass³⁴ while its restoration costs about 700,000 USD per hectare³⁵.

5. Conservation / restoration perspectives including recommendations and best practice to follow (eg endemic species, SER guidelines/principles)

Nature based solutions (NbS) using the capacity of these ecosystems to act as carbon sinks can be crucial solutions for climate mitigations³⁶. For effective protection of the ecosystem services, there should be a synergistic approach between passive restoration and protection measures, and active restoration. We suggest developing restoration and protection activities following the Society for Ecological Restoration's international principles and standards³⁷. The UN recognizes these efforts highlighting examples of mangrove restoration in Indonesia using natural materials to protect mangroves and improve fishing and farming techniques of local populations in a sustainable way³⁸.

For example, 42% of mangroves are currently under some form of protection, but the level of protection is not sufficient³⁹, as only 13.5% are under strict protection⁴⁰. Only 26% of seagrass meadows⁴¹ and 45% of tidal marshes are included in Marine Protected Areas⁴².

There is a financial gap that must be filled in order to reach these goals, as investments for nature-based solutions should triple by 2030 to meet global targets including climate change mitigation, land degradation and biodiversity protection⁴³. Currently, more funding is allocated to climate change than restoring natural ecosystems.

6. Proposition

We propose that the COP ask the Parties to:

- Include conservation and restoration of blue carbon- storing ecosystems in their National Contributions
- Allocate additional funds to the restoration of carbon-storing marine ecosystems to address the existing financial gap to meet targets in climate change mitigation
- To increase the surface of highly protected areas covering these critical ecosystems and allocate more resources to the monitoring of existing protected areas and enforcement of regulations
- For developed countries to aid developing countries in achieving these objectives through financial support, capacity-building and technology transfer
- Engage discussions on incentive measures for blue carbon similar to REDD+. Such mechanism should be based on similar characteristic to REDD+ such has the elaboration by implementing country of a national strategy, and of a robust monitoring system. Simultaneously, developed country shall provide for financial and technical assistance prior to implementation and ex post payment for verified results. In all phase of implementation safeguards preserving biodiversity and the rights/participation of local population shall be respected.

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