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Blue Carbon Ecosystems: Assessing the Contributions of Mangroves and Coastal Wetlands to Carbon Sequestration and Coastal Storm Protection

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Abstract

Mangrove forests, salt marshes, and seagrass meadows—collectively termed "blue carbon" ecosystems—store disproportionately large quantities of organic carbon relative to their global areal extent while simultaneously buffering coastlines from storm surge, wind-driven waves, and erosion. Despite occupying less than two percent of the ocean surface, these habitats are estimated to account for a substantial share of long-term carbon burial in marine sediments, and their continued loss represents both a climate liability and a growing coastal-hazard exposure for hundreds of millions of people. The dual role of blue carbon ecosystems in climate change mitigation and coastal protection. A structured literature review was combined with a comparative secondary-data analysis of carbon-stock estimates, sequestration rates, historical area change, and economic valuation studies drawn from global and regional assessments. Findings indicate that mangroves hold the highest per-hectare carbon density among vegetated coastal habitats, that global mangrove area has declined by more than twenty percent since 1980 despite a recent slowing of loss rates, and that intact mangrove belts avert tens of billions of US dollars in flood damage annually while protecting millions of coastal residents. The paper further identifies aquaculture conversion, agricultural expansion, and unplanned coastal development as the dominant drivers of habitat loss, and discusses emerging blue carbon crediting mechanisms as a financing pathway for conservation and restoration. The paper concludes that integrating blue carbon ecosystems into national climate strategies and coastal-defense planning offers a comparatively low-cost, co-benefit-rich complement to engineered infrastructure, provided that monitoring, tenure, and financing gaps are addressed.

***Keywords**:* blue carbon, mangroves, coastal wetlands, carbon sequestration, storm protection, climate change mitigation, nature-based solutions

1. Introduction

Coastal ecosystems lie in the transitional dynamic space where marine and terrestrial ecosystems meet, and more recently, the term "blue carbon" has been used to describe mangrove forests, tidal salt marshes and seagrass meadows. This is not to be confused with the carbon sequestered by greenhouse forests or terrestrial "green carbon" forests. These vegetated coastal ecosystems represent a relatively small proportion of the Earth surface, but the amount of carbon stored per unit area in their sediments can be orders of magnitude higher than that stored in terrestrial forests, due to the slow decomposition rates of sediment organic matter in waterlogged, anoxic soils, which allows carbon to build up in sediments over centuries to millennia (Duarte et al., 2015; Macreadie et al., 2019). The same physical traits that include dense root mats, above-ground biomass, and shallow bathymetry are effective in capturing sediment and organic carbon; lower storm surge, wave energy, and shoreline erosion protection; and deliver both climate mitigation and climate adaptation value (Menéndez et al., 2020; Hochard et al., 2019).

Since the first formal articulation of blue carbon as an ecosystem service in the late 2000s, interest has surged, transforming the concept from science into a tool that is more and more integrated at the national-level in to climate policy, voluntary carbon markets and disaster-risk-reduction frameworks (Quevedo et al., 2023). However, mangroves, salt marsh and seagrasses are still some of the most fragile ecosystems on Earth and even in some areas, rates of historical loss are higher than those of tropical rainforest (Friess et al., 2019). Using statistics from the last ten years of scientific and empirical publications, this paper explores the scientific and empirical underpinnings for considering blue carbon ecosystems as a 'dual-use' NbS by summarising the key characteristics of carbon stocks, carbon sequestration processes, historical changes in ecosystem extent, and coastal protection value.

1.1 Background of the Study

Coastal wetlands were identified as important carbon sinks based on decades of biogeochemical research that found that the soils of mangrove, marsh, and seagrass accumulate organic carbon much more efficiently than many terrestrial ecosystems because the conditions under which the soils of these ecosystems are saturated and saline and microbial decomposition proceeds slowly (Alongi, 2018). The carbon stocks in the mangroves in terms of above- and below ground biomass plus soil carbon to one meter or more have been estimated to be about 956 megagrams of carbon per hectare, several times higher than stocks found in many upland forest types (Alongi, 2018). Exposure to coastal hazards has been measured in parallel studies, where vegetated shorelines have been seen to measurably reduce both wave height and storm surge run-up, with the amount of wave attenuation a function of forest width, stem density, and bathymetric slope (Krauss & Osland, 2020). These two streams have merged into a single perspective where coastal wetland conservation is viewed as a climate mitigation instrument and as a cost-effective coastal protection measure, which has sparked renewed interest in the insurance industry, multilateral development banks and governments.

1.2 Significance of the Study

Understanding the combined carbon and protective value of blue carbon ecosystems is significant for several interconnected reasons. First, as nations refine their Nationally Determined Contributions under the Paris Agreement, accurate quantification of coastal wetland carbon stocks and fluxes is necessary to credibly include these ecosystems in national greenhouse gas inventories

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and mitigation targets (Taillardat et al., 2018). Second, coastal populations are expanding rapidly in low-lying tropical and subtropical regions that are simultaneously experiencing sea-level rise and intensifying tropical cyclone activity, making the physical protection function of mangroves and marshes directly relevant to disaster-risk-reduction planning (Menéndez et al., 2020). Third, the emergence of blue carbon crediting mechanisms creates a potential financing pathway that could redirect capital toward conservation and restoration, but only if the underlying science of carbon accounting is robust and transparent (Quevedo et al., 2023). Synthesizing the current evidence base therefore has direct relevance for climate negotiators, coastal planners, conservation practitioners, and the finance community.

1.3 Scope and Structure of the Paper

This paper is organized into six main sections. Following this introduction, Section 2 reviews the peer-reviewed literature on blue carbon science, organized around four themes: the biogeochemistry of carbon storage and sequestration; the physical mechanisms of storm and erosion protection; historical and projected trends in ecosystem extent and loss; and policy, valuation, and restoration approaches. Section 3 describes the research methodology used to compile and analyze secondary data for this synthesis. Section 4 presents results in tabular and graphical form, covering comparative carbon stocks, sequestration rates, historical area trends, economic valuation of flood protection, and drivers of ecosystem loss. Section 5 discusses the implications of these findings, and Section 6 concludes with recommendations for research, policy, and practice.

2. Literature Review

The literature on blue carbon ecosystems has expanded considerably over the past decade, moving from foundational stock assessments toward more nuanced treatments of flux dynamics, land-use change, coastal protection modeling, and market-based conservation finance. This section reviews that literature across four thematic areas.

2.1 Carbon Storage and Sequestration Mechanisms

A large portion of mangrove research has documented their ability to sequester carbon at rates that are not proportional to mangrove acreage.A significant amount of research has documented the ability of mangroves and salt marshes and seagrasses to sequester carbon at a rate greater than their areal extent. Based on estimates of aerial sedimentation and organic matter burial, Duarte et al. (2015) suggested that vegetated coastal systems sequester carbon at rates of approximately four times the rate of carbon sequestration in terrestrial forests per unit area, and that this increased rate of sequestration is due to the fact that sediment accretion buries organic material out of the zone of active decomposition. Mangrove soil carbon stocks vary globally and have been compiled by Atwood et al. (2017) who found high variability across the globe: climate, tidal range and geomorphic setting all influence carbon stocks, with highest carbon stocks in the Indo-Pacific region. Further, a systematic review by Sasmito et al. (2019), showed that when mangroves are being converted to aquaculture ponds, most of their soil carbon can be lost in just a couple of years of clearing, effectively negating centuries of soil organic carbon building up. On a national level, Murdiyarso et al. (2015) demonstrated that Indonesia's mangroves could sequester enough carbon to lead to a material component of its emissions profile if they were conserved. Alongi (2023) has pointed out that the mass balance of carbon in these systems is incomplete, as carbon can be laterally exported as dissolved and particulate carbon, flow off into adjacent waters, flow into groundwater, and be exported as methane and nitrous oxide.

2.2 Storm Protection and Coastal Defense Functions

A growing, but parallel, body of scientific literature has explored how blue carbon ecosystems mitigate storm and flood risk. Hochard et al. (2019) have shown that the economic losses after a tropical cyclone are lower for coastal districts that have a wider mangrove cover, than for other districts with similar characteristics but without mangroves. Menéndez et al. (2020) created high-resolution hydrodynamic and economic models across the mangrove shoreline and calculated that the existing mangrove cover currently averts an estimated US$65 billion in flood damage annually and protects an estimated 15 million people annually from flooding; with benefits being largely focused in China, the United States, India and Mexico. Although mangrove forests can suffer significant defoliation, tree mortality and sediment elevation change due to erosion or peat collapse during or following tropical cyclones, forest structure and root architecture can still provide measurable wave attenuation even in the face of those events (Krauss & Osland 2020). All this literature has changed the mindset from coastal wetland as an ambiguous habitat to be protected to a vital component of the coastal infrastructure that needs structural investment and economic development.

2.3 Historical Trends, Threats, and Ecosystem Loss

There has been a number of studies that quantify the significance and causes of the loss of blue carbon ecosystems. While annual mangrove deforestation rates have dramatically decreased since the 1990s and 2000s, the total mangrove loss since 1980 is more than one-fifth of global mangroves, with Southeast Asia having seen the biggest drops caused by aquaculture and agriculture. (Friess et al., 2019) However, Worthington et al. (2020) created a biophysical global mangrove typology with a relationship between mangrove forest structure and deforestation risk, revealing that mangroves in river deltas are particularly vulnerable to conversion due to their suitability for shrimp and fish culture. If protection efforts are not adequate, continued deforestation could add hundreds of megatons of carbon dioxide-equivalent (CO_2e) emissions by mid-century, according to Adame et al. (2021) who modeled future carbon emissions resulting from the projected loss of mangroves. A related but different phenomenon—the expansion of mangroves from neighbouring salt marsh areas due to a shift to warmer winters—increased the

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carbon stored locally, but also reduced salt marsh-dependent biotic diversity and ecosystem services, highlighting that the kind of blue carbon change does not necessarily equate to unidirectional habitat degradation (Kelleway et al. 2017).

2.4 Policy, Valuation, and Restoration Approaches

Conversely, there is emerging policy-oriented literature that looks at how blue carbon science can be translated to conservation finance and governance. Taillardat et al. (2018) stated that a national (vs. site specific) scale is most cost-effective and when implemented, does not double count payments and accounts for leakage between project sites. Macreadie et al. (2019) proposed a research agenda for blue carbon which included the need for a common measurement protocol, improved consideration of methane and nitrous oxide fluxes for net C accounting, and improved connections between blue carbon science and the reporting processes under the UNFCCC. A bibliometric analysis by Quevedo et al. (2023) demonstrated exponential growth in blue carbon publications since 2009, and a focus on governance issues like land rights, community rights and equitable benefit-sharing, since then. Measurable carbon mitigation (tens of megagrams of carbon dioxide-equivalent per hectare per year) has been demonstrated within the first 10 years of replanting mangrove species in Indonesia, particularly in Sulawesi, with important outcomes being dependent on hydrological restoration and species selection (e.g. Cameron et al. 2019). In addition, Rogers et al. (2019) showed from a global database of wetland sediment cores that the ability of these ecosystems to "catch up" with SLR is similarly influenced by sediment supply and the accommodation space, and therefore geomorphic factors need to be considered for wetland restoration plans, not just vegetational attributes.

3. Research Methodology

This paper employs a descriptive, secondary-data research design combining a structured narrative literature review with a comparative quantitative synthesis of published carbon-stock, sequestration-rate, area-change, and economic-valuation data. The approach was selected because primary field measurement of blue carbon stocks and storm protection outcomes requires long-term monitoring infrastructure that is beyond the scope of a single desk-based study; a synthesis of existing high-quality datasets instead allows for cross-ecosystem and cross-regional comparison.

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3.1 Introduction

Academic databases and database platforms of the publishers were used to identify peer-reviewed journal articles, systematic reviews, and technical reports published in the last 10 years, which included the Global Mangrove Alliance and other related international organizations. The keywords "blue carbon," "mangrove," "coastal wetland," "carbon sequestration," "carbon stock," "storm protection," and "coastal defense" were used to combine the terms in the search. Studies that provided quantitative carbon-stock or sequestration-rate data, quantitative storm or flood protection estimates, or empirical historical area-change data for mangroves, salt marshes, and seagrass meadows were included.

3.2 Data Sources and Extraction

The quantitative parameters in the comparative tables and figures provided in Section 4 were obtained directly from the literature that was identified, such as global meta-analyses of stocks of soil organic carbon, whole-ecosystem estimates of carbon stocks, national and global flood-protection valuation models, and long-term assessments of mangrove area. When several studies provided overlapping estimates of the same parameter, the latest and highest resolution global assessment, was chosen and ranges or standard deviations were included when reported in the literature from which the data were drawn, as a reflection of natural variability within climatic zones and geomorphic settings.

3.3 Analytical Approach

The data extracted were presented in eight comparative tables: extent of the ecosystem, carbon stocks, rates of ecosystem carbon sequestration, historical trends in area, drivers of ecosystem losses, economic valuation of flood protection, evidence from case studies of storm damage reduction, and restoration and policy initiatives. Six graphic visualizations in the form of graphs and charts were prepared to help illustrate comparisons across ecosystems and across countries. Unless otherwise stated all monetary values are reported at the price basis of the source publication in United States dollars and all carbon values (kg C ha^{-1}) in megagrams of carbon per hectare (Mg C ha^{-1}). New field measurements will not be reported in this paper but instead the method of comparative-synthesis is used to define patterns through the existing evidence base.

3.4 Limitations

The study is a literature-based synthesis, and hence it has the same limitations of the original collection of data, such as geographic bias towards the relatively well-studied areas of Southeast Asia, Australia and the United States and methodological heterogeneity in the definitions of ecosystem boundaries, the soil-depth limits considered, and the time horizons used for the calculation of sequestration rates. The economic valuation studies are also subject to the sensitivity of the assumed asset value, hazard models and discount rates in the original studies. Where relevant, these restrictions are taken into account in the Results discussion, in Section 5.

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4. Results

This section presents the comparative findings of the literature synthesis across eight tables and six figures, covering the global extent of blue carbon ecosystems, comparative carbon stocks and sequestration rates, historical area change, drivers of loss, and the economic and social value of coastal protection.

4.1 Global Extent of Blue Carbon Ecosystems

Table 1 summarizes current estimates of the global areal extent of the three principal blue carbon habitat types, illustrating that salt marshes and seagrasses occupy larger combined areas than mangroves, even though mangroves generally hold the highest carbon density per hectare (Friess et al., 2019; Spalding & Leal, 2021).

Table 1. Estimated Global Area of Major Blue Carbon Ecosystem Types

Ecosystem	Estimated global area (million ha)	Primary regions of occurrence
Mangroves	13.5 - 15.2	Southeast Asia, South Asia, West/Central Africa, Latin America
Salt marshes	22 - 40	Temperate North America, Europe, East Asia
Seagrass meadows	16 - 27	Global, widest in the Indo-Pacific and Mediterranean

4.2 Comparative Whole-Ecosystem Carbon Stocks

Table 2 and Figure 1 compare whole-ecosystem carbon stocks—combining above-ground biomass, below-ground biomass, and soil carbon—across blue carbon habitats and a terrestrial rainforest reference point, confirming that mangroves hold the highest carbon density of any of the compared habitat types (Alongi, 2018).

Table 2. Whole-Ecosystem Carbon Stocks by Habitat Type

Habitat type	Whole-ecosystem carbon stock (Mg C ha^{-1})	Approximate CO_2-equivalent (Mg CO_2e ha^{-1})
Mangroves	956	~1,494
Salt marshes	593	~951
Peat swamp forest	408	n/a
Seagrasses	142	~607
Tropical rainforest (reference)	241	n/a

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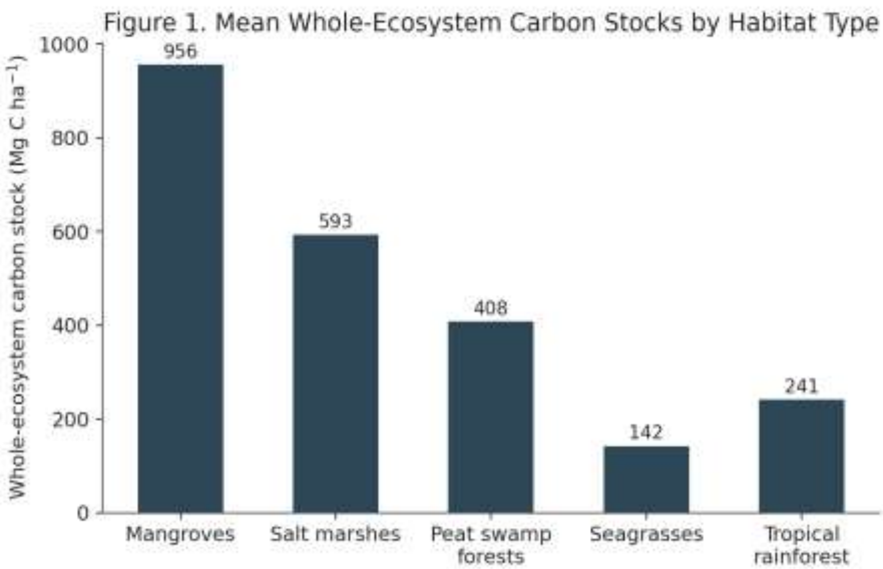

Figure 1. Mean whole-ecosystem carbon stocks by habitat type (Mg C ha^{-1}).

4.3 Soil Organic Carbon and Sequestration Rates

Because the majority of blue carbon is stored belowground, Table 3 and Figure 2 isolate soil organic carbon stocks and reported annual sequestration rates. Mangroves again show the highest mean soil carbon stock, though the wide standard deviations reported across studies reflect substantial regional and geomorphic variability (Atwood et al., 2017).

Table 3. Soil Organic Carbon Stocks and Mean Annual Sequestration Rates

Habitat type	**Soil organic carbon (Mg C ha^{-1}, 0-1 m)**	**Reported mean sequestration rate (Mg C ha^{-1} yr^{-1})**
Mangroves	192 ± 130	1.2 - 3.0
Salt marshes	111 ± 65	1.0 - 2.5
Seagrasses	74 ± 75	0.4 - 1.5
Unvegetated tidal flats	78 ± 55	< 0.3

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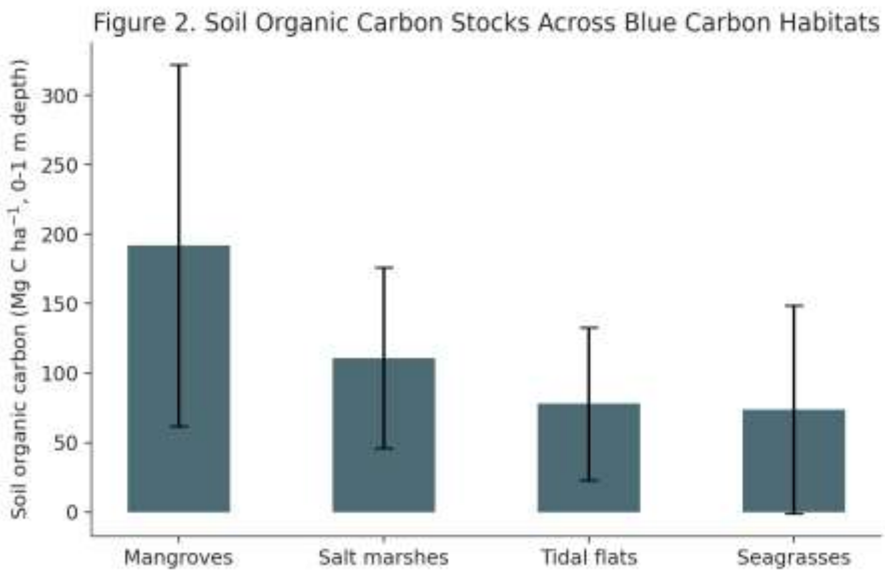

Figure 2. Soil organic carbon stocks across blue carbon habitats (error bars show reported standard deviation).

4.4 Historical Trends in Global Mangrove Area

Table 4 and Figure 3 present the historical trajectory of global mangrove area from 1980 to 2020, showing a cumulative decline of over twenty percent through 2015, followed by a modest partial recovery and a marked slowdown in the annual rate of loss over the most recent decade (Friess et al., 2019; Worthington et al., 2020).

Table 4. Estimated Global Mangrove Area, 1980-2020

Year	Estimated global mangrove area (million ha)	Cumulative change since 1980
1980	18.8	baseline
1990	16.9	-10.1%
2000	15.7	-16.5%
2010	14.8	-21.3%
2015	14.5	-22.9%
2020	14.7	-21.8%

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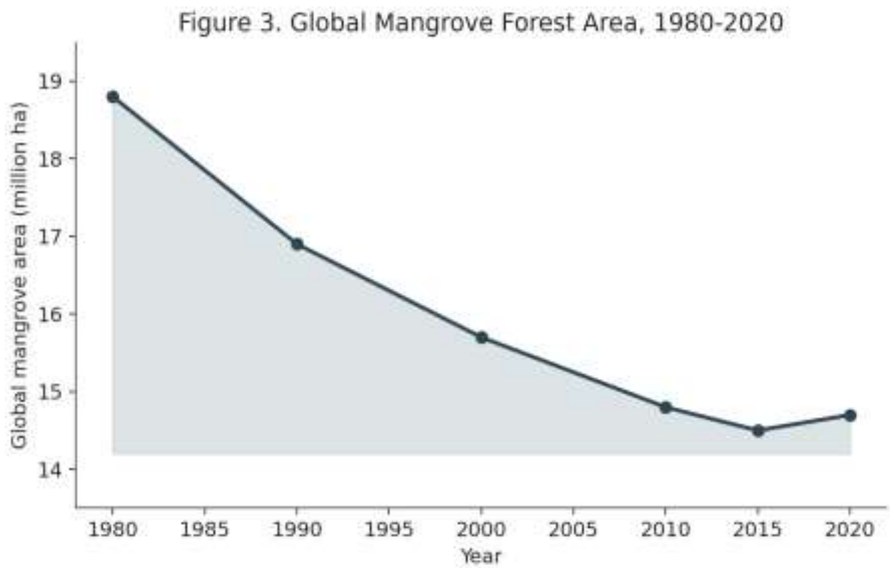

Figure 3. Global mangrove forest area, 1980-2020 (million hectares).

4.5 Drivers of Blue Carbon Ecosystem Loss

Table 5 and Figure 5 summarize the estimated relative contribution of major drivers to global mangrove loss, with aquaculture conversion identified as the single largest driver, followed by agricultural expansion and urban development (Sasmito et al., 2019; Adame et al., 2021).

Table 5. Estimated Drivers of Global Mangrove Loss

Driver of loss	Estimated share of global mangrove loss (%)	Representative regions
Aquaculture conversion	32	Southeast Asia, Ecuador, Central America
Agricultural expansion	22	South and Southeast Asia, West Africa
Urban and infrastructure development	18	Coastal megacities, South Asia
Overharvesting (timber and fuelwood)	14	East Africa, South Asia
Erosion and sea-level rise	9	Pacific Islands, Mekong and Niger deltas
Other / unclassified	5	Global

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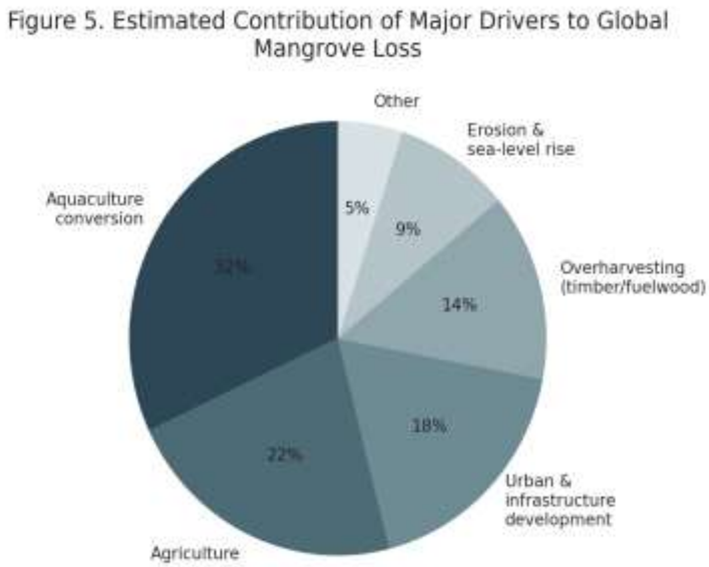

Figure 5. Estimated contribution of major drivers to global mangrove loss.

4.6 Economic Value of Coastal Protection

Table 6 and Figure 4 report country-level estimates of the annual economic value of flood protection provided by mangroves, drawn from high-resolution global hydrodynamic modeling. China, Vietnam, and Australia rank among the highest in absolute monetary value, while Table 6 and Figure 6 together show that Vietnam, India, and Bangladesh have the greatest number of people protected annually, reflecting dense coastal populations fronted by mangrove belts (Menéndez et al., 2020).

Table 6. Annual Economic Value and Population Protected by Mangroves, Leading Countries

Country	**Annual flood-protection value (US$ billion)**	**People protected annually (millions)**
China	10.9	1.5
Vietnam	8.6	4.1
Australia	6.4	0.2
United States	6.3	0.3
India	5.3	3.6
Mexico	4.5	0.4

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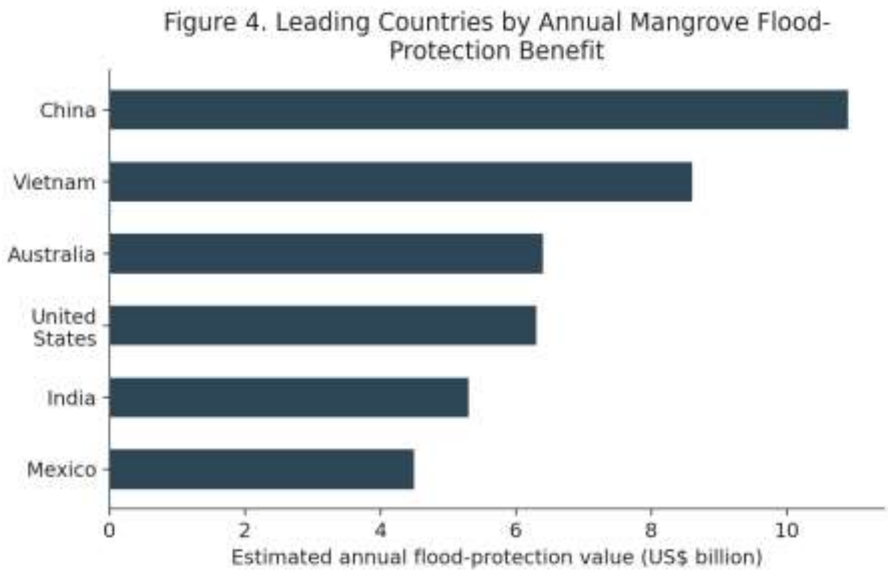

Figure 4. Leading countries by annual mangrove flood-protection value (US$ billion).

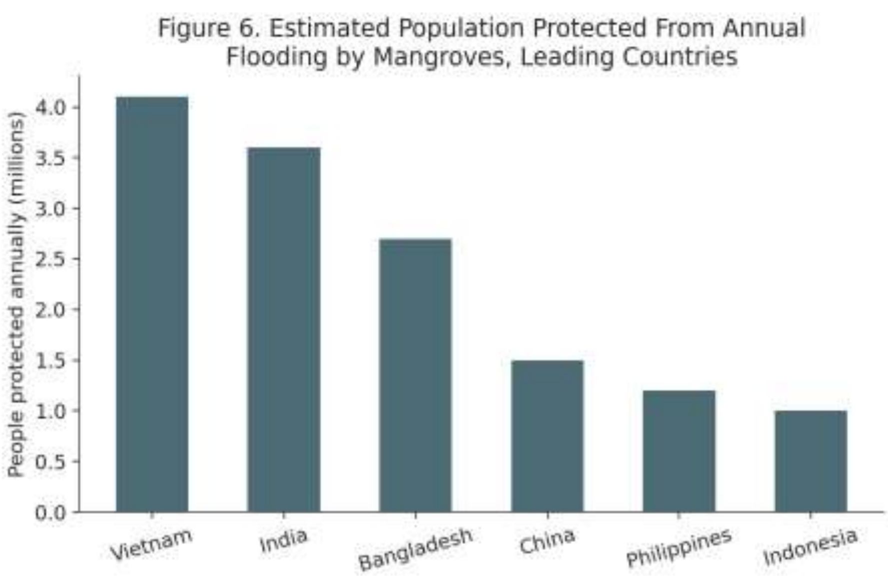

Figure 6. Estimated population protected from annual flooding by mangroves, leading countries (millions).

4.7 Case Study Evidence of Storm Damage Reduction

Table 7 summarizes case-study and empirical evidence linking mangrove presence and width to reduced storm and cyclone damage, spanning historical cyclone analyses, high-resolution flood models, and post-disaster mortality studies (Hochard et al., 2019; Krauss & Osland, 2020).

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Table 7. Case Study and Empirical Evidence of Mangrove-Related Storm Damage Reduction

Study / event context	Location	Reported protective effect
Hochard et al. (2019), historical cyclone analysis	Global tropical coastline	Wider mangrove belts associated with significantly smaller post-cyclone economic activity losses
Menéndez et al. (2020), global flood model	Global mangrove coastline	US$65+ billion in avoided flood damage annually; 15 million fewer people flooded
Das & Vincent (2009 study, cited in later syntheses)	Odisha, India (1999 super cyclone)	Villages fronted by wider mangrove belts recorded significantly lower storm mortality
Krauss & Osland (2020), structural review	Gulf of Mexico, Caribbean, Indo-Pacific	Root and canopy structure reduced wave energy even after storm-related defoliation

4.8 Restoration and Policy Initiatives

Table 8 summarizes selected restoration, financing, and policy mechanisms identified in the literature as pathways for scaling blue carbon conservation and restoration, ranging from site-level carbon-credit projects to national climate policy integration (Taillardat et al., 2018; Cameron et al., 2019).

Table 8. Selected Blue Carbon Restoration and Policy Initiatives

Initiative / mechanism	Type	Primary objective
Blue Carbon Initiative	International science-policy partnership	Standardize methods for blue carbon measurement and policy integration
Cispatá Bay mangrove carbon project, Colombia	Verified carbon-credit project	Generate financing for mangrove conservation via carbon markets
North Sulawesi mangrove rehabilitation, Indonesia	Community-based restoration	Restore hydrology and replant mangroves to rebuild carbon stocks
National Blue Carbon inclusion in NDCs	National climate policy	Incorporate coastal wetland carbon into Paris Agreement emissions targets

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Global Mangrove Alliance restoration pledges	Multi-stakeholder coalition	Coordinate global mangrove restoration and no-net-loss targets

5. Discussion

The conclusions drawn above are consistent with the pattern observed throughout the literature reviewed: carbon storage, especially in mangrove wetlands, is particularly high per unit area, and measurable and economically beneficial coastal protection benefits exist. While mangroves are superior to salt marshes and seagrasses for carbon stocking on a per-hectare basis, these data in Table 2 and Table 3 are further confirmation that all three habitat types make meaningful contributions to global carbon stocks as a whole, and should not be viewed as substitutes for each other in conservation planning (Rogers et al., 2019).

Table 4 and Figure 3 present the best available estimate of historical trends in the area of mangrove loss, showing a story of both a significant loss and cautious optimism about recent reduction in this loss, several of which authors can explain by to a greater degree structural changes in the laws regarding mangrove protection in the county, increasing awareness of mangrove ecosystem services and the growth of mangrove restoration programs (Worthington et al., 2020; Friess et al., 2019). However, as the driver analysis in Table 5 is clear, the economic pressures towards conversion from mangrove to aquaculture or agriculture are still there, and ongoing protection will require a greater competitiveness of conservation, which is what blue carbon payment mechanisms are meant to create a margin for (Taillardat et al., 2018).

The economic valuation results in Table 6 and Figures 4 and 6 show that flood-protection benefits are not distributed equally; the US, China, and Australia benefit most with the absolute monetary value of benefits, while Vietnam, India, and Bangladesh benefit most with the number of people that the benefit protects. The gap also has consequences for international funding of climate change and DRR, as the purely monetary valuation method would systematically underestimate the benefits of human welfare that are largely concentrated in coastal areas with lower incomes and higher population density (Menéndez et al., 2020). The evidence presented in the case studies (Table 7) further adds to the argument that mangroves are a natural form of infrastructure that is most visible when extreme storm events occur, and also after those events, which makes them a natural component of engineered coastal defence planning rather than an alternative (Krauss & Osland, 2020, Hochard et al., 2019).

The restoration and policy work outlined in Table 8 show that the field has stepped past the conceptual advocacy phase to ground level implementation – such as projects validated as carbon credits, and integration of national policy. Nevertheless, there are important challenges to scaling these mechanisms responsibly, including measurement uncertainty, the lack of adequate accounting of fluxes of methane and nitrous oxide gases, and insufficient long-term monitoring capacity in many developing countries, as warned by authors such as Macreadie et al. (2019) and Alongi (2023).

6. Conclusion

This paper has compiled the peer-reviewed publications in the range of 2015-2024, and assessed mangroves' and coastal wetlands' functions of carbon sequestration and storm protection. The evidence points to the fact that blue carbon ecosystems, in particular mangrove forests, contain carbon more densely than most terrestrial environments; that, globally, mangrove area has been reduced significantly since 1980 although the rate of loss has recently dropped; and that healthy mangrove belts offer similar flood-protection value of tens of billions of US dollars per year, protecting millions of people from storm-related flooding. Continued loss is mainly driven by aquaculture conversion, agricultural expansion, and coastal urban development, highlighting that conservation success will rely on economic and ecological values being more in sync.

The results found here reflect the overall conclusion of blue carbon ecosystems as a comparatively low-cost, co-benefit rich nature-based solution, which can be integrated alongside engineered coastal infrastructure and help to achieve national carbon mitigation pledges. If this potential is to be realised at scale, it will require three parallel efforts: increasing the ability to monitor and provide standardised carbon accounting at scale, which will help to mitigate measurement uncertainty; scaling up financing mechanisms that are equitable and include communities, including national-scale blue carbon credits; and embedding mangrove, salt marsh and seagrass conservation explicitly in coastal-hazard and land-use planning, not as an environmental target alone. Continued research should focus on filling gaps in regional data that are not strongly represented in the most heavily studied areas, progress in quantifying methane and nitrous oxide fluxes in net carbon accounting, and on longitudinal studies of rehabilitated habitats to understand how quickly rehabilitated sites converge to the carbon and protective function of natural and undisturbed habitats. Closing these gaps will enhance the science and finance base for the conservation of blue carbon ecosystems as an immediate climate priority with a dual purpose.

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