CLIMATE ANALYTICS

Troubled waters

Risks and realities of blue carbon in climate action

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About Climate Analytics

Climate Analytics is a global climate science and policy institute. Our mission is to deliver cutting-edge science, analysis and support to accelerate climate action and keep warming below 1.5°C.

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Summary

Blue carbon has rapidly risen up the climate agenda as countries seek new pathways to meet and enhance their Nationally Determined Contributions (NDCs). Once a niche scientific topic, the carbon stored in coastal and marine ecosystems, such as mangroves, salt marshes, and seagrass meadows, is now viewed as a potential bridge between mitigation, adaptation, and climate finance. Yet, many uncertainties persist in the science, policy, and governance foundations necessary for the responsible use of blue carbon. The level of effort in this area must also reflect the very limited global mitigation potential of blue carbon ecosystems, estimated with large uncertainties as approximately 2% of 2024 global annual GHG emissions (3% of global fossil CO_2 emissions).

This brief reexamines blue carbon at a time when the world has warmed by about 1.4°C and climate tipping points are being approached or exceeded. Associated climate changes threaten the persistence of the very ecosystems positioned as carbon sinks. While blue carbon systems can store carbon for centuries, their permanence depends on stable ecological and climatic conditions that are rapidly eroding. Disturbances such as sea-level rise, erosion, marine heatwaves, and extreme storms can quickly reverse sequestration gains, transforming these sinks into sources.

Scientific advances have clarified both the potential and fragility of these systems. Blue carbon ecosystems remain vital sinks in the earth system, and the protection of intact ecosystems delivers immediate, verifiable climate and resilience benefits. However, uncertainties and risks persist around the role and viability of the ecosystems, in particular for offsetting purposes. New evidence suggests that blue carbon ecosystems may cease functioning as net sinks beyond 1.5°C of warming, underscoring the urgency of deep emissions cuts elsewhere. As our understanding of blue carbon systems grows, the message from current science is clear: the sequestration value of blue carbon is inseparable from the broader success of global decarbonisation. The warmer the planet becomes, the greater the weakness and unreliability of the blue carbon sink.

The viability of blue carbon as a mitigation option is therefore questionable and the use as offsets counterproductive. More broadly, it is becoming increasingly clear that humanity will need substantial Carbon Dioxide Removal (CDR) capacity to compensate for lack of past global mitigation and simultaneously respond to likely feedback from warming, whereby the earth system will take up an ever-smaller fraction of emitted CO_2 over time. The limited CDR capacity available, as well as its uncertainty, means that CDR should not be counted on via offsets to counter-balance residual fossil fuel emissions that could have otherwise been eliminated.

Despite these uncertainties and cautions, policy momentum is outpacing awareness and readiness. Many countries have begun referencing blue carbon in NDCs, often qualitatively, without the robust measurement, reporting, and verification (MRV)

systems required for credible accounting. While the IPCC Wetlands Supplement provides methodological guidance, the actual implementation of these measures remains limited.

Blue carbon's contribution to adaptation and resilience, however, is clearer and immediate. Healthy coastal ecosystems attenuate wave energy, buffer storm surges, stabilise shorelines, and sustain fisheries and local economies. Protecting them safeguards livelihoods and natural defences for millions of people in low-lying and island nations. Their benefits for water quality, biodiversity, and cultural heritage are tangible and enduring, even where mitigation gains are uncertain. Improving inventories, understanding Blue Carbon potential as adaptation option and improving governance, laboratory and technical capacity should be prioritised.

In climate finance, blue carbon now features in innovative instruments, including blue bonds, debt-for-nature swaps. It is also increasingly being discussed in relation to carbon markets. Despite this growing interest, these markets pose major integrity risks if pursued as substitutes for fossil fuel mitigation. Attempting to offset emissions through blue carbon credits would undermine 1.5°C pathways by delaying deep, cross-sectoral decarbonisation and exposing vulnerable states to reversal, double-counting, and equity risks.

Accordingly, the report outlines a recommended approach for responsible engagement:

1. **Protect and restore first:** Prioritise avoided loss of existing ecosystems to ensure that the co-benefits of blue carbon ecosystems for mitigation and adaptation are retained.
2. **Build MRV capacity:** Invest in science, data, and institutional systems to robustly monitor blue carbon ecosystem dynamics before seeking to establish baselines for the assessment of sequestration potential.
3. **Integrate cautiously:** Reflect blue carbon in NDCs through qualitative, resilience-focused metrics, with a particular emphasis on adaptation-centred interventions.

4. **Exercise extreme caution toward carbon markets:** Engaging in offsetting or trading mechanisms with blue carbon-based activities is not advised under current conditions. The inherent measurement uncertainty and impermanence of these approaches, taken together with growing climate impacts, risk undermining environmental integrity if connected to mitigation targets and impose liabilities upon reversal. Any future consideration of blue carbon quantification for accounting or financing purposes should be preceded by extensive regulatory, technical, and institutional preparatory groundwork, which will produce a long time series of inventories to support decision making as part of a robust MRV system. Environmental and social safeguards should also be sufficiently accounted for in any groundwork.

Instead of high-risk engagement with carbon markets, countries are encouraged to explore alternative innovative instruments of finance that favour results-based payments centered around ecosystem conservation and restoration, such as the Tropical Forest Forever Facility (TFFF). A blue carbon finance mechanism informed by the principles of the TFFF could prioritise the conservation and enhancement of ecosystem function rather than the monetisation of carbon. Payments would reward policy performance and verified environmental outcomes, providing countries with a predictable resource stream that strengthens national adaptation and coastal management systems without exposing them to the risks of offset markets.

However, direct replication of the TFFF model for blue carbon ecosystems is neither technically nor institutionally feasible. Further research and analysis is still needed to understand the articulate the instruments, costings, and potential returns of a financing facility for blue carbon ecosystem preservation. While unlikely to be directly transferrable to the context of blue carbon, the TFFF does illustrate the fact that climate finance can be mobilised at scale through non-market, policy-based mechanisms that reward ecosystem protection rather than the creation of carbon commodities. For countries seeking to strengthen resilience, support coastal communities, and safeguard ecosystems that are increasingly threatened by climate change, this offers a potentially compelling and lower-risk pathway that aligns with the priorities set out in this brief.

Blue carbon should currently be treated as a fragile, but vital asset with the potential to reinforce rather than replace the systemic decarbonisation required across all sectors. In this regard, blue carbon is not a silver bullet for countries seeking to meet mitigation targets, or generate climate finance, while avoiding emissions cuts in critical sectors across the national economy domestically and elsewhere.

Table of Contents

Blue carbon at a crossroads

The global discourse on "blue carbon" has accelerated considerably over the past decade. While carbon sequestration by aquatic ecosystems was once a technical subtopic of ocean science, the concept of blue carbon now comes up regularly in the language of national climate strategies, international finance mechanisms, and multilateral negotiations. It sits at the crucial intersection of climate mitigation, adaptation, and nature-based solutions. This is a nexus that has grown only more politically salient as countries search for pathways to meet – and enhance – their Nationally Determined Contributions (NDCs), as well as access new sources and forms of climate finance. Yet, the heightened interest in blue carbon has often outpaced the maturity of the science, governance, and monitoring frameworks that must underpin its sustainable use.

Climate Analytics first assessed the global blue carbon landscape in 2017, when the concept was still emerging as a potential means of aligning ocean and climate agendas (Fyson, 2017). Since then, the maritime context has evolved dramatically, and oceans and blue carbon ecosystems are particularly threatened and in need of attention (World Meteorological Organization, 2025). Global warming has already reached around 1.4°C above pre-industrial levels, bringing the world perilously close to (and in some cases beyond) critical earth system tipping points. The 2025 Global Tipping Points Report warns that warm-water coral reefs may have already crossed their thermal thresholds, the Amazon rainforest may face widespread dieback at global warming level even below 2°C, and both the Greenland and West Antarctic ice sheets could melt irreversibly at around 1.5°C of warming, committing the world to disastrous sea-level rise (Lenton et al., 2025). These developments reshape the very ecosystems that anchor blue carbon potential. The blue carbon ecosystems that were once framed primarily as carbon sinks, including mangroves, salt marshes, and seagrass meadows, are now also frontlines of vulnerability. In this rapidly changing climate, blue carbon ecosystems are increasingly exposed to accelerating sea-level rise, ocean acidification, and marine heat waves that threaten their persistence.

This scientific outlook calls for a sober assessment of blue carbon's place within the climate policy toolkit. The notion that coastal and marine ecosystems can serve as stable, large-scale carbon sinks for offsetting emissions or generating tradeable credits is deeply uncertain and should be approached accordingly. While these ecosystems indeed store vast amounts of carbon (often more per hectare than terrestrial forests), their permanence is conditional and exposed to climate risks. Disturbances such as storm surges, erosion, and ecosystem degradation can rapidly reverse sequestration gains, releasing previously stored carbon back into the atmosphere (Brunner et al., 2024; Ruseva et al., 2020). The understanding of blue carbon must therefore evolve: rather than being viewed as a guaranteed mitigation asset, it should be recognised as a climate-sensitive system whose carbon value depends on its ecological integrity and protection under rising temperatures.

The policy landscape has shifted just as significantly. The ongoing third round of NDC submissions (NDC 3.0) under the Paris Agreement represents a decisive moment for countries to translate the outcomes of the first Global Stocktake into more ambitious, implementable action. Many are exploring new sectors and systems to close mitigation gaps and mobilise innovative finance amid turbulent domestic and international political landscapes and constrained public budgets. In parallel, international attention to the ocean-climate interface has surged, as seen through the High-Level Panel for a Sustainable Ocean Economy, the Mangrove Breakthrough, and the calls within the COP30 presidency agenda to treat oceans as a cornerstone of resilience and finance. For coastal and island nations, particularly Small Island Developing States (SIDS), blue carbon ecosystems have become symbolic of both opportunity and risk. On the one hand, they offer a tangible entry point to integrate ocean action into NDCs and access funding. On the other hand, the institutional resources and extended timeframe needed to establish credible inventories and baselines are daunting. Even where the prospect of possible market engagement is a consideration, there is a need to establish appropriate governance and accounting systems and address the potential for responsibility or liability in the event of reversals – both of which serve as deterrents.

At the same time, the structure of international climate finance is in flux. While the $100 billion collective finance goal has been nominally reached, the composition and accessibility of funds remain contentious, and attention is now turning to the New Collective Quantified Goal (NCQG) for post-2025 finance. In this environment, where international public finance and concessional resources remain scarce and private-sector engagement increasingly shapes access to finance, blue carbon is often promoted as a potential self-financing mechanism through Article 6 and voluntary carbon markets. However, these instruments carry considerable integrity and sovereignty risks, especially for SIDS and LDCs with limited monitoring capacity, indigenous communities at risk of marginalisation, and ecosystems exposed to climate-induced reversals. It is crucial to manage expectations and understand the financial potential of blue carbon alongside the substantial environmental, social, and financial risks that would emerge.

Revisiting blue carbon at this juncture is therefore both timely and necessary. The science has advanced, revealing both fragility of these ecosystems and their extraordinary value, well beyond their carbon sequestration potential. Simultaneously, the policy environment has matured, with the finalisation of Article 6 frameworks and an expanding set of national blue carbon initiatives demanding clearer guidance.

This brief seeks to update the evidence base and unpack these intersecting dynamics, offering countries (particularly SIDS and coastal developing states) a measured perspective on what blue carbon can realistically deliver, where its risks lie, and how it could be integrated responsibly within national strategies.

The window to limit global warming to a level around 1.5°C and return to well below 1.5°C by the end of the century is narrowing, and mitigation through ocean and land sinks cannot substitute the deep decarbonisation required across energy, transport, industry, buildings, agriculture and waste.

Favouring carbon offsetting, be it through land or ocean systems, can delay or stymie the efforts to eliminate fossil fuel emissions in other sectors, and lock in stranded assets through expenditure on carbon intensive infrastructure. Because global mitigation action has been insufficient to date, a substantial volume of negative emissions will be needed in addition to ambitious action in all other sectors. Consequently, there is no space in emissions pathways for the use of mitigation from nature-based systems to offset emissions in other sectors (Fyson et al., 2019). As the following sections will discuss, blue carbon's greatest contribution does not lie in offsetting emissions, but in reinforcing ecological resilience, protecting livelihoods, and anchoring the ocean-climate interface within the broader architecture of just and sustainable climate action.

Evolving knowledge on blue carbon

Blue carbon in the earth system

Over the past decade, scientific understanding of blue carbon has deepened substantially. Oceans act as a critical buffer to the climate system, absorbing roughly 23% of anthropogenic CO_2 emissions over the last ten years (Canadell et al., 2021). Of the carbon circulating in the oceans, roughly 95 % is dissolved inorganic carbon, with the rest stored as dissolved organic carbon, biomass of marine organisms and in ocean sediments.

Coastal and nearshore ecosystems represent the most carbon-dense portions of this ocean sink, and consist of mangroves, seagrass meadows, salt marshes, and macroalgae (Cooley et al., 2022). Despite collectively covering only around 7.6% of the global ocean, these ecosystems contribute approximately 50% of the annual organic carbon that is transported to the deep ocean (Bindoff et al., 2019), leading to blue carbon ecosystems emerging as important carbon sinks within the marine system (Duarte et al., 2005).

Unlike the open ocean, where carbon exchange occurs rapidly, these coastal systems retain carbon over timescales spanning from decades to millennia (McLeod et al., 2011), because much of it is stored below-ground under low-oxygen conditions (Jiang et al., 2019; Middelburg et al., 2020). This below-ground storage means that blue carbon is more comparable to soil carbon in terrestrial ecosystems than to the transient carbon absorbed by plankton in the open sea. The long-term value of blue carbon therefore lies not only in its capacity to sequester carbon but also in the stability of its buried stocks. Crucially, however, this stability depends on ecological and climatic conditions that are rapidly changing for the worse (May et al. 2023; IPCC, 2021). Mangrove ecosystems, for example, are rapidly deteriorating by a combination of human activities and increased marine heat stress, which reduce mangrove growth, increase mortality, and increase vulnerability to erosion and carbon release (Choudhary et al., 2024). Increasing ocean temperatures and intense marine heatwaves are also threatening seagrass meadows and their organic blue carbon: in one study, a single heat wave event was observed to cause widespread (but non-uniform) reductions in shoot density and sediment carbon loss which were as high as 90% and 20% respectively in some parts of the meadow (Aoki et al., 2021). As the impacts of climate change worsen, the stability and viability of blue carbon ecosystems will become increasingly uncertain and tenuous.

Recent research has also broadened the definition of blue carbon to include macroalgae and kelp forests, which contribute significantly through the export of organic matter to deep-sea sediments (Queirós et al., 2019). Yet this contribution remains difficult to quantify, as a large fraction of macroalgal carbon is stored or decomposed far from its source, complicating efforts to attribute removals to national inventories (Williamson & Gattuso, 2022). The science thus continues to point toward a more integrated view of blue carbon as part of the wider ocean carbon cycle, rather than a discrete or easily isolable mitigation category.

Mitigation potential and its limits

Blue carbon ecosystems are demonstrably valuable in maintaining the global oceans as a net carbon sink, but their mitigation potential is limited. It is estimated to be roughly (0.06-2.14) $GtCO_2$/year, equivalent to approximately 3% (0.2-5.4%) of 2024 global fossil CO_2 emissions (39.6 $GtCO_2$), 2.5% (0.1-4.9%) of 2024 global total CO_2 emissions (44 $GtCO_2$) and roughly 2% (0.1-3.7%) of 2024 global GHG emissions (57.7 $GtCO_2e$) (Reise et al., 2024; Williamson and Gattuso, 2022; United Nations Environment Programme, 2025).

Mangrove forests, for example, can have an annual background carbon sequestration rate that is four to five times greater per hectare than boreal, temperate, and tropical highland forests (Alongi, 2022; Hilmi et al., 2023). However, despite being highly carbon-dense, mangroves occupy a relatively small area, and therefore only account for approximately 1% of carbon sequestration by the world's forests (Alongi, 2012), thus indicating that mitigation potential is very limited. For countries with high mangrove deforestation rates, the carbon storage potential of remaining undisturbed mangroves was less than the emissions generated by mangrove deforestation. At national scale, conservation can prevent further emissions from their loss and encourage future carbon sequestration through restoration (Taillardat et al., 2018).

Therefore, while unable to substantially contribute to global emissions mitigation, mangroves – and other blue carbon ecosystems – can still play a useful role for countries with moderate fossil fuel emissions and extensive coastlines. Protecting and restoring these ecosystems from degradation or conversion can maintain important mangrove sequestration and storage functions, especially at the national level (McLeod et al., 2011).

The permanence of these carbon sinks is, however, conditional on their ability to persist physically in a warming world. Mangroves and tidal wetlands can only keep pace with relative sea-level rise through sediment accretion up to a point: losses are likely for local sea-level rise above roughly 4 mm per year, and very likely above 7 mm per year, with sensitivity further depending on local conditions. At present, sea-level rise is about 3.6 mm per year and accelerating, and by the 2080s, it will be approaching 7 to 8 mm per year under current policies. At 2°C of global warming, which could be reached by mid-century under current policies, nearly all mangrove ecosystems would face likely losses by the end of this century, with one-third facing very likely losses; at 3 °C, nearly all mangrove forests and coral reef islands and almost 40% of tidal marshes are expected to face very likely losses (Saintilan et al., 2020; 2022; 2023). The 1.5°C limit is therefore a crucial threshold for avoiding the worst degradation of blue carbon ecosystems due to anthropogenic climate change. Without rapid and deep cuts in global greenhouse-gas emissions, however, the value of the ecosystems as a global carbon sink and socioeconomic service provider will become increasingly diminished and uncertain.

More broadly, around 40-56% of the global mangrove area would be subjected to high to severe risk of loss if sea-level rise exceeds approximately 4-7mm per year and tropical cyclone intensity increases, underscoring the importance of limiting global temperature increases to 1.5°C. This risk of loss includes many mangrove systems that provide the most critical ecosystem services to people (Hülsen et al., 2025). Such compound pressures mean that the mitigation benefit of restoration or offset projects – as well as existing blue carbon ecosystems – are likely to be swiftly reversed by physical loss events that lie outside local management control (Brunner et al., 2024; Ruseva et al., 2020).

Blue carbon protection actions should therefore be understood not as a permanent emissions removal pathway and more as risk-sensitive prevention of carbon stock loss and the importance of these systems for resilience (see Section 5). The sustained role of blue carbon ecosystems as a carbon sink depends on maintaining the climatological, geomorphic, and hydrological conditions that allow these systems to survive. Avoiding degradation and conserving intact ecosystems would therefore likely deliver faster and more reliable climate and resilience benefits than speculative crediting of future sequestration. The mitigation contribution of these ecosystems, though limited in scale, is also more durable when framed around avoided loss and ecosystem protection, which yield substantial co-benefits for biodiversity and coastal resilience (Canadell et al., 2021).

Climate risks and tipping points

Scientific advances have illuminated the growing exposure of blue carbon systems to climate change impacts, including sea level rise, ocean warming and acidification, deoxygenation, and hydroclimatic extremes (Bindoff et al. 2019). Prolonged drought, for example, can lower the water level for an extended period, increase salinisation of the soil, and induce stress and a higher rate of mortality in water-sensitive plants. Severe storms can uproot trees and cause massive flooding, erosion and sediment deposition (May et al. 2023). The Global Tipping Points Report identifies several coastal ecosystems as potential or emerging tipping systems, where incremental change could trigger abrupt functional loss (Lenton et al., 2025).

For mangroves, the interplay of rising seas, stronger storms, and sediment-supply limits is pushing many regions toward collapse. Mangrove productivity and root accretion rates decline sharply at warming levels above 1.5°C, and pass critical sea-level rise thresholds from 2°C and onwards. Modelling further suggests that compounding cyclone impacts could double the area at risk of loss by the end of the century (Hülsen et al., 2025).

Seagrass meadows were classified by the Global Tipping Points Report as regional-scale tipping systems with medium confidence, with thresholds likely to be reached by 1.5°C of warming and mid-century, exacerbated by local pollution and sea-level-rise pressures (Lenton et al., 2025). Empirical research in the Gulf of Mexico shows that even relatively undisturbed seagrass meadows can undergo rapid decline as sea-level rise accelerates (Capistrant-Fossa & Dunton, 2024). Similar events elsewhere further underscore the fragility of these sinks, such as the 2010/2011 heatwave in Shark Bay, Western Australia, which caused the loss of 36% of seagrass meadow cover, with negative implications for carbon storage (Arias-Ortiz et al., 2018).

Salt-marsh ecosystems, while more tolerant of moderate inundation, are increasingly threatened by coastal squeeze as human infrastructure blocks landward migration (Enwright et al., 2016; Borchert et al., 2018).

Many climate-related impacts on blue carbon ecosystems have already been observed and many more are likely to occur if the world continues to follow a high emissions pathway. Collectively, these processes indicate that if global warming exceeds 1.5°C, blue carbon ecosystems may no longer operate as net sinks. Indeed, the loss of blue carbon ecosystems like mangroves will not only halt carbon storage, but also release stored carbon (Ouyang & Lee, 2020).

As our understanding of blue carbon systems grows, the message from current science is clear: the sequestration value of blue carbon is inseparable from the broader success of global decarbonisation. The warmer the planet becomes, the greater the weakness and unreliability of the blue carbon sink.

Uncertainties and permanence

Despite major advances in observation and synthesis, significant uncertainties still surround the quantification and durability of blue carbon sinks (Feng et al., 2023). Regional estimates can vary widely based on local climatic and soil conditions (Cooley et al., 2022) as well the methodologies used for data collection and analysis. These data gaps are particularly acute for tropical seagrass meadows and macroalgal systems, which remain among the least-measured components of the ocean carbon cycle.

A further challenge lies in distinguishing autochthonous carbon (which is fixed and buried within a given ecosystem) from allochthonous carbon (which is transported from adjacent areas).[1] The two can be difficult to separate, and current monitoring approaches frequently conflate the two, risking double counting, overestimation of net sequestration, and complicating national greenhouse-gas inventories (Friess & Webb,

[1] In the context of blue carbon ecosystems, autochthonous carbon refers to the direct uptake and storage of CO_2 through conversion into biomass or organic matter. It is internally produced and directly contributes to active removal of CO_2 from the atmosphere. In contrast, allochthonous carbon refers to the large (but highly variable) amounts of externally produced organic matter that blue carbon ecosystems also store through continuous exchange with adjacent terrestrial and marine ecosystems.

2014). Beyond this, where hydrological connectivity or sediment exchange is strong, it can also be difficult to determine which jurisdiction – or even which ecosystem type – should claim a given stock or flux. Indeed, the distinction between autochthonous and allochthonous carbon continues to pose a challenge to emissions trading markets that need to ensure that only direct activities are accounted for and certified.

Blue carbon systems are dynamic, climate-sensitive, and reversible on decadal timescales. While some studies do suggest that blue carbon could enhance mitigation efforts, uncertainties in sequestration rates, vulnerability to climate change, and governance complexities ultimately prevent its widespread incorporation into scenario projections of long-term mitigation (IPCC, 2018, 2022a). As scenario frameworks evolve, they will need to incorporate the complex feedback loops between ocean warming, sediment dynamics, and ecosystem collapse, alongside the time-lagged recovery of disturbed carbon pools.

These uncertainties can lead to both over- or underestimations of carbon burial rates, and by extension, potential or achieved sequestrations. However, such uncertainties do not diminish the importance of protecting and conserving blue carbon ecosystems. Instead, they underscore the need for the conservation of these ecosystems, as well as the need for further research to better understand its value. In this regard, protection and adaptive management (especially where ecosystems remain intact) are already more defensible, lower-risk climate actions that can be taken now, compared to speculative offsetting based on restoration promises or uncertain sequestration rates (McLeod et al., 2011).

Taken together, the latest evidence shows that the contribution of blue carbon ecosystems to long-term carbon storage is unique, rooted in the slow accumulation of organic matter beneath coastal wetlands and tidal forests, and extending over centuries or millennia (IPCC, 2022b). Yet this contribution remains difficult to quantify with precision. Despite rapid advances in mapping and measurement, blue carbon mitigation potential is still imperfectly understood, with estimates spanning wide ranges depending on ecosystem type, data coverage, and methodological assumptions. Moreover, recent analyses highlight a key accounting risk, whereby the inclusion of passive or unmanaged uptake from coastal and marine ecosystems in mitigation frameworks may inflate claimed removals and reduce the impetus for decarbonizing fossil-fuel systems (Allen et al., 2025). In the context of blue carbon ecosystem, this means countries must be cautious not to treat natural growth or existing stocks as substitute credits for fossil emissions, since doing so would undermine genuine decarbonisation efforts and ambitions.

Blue carbon, while vital for sustaining the ocean’s natural buffering capacity, is simultaneously beset by measurement gaps, modelling uncertainties, and climate-driven fragility.

Blue carbon in Nationally Determined Contributions

As countries submit and implement their third generation of NDCs, attention is turning to how ocean and coastal ecosystems might feature more prominently in future national mitigation and adaptation planning. Indeed, several countries have already begun incorporating blue carbon into their NDCs. For instance, Indonesia has emphasised the carbon value of mangrove conservation and restoration, citing them as a core part of its mitigation and adaptation commitments. Belize's updated NDC includes the protection and expansion of mangrove ecosystems, backed by national legislation and a robust ecosystem valuation framework.

However, blue carbon is rarely identified as a standalone thematic action area in NDCs. Instead, the concept is embedded into broader mitigation and adaptation actions, especially as part of the IPCC Land Use, Land Use Change and Forestry (LULUCF) sector. For countries with economy-wide targets, incorporating blue carbon ecosystems into greenhouse gas inventories may bring these systems directly into these Parties' NDCs. Accordingly, caution is needed to ensure that these inventories are not overestimated, which remains a challenge given the climate impacts on these systems and the many measurement uncertainties and non-anthropogenic influences mentioned above (Burden & Clilverd, 2021; Williamson & Gattuso, 2022).

There is partial IPCC guidance for incorporating blue carbon into national GHG inventories, but it remains incomplete. Mangroves can be reported as forest land, and tidal marshes and seagrasses are covered under the 2013 Wetlands Supplement. However, many other coastal and marine ecosystems that are classified as blue carbon ecosystems, such as macroalgae, kelp forests, and broader ocean carbon processes, have no agreed inventory methodologies. As a result, countries lack a standardised basis for integrating blue carbon into NDCs, and most references remain qualitative rather than consistently quantified.

Besides general uncertainties at the national level, limited laboratory capacity and the absence of standardised field methods make it difficult to generate verifiable emission and removal estimates. In mangrove ecosystems, for example, differences in data points used can result in contradictory trends across different countries, leading to unrealistic estimates of mangrove lost in deforestation extrapolations (Friess & Webb, 2014).

Blue carbon accounting is also faced with the same uncertainties and challenges that are pervasive in land sector GHG inventories. One example is methodological difficulties in distinguishing between fluxes from anthropogenic and natural processes (Perugini et al., 2021), which are compounded in blue carbon ecosystems by the need to distinguish between autochthonous and allochthonous carbon. The shifting of some ecosystems from carbon sinks into sources (Kellou et al., 2024; Zickfeld et al., 2023; Giebink et al., 2022) and the measurement of interannual variability caused by natural disturbances and human activities further complicate blue carbon accounting processes (IPCC, 2019).

The IPCC's 2013 Wetlands Supplement provides a foundation for integrating coastal wetlands into national inventories, but its use remains voluntary and has only been fully operationalised by a few countries (IPCC, 2014). For most developing coastal states, applying these methodologies requires substantial investment in technical and human capacity to execute new sampling campaigns, improve soil-carbon datasets, and align data with the national accounting strategies. As a result, the inclusion of blue carbon systems in NDCs today is often qualitative and expressed as commitments to conserve or restore mangroves and seagrasses, rather than quantitative estimates in tonnes of CO_2 equivalent.

This underscores the importance of reporting readiness preceding policy integration. Before blue carbon can be credibly reflected in NDC targets or transparency reports, countries need to invest in the underlying measurement, reporting, and verification (MRV) infrastructure. Establishing these systems entails a significant administrative and scientific undertaking that requires consistent datasets, regional baselines, and cooperation across oceanographic, forestry, and climate agencies. For many countries that share or transverse blue carbon systems, cross-border and regional collaborations may also be necessary to fully capture sequestration dynamics and potential (Boettcher et al., 2025). Further still, countries need to be cognizant of the risk of reversal of stored carbon stocks. Commensurate monitoring and verification systems need to be in place to detect, report, and integrate these dynamics into national GHG inventory systems and subsequent ambition-setting.

Under the implementation of the current NDC 3.0 cycle, therefore, the conversation should not be focused on extracting precise quantified blue carbon sequestration contributions or goals. Instead, they should focus on building the scientific and institutional basis to possibly facilitate an accurate articulation of such goals in the future. The discussions emerging at COP30 and within the enhanced transparency framework (ETF) should be viewed as an opportunity to close these gaps. Where necessary, countries should leverage their NDC 3.0s to signal requests for support in improving inventories, harmonizing coastal and terrestrial carbon accounting, and ensuring that any eventual blue carbon commitments are informed by credible, comparable data. A large benefit of such improvements lies in the ability to monitor the functioning of these systems and provide early warnings for these becoming carbon sources, instead sinks, as global warming rises. Inclusion of blue carbon in carbon trading should not be encouraged.

Indeed, as countries refine their NDCs, it is critical that blue carbon is not misconstrued as a compensatory mechanism for the continued use of fossil fuels. Offsetting domestic emissions through coastal ecosystems risks undermining the deep structural decarbonisation that is urgently required across energy, transport, industry, and agriculture. For high-emitting economies, such reliance can delay or displace mitigation within sectors where permanent reductions must occur. For coastal and island nations, using blue carbon to offset rather than complement mitigation efforts can expose them to double-counting risks, ecological reversals, and a range of sociopolitical challenges. With global emissions still rising and increasingly incompatible with 1.5°C pathways, there is no space for offsets that are used to justify new emissions elsewhere. Instead, every tonne of carbon sequestered in blue carbon systems will be needed simply to safeguard the ecosystems' common carbon sink and storage functions. Accordingly, blue carbon should be valued for its resilience and protection benefits, not as a license for further delay in eliminating emissions at their source.

Integrating blue carbon into NDCs should ultimately not be seen as a shortcut to meeting mitigation pledges, but as a long-term scientific and institutional investment. Strengthening national understanding of coastal carbon dynamics will help countries report more accurately, design better-tuned adaptation measures, and position themselves to harness future finance flows once measurement uncertainties are reduced.

Adaptation and resilience dividends of blue carbon

Compared to the uncertainty and risks surrounding blue carbon's role in global mitigation, its contribution to adaptation and resilience is clearer in its benefits. Coastal and marine ecosystems contribute as much as two-thirds of the total ecosystem services that make up the planet's natural capital (Leslie et al., 2012), making them central to our ways of life. Coastal and marine ecosystems that store carbon also provide a suite of services that directly protect people, infrastructure, and livelihoods from the intensifying impacts of climate change, but crucially, only as long as climate change does not exceed the tolerance thresholds of these systems themselves (Canadell et al., 2021).

Mangrove forests, for example, provide physical protection against extreme weather events, such as storms and floods, and their preservation offers multiple benefits, including enhanced storm protection, improved water quality, biodiversity preservation, and reduced carbon emissions (Selig et al., 2019; Windham-Myers et al., 2018). Coastal vegetated ecosystems as a whole provide a diverse range of ecosystem services, including disproportionately high biodiversity per unit area, important habitat for a wide range of species, natural filtration of waste and stormwater runoff into the coastal ocean, and protection from coastal erosion and storm surges (Ouyang et al., 2018; Pörtner et al., 2021) Additionally, these ecosystems supply food and natural materials for human use and support livelihoods and cultural activities, including tourism (Cooley et al., 2022). These benefits manifest immediately and locally, and are often accompanied by many of the mitigation co-benefits highlighted in preceding sections.

Healthy mangroves, salt marshes, and seagrass meadows act as natural buffers against coastal hazards. Blue carbon ecosystems attenuate wave energy, stabilise shorelines, and buffer the impacts of sea-level rise and storm surges, particularly in low-lying and highly exposed coastal areas (Alongi, 2008). All of these are functions that become ever more critical as sea-level rise accelerates, and extreme weather events intensify. These same ecosystems also support sediment accretion, which allows coasts to adjust naturally to moderate sea-level rise, provided they have space to migrate landward (Vanderklift et al., 2019). In Jamaica, for example, mangroves are estimated to reduce the number of people flooded and damaged avoided by nearly 50% during 200-year storm events, but still reduced in range by over 770 hectares by 2019 due to various human- and global warming-induced factors (World Bank, 2023). Jamaica experienced catastrophic losses and damages equivalent to between 28% and 32% of national GDP, as well as over 200,000 people affected, during the Category 5 Hurricane Melissa in October 2025 (World Food Programme, 2025). Despite ongoing efforts to restore and conserve mangrove forests (Forestry Department, 2024), it is likely that the degradation of mangrove systems amplified the impacts of the third-most intense Atlantic hurricane on record.

Beyond physical protection, blue carbon ecosystems underpin food security and livelihoods through a range of crucial services (Reise et al., 2024). Mangroves and seagrasses serve as nursery habitats for commercially important fish species, while salt marshes and estuaries sustain shellfish populations that support small-scale fisheries and local economies (Eco-Business, 2025). The nutrient-cycling and water-filtration functions of these ecosystems also improve nearshore water quality, reducing turbidity and eutrophication, which in turn enhances coral reef health and coastal productivity.

For many SIDS and low-lying coastal nations, these functions are foundational to human wellbeing, sociocultural identity, and economic stability. As climate impacts escalate, protecting and restoring blue carbon ecosystems doubles as an adaptation investment with high social returns. It supports the maintenance of tourism assets, preserves culturally important coastal landscapes, and safeguards the livelihoods of the communities most dependent on marine resources (Cooley et al., 2022).

These adaptation benefits also reinforce mitigation integrity. By maintaining ecosystem health, countries simultaneously secure the carbon stocks already stored in coastal sediments. Restoration and conservation, even if pursued primarily for resilience, thus have an indirect climate benefit by avoiding emissions from degradation. In this sense, adaptation and mitigation are not competing objectives but co-dependent processes, with each reliant on the other for keeping these ecosystems ecologically intact.

However, realizing these myriad co-benefits is not automatic. The same physical and governance challenges that constrain blue carbon accounting also threaten its resilience value. Hard infrastructure development, unplanned tourism expansion, and the absence of integrated coastal management can block the natural landward migration of mangroves and marshes, trapping them between rising seas and human settlements. This phenomenon is widely described as coastal squeeze (Enwright et al. 2016; Borchert et al. 2018), and without careful spatial planning and community engagement, the adaptive services of blue carbon ecosystems can erode faster than restoration efforts can replace them. This is all the more the case in the current context, where climate impacts – both extreme and subtle – are only increasing in frequency and intensity.

These risks highlight the need to situate blue carbon within broader adaptation frameworks such as National Adaptation Plans (NAPs) and local resilience strategies, rather than treating it as a discrete carbon management instrument. When integrated effectively, blue carbon conservation aligns with disaster risk reduction, fisheries management, and biodiversity objectives, thus advancing resilience and livelihood development goals while also ensuring existing mitigation capacities are maintained.

While the global mitigation potential of blue carbon ultimately remains uncertain, its resilience dividends are immediate, quantifiable, and deeply relevant to the lived realities of coastal populations. Protecting these ecosystems is therefore not only a nature-based solution, but a development necessity that strengthens national adaptation capacity while safeguarding natural carbon stores for the long term.

Blue carbon and innovative climate finance: markets, mechanisms, and risks

As climate finance landscapes evolve, blue carbon is increasingly viewed not only as a mitigation tool but also as a financial asset class. Governments, development banks, and private investors are exploring new ways to mobilise capital around coastal ecosystems, ranging from sovereign debt instruments to carbon-based market mechanisms. These efforts reflect both the rising prominence of the ocean in global climate policy and the persistent funding gap for adaptation and nature-based solutions.

Emerging blue finance instruments

Several pioneering initiatives have demonstrated the potential for blue carbon ecosystem–linked finance to attract private capital while supporting conservation goals. The Seychelles Blue Bond issued in 2018 (March et al., 2024) remains one of the most cited examples. The USD 15 million sovereign bond was issued by the Government of Seychelles with the aim of using proceeds to support initiatives for sustainable fisheries management, marine conservation, and the transition to a blue economy. The bond was partially guaranteed by the World Bank, and further buttressed by a concessional loan from the Global Environment Facility to lower interest costs. The Blue Bond is widely cited as a positive early foray in the arena of blue carbon finance, including the expansion of the management coverage of marine protected areas to about 22 million hectares (from 5 million), monitoring and efficiency improvements in the fisheries sector, and increased access to domestic finance for fisheries in the Seychelles (World Bank, 2025). It did not monetise carbon directly, but instead focused on the future economic productivity of sustainably managed fisheries and marine ecosystems as the underlying asset. In other words, the bond monetised the anticipated financial and social returns of marine ecosystem stewardship (e.g. improved fisheries yields, protection of vital ecosystem services, and creation of new revenue streams in eco-tourism and value-added fisheries) without the commodification of carbon.

Since then, similar approaches have proliferated. Belize's 2021 "Blue Loan" debt-for-nature swap, supported by The Nature Conservancy (n.d.), restructured USD 553 million of sovereign debt in exchange for long-term marine-conservation commitments. Other countries, including Barbados, Fiji, and Cabo Verde, are assessing comparable instruments that link fiscal relief or concessional lending to measurable ocean-conservation outcomes. Some multilateral development banks have also launched blue-finance facilities, combining grants and private capital to fund mangrove restoration, coral rehabilitation, and coastal adaptation projects.

In each case, blue carbon ecosystems are monetised, not as a tradable commodity, but as natural resources that should be protected for their socioeconomic and ecological value. This framing is leveraged to acquire concessional terms or de-risk private investment. While these approaches are innovative, they also require rigorous monitoring frameworks to ensure that promised ecological and social benefits are realised, and that financialisation does not displace community or conservation priorities. Indeed, both the Blue Bond and debt-for-nature swap have not been without their criticisms, with one study finding that neither intervention managed to meaningfully mitigate the Seychelles' sovereign debt, and simultaneously also reduced sovereign control over oceanic resources through shared governance interventions (Hunt and Hilborn, 2025). These findings underscore the novelty of blue carbon-dedicated financing instruments, and the various risks and limitations that persist in ongoing innovative efforts.

Carbon markets and Article 6

Parallel to these innovations, blue carbon has also entered discussions on carbon trading and offsetting, particularly through the Article 6 mechanisms of the Paris Agreement. Under Article 6.2, Parties can trade Internationally Transferred Mitigation Outcomes (ITMOs) on a bilateral basis, while Article 6.4 establishes a centralised crediting mechanism overseen by the UNFCCC Supervisory Body. In theory, blue carbon projects (BCP) such as mangrove restoration or avoided wetland loss could generate credits for sale under either mechanism.

Carbon markets are trading systems where companies and organisations can compensate greenhouse-gas emissions on one side with rapid reductions on another side. Carbon markets could function to drive cost-efficient overall carbon emissions reductions, if coupled to a sufficiently strict cap on total emissions that reduces in time consistent with global (and sectoral) pathways achieving the global 1.5°C warming limit. This would result in a high enough carbon price that increases sufficiently over time. Carbon credits represent a tonne of CO_2 that can be traded between an entity that does not (yet) reduce emissions sufficiently and an entity that reduces its own emissions more than sufficiently, strictly regulated within the particular carbon market. Carbon credits could be used as carbon offset, but this becomes problematic when carbon offsets are outside of a well-regulated carbon market and used to avoid reductions in one place, without assurances on additionality, permanence, accuracy, etc. of the reductions in another place.

In practice, no standardised methodologies currently exist for accounting, monitoring, or verifying blue carbon credits under Article 6.4. The Supervisory Body has only recently begun reviewing proposals for methodologies related to wetlands and coastal ecosystems, and unresolved questions remain about baselines, additionality, and permanence. Article 6.2 transactions, meanwhile, are governed by bilateral agreements and face similar data and integrity challenges.

Furthermore, avoided carbon loss activities (e.g. avoided mangrove and forest loss, avoided wetland conversion, and avoided ecosystems degradation) currently have no agreed methodology under the Paris Agreement. They are not eligible under Article 6.4, where Parties have not reached agreement on standardised baselines, additionality, or permanence rules, and remain contentious under Article 6.2 for various reasons, including high reversal risks. As a result, blue carbon offsetting projects based on avoided loss cannot presently produce UNFCCC-recognised credits, and would carry substantial integrity and liability risks if pursued through bilateral or voluntary mechanisms.

Beyond the UNFCCC process, blue carbon features increasingly in Voluntary Carbon Markets (VCMs), where private developers and conservation organisations have launched dozens of pilot projects, particularly in Southeast Asia, East Africa, and the Caribbean. Some of these have achieved certification under standards such as Verra's VM0033 Methodology for Tidal Wetland and Seagrass Restoration. However, even these voluntary approaches are grappling with questions of long-term liability, community rights, and double counting. This may not fall under the definition of a well-regulated carbon market as mentioned above.

The core risks mirror those identified in terrestrial offsetting, but are amplified by the physical volatility of coastal systems. Reversal risk is high (Arcusa & Hagood, 2025), with a single cyclone, erosion event, or policy lapse having the ability to release decades of stored carbon. Systemic issues surrounding methodologies and the quality of issued carbon credits have rendered the contributions of carbon markets to mitigation efforts uncertain (Romm et al., 2025). Indeed, a recent assessment of over 2,300 voluntary carbon crediting schemes (primarily focused on forests and renewable energy) estimated that less than 16% of the carbon credits issued to the investigated projects constitute real emission reductions, underscoring the deep flaws and negligible mitigation potential of the mechanism in its current form (Probst et al., 2024). Tenure and benefit-sharing arrangements are often unclear, raising equity concerns in coastal communities. And at a macro level, reliance on offsetting can divert attention from the need for deep, cross-sectoral domestic decarbonisation. All these challenges observed in terrestrial offsetting are likely to manifest in blue carbon offsetting initiatives as well.

Therefore, despite carbon offsets often being presented as vehicles for achieving mitigation targets and channelling finance toward coastal protection, their potential use for avoiding the necessary mitigation action remains deeply problematic and often counterproductive for global efforts to limit warming to 1.5°C (see also Information Box below). Treating blue carbon ecosystems as tradable mitigation units risks normalizing the use of offsets at a moment when long-term global warming is very near 1.5°C. For high-emitting countries and industries, purchasing blue carbon credits to balance continued fossil fuel emissions effectively delays the systemic decarbonisation required across energy and industrial systems. This would only serve to further lock in an overshoot of the 1.5°C target and add further fossil fuel emissions to the atmosphere that would not otherwise have been emitted.

For coastal and island states, monetizing blue carbon sequestration through Article 6 or VCMs can create exposure to reversal, tenure, and double-counting risks, while simultaneously diverting scarce capacity toward complex MRV and certification schemes with uncertain returns (Boettcher et al., 2025).

In this context, the responsible and 1.5°C-aligned policy pathway is one that prioritises safeguarding and restoring blue carbon ecosystems as national public goods, while simultaneously pursuing ambitious decarbonisation across key sectors in the economy.

Carbon offsets and the 1.5°C global warming limit

A fundamental problem with carbon offsets is related to limiting global warming to 1.5°C. For this to succeed and – directly related to that – reach net zero CO_2 emissions by 2050 and net zero GHG Emissions by the 2070s, greenhouse gas emissions need to be reduced as close to zero as possible, across all sectors, deploying all abatement options.

Residual emissions in any sector must be very low, if not eliminated, and should only be counterbalanced by carbon dioxide removal (CDR) offsets for the "truly" unavoidable residual greenhouse-gas emissions. There is clear evidence that offsets act as a mitigation deterrent (Moioli et al., 2025), manifesting as lowering carbon prices while discouraging emissions reductions, clean-energy deployment, and innovation in low-carbon technologies. The 'hard-to-abate' label for some industries, and directly related reliance on offsets, has often served to lower expectations, delay viable emissions reductions and weaken incentives for long-term transformation. In reality, zero-emissions technologies are already commercially available in most such sub-sectors, including e.g. steel, but need strong policy support for scale-up.

Availability of offsets and proliferation of commercial actors on the global market undermines such policy support, as well as motivation and economic incentives of industry forerunners.

In addition, it is becoming increasingly clear that humanity will need substantial CDR capacity to respond to likely feedback from warming, as the earth system will take up an ever-smaller fraction of emitted CO_2 over time. The limited CDR capacity available, as well as its uncertainty, means that CDR should not be counted on via offsets to counter-balance residual fossil-fuel emissions that could have otherwise been eliminated.

Ultimately, blue carbon occupies an ambiguous position in the emerging climate finance architecture. It is both a potential bridge between adaptation and mitigation finance and a potential fault line if over-monetised without safeguards. While policymakers should not necessarily seek to reject innovation emerging in this space, it is crucial to understand the substantial risks and implications of engaging in carbon markets when the window to maintain a 1.5°C-compatible pathway is rapidly narrowing.

Aside from the contradictions between rapid decarbonisation and offsets, countries would need to expend substantial time and resources to create the regulatory, technical, and operational frameworks necessary to safeguard against the myriad risks posed, as the current MRV methodologies and accounting frameworks remain insufficient to accurately capture blue carbon dynamics (Boettcher et al., 2025). Carbon markets cannot offer a quick, consistent, or guaranteed path to using blue carbon for finance or emissions offsetting. They cannot be the primary motivator for national engagement with blue carbon ecosystems. If engaged with at all, carbon trading should therefore be approached as a potential area for future exploration, with befitting caution and preparation to mitigate the impacts of any negative consequences.

Given these risks, the exploitation of blue carbon for offsetting is not advisable. Instead, countries should prioritise protection and MRV readiness, which provide low-risk and high-integrity benefits for adaptation, resilience, and improving our collective understanding of blue carbon dynamics. Participation in markets – whether under Article 6 or VCMs – requires transparent baselines, conservative accounting, and provisions for reversal management as a minimum. Corresponding adjustments would also have to ensure environmental integrity and avoid double counting of emissions reductions. All these conditions remain unmet in the broader blue and land-based carbon trading arena for various reasons, ranging from problematic methodologies for offset calculation and verification, to the inability to reconcile the sale of carbon credits with NDC targets and social safeguards for the most vulnerable. By delaying the urgently needed real emissions reductions in the energy sector and elsewhere, carbon offsets are fundamentally at odds with the viability of the 1.5°C target. With all these inherent risks and uncertainties, leveraging blue carbon as an asset for trade is therefore most likely to be a prescription for disaster.

Moreover, not all finance needs to flow through carbon markets. Subsection 5.1 highlighted some of the already-existing innovative blended-finance models, sovereign blue bonds, and debt-for-nature swaps that may provide more predictable and less risky pathways to mobilise capital for coastal conservation, especially in SIDS and least-developed countries with limited monitoring capacity. These approaches also allow benefits to remain primarily domestic rather than being exported through credit sales. However, the areas of intersection between blue carbon and innovative climate finance instruments are only just emerging, and the effectiveness of blue carbon-centred financial instruments is yet to be determined. Countries should continue to exercise caution when engaging in financing for blue carbon to maximise adaptation and mitigation co-benefits. Indeed, as the following subsection discusses, new instruments are constantly emerging that could offer valuable insights and examples for generating climate finance through blue carbon ecosystems without compromising mitigation targets and priorities through carbon market engagement.

Alternatives to carbon markets: lessons from Brazil's Tropical Forests Forever Facility

With rising climate impacts and constrained international public finance, many governments feel compelled to explore novel opportunities to support national adaptation and conservation efforts. This often still includes considering participation in carbon markets, given their frequent promotion as a means of mobilizing private capital and generating self-sustaining revenue streams. Yet, as highlighted throughout this brief, the risks associated with carbon markets and counter-productivity of offsets are substantial, and are only amplified with blue carbon ecosystems.

At the same time, the need for new sources of finance remains acute, especially for coastal and island countries facing accelerating losses and rising adaptation costs. In this context, it is worth considering emerging models of non-market, results-based finance that could offer an alternative pathway that supports ecosystem protection without turning blue carbon into a purely offset-oriented commodity. One of the most prominent recent innovations is Brazil's Tropical Forests Forever Facility (TFFF), presented at COP28 and launched at COP30, which offers insights that could inform approaches to blue carbon finance.

The TFFF is designed as a long-term, results-based mechanism to mobilise large-scale, predictable finance for reducing tropical deforestation. The facility departs from both REDD+ and voluntary carbon market approaches in a crucial respect, in that it does not generate or sell carbon credits (Tropical Forests Forever Facility, 2025b). Instead, it provides results-based payments to countries that demonstrate reductions in deforestation against national baselines. Simply put, the TFFF will mobilise funds to pay participant countries an annual lumpsum per hectare of standing native forest.

Countries will likely be required to have a 3-year rolling average deforestation rate of below 0.5% to be eligible to participate, and beneficiary countries of the TFFF are required to have a stable or decreasing annual deforestation rate to remain eligible. The resources mobilised by the TFFF are allocated based on the sise of qualifying forests and conservation performance of each country, with a x100 to x200 time penalty per deforested hectare (Tropical Forests Forever Facility, 2025a).

Notably, the TFFF will not strive to meet its USD 125 billion mobilisation target through donor grants. Instead, the Facility takes a blended financial approach, borrowing an initial capital based (targeted at USD 25 billion) from traditional "donor" countries, philanthropic foundations, and other entities. These sovereign investments and guarantees will be provided in the form of attractive long-term loans, grants, or guarantees, and will serve as the safety net to then seek a "vanilla debt" of USD 100 billion, which would be issued on international capital markets in the form of fixed income bonds with attractive terms (Tropical Forests Forever Facility, 2025a). The funds generated will then be used to provide annual payments to each participating country, providing them predictable, long-term funding to support forest conservation.

Monitoring is conducted primarily through transparent, satellite-based observation systems, building on Brazil's longstanding PRODES and DETER platforms (Tropical Forests Forever Facility, 2025b). This design substantially reduces the MRV capacity-building burdens imposed on individual countries, while simultaneously ensuring scientific credibility and public accountability. Funding is directed toward policy-level actions such as enforcement, land-tenure reforms, and protected-area management, rather than toward individual projects or offset-generating interventions. In other words, the TFFF will not prescribe how countries must use the facility's resources, but simply issue payments based on the annual deforestation outcomes for each country. This reflects a broader shift from financing discrete activities to supporting the governance systems that deliver sustained environmental outcomes. In addition, the TFFF explicitly centres local communities and indigenous communities in its funding model, with at least 20% of payments required to be directed to them. This further underscores the prioritisation of adaptation, resilience, and livelihood co-benefits in climate interventions.

Relevance for blue carbon ecosystems

While developed for terrestrial forests, the TFFF model offers conceptual lessons that may be instructive for blue carbon contexts and offer an alternative pathway for enhancing access to climate finance through blue carbon ecosystems. Indeed, blue carbon ecosystems share many of the characteristics that make tropical forests central to climate policy. They underpin livelihoods, support biodiversity, and deliver essential ecosystem and adaptation services.

However, blue carbon ecosystems also face distinct scientific uncertainties and monitoring challenges that complicate their use in carbon markets. While only in its nascent stages of emergence itself, a facility inspired by the TFFF could allow countries to focus on policy-driven conservation outcomes and ecosystem integrity, rather than on generating tradable carbon units. In this regard, the TFFF approach could offer coastal and island countries a viable pathway to generate climate finance through the protection of blue carbon ecosystems, without compromising domestic mitigation commitments and environmental and social safeguards.

Such an approach could support actions to reduce mangrove loss, strengthen coastal-zone governance, improve hydrological and sediment-management regimes, and invest in community-led stewardship. Payments could be aligned with measurable improvements in ecosystem condition or reduced rates of degradation, mirroring the TFFF's emphasis on verified environmental performance rather than on quantified carbon removals or completion of individual projects. While satellite monitoring is more complex for submerged ecosystems such as seagrasses and tidal marshes, complementary tools (e.g. drone mapping, multispectral imagery, shoreline-change analysis, and bathymetric LIDAR) may be able to support the development of credible, low-burden monitoring systems that are tailored to the unique dynamics of blue carbon ecosystems.

A policy-oriented, non-market model would also avoid the structural vulnerabilities inherent in offset markets, including reversal liabilities, speculative pricing, and the possibility that credits could be used to justify continued fossil emissions elsewhere. Instead, it would channel finance toward the ecological and societal values that make blue carbon ecosystems indispensable for coastal resilience.

Financial dimensions: costs, returns, and policy incentives

Tropical forests have distinct dynamics and needs, making it unlikely that the potential financial returns offered under the TFFF can be replicated in the context of blue carbon ecosystems. Nonetheless, the available costing evidence for blue carbon ecosystems suggests that there is a strong rationale for a policy-focused payment approach.

For blue carbon ecosystems, the most credible available literature on costing and financial returns is restricted to mangrove forests, with other ecosystems (e.g. seagrass meadows and tidal marshes) rarely focused on exclusively in large-scale conservation or restoration efforts. A global study of 249 restoration projects across 25 countries found that mangrove restoration costs vary widely and depend upon site conditions, ranging from as little as USD 9 per hectare to more than USD 700,000 per hectare, with a global median of approximately USD 8,143 per hectare (Goto et al., 2025). Restoration can take decades to recover full ecological function and carbon storage capacity, making the financial returns from carbon-credit sales uncertain, slow, and vulnerable to disruption by climate-driven impacts.

By contrast, protecting intact ecosystems – as the TFFF model seeks to ensure – is consistently more cost-effective than restoring degraded ones and generates immediate benefits for adaptation and resilience. Avoided-loss interventions such as improved enforcement, sustainable fisheries management, and coastal-zone planning often require comparatively modest investment, but still protect ecosystem services that have substantial economic value, including storm-surge buffering, shoreline stabilisation, and support for fisheries. International climate finance already reflects this logic, as demonstrated by recent large-scale investments by the GCF and GEF in mangrove restoration- and conservation-centred coastal resilience initiatives in countries such as Ecuador, the Gambia, Liberia, and Viet Nam.

A blue carbon finance mechanism informed by the principles of the TFFF could prioritise the conservation and enhancement of ecosystem function rather than the monetisation of carbon. Payments would reward policy performance and verified environmental outcomes, providing countries with a predictable resource stream that strengthens national adaptation and coastal management systems without exposing them to the risks of offset markets. However, further research and analysis is still needed to understand the articulate the instruments, costings, and potential returns of a financing facility for blue carbon ecosystem preservation.

Limitations and considerations for replication in blue carbon ecosystems

Given the fundamental differences in terrestrial forest and blue carbon ecosystems, the direct replication of the TFFF model for blue carbon ecosystems is neither technically nor institutionally feasible. Seagrass meadows and tidal marshes are more difficult to monitor remotely than terrestrial forests, and national baselines for coastal ecosystem degradation are far less defined. Coastal governance is often more fragmented than forest governance, and the scientific understanding of blue carbon dynamics remains incomplete. These constraints underscore the need for careful adaptation of the TFFF principles rather than wholesale transfer. They also underscore the need to enhance M&E capacities relevant to tracking the maintenance of blue carbon ecosystems.

While unlikely to be directly transferrable to the context of blue carbon, the TFFF does illustrate the fact that climate finance can be mobilised at scale through non-market, policy-based mechanisms that reward ecosystem protection rather than the creation of carbon commodities. For countries seeking to strengthen resilience, support coastal communities, and safeguard ecosystems that are increasingly threatened by climate change, this offers a potentially compelling and lower-risk pathway that aligns with the priorities set out in this brief.

Policy steps for responsible blue carbon engagement

The growing interest in blue carbon as a source of mitigation and finance has outpaced the readiness of most national systems to conduct the assessment, monitoring, and reporting of carbon fluxes and flows necessary for robust management. For many coastal and island countries, the challenge is not whether to engage in blue carbon initiatives, but the most appropriate context and strategy for this engagement. The order in which steps are taken can strongly influence whether blue carbon ecosystems become durable national assets or liabilities that expose governments to environmental and financial risks.

Blue carbon ecosystems operate at the interface of climate, ecology, and community livelihoods. Their carbon value is contingent upon ecological health, and simultaneously, their market value depends on credible data, tenure clarity, and long-term monitoring. Entering carbon markets or committing to quantified targets before these enabling conditions exist risks over-promising mitigation outcomes and under-delivering benefits to local communities. Premature crediting can also lock countries into reversal liabilities that are difficult to manage if projects fail or ecosystems degrade.

The recommendations that follow outline key priorities for responsible engagement, representing parallel actions that collectively strengthen the integrity, resilience, and policy coherence of blue carbon efforts. They emphasise protection and understanding before valuation, and institutional readiness before any consideration of financial mechanisms. Together, these actions chart a prudent course for countries seeking to integrate blue carbon into their climate strategies without undermining mitigation ambition or exposing themselves to unnecessary risk.

Recommendation 1: Prioritise blue carbon ecosystem protection and restoration

The first and most effective step is to protect existing blue carbon ecosystems to retain and reinforce their resilience and socioeconomic functions. Intact mangroves, marshes, and seagrasses not only store vast carbon stocks, but also buffer coasts against climate impacts, thus avoiding damages from storm surges and erosion, all while simultaneously sustaining fisheries and livelihoods. Protecting and enhancing the resilience of these systems to increasing climate hazards from global warming can meaningfully support adaptation efforts and coping with some of the inevitable impacts of climate change. Restoration activities should be made complementary to these conservation efforts by targeting degraded but viable areas and prioritizing ecological recovery over short-term carbon gains. These interventions should be embedded within integrated coastal-zone management (ICZM) frameworks and NAPs, where resilience and community benefits remain primary objectives.

Recommendation 2: Build robust measurement, reporting, and verification systems

The credible incorporation of blue carbon into climate action initiatives depends on scientific readiness. Governments should invest early in MRV systems that combine field measurements (e.g. soil and biomass sampling) with remote sensing and modelling tools. Establishing national or regional baselines, harmonizing data formats, and training local technical experts are prerequisites for accurate carbon accounting. Integration of blue carbon into NDCs or financing strategies is only possible with a detailed and accurate understanding of the stock and dynamics of national blue carbon systems.

In this regard, MRV development should itself be recognised as a form of climate action and finance investment. These investments are foundational steps that enable transparent reporting and an enhanced understanding of blue carbon ecosystem dynamics. Countries should therefore include capacity building support for blue carbon in broader requests for support surrounding national climate action targets.

Recommendation 3: Integrate blue carbon thoughtfully into national climate planning

Once MRV systems are functional and data reliability improves, countries can integrate blue carbon into NDCs and long-term strategies in a cautious, evidence-based manner. Initially (and as is the case for some countries already), blue carbon should be reflected primarily through an adaptation lens and qualitative or area-based indicators (such as hectares conserved or restored, or percentage of national coastline under protection) rather than speculative emission-reduction figures. Over time, as measurements and methodologies improve, these metrics can evolve into quantitative targets within national greenhouse-gas inventories, aligned with the IPCC Wetlands Supplement.

Integration at this stage also allows countries to link blue carbon actions with adaptation priorities, biodiversity goals, and disaster risk reduction (DRR) strategies. Given the lack of clarity surrounding the mitigation benefits of blue carbon, these adaptation- and resilience-centred policies should continue to be the main driving force behind the preservation of existing blue carbon ecosystems. By integrating blue carbon initiatives in a cross-cutting manner, it is possible to build a unified policy narrative that enhances access to both adaptation and mitigation outcomes and finance.

Recommendation 4: Exercise extreme caution toward carbon markets

Only after the first three recommendations have been satisfied should countries even consider participation in carbon markets or crediting schemes. As discussed in Section 5, engaging in blue carbon trading or offset mechanisms is highly unadvisable under current conditions, and risks undermining national and global mitigation integrity. For high-emitting countries, this practice delays the structural decarbonisation urgently needed across energy, industry, and transport. For developing coastal and island states, it can expose governments to complex liabilities, uncertain returns, and reversal risks if ecosystems degrade. With global emissions persisting far above 1.5°C-compatible pathways, offsetting through blue carbon would contradict both scientific evidence and the objectives of the Paris Agreement.

Despite this, some countries may nonetheless seek to explore carbon market participation. In such cases, participation in carbon markets should only be considered after a multi-year process of scientific, regulatory, and institutional groundwork to ensure any eventual activity does not compromise NDC targets or community and environmental integrity. Governments should first establish national inventories and data systems capable of tracking blue carbon stocks, fluxes, and ecosystem health. These inventories can inform management decisions and risk assessment without committing to crediting or offsetting. If, after this foundational work, participation in carbon markets is still pursued, the following minimum integrity provisions are essential:

- Transparent, conservative baselines and accounting methods;
- Corresponding adjustments to avoid double claiming in NDCs;
- Provisions for reversal risk through buffer pools or contingent liabilities;
- Clear benefit-sharing and Free, Prior and Informed Consent (FPIC) with affected communities;
- Full public transparency of data, contracts, and financial flows.

Even with such safeguards, blue carbon markets will remain volatile, data-intensive, and difficult to manage. High-emitting countries should therefore focus their efforts on deep cross-sectoral decarbonisation rather than offset purchases, while SIDS and LDCs should navigate carbon markets with extreme caution, prioritizing ecosystem protection and resilience finance over speculative credit generation teeming with the potential loss of full control over domestic resources, and reversal liabilities.

To this end, it is recommended that countries explore other emerging and innovative forms of financing that are centred around the adaptation, resilience, and ecosystem service benefits of blue carbon ecosystems. Section 5 also discusses the recently launched TFFF as an example of an innovative blended-finance approach that provides results-based payments to countries that can demonstrate measurable conservation outcomes for forest conservation. While differences in terrestrial forest and blue carbon ecosystems prevent a direct expansion or replication of the TFFF, it provides a blueprint for enhancing access to climate finance without needing to engage carbon offset markets and mechanisms.

Safeguards for integrity and equity

Regardless of where a country stands in this sequence, certain safeguards are non-negotiable. These include:

- **Ecological integrity:** ensuring projects enhance, not degrade, ecosystem health; maintaining natural hydrology and biodiversity.
- **Social inclusion and rights:** upholding Free, Prior and Informed Consent (FPIC), clarifying tenure and access rights, and guaranteeing equitable benefit-sharing.
- **Transparency and accountability:** making methodologies, monitoring data, and financial flows publicly accessible.
- **Alignment with 1.5 °C pathways:** avoiding the use of impermanent blue carbon credits to offset fossil fuel emissions that must be permanently phased out.

Embedding these safeguards within national legislation, project standards, and international agreements is essential to protect both people and ecosystems from unintended harms. If approached in this deliberate, sequenced manner, blue carbon can serve as a strategic enabler rather than a speculative instrument. It can help countries meet multiple objectives, including enhancing coastal resilience, safeguarding biodiversity, and contributing modestly to national mitigation, all while building readiness for future finance opportunities.

Conclusion: measured ambition for a fragile asset

The renewed attention to blue carbon reflects a growing recognition that the ocean is central to achieving the goals of the Paris Agreement. Coastal and marine ecosystems form part of the earth's most effective natural defenses, and play a crucial role in absorbing carbon, buffering climate impacts, and sustaining biodiversity and livelihoods. However, their precise role in global mitigation (and by extension, potential contribution to national emissions reductions efforts) remains questionable.

The science confirms that blue carbon ecosystems are integral to the ocean sink, storing carbon over centuries and offering clear adaptation and resilience benefits. However, their mitigation potential is constrained by measurement gaps and compromised by physical fragility related to accelerating pressures of sea-level rise, warming, and extreme weather. These uncertainties make it essentially impossible to predict their long-term contribution to mitigation.

At the same time, the policy and finance landscape around blue carbon is expanding rapidly. Countries are seeking creative ways to leverage these ecosystems for investment through sovereign blue bonds, debt-for-nature swaps, blended-finance facilities, and, increasingly, carbon trading. Each of these approaches can help mobilise much-needed resources for coastal protection, but each also carries risks of over-monetisation, ecological degradation, and inequitable benefit-sharing if pursued without adequate safeguards, while use for offsetting undermines mitigation ambition elsewhere.

For both achieving national mitigation ambitions and generating climate finance, blue carbon is no silver bullet. It cannot substitute for the deep decarbonisation required across energy, transport, industry, buildings, agriculture and waste, nor can it deliver predictable mitigation outcomes without robust scientific foundations. However, when approached with caution and integrity, it can reinforce resilience, protect existing carbon stocks, and anchor ocean ecosystems within broader climate and development strategies.

To that end, countries considering or expanding blue carbon initiatives should adhere to a prudent, integrity-first approach:

1. **Protect and restore first:** Prioritise the conservation of existing blue carbon ecosystems, including mangroves, salt marshes, and seagrasses. Avoided loss is one of the fastest, most reliable ways to retain carbon stocks and preserve adaptation benefits.

2. **Measure:** Invest in scientific and institutional capacity for the MRV and stocktaking of blue carbon ecosystems. Credible inventories are a crucial foundation for appropriately defining the impacts and potentials of blue carbon, which can ultimately shape policy and financing efforts.

3. **Integrate into national planning prudently:** Blue carbon should be integrated into NDCs and long-term strategies only when supported by verified data. Given existing scientific and national capacity constraints, the focus of blue carbon integration in NDCs should be centred on co-benefits and ecosystem protection, not speculative mitigation.

4. **Exercise extreme caution toward carbon markets:** Bringing blue carbon into the offsetting market arena is not advised under current conditions, as these mechanisms risk undermining national mitigation integrity and delaying the deep decarbonisation required to align with 1.5 °C pathways. Indeed, it would be counterproductive. Instead, countries are encouraged to explore alternative innovative instruments of finance that favour results-based payments centered around ecosystem conservation and restoration, such as the TFFF. If countries choose to proceed with blue carbon market engagement despite these disqualifying problems, it must be preceded by extensive groundwork to establish comprehensive national inventories, robust MRV and governance systems, and clear safeguards to ensure environmental and social integrity.

If protected and managed wisely, blue carbon ecosystems can serve as both a climate and development asset by helping countries safeguard their coasts, strengthen their economies, and contribute to global climate stability. But if treated as quick fixes or tradable substitutes for genuine emissions reductions across key sectors like energy, transport, and industry, they risk becoming another source of over-promised potential and under-delivered results.

In a decade defined by both urgency and opportunity, the most strategic approach is one of measured ambition, where the priority should be to protect what we already have, build the knowledge we still lack, and progressively ensure blue carbon plays a commensurate role in scientific, policy and financing efforts for a more resilient and sustainable future.

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